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GEOLOGY OF THE BIRRINDUDU AND TANAMI 1:250 000 SHEET AREAS, NORTHERN TERRITORY.

REPORT ON THE 1971 FIELD SEASON

by

D.H. Blake, I.M. Hodgson, and P.A. Smith

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SUMMARY

Within the Birrindudu and Tanami Sheet areas, situated between the Kimberleys 150 km to the northwest and Alice Springs 600 km to the southeast, scattered low outcrops of Proterozoic and Cambrian rocks are separated by expanses of Quaternary sand and Tertiary laterite. There are also outcrops of Tertiary travertine and silcrete and terrestrial sediments of possibly Cretaceous age.

The oldest rocks exposed are those of the Tanami Group, mapped as Lower Proterozoic. These are tightly folded and cleaved low-grade metasediments and metavolcanics which can probably be correlated with the Halls Creek Group of the Kimberleys. They crop out in several basement inliers in both Sheet areas, and are intruded and thermally metamorphosed by the Winnecke Granophyre and three unnamed granite bodies mapped as Upper Proterozoic. The Winnecke Granophyre also intrudes the Mount Winnecke Formation which consists of folded sandstone and acid volcanics, and is probably comagmatic with the acid volcanics. The Lower Proterozoic Tanami Group is unconformably overlain by a sequence of unmetamorphosed Upper Proterozoic rocks, mainly sandstone and some shale, siltstone, conglomerate, glauconitic sandstone, and stromatolitic chert. The Upper Proterozoic rocks have been affected by broad doming and irregular folding. At the base of this sequence in the west is the Gardiner Formation, which may be correlated with the Carpentarian Speewah Group of the Kimberleys or possibly with the Adelaidean Vaughan Springs Quartzite of the Ngalia Basin to the south. The Upper Proterozoic rocks are overlain unconformably by flat-lying Lower Cambrian Antrim Plateau Volcanics and, in the east, by Cambrian sediments on the western margin of the Wiso Basin.

Of economic interest are gold-bearing quartz veins at Tanami, and uranium-bearing conglomerate at the base of the Upper Proterozoic in the Killi Killi Hills, on the Western Australia/Northern Territory border.

INTRODUCTION

The Birrindudu and Tanami 1:250 000 Sheet areas cover the northern part of the Granites-Tanami region. The two Sheet areas were mapped in late June to early October 1971 by D.H. Blake (party leader), I.M. Hodgson, and P.A. Smith.

The Granites-Tanami region (Fig. 1) is an area of mainly Precambrian rocks lying between the Palaeozoic Wiso Basin to the east and the Canning Basin to the west, and between the mainly Precambrian Arunta region to the south and the Kimberley and Victoria River regions to the northwest and north respectively.

The area mapped is bounded by latitudes 18° and 20°S and longitudes 129° and 130°30'E. The western boundary is the Western Australia/Northern Territory border. Tanami, an abandoned gold-mining centre, lies at the southern edge of the area, on a track connecting Alice Springs, 640 km to the southeast, with Halls Creek, 400 km to the northwest.

The main access routes to the area (Fig. 2) are the Buchanan Highway in the north, which connects the Stuart Highway near Dunmarra with Halls Creek in Western Australia, and the track from Alice Springs to Halls Creek via Tanami. Tracks branch south from the Buchanan Highway to Birrindudu homestead in the west, and from Wave Hill to Tanami via Hooker Creek in the east.

Within the mapped area several tracks branch out from Birrindudu homestead. One of these runs eastwards to join the Tanami Hooker Creek track. In the south the track from Tanami to Halls Creek formerly passed northwest through the Gardiner Range, but is now disused and replaced by a new track west from Tanami to Halls Creek via Billiluna homestead. Most of the tracks in the area are suitable only for four-wheel-drive vehicles. Travel cross-country by vehicle is relatively easy, the main hazards being grass seeds,

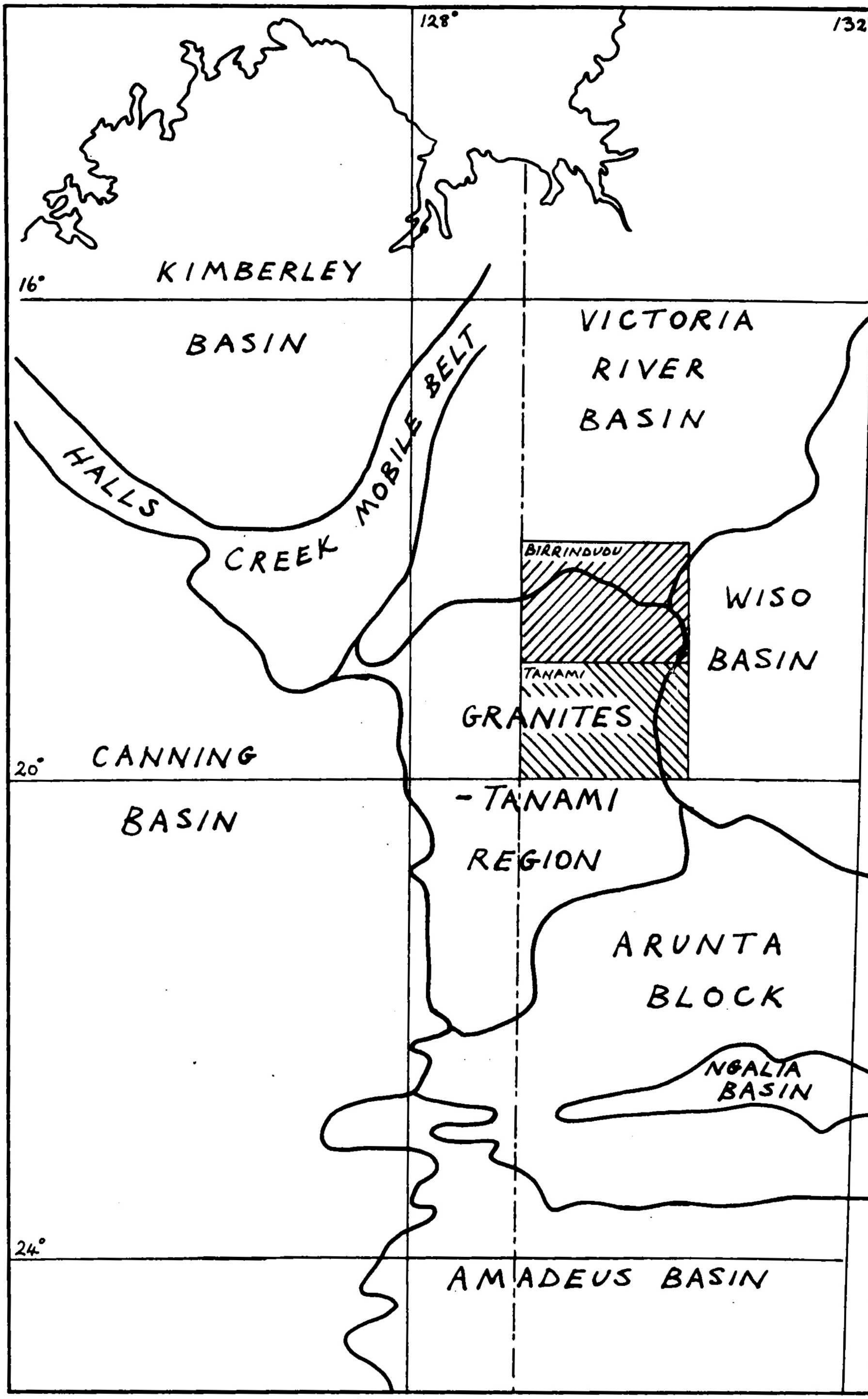

Fig 1 LOCALITY MAP

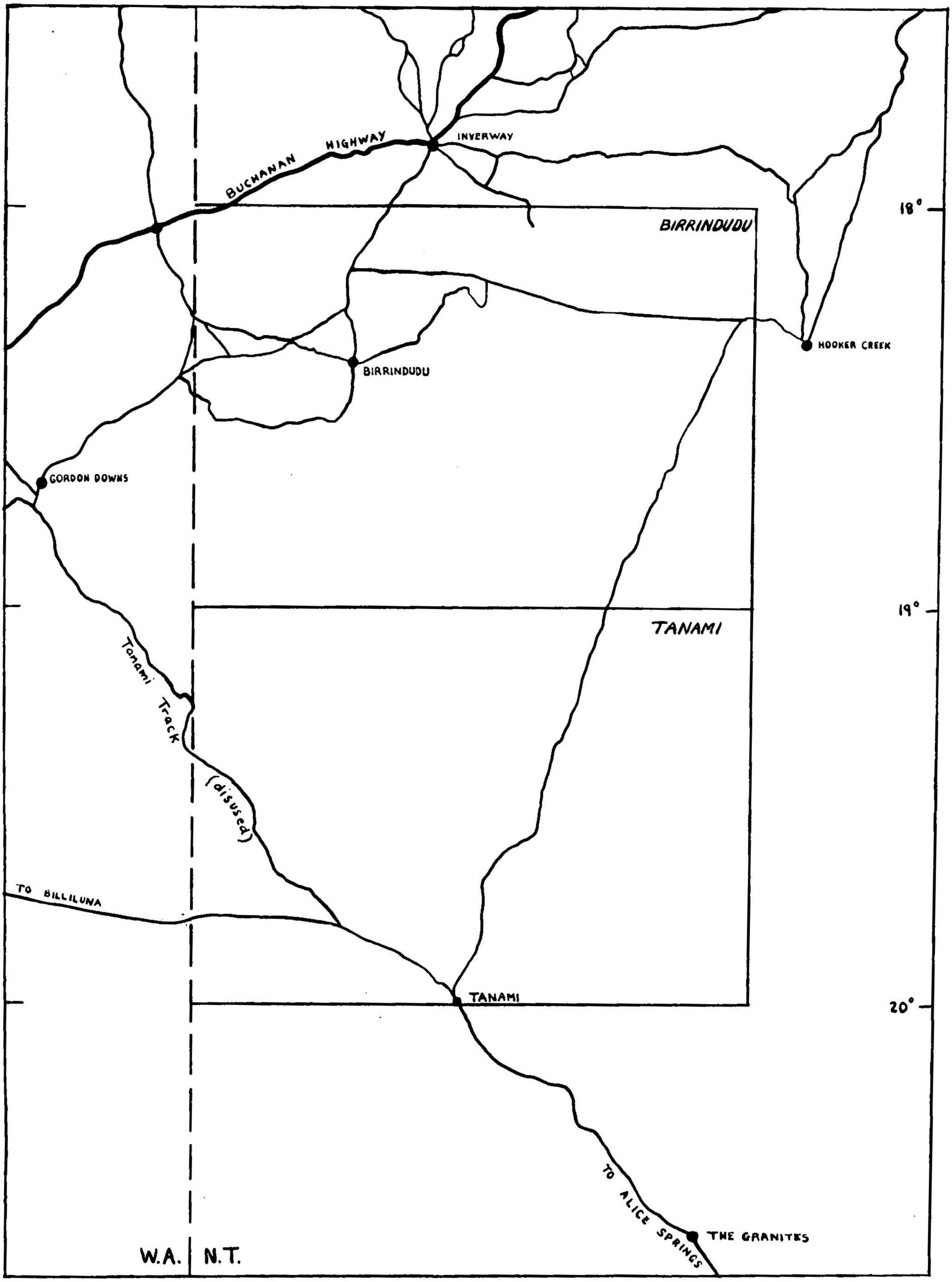

Fig 2. ACCESS TO AND WITHIN THE TANAMI AND BIRRINDUDU 1:250 000 SHEET AREAS

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which clog up radiators, short sharp stakes, which result in numerous punctures, and a paucity of land marks, making navigation difficult.

There are no towns and only two homesteads within the area: Birrindudu homestead on a pastoral property in the northwest, and Supplejack Downs homestead on a grazing property to the southeast. Both properties are engaged in cattle raising for beef production. Each homestead has an airstrip suitable for light aircraft, and there is an unmaintained airstrip at Tanami. Most of the area is ideal for helicopter work, as there are virtually unlimited landing sites. Halls Creek, the nearest town (population about 600), is served by regular flights from Derby, Kununurra, and Alice Springs.

Climate and vegetation

The following notes on climate and vegetation are based on reports by Slatyer (1970) and Perry (1970) on the Ord-Victoria area, which includes the Birrindudu but not the Tanami Sheet area.

The Birrindudu-Tanami area lies in a semi-arid region and has a warm dry monsoonal climate. The nearest stations with 30 years of rainfall data are Halls Creek and Wave Hill. The mean annual rainfall at Wave Hill is 484 mm and at Halls Creek 424 mm, based on records for the period 1931-1960. At both stations almost all the rain falls in the period December to March, although at Halls Creek at least one wet day can be expected each month. The data from these two stations and stations farther north indicate that in the area mapped the average annual rainfall decreases from about 450 mm in the northwest to about 300 mm in the south.

Temperature data are available for Halls Creek, and indicate that in the Birrindudu-Tanami area maximum temperatures of over 38°C can be expected in October, November and December, and also in March. Mean minimum temperatures of less than 10°C occur during June, July, and August, when frosts are common, especially in the south.

The vegetation becomes generally sparser southward, owing to the increasingly arid conditions. In the north, where the annual rainfall is over 380 mm, the vegetation typically consists of low savanna, the main tree being snappy gum (Eucalyptus brevifolia), and, on clay plains, extensive grasslands, mainly of Mitchell grass. In the south, where the annual rainfall is less than 380 mm, desert shrubland predominates. Spinifex is common throughout the area. Few trees are more than 8 m high.

Survey methods

The field work was planned from 1:250 000 photogeological sheets of Birrindudu and Tanami prepared at BMR by Simpson (1971), and was mostly carried out by ground traverses using Landrovers.

A helicopter was used for four weeks (80 flying hours) near the end of the field season to map the more inaccessible parts of the area and to check on some areas visited previously. In addition a BMR drilling rig was used to drill shallow stratigraphic holes in parts of the Tanami Sheet area where the bedrock is covered by superficial Cainozoic deposits.

Observation sites were recorded on vertical air-photographs which were at nominal scales of 1:50 000 and 1:80 000. Geological data were plotted on overlays on the air-photographs, from where they have transferred to planimetric sheets compiled by the Division of National Mapping. These sheets were at scales of 1:50 000 for the Birrindudu Sheet area and 1:46 500 for the Tanami Sheet area. The resulting compilations were photographically reduced to 1:250 000 scale and redrawn for the preliminary editions accompanying this report.

Air-photographs

The Birrindudu Sheet area is covered by vertical air-photographs taken by RAAF in 1948 and by Adastra in 1967. The Tanami Sheet area is covered by vertical air-photographs taken by RAAF in 1950 and by Adastra in 1967 (run 1) and 1971 (runs 2-8). The RAAF air-photographs are at a nominal scale of 1:50 000 and those of Adastra are at a nominal scale of 1:80 000; they can be obtained from the Division of National Mapping, Canberra

Previous geological investigations

The area was first explored in 1900, when Davidson (1905) led a prospecting expedition west from Tennant Creek to the Browns Range Dome area and the Gardiner Range. During his return journey by a more southerly route he discovered gold at Tanami.

Brown (1909), a South Australian Government geologist, travelled to Tanami via Hooker Creek in 1909 and then northwards across the Browns Range Dome to Birrindudu. He reported on the mines at Tanami and the geology along his route. In the same year Talbot (1910) travelled from Halls Creek to Tanami and investigated the metamorphic rocks near Larranganni Bluff. The following year Gee (1911) reported on the Tanami goldfields and surrounding district.

In 1914 Jensen (1915) travelled to Tanami and made notes on the geology between Hooker Creek and Tanami.

Terry (1932) made several journeys in the region and in 1928 prospected the area near Larranganni Bluff in the course of an investigation of the Granites-Tanami district.

A detailed survey of the mines at Tanami was carried out in 1937-38 by Hossfeld (1940).

Part of the Birrindudu Sheet area was included in a regional geological survey of north-west Australia by Traves (1955).

In 1959 Phillips made a geological reconnaissance of the Tanami sheet area for Enterprise Exploration Pty Ltd, and Roberts (1968) carried out geological mapping and geochemical sampling in the Black Hills area for Anaconda Aust. Inc. in 1968.

Simpson (1971) photo-interpreted the Birrindudu and Tanami Sheet areas in 1969.

The adjoining Sheet areas to the west were mapped during regional geological surveys carried out jointly by BMR and the Geological Survey of Western Australia; the Billiluna Sheet area was mapped in 1955 as part of the Canning Basin Survey (Casey & Wells, 1960, 1964), and the Gordon Downs Sheet area in 1962-4 during a survey of the East Kimberley region (Dow & Gemuts, 1969). The adjoining Tanami East and Winnecke Creek Sheet areas to the east were mapped during a regional geological survey of the Wiso Basin (Milligan et al; 1966). The Limbunya Sheet area to the north was mapped in 1969 (Sweet et al., 1971).

Topography and drainage

The Birrindudu-Tanami area ranges in altitude from 530 m at Mount Frederick, 63 km northwest of Tanami, to 330 m in the valley of Hooker Creek in the northeast and possibly lower near Lake Buck in the southeast. It can be divided into four main topographic divisions (Fig. 3): Sturt Plateau, dissected plateau margin to the east, Victoria River plains and terraces in the northeast, and low-level plains east of the dissected plateau margin.

Sturt Plateau

Most of the area mapped is part of the Sturt Plateau (Traves, 1955; Patterson, 1970; Simpson, 1971), a mainly flat to very gently undulating surface from which rise ancient monadnocks. These form low ranges generally less than 30 m high and having accordant or sub-accordant summits. Most of the ranges are strike ridges and plateau areas formed on rocks highly resistant to erosion, mainly Precambrian sandstones. The ranges have incised drainage channels which pass outwards onto outwash fans on narrow flanking piedmont slopes. The channels disappear on the surrounding plains. Low

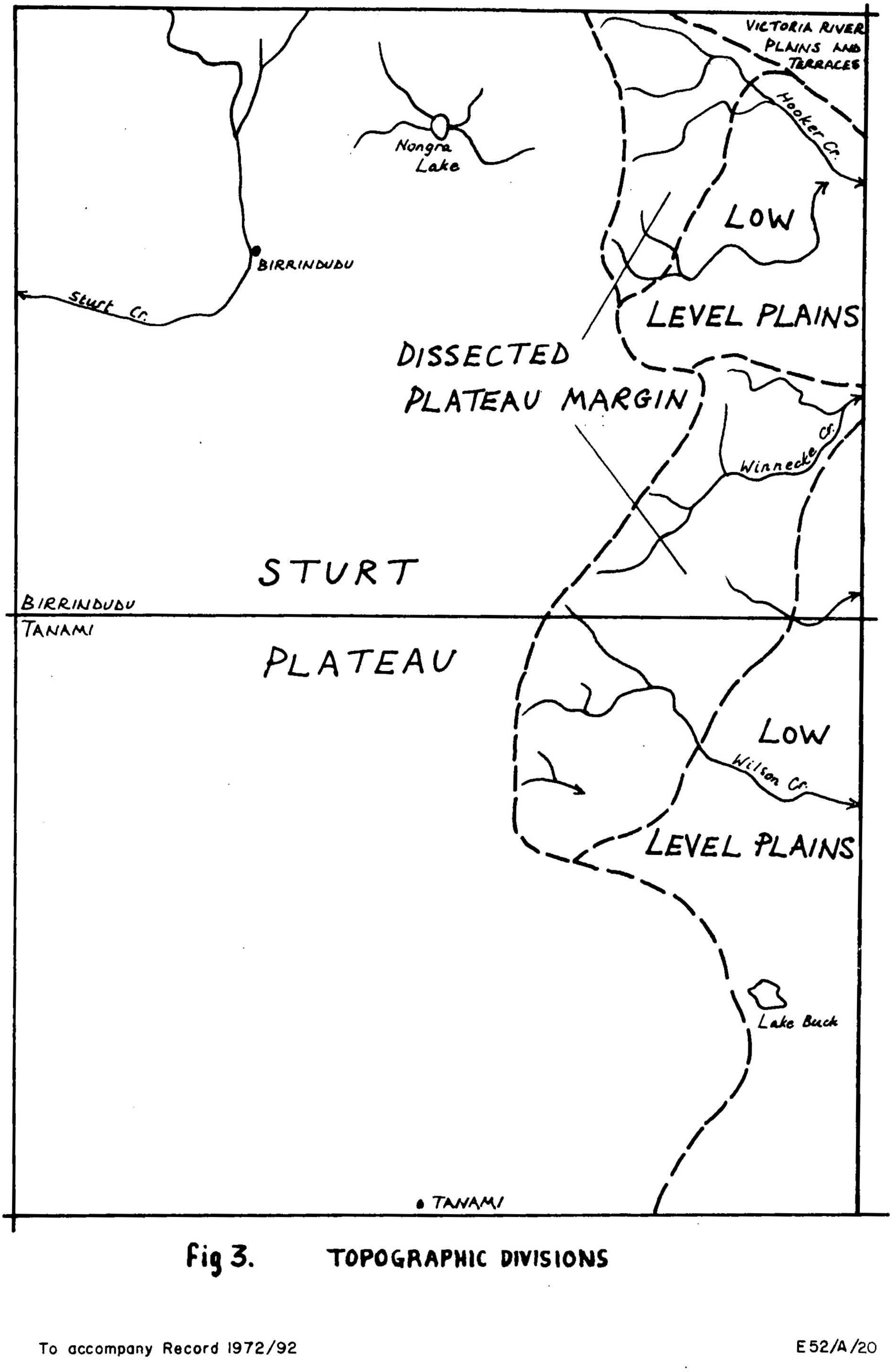

Fig 3. TOPOGRAPHIC DIVISIONS

breakaways are common locally. Barely perceptible drainage depressions, some with small claypans (Fig. 52), occur between many of the ranges. The main drainage lines are those of Sturt Creek and its tributaries in the northwest.

Only a few of the ranges on the Sturt Plateau have been named on previous maps. These are, from north to south, Ware Range, Stake Range, Gardiner Range, Pargee Range, Killi Killi Hills, Black Hills, and Tanami Range. Several of the other ranges are given provisional names on the accompanying geological maps. These names are, from north to south, the Birrindudu and Northern Ware Ranges, Winnecke Range (on the dissected plateau margin), Northern Browns Range, Mana Range, Southern Browns Range, Crazy Dingo Range, Supplejack Range, Savage Hills, North Coomarie Range, Pingidijarra Hills, West Pargee Range, Talbot Hills, and East Coomarie Range. These new names have yet to be approved by the Northern Territory Lands Department.

Dissected plateau margin

The Sturt Plateau is partly bounded to the east by a broad dissected margin which contains the headwaters of creeks draining to the east (Simpson, 1971). This dissected plateau margin is not present in the southeast, where the low-level plains abut directly against the Sturt Plateau. The terrain on the plateau margin, as on the Sturt Plateau, consists partly of residual hills and plateau areas formed of resistant sandstone, but also includes some prominent breakaways and undulating terrain descending eastwards. The unit has a dendritic pattern of drainage channels and depressions. The local relief is mostly less than 30 m.

Victoria River Plains and Terraces

A small part of the Victoria River Plains and Terraces (Traves, 1955; Simpson, 1971), which cover an extensive area north of the area mapped, occupies the northeast corner of the Birrindudu Sheet area, within the catchment of the northward-flowing Victoria River. This unit is also known as the Victoria River Plains and Benches (Paterson, 1970; Sweet et al., 1971). The terrain consists of an undulating plain from which rise mesas and buttes, some of which have benched sides.

Low-level Plains

The dissected plateau margin and, in the south, the Sturt Plateau, pass eastward into low-level plains (Simpson, 1971) which have been subdivided into several units by Milligan et al. (1966) in the Winnecke Creek and East Tanami Sheet areas to the east; four of these units, the Hooker Creek Uplands, Winnecke Tableland, Lowland Dunefields, and Hanson-Lander Plains, were recognized by Simpson in the Birrindudu-Tanami area. The low-level plains consist of mostly flat to very gentle undulating terrain and include, in the southeast, Lake Buck (which is usually dry), several salt pans, and groups of low longitudinal dunes trending east-west.

Surface drainage

The main surface drainage systems are Sturt Creek in the northwest, which drains south and then west into Western Australia, and Hooker Creek, Winnecke Creek, and Wilson Creek, which drain eastwards off the edge of the Sturt Plateau. The main creeks and their tributaries are ephemeral, but several have waterholes that are permanent to semi-permanent. A local area of inland drainage in the north is centred on Nongra Lake, a permanent body of brackish water which fluctuates in area both seasonally and anually (Fig. 53).

As well as waterholes along the larger creeks, there are also some rockholes containing supplies of water. These include Jellebra Rockholes northwest of Mount Frederick and Camel Waterholes on the east side of the Tanami Range. The semi-permanent Coomarie Spring, on the Tanami/Hooker Creek track northeast of Tanami, is a small soak on flat ground between low ridges of sandstone.

Correlation of land surfaces

In the north part of the Northern Territory Hays (1967) has recognised four main erosion surfaces. The oldest and highest, the Ashburton Surface, is considered by Hays to be Cretaceous and is represented in the Birrindudu-Tanami area by the accordant to sub-accordant summits of the residual ridges and plateau areas on the Sturt Plateau and dissected plateau margin, and by the summits of the mesas and buttes of the Victoria River Plains and Terraces. The second oldest erosion surface is the Tennant Creek Surface, which is probably mid-Tertiary, and is represented by the widespread cappings of laterite present on low rises west of the low-level plains. The younger Wave Hill and Koopinyah Surfaces have not been recognized in the area, but may be present east of the Sturt Plateau.

Rock nomenclature

In this work three main sandstone types are distinguished (after Pettijohn, 1957, p.291); orthoquartzite, in which at least 95% of detrital grains are quartz, quartzite, or chert; lithic sandstone, in which 5-25% of grains are rock fragments and feldspar; and greywacke, which differs from the other two in containing more than 15% matrix. Glauconitic sandstone is used for sandstone containing glauconitic.

Grainsizes of sandstones are: 0.125-0.25 mm, fine; 0.25-0.5 mm, medium; 0.5-1 mm, coarse; 1-2 mm, very coarse.

Bedding thicknesses used for sedimentary rocks are laminated, less than 1 cm; thin-bedded, 1-50 cm; medium-bedded, 50 cm-2 m; thick-bedded, over 2 m.

For igneous rocks the classification of Hatch, Wells, & Wells (1961) is used where practicable. However, because of the alteration of many of these rocks, and the lack of chemical analyses, general terms such as acid porphyry and acid lava are used instead of rhyolite or rhyodacite. If the grain-size of granitic rocks is less than 1 mm, it is described as fine; if 1 to 5 mm, as medium; if 5 mm to 3 cm, as coarse; if over 3 cm, as pegmatitic.

Among the metamorphic rocks, phyllite and phyllitic rocks are distinguished from shale and other sedimentary rocks in having white mica along cleavage planes. Terms describing metamorphic facies are as defined by Turner & Verhoogen (1960).

Introduction to stratigraphy

At present no isotopic ages have been determined on any rocks in the area, nor have any datable fossils been found. Therefore the ages of stratigraphic units are based on lithological and structural correlations with adjacent areas, and are provisional.

Two main problems were encountered during the reconnaissance mapping. Firstly, exposures of the pre-Tertiary rocks tend to be widely separated, because of the extensive cover of superficial deposits. This made correlations between different outcrops difficult, especially as few useful marker-beds were found. Secondly, weathering is characteristically deep and intense. This has involved both lateritization and silicification, and is due to subaerial denudation of the area for at least the entire Cainozoic Era. It affects all rocks except some consisting almost entirely of quartz, and hinders rock identification in both the field and the laboratory.

A summary of the stratigraphy is given in Table 1. The oldest rocks exposed are low-grade metasediments and metavolcanics mapped as Lower Proterozoic. These rocks make up the Tanami Group, which crops out in several inliers in both the Birrindudu and Tanami Sheet areas. After being tightly folded and cleaved, the Lower Proterozoic rocks were intruded by granitic bodies, one of which, the Winnecke Granophyre, also intruded sandstone and intercalated acid volcanics of the Mount Winnecke Formation. The granitic intrusions and the Mount Winnecke Formation, which are mapped as Upper Proterozoic, are overlain unconformably by younger Upper Proterozoic sediments, mainly sandstone, of the Birrindudu Group, and possibly also by the Supplejack Downs Sandstone. Folded sandstone in the north, isolated from the Birrindudu Group, is mapped as part of the Upper Proterozoic Limbunya Group. The Proterozoic rocks were folded and then eroded before the Lower Cambrian Antrim Plateau Volcanics and Cambrian sediments on the western margin of the Wiso Basin were laid down. Younger sediments in the area are represented by the Larranganni Beds, which are probably Cretaceous; Tertiary laterite, silcrete, and travertine; and Quaternary aeolian sand, lacustrine clay, residual soil, and alluvium.

LOWER PROTEROZOIC

TANAMI GROUP

The Tanami Group comprises the oldest known rocks in the area. They are steeply dipping and commonly cleaved sedimentary and volcanic rocks which are tightly folded and have been affected by low-grade regional metamorphism. They were termed the Tanami Metamorphic Series by Jensen (1915), but as many of the rocks are little altered, the name Tanami Group is preferred. The name is derived from the abandoned gold mining settlement of Tanami.

The group forms the basement throughout most of the Birrindudu-Tanami area, and outcrops occur in both Sheet areas, the most extensive being in the south of Tanami. It comprises the following six provisionally named formations: Mount Charles, Killi Killi, Nanny Goat Creek, Nongra, and Helena Creek Formations and the Pargee Sandstone.

Rocks of the group crop out to the west on the adjoining Gordon Downs, Billiluna and Lucas Sheet areas, where they have been mapped as Undifferentiated Halls Creek Group (Gemuts & Smith 1968; Dow & Gemuts 1969) and Halls Creek Metamorphics (Casey & Wells 1964; Wells 1962a, b). Outcrops extend southwards into The Granites Sheet area.

TABLE 1

SUMMARY OF STRATIGRAPHY OF BIRRINDUDU AND TANAMI SHEET AREAS

AGE	Rock unit and map symbol	Maximum thickness (m)	Main rock types	Stratigraphic relationships	Remarks
QUATERNARY	Qa	20+	Sand, silt, clay	Superficial veneer on older units	Alluvial and lacustrine deposits
	Qs	10+	Sand	Superficial veneer on older units	Alluvial and aeolian deposits in drainage depressions
	Qz	10+	Sand, local gravel	Superficial veneer on older units	Mainly aeolian, includes sand and gravel on piedmont slopes flanking residual hills and ridges
	Qb	?	Black and grey cracking clay	Superficial veneer mainly on Ꞓla	Residual soil. Birrindudu Sheet only
TERTIARY	Tt	?	Travertine, partly silicified to chert	Unconformable on Cambrian and Proterozoic rocks	In SE not reliably distinguished from Cambrian limestone and chert
	Ts	?	Silcrete	Unconformable on Kl and Proterozoic rocks	Small patches common, rarely large enough to show on map
	(Tl)	20+	Laterite	Veneer on pre-Tertiary units	Widespread cappings on positive topographic features
CRETACEOUS?	Larranganni Beds Kl	8	Sandstone, probably partly calcareous	Unconformable on Blk, Buf, Ꞓla	Tanami Sheet area only. Terrestrial waterlaid deposits
	MAJOR UNCONFORMITY				

AGE	Rock unit and map symbol	Maximum thickness (m)	Main rock types	Stratigraphic relationships	Remarks
CAMBRIAN		67+	Orthoquartzite, lithic sandstone, mudstone, chert, limestone, dolomite	Unconformable on Bg, Bu, and probably also on Buw, Bgw	Restricted to E, on W edge of Wiso Basin. Flat-lying
	Antrim Plateau Volcanics Ꞓla	30+	Tholeiitic basalt, tuffaceous sandstone, lithic sandstone, stromatolitic chert	Unconformably on Proterozoic rock units; overlain unconformably by Kl	Flat-lying terrestrial lava flows. Widespread in both Sheet areas. Extensively lateritized
	MAJOR UNCONFORMITY				
UPPER PROTEROZOIC	Bu	800	Lithic sandstone, orthoquartzite, siltstone, shale	Probably unconformable on Bg; overlain unconformably by Ꞓ	Mapped only in E Tanami Sheet area. Variable dips
	Limbunya Group Undivided Bhu	400	Lithic sandstone, orthoquartzite	Overlain unconformably by Ꞓla	Restricted to NW Birrindudu Sheet area, where it is folded into NW-trending synclines and anticlines
	BIRRINDUDU GROUP Stake Range Beds Buk	2500¢	Lithic sandstone	Conformable on But; overlain unconformably by Ꞓla	Main outcrops in Tanami Sheet area, where exposed in synclinal structures
	Talbot Well Formation But	300	Stromatolitic chert, cherty sandstone, siltstone, mudstone, limestone	Conformable on Buf and Bur; overlain conformably by Buk and unconformably by Ꞓla	Main outcrops in Tanami Sheet area. Mostly gently dipping
	Ware Range Sandstone Bur	3000	Lithic sandstone, orthoquartzite	Lateral equivalent of Buf. Unconformable on Plw, Bls, and possibly Buw and Bgw; overlain conformably by But and unconformably by Ꞓla	Extensive outcrops in Birrindudu Sheet area. Broadly folded

AGE	Rock unit and map symbol	Maximum thickness (m)	Main rock types	Stratigraphic relationships	Remarks
UPPER PROTEROZOIC	Gardiner Formation Buf	2600+	Lithic sandstone conglomerate ortho-quartzite, shale, silt-stone	Lateral equivalent of Bur Unconformable on Blk, Blg Blt, Bls, Buw, Bg and possibly Bus; overlain conformably by But and un-conformably by Ꞓla and Kl	Extensive outcrops on Tanami Sheet area. Affected by doming, broad and tight folds. Uraniferous basal conglomerate at Killi Killi Hills.
	UNCONFORMITY?				
	Supplejack Downs Sandstone Bus	1300+	Lithic sandstone, ortho-quartzite	Unconformable on Blw and possibly Buw; overlain unconformably by Ꞓla and probably also by Buf.	Tanami Sheet area only. Irregularly folded.
	UNCONFORMITY?				
	Unnamed granite Bg	-	Medium to coarse biotite and muscovite granite	Intrudes Blk, Blt; overlain by Buf,Ꞓ and probably also Bu.	Forms central parts of Browns Range and Coomarie Domes; also forms an intrusion E of Black Hills. Possibly co-magnetic with Bgw
	Winnecke Granophyre Bgw	-	Biotite granophyre, biotite granite, biotite-quartz-feldspar porphyry	Intrudes Blh, Buw and probably also Blw; overlain bv Ꞓla and possibly also Bur.	Probably comagnetic with acid volcanics of Mount Winnecke Formation and possibly also with Bg.
	Mount Winnecke Formation Buw	4800	Lithic sandstone, tuff-aceous sandstone and silt-stone, porphyritic and non-porphyritic acid lava	Intruded by Bgw; possibly overlain unconformably by Bur	Folded to form large anti-clines and synclines. Acid volcanism probably under water
	MAJOR UNCONFORMITY				

AGE	Rock unit and map symbol	Maximum thickness (m)	Main rock types	Stratigraphic relationships	Remarks
LOWER PROTEROZOIC	TANAMI GROUP Helena Creek Formation Ᵽlh	?	Lithic sandstone, conglomerate, tuff	May be lateral equivalent of Ᵽls, Ᵽlw. Intruded by Ᵽgw	Crops out only in NE Birrindudu Sheet area, SW of Hooker Creek
	Nongra Formation Ᵽls	1000+	Phyllite, shale, siltstone, greywacke, lithic sandstone, banded chert, tuff, extrusive acid porphyry	Unconformably overlain by Ᵽuf, Ᵽur and Єla; may be intruded by granite	Steep to vertical dips; cleaved. May be lateral equivalent of Ᵽlw
	Nanny Goat Creek Formation Ᵽlw	1000+	Extrusive acid porphyry basalt, tuff, greywacke, lithic sandstone, phyllite, shale, siltstone	Unconformably overlain by Ᵽus and Ᵽur; probably intruded by Ᵽgw	Tanami Sheet area only. Steeply dipping, generally cleaved. May be lateral equivalent of Ᵽls and Ᵽlt
	Mount Charles Formation Ᵽlt	1000+	Phyllite; phyllitic shale, siltstone and greywacke; siltstone; chert; basalt; gossaneous ironstone	Overlies or is overlain by Ᵽlg. Intruded by Ᵽg and overlain unconformably by Ᵽuf and Ᵽuw	Tanami Sheet area only. Steeply dipping and tightly folded; cleaved. May be lateral equivalent of Ᵽlw and Ᵽlk. Host for gold mineralization at Tanami
	Pargee Sandstone Ᵽlg	1500+	Lithic sandstone, orthoquartzite, conglomerate, greywacke.	Unconformably overlain by Ᵽuf	Tanami Sheet area only. Steeply dipping and tightly folded
	Killi Killi Formation Ᵽlk	3000+	Greywacke, lithic sandstone, shale, mudstone, tuff, acid porphyry	Overlies or is overlain by Ᵽlg. Intruded by Ᵽg and overlain unconformably by Ᵽuf and Kl	Tanami Sheet area only. Steeply dipping and tightly folded; cleaved. May be lateral equivalent of Ᵽlt

Because of tight folding, probable complex faulting, and poor exposures, especially near contacts, no sequence has been established within the group. For these reasons, and because the base is not exposed the thickness of the group is unknown, though it is probably several thousands of metres.

The group is overlain unconformably by the Upper Proterozoic Supplejack Downs Sandstone and Birrindudu Group, by the Lower Cambrian Antrim Plateau Volcanics, and probably also by the Mount Winnecke Formation, which may be lowermost Upper Proterozoic. It is intruded by the Winnecke Granophyre and by unnamed granitic bodies; these intrusions are probably Upper Proterozoic.

The lithology, structure, and metamorphism of the Tanami Group are similar to those of the Halls Creek Group of the East Kimberleys, Western Australia, with which the Tanami Group is correlated. The Halls Creek Group is mapped as Archaean or Lower Proterozoic (Dow & Gemuts, 1969), but the younger age is considered the more likely for the Tanami Group at present because many of the rocks are little altered.

Killi Killi Formation (Blk) (provisional new name)

The Killi Killi Formation comprises the weakly metamorphosed sedimentary and volcanic rocks that crop out in the Tanami Sheet area mainly south and southeast of the Killi Killi Hills, after which the formation is named, and extend into The Granites, Lucas, and Billiluna Sheet areas.

The most northerly outcrops are near the Southern Browns Range, where Davidson (1905) reported micaceous schist and the occurrence of copper carbonate and pyrite. He also recorded quartz-veined ironstone in metamorphic rocks of the Killi Killi Formation around Larranganni Bluff. These were later described by Talbot (1910) and Phillips (1959). In the Billiluna and Lucas Sheet areas the formation was mapped by Casey & Wells (1964) as Halls Creek Metamorphics.

Fig. 4 Larranganni Bluff. Killi Killi Formation (K) overlain by gently dipping Gardiner Formation (G) (Neg. G A/5709)

Fig. 5 Steeply dipping beds of Killi Killi Formation overlain by gently dipping Gardiner Formation. Gossans (g) on Killi Killi Formation (neg M/1328)

The land surface developed on the formation is broadly undulating but includes scattered jagged hills and ridges up to 15m high (Fig. 4). On the tops of undulations the formation is commonly exposed as low ribs of rock barely protruding through Cainozoic superficial deposits.

The photo-pattern is characterized by wavy trends indicated by closely spaced light and dark bands. The margins of outcrop areas are usually poorly defined. Some deeply weathered outcrops have a light smooth pattern, and several outcrops have cappings of laterite which show up as smooth dark grey areas.

The thickness of the formation cannot be measured because the formation is tightly folded, there is a lack of marker beds, and in the area mapped exposure is poor; it is estimated from air-photographs to be several thousand metres. The formation is best exposed in the adjoining Billiluna Sheet area, which will be mapped in 1972, and this is where the type section will probably be selected.

Lithology. Rock types represented are greywacke, lithic sandstone, shale, mudstone, siltstone, tuff and acid porphyry, ironstone, minor orthoquartzite, and rare conglomerate. Regional metamorphism of very low grade is indicated by the widespread sericitization of the pelitic fraction of most rocks observed. A very steep to vertical cleavage is characteristic of the medium and fine clastic rocks, and is usually sub-parallel to bedding. Gossans are developed on the formation but are more common west of the Tanami Sheet area. Veins of white quartz cut the formation and the larger ones form low ridges or mounds. Specular hematite is a common inclusion in the quartz-veins. Quartz-tourmaline veins cut the formation on the south side of the Browns Range Dome; they are probably related to the granite that forms the core of the dome.

Greywacke is the most common rock type exposed. It is poorly sorted, fine to medium-grained, mostly medium-bedded, and contains grains of quartz, chert, and volcanic rock fragments. Sericite is abundant in the matrix and also as an alteration product after lithic fragments and possibly also after feldspar. Clay minerals formed by the break-down of rock fragments during weathering are commonly present. Sericite aggregates locally give the rock a white spotted appearance, as in purplish grey medium-bedded greywacke forming low pinnacles 3 km east of the Killi Killi Hills. Light grey and brown micaceous greywacke crops out on the south side of the Killi Killi Hills, and similar greywackes are exposed farther south. Fine-grained brownish maroon greywacke containing about 10 percent quartz grains was encountered in stratigraphic hole 85, beneath 2 m of sand.

With a reduction in the amount of matrix, greywacke grades into lithic sandstone, and the two rock types are commonly interbedded. The lithic sandstone is medium to coarse and shows a wide variation in the ratio of quartz to rock fragments (including chert). Quartz grains are predominant in the lithic sandstone south of Larranganni Bluff. Red chert fragments are conspicuous in a grey lithic sandstone south of the Pingidijarra Hills, where bands up to 12 m thick of medium-bedded lithic sandstone are interbedded with siltstone and acid porphyry. The lithic sandstone here is more resistant to weathering than the other rocks and stands out as strike ridges up to 3m high. It is poorly sorted, cross-bedded, and contains up to 80 percent quartz. In the lithic sandstone the rock fragments are partly altered to kaolin, and accessory minerals include chlorite, blue-grey tourmaline, and rare zircon.

Shale, mudstone, and siltstone commonly interbedded with greywacke and lithic sandstone are generally maroon, brown, or black, owing to iron staining. However, light-grey shale dipping 75° southeast was observed interbedded with brown micaceous lithic sandstone on the southern margin of the Sheet area. Some of the siltstone is probably tuffaceous. Maroon mudstone was found in drill hole 83 beneath 21 m of Cainozoic sand.

Acid volcanic rocks interbedded with greywacke and sandstone are well exposed south of the Pingidijarra Hills and also 9 km north of Jellabra Rockholes. At the first locality purple and purplish brown non-porphyritic tuff shows well developed spheroidal weathering. In thin section the tuff consists of sericitic blebs in a fine-grained silicified groundmass. The blebs are associated with shard-like siliceous material, and may be altered pumice fragments. Acid porphyry is present at both localities. It consists of up to 30 percent phenocrysts of white euhedral and subhedral feldspar and mica and glassy quartz in a purplish felsitic groundmass. Thin sections show that the feldspar phenocrysts are pseudomorphed by clay minerals and turbid quartz, as also are biotite phenocrysts which make up to 10 percent of the rock. Altered pyroxene was observed in one specimen. The groundmass has been silicified to a fine quartz mosaic with sericite and iron oxides, and the original groundmass textures have been destroyed. However, field relationships indicate that the porphyry probably originated as crystal tuff.

Iron-rich rocks described in the field as ironstone, hematitic and limonitic shale and jaspilite, are widespread, especially south of Larranganni Bluff, where they are interbedded with grey and brown micaceous greywacke and lithic sandstone. One bed close to the W.A. border has a distinctive appearance owing to white ellipsoidal chert pods in dark brown to black jaspilite. The pods are 1 to 2 cm long and their long axes are parallel to the bedding. Finely laminated cherty ironstone dipping at 50° crops out as a low rounded ridge about 3 m high forming an isolated exposure 8 km southeast of Larranganni Bluff.

Banded chert crops out on the south side of the Crazy Dingo Range, where it forms a prominent isolated hill about 30 m high 5 km north-northwest of Mallee Hill. The chert here is red, cream, grey, and black. West of the hill are some low, scattered, and partly lateritized outcrops of chert and ferruginous shale.

Thin beds of orthoquartzite occur sparsely within the formation. A white, coarse-grained, medium-bedded orthoquartzite with a ferruginous matrix is interbedded with tuff and porphyry at the Pingidijarra Hills. A fine-grained grey to reddish-brown orthoquartzite with small-scale cross-bedding crops out 9 km north of Jellebra Rockholes. The matrix is richly sericitic, and scattered mica flakes and minor detrital tourmaline are present. A medium-grained orthoquartzite was encountered under 8 m of sand in drill hole 84.

The only conglomerate observed in the formation was a sheared conglomerate containing stretched pebbles (Fig. 6) on the south side of the Browns Range Dome, at 19°02'S, 129°09'E.

Folding, metamorphism, stratigraphic relationships, and age. The formation has been tightly folded. Several tight small folds were observed in the field, and the closures on several large folds are visible on air-photographs. Consistently steep dips, parallel straight bedding trends locally traceable over several kilometres, and a vertical cleavage that is generally sub-parallel to bedding indicate that the folding may be isoclinal.

Low-grade regional metamorphism probably accompanied the folding. However intense weathering with widespread silicification and ferruginization has so altered the mineralogy of the rocks that details of the metamorphic history are obscure. The most highly altered rocks observed crop out on the south side of the Browns Range Dome, where schistose greywacke of the Killi Killi Formation and schistose granite occur in a sheared contact zone.

The relationship between the Killi Killi Formation and the Pargee Sandstone is uncertain as no contacts are exposed. The Pargee Sandstone may be higher in the sequence as it contains widespread detrital chert which could be derived from banded chert of the Killi Killi Formation. The granite of the Browns Range Dome intrudes the Killi Killi Formation and both rock units are

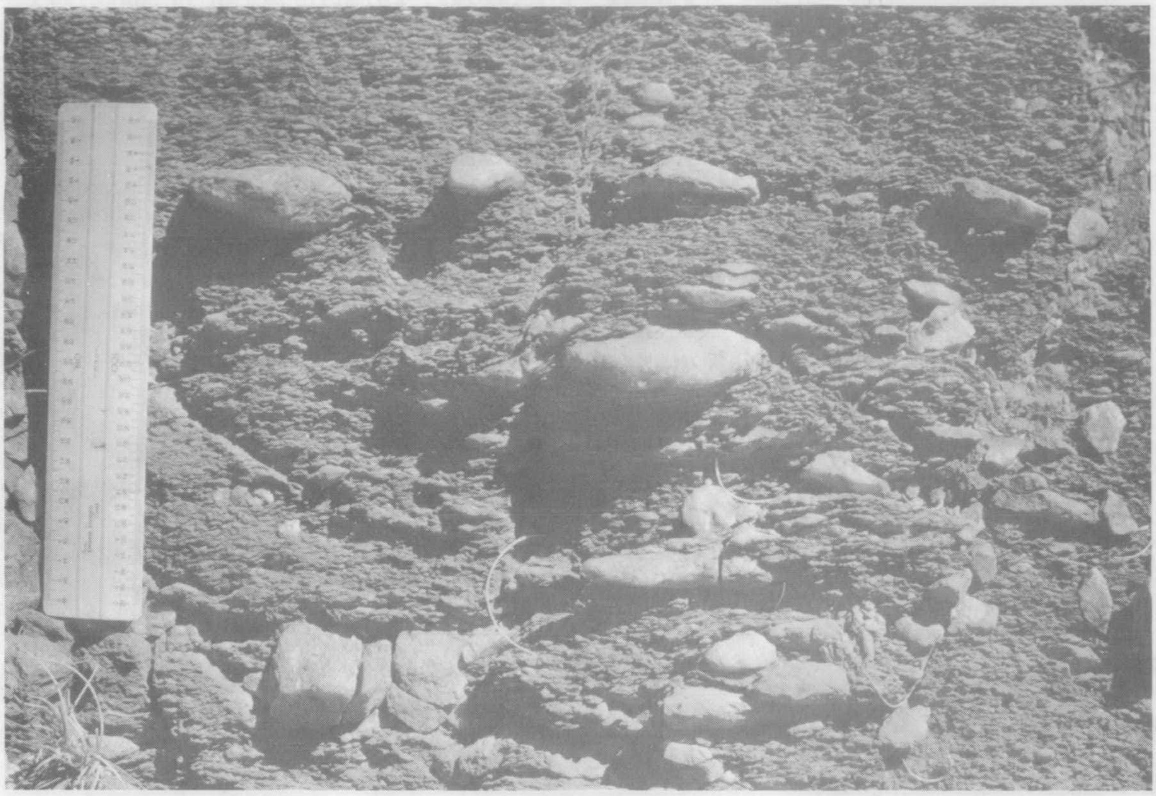

Fig.6. Sheared conglomerate within the Killi Killi Formation, south side of the Browns Range Dome (Neg. GA/5698)

Fig. 7. Steeply dipping black and white banded chert, Mount Charles Formation; SSE of Pargee Range (Neg. GA/5701).

unconformably overlain by the Gardiner Formation. Relationships between the Killi Killi Formation and the Gardiner Formation are well exposed at the Killi Killi Hills, the Pingidijarra Hills, south of Larranganni Bluff, 3 km north of Jellebra Rockholes (Fig. 5), and along the Southern Browns Range. At these localities steeply dipping beds of the Killi Killi Formation are overlain by gently dipping sandstone of the Gardiner Formation, at the base of which a thin conglomerate bed is commonly present.

The Killi Killi Formation is probably Lower Proterozoic. It is lithologically and structurally similar to rocks within the Halls Creek Group and is undoubtedly much older than the Gardiner Formation, which is Adelaidean or Carpentarian in age. The deformation and lithology of the Killi Killi Formation is similar to that of the Mount Charles, Nanny Goat Creek, and Nongra Formations and all four formations are mapped as part of the Lower Proterozoic Tanami Group.

Pargee Sandstone (Blg) (provisional new name)

The Pargeé Sandstone crops out in the western half of the Tanami Sheet area as a north-northwesterly-trending strike belt up to 8 km wide. It does not crop out in the Birrindudu Sheet area. It is exposed along the western side of the Pargee Range, after which it is named, and around the southern end of Mount Frederick, where it is unconformably overlain by the Gardiner Formation. The main outcrop is west of Mount Frederick, where the formation forms a low range, here named the West Pargee Range. This is selected as the type area. Outcrops consisting of parallel strike ridges continue south to the southern Sheet margin.

On air-photographs the Pargee Sandstone has a smooth medium tone. Bedding traces are visible, as also are joints along which gullies have developed.

Fig 8 Steeply dipping conglomerate, Pargee Sandstone, West Pargee Range. (Neg. GA/5702)

Fig 9 Boulders of Pargee Sandstone in the basal conglomerate of the Gardiner Range Formation. Gully northeast of Mount Frederick. (Neg. GA/5688)

<u>Lithology</u> In the type area a minimum thickness of 1 500 m of lithic sandstone and orthoquartzite, conglomerate and greywacke is exposed, and similar rock types were seen at the other outcrops. The lithic sandstone and orthoquartzite are mostly medium-bedded and fine to medium-grained. They almost always show current bedding, and ripple marks are locally common. The sandstones are mostly harder and more compact than the Upper Proterozoic sandstones and have a subconchoidal fracture. Their colour varies between beds from pink to purple, maroon, and red brown, the differences being due to iron staining. In thin section they consist predominantly of rounded to subangular quartz grains and up to 30 percent turbid and lithic grains. The turbid grains are diffuse quartz mosaics, and some are pseudomorphing feldspar. The lithic grains include chert, jasper and volcanic rock fragments. The sandstones have a quartz overgrowth cement. The original grains are outlined by dust and iron staining. The lithic sandstone is locally conglomeratic (Fig. 8).

The conglomerate is interbedded with the lithic sandstone and orthoquartzite. It is mainly pebble conglomerate, though in places such as on the east side of Mount Frederick granule conglomerate is present. The conglomerate consists of jasper, yellow and greenish chert, vein quartz, and quartz sandstone clasts in a quartz sandstone matrix. The conglomerate beds are generally about 1 m thick. Five such beds occur in a sequence about 25 m thick on the southwest side of Mount Frederick.

The greywacke is dark grey to maroon, medium to fine-grained, and poorly sorted, and mostly has a subconchoidal fracture. In the thin sections examined clear and turbid quartz grains are present in about equal amounts and predominate over lithic grains. The grains are mostly angular to subangular, very few are well rounded. The turbid grains are similar to those in the lithic sandstone and orthoquartzite, and are mostly more rounded than the clear grains; One grain consisted of a micrographic intergrowth of clear quartz and feldspar pseudomorphed by turbid quartz. A matrix composed of an iron-stained fine-grained mosaic of quartz and sericite makes up about 20 percent of the rock. Iron oxide forms patches and also occurs as discrete grains. Quartz overgrowth cement is present.

Stratigraphic relationships and age. The Pargee Sandstone is tightly folded and is unconformably overlain by the Gardiner Formation, which is mapped as Upper Proterozoic and is mostly gently and irregularly folded. A conglomerate formed of Pargee Sandstone boulders is locally present at the base of the overlying formation (Fig. 9). The relationships of the Pargee Sandstone with other Lower Proterozoic formations are less clear as contacts are not exposed. The chert and jasper component of the conglomerate and the lithic grains in the lithic sandstone and greywacke could be derived from either or both the Killi Killi and Mount Charles Formations. The relationships between these formations may be resolved when The Granites Sheet area to the south is mapped. The Pargee Sandstone is tentatively included in the Lower Proterozoic Tanami Group.

Mount Charles Formation (Blw) (provisional new name)

The Mount Charles Formation comprises the low-grade metasediments and metavolcanics that crop out in the southern part of the Tanami Sheet area between longitudes 129°30'E and 130°00'E. The type area for the formation is the northern part of the Black Hills near Mount Charles (19°50'00"S, 129°50'4"E), after which the formation is named (Fig. 10). The formation was described but not named by Roberts (1968) and previously but in less detail by Brown (1909), Jensen (1915) and Hossfeld (1940). It was included in 'the Tanami Metamorphic Series' by Jensen.

Rocks of the formation form mainly low smoothly rounded hills and strike ridges, many of which are covered by laterite and lateritic gravel. However in the Black Hills area some of the hills are surmounted by prominent steep-sided rocky ridges several metres high. Where the laterite cover is thin

Fig 10 View south from Mount Charles, Black Hills. Mainly phyllite and phyllitic greywacke of the Mount Charles Formation exposed in the foreground. The low ridges in the middle distance are formed on gently dipping sandstones of the Gardiner Formation. (Neg. GA/5762)

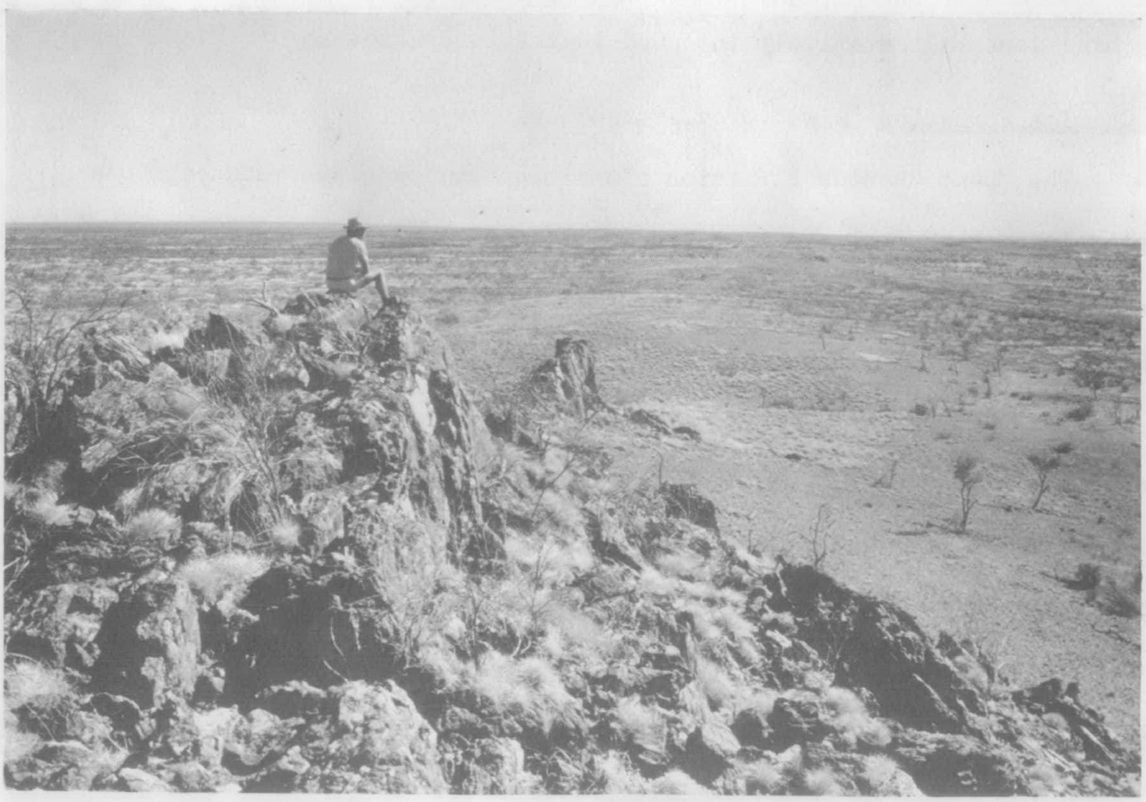

Fig 11 Gossan ridge at Mount Charles, looking north (Neg. GA/5760)

or absent, rocks are exposed on the surface, projecting through an impersistent soil cover. Bedding, where discernible on the air-photographs, does not show the wavy trends characteristic of the Killi Killi Formation

The thickness of the Mount Charles Formation is unknown but is probably several thousands of metres. The beds are generally very steeply dipping and may be isoclinally folded, although this is not established because of restricted exposures and the lack of marker beds.

Gold-bearing lodes in the formation at Tanami were found by A. Davidson in 1900 and were worked sporadically up to 1940. They are described in the section on Economic Geology.

Lithology Rock types are phyllite, phyllitic shale, siltstone and greywacke, shale and siltstone, chert, jaspilite, basalt and amphibolite, and gossanous bands. Following Roberts (1968), three main lithological units have been mapped, characterized respectively by phyllite, chert, and basic volcanics. Quartz veins are common in all three units.

Unit 1 (Blt_1). This unit is exposed in the type area at Mount Charles and along the Black Hills to the south and southeast (Fig. 12). It consists of phyllite, phyllitic shale, siltstone and greywacke, and gossanous bands. A prominent cleavage is generally developed, approximately parallel to the very steep to vertical bedding that strikes north to northwest. The phyllitic rocks are thinly bedded to laminated, and are yellow-brown, maroon, mauve, purple, grey, and dark grey. Patchy silicification to chert and quartzite occurs locally. Limonitic spots are common, especially in phyllite, and probably represent altered pyrite crystals. The greywacke is medium to fine-grained and locally shows current bedding. It consists of quartz grains (generally making up less than 50 percent of rock), fine-grained rock fragments, white mica, iron oxide, and minor detrital tourmaline enclosed in an altered silty and clayey matrix. Cellular gossanous bands composed mainly of kaolinite, quartz, hematite, goethite, and limonite, are interbedded with the phyllitic rocks. They form the prominent rocky ridges of the eastern Black Hills, including those of Mount Charles (Fig. 11) and Mount Twigg. The gossanous bands are stratified and some at least are known from drilling to be developed on black carbonaceous pyritic shales at depth (Roberts, 1968).

Unit 2 (Plt) This unit is generally finer-grained than unit 1. It is made up of banded chert (Fig. 7) thinly interbedded with laminated, partly silicified shale and siltstone; thinly interbedded siltstone and quartzitic fine-grained greywacke; basalt, gossanous rocks, jaspilite, and minor phyllite. Some of the chert is pale white to pinkish, greyish green or black, but the most common colours are similar to those of unit 1. The unit is well developed along the Black Hills west of Mount Charles, at Tanami, southeast of Mount Frederick, and west of the Tanami Range. The beds are commonly contorted, and tight to isoclinal minor folds and crenulations are visible at most exposures. Cleavage is not as well developed as in unit 1.

Intercalations of basalt are common in the succession at Tanami, and are present at all abandoned mines (Fig. 13). It is probably the rock type described by Brown (1909) as diorite and by Hossfeld (1940) as possible tuff. The basalt is maroon to purple, deeply weathered, and consists mainly of hematite, kaolinite, and variable amounts of quartz. The original fine-grained basaltic texture can usually be recognised both in hand specimen and thin section (Fig. 14). Small amygdales and microphenocrysts are present locally. The best exposures of the basalt were seen in the sides of a recently bulldozed costean 2.3 m deep at Tanami. Here basalt is intercalated with folded thinly interbedded shale, siltstone and fine sandstone. The basalt is somewhat sheared but otherwise appears massive, and it is uncertain whether it is extrusive or intrusive. Gossans are less widespread in unit 2 than in unit 1, and do not form such prominent topographic features, but are otherwise similar. Jaspilite, consisting of thinly interbedded jasper and hematite, crops out 7 km southeast of Mount Frederick.

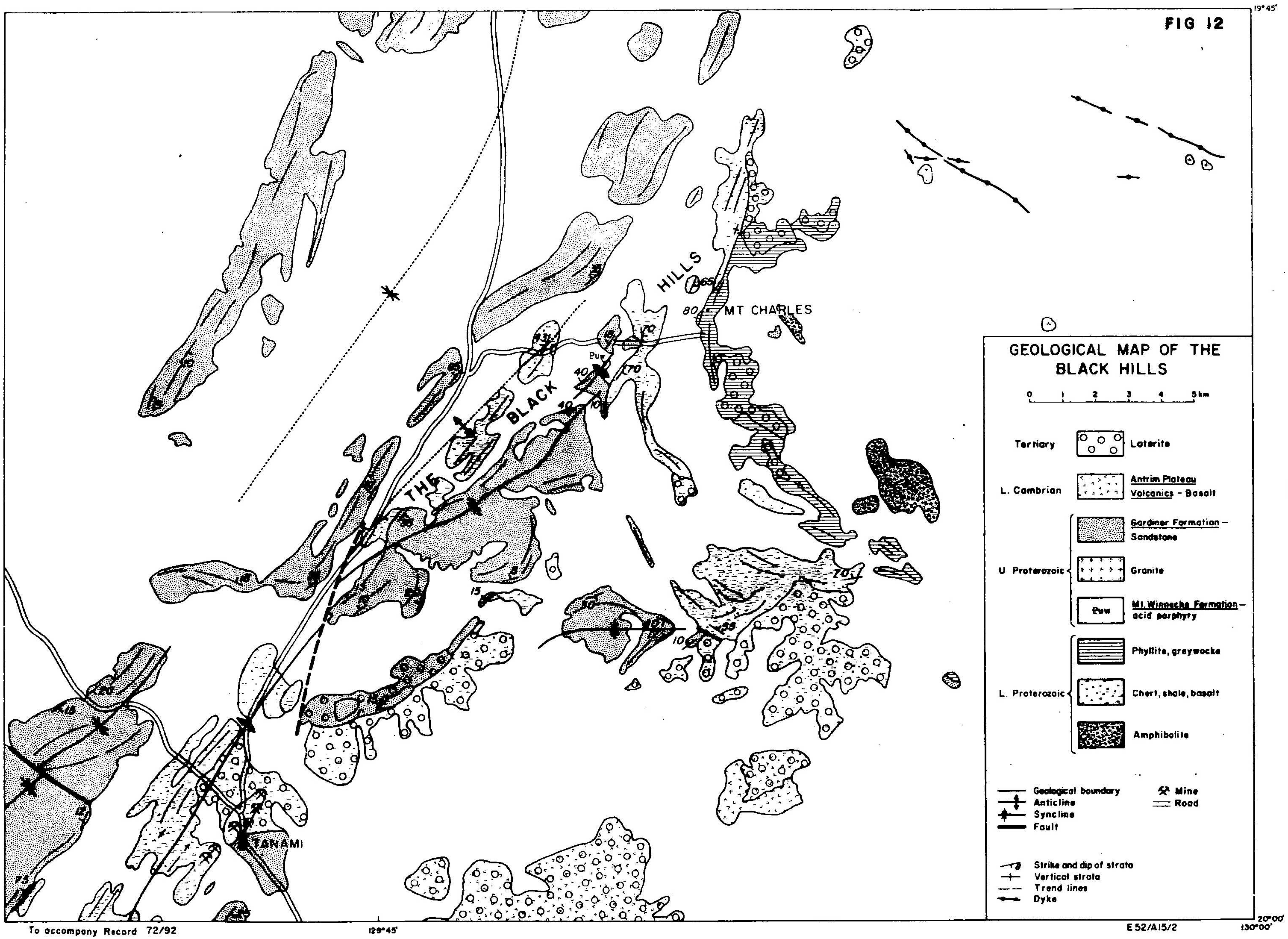

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Fig 13 Abandoned gold mine at Tanami. Basalt and banded shale shale and siltstone are exposed in the foreground. (Neg. GA/5756)

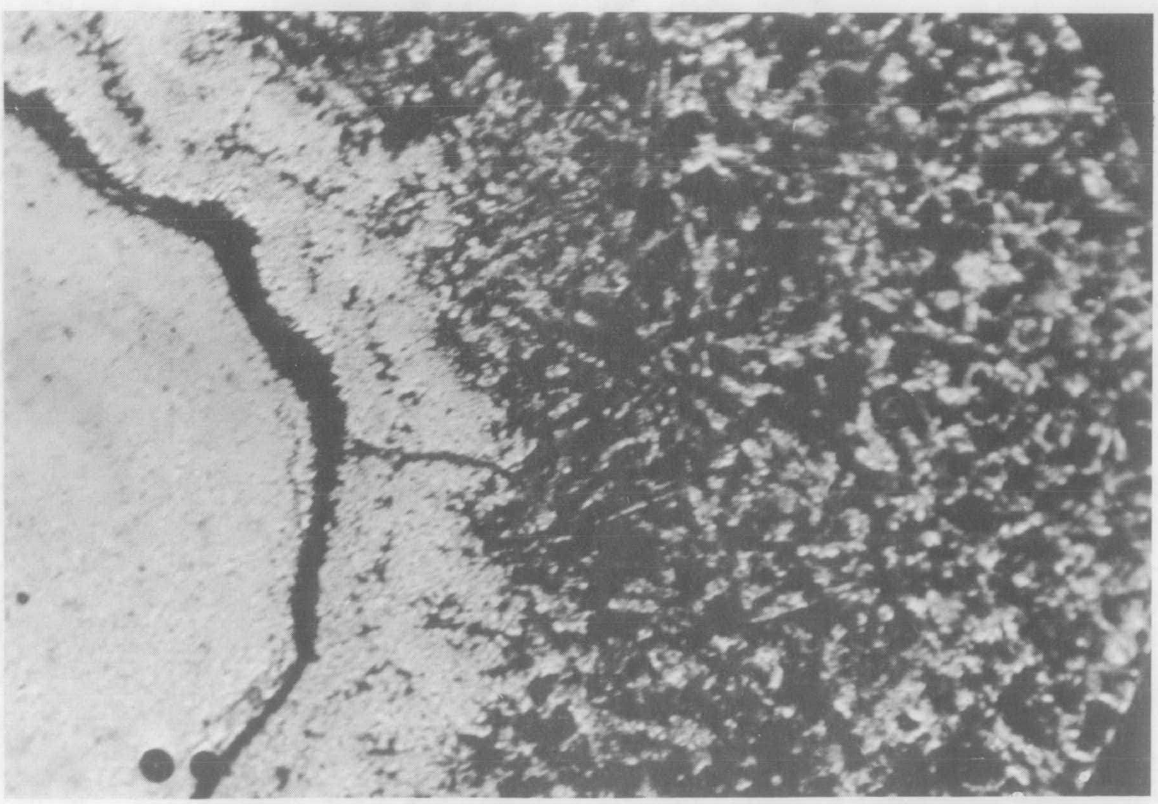

Fig 14 Photomicrograph of altered amygdaloidal basalt from the Mount Charles formation at Tanami showing preserved basaltic texture. The amygdale on the left is filled with a mosaic of quartz. (Neg. M1293/37)

Unit 3 (Blt_2) This unit consists solely of amphibolite and basalt. Amphibolite forms rubbly exposures on low mounds and undulating terrain east and southeast of Mount Charles, where it has a prominent vertical cleavage trending north-northwest. Deeply weathered basalt is exposed in contact with phyllite on the east side of a bluff 1.7 km southeast of Mount Charles. Amphibolite was also intersected in drill holes Nos 53, 54, 55 and 56 east of Mount Charles, and Nos 68, 72 and 76 northwest of Tanami. In three of the drill holes east of Mount Charles, amphibolite underlies basalt near the surface and overlies granite at depths of about 16 m, whereas in the holes northwest of Tanami the amphibolite occurs to depths of at least 30 m. The amphibolite is mostly fine-grained and dark greenish or grey. It is made up of aggregates of green to blue-green amphibole, altered turbid feldspar, opaque granules, and some interstitial quartz. A basaltic texture is preserved in places, and most if not all the amphibolite is the product of basalt thermally metamorphosed by underlying granite.

Other drill holes, besides those in amphibolite, have intersected rocks of the Mount Charles Formation. These are Nos 69 and 70 west of Mount Twigg, and Nos 77, 78, 79, 80, 81 and 82 northwest and west of Tanami. All these drill holes, even where close to exposures of unit 2, passed only through phyllite, phyllitic siltstone and greywacke, which are the typical rock types of unit 1. This indicates that much of the chert in unit 2 may be a secondary product due to silicification of shale and siltstone during weathering.

Folding, metamorphism, stratigraphic relationships and age. The very steep to vertical dips, and the commonly prominent cleavage that is approximately parallel to the bedding indicate that the Mount Charles Formation is probably tightly folded, possibly isoclinally, about nearly vertical fold axes. A major steeply plunging fold was mapped 42 km west-northwest of Tanami, and another is indicated in the southern part of the Black Hills, where two prominent gossan ridges converge (Roberts, 1968). The bedding, cleavage and

Fig 15 Outcrop of acid porphyry, Nanny Goat Creek Formation, eastern side of the Ware Range. (Neg. GA/5738)

Fig 16 Cleaved acid porphyry of the Nanny Goat Creek Formation exposed in the Tanami/Hooker Creek track near Wilson Creek. The hammer handle is parallel to the cleavage. (Neg. GA/5747)

Fig 17 Aerial view of waterhole (centre of photo) on Wilson Creek. The lineament to the right is the trace of the faulted junction of the Nanny Goat Creek Formation on the left and the Supplejack Downs Formation to the right (Neg. GA/5706)

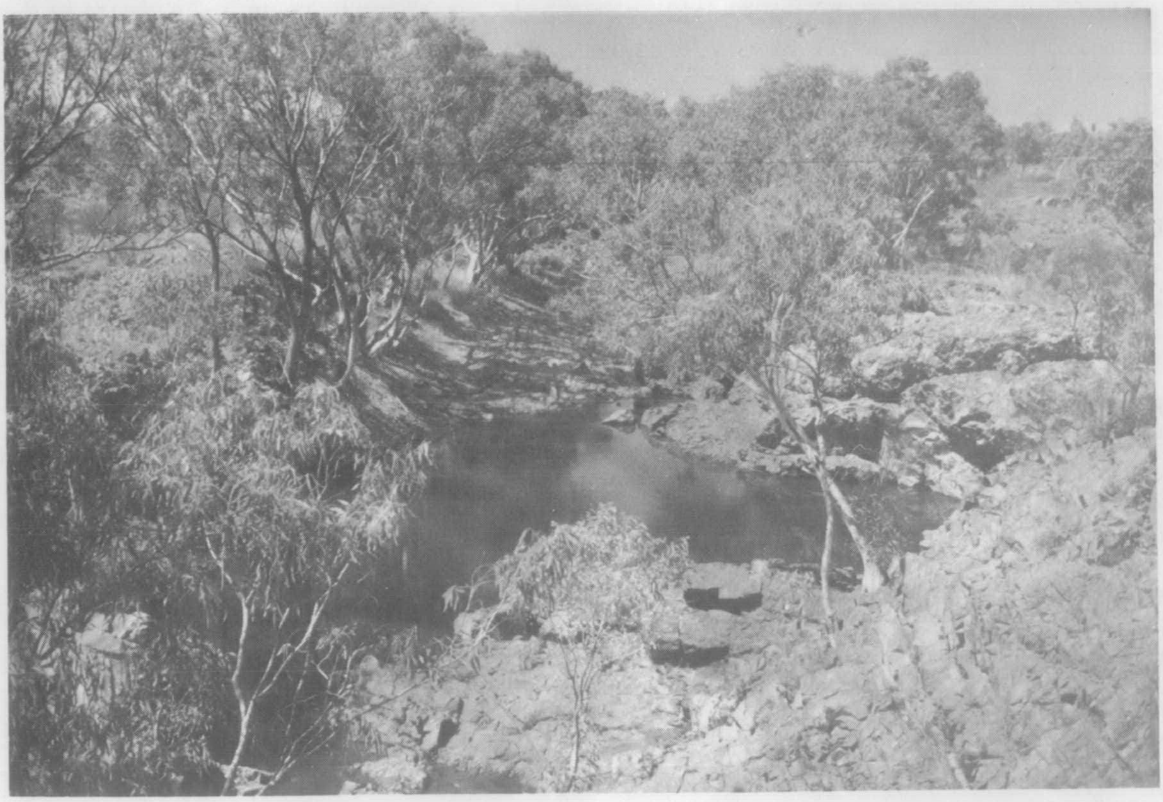

Fig 18 Waterhole on Wilson Creek in basalt and tuff of the Nanny Goat Creek Formation (Neg. GA/5724)

fold axes trend west-northwest to northeast. Minor folds and contortions are common locally but are too irregular to give reliable indications of the major structures. Because of an absence of marker beds and a paucity of suitable exposures, there is little evidence of repetition of beds.

The formation has been affected by low-grade regional metamorphism, and probably belongs mostly to either the zeolite or greenschist metamorphic facies of Turner & Verhhoogen (1960). However, this has not been established with certainty because the metamorphic minerals, except quartz and some mica, have been altered during weathering.

Most if not all the amphibolite within the Mount Charles Formation is a product of thermal metamorphism of basalt. This relationship is clear from the section intersected in drill holes east of Mount Charles, which passed through soft weathered basalt near the surface, then hard amphibolite and then granite. The occurrence of amphibolite and granite in adjacent drill holes northwest of Tanami indicates that here also the formation is intruded by granite.

The relationship of the Mount Charles Formation to the Pargee Sandstone in the west is uncertain, because contacts are not exposed. However, sandstone and conglomerate of the Pargee Sandstone contain lithic fragments that can be matched with rocks of the Mount Charles Formation. This indicates that the Mount Charles Formation may underlie the Pargee Sandstone.

A major unconformity separates the steeply dipping Mount Charles Formation from the overlying and mostly gently dipping Gardiner Formation. The Gardiner Formation is younger than the isoclinal folding and regional metamorphism of the Mount Charles Formation, and is also younger than the unnamed granite. The unconformity is not exposed, being concealed beneath Cainozoic superficial sediments. The Mount Charles Formation is also overlain (probably unconformably) by acid porphyry mapped as Mount Winnecke Formation west-southwest of Mount Charles.

The folding and regional metamorphism of the Mount Charles Formation are similar to those of the other formations of the Tanami Group, and indicate a Lower Proterozoic age. The formation differs from the other formations of the group in that it consists of sedimentary rocks that are finer-grained than those of the Pargee Sandstone, and does not include acid volcanics which are found in the Killi Killi, Nanny Goat Creek, and Nongra Formations.

Nanny Goat Creek Formation (Blw) (provisional new name)

The Nanny Goat Creek Formation comprises steeply dipping and generally cleaved volcanics and sedimentary rocks that crop out in the northeast Tanami Sheet area. The outcrop area lies east of the Ware Range and is crossed by Wilson Creek and its main tributary Nanny Goat Creek, after which the formation is named.

The type area for the formation is along latitude 19°21'S between the Tanami/Hooker Creek track and Wilson Creek. The beds are steeply dipping and probably tightly folded, and neither the top nor the base of the formation is exposed. Hence the thickness of the formation is unknown, although it must be several thousands of metres.

The formation forms gently undulating terrain and minor small flat-topped low plateaux. Some rocky hillocks and strike ridges generally less than 3 m high occur on gentle rises. The plateaux are capped by laterite and partly bounded by breakaways. Most exposures are rubbly, but good exposures occur in creeks, especially at a group of waterholes in Wilson Creek (Figs 17 and 18) 9 km southeast from the Tanami/Hooker Creek track. Exposed rocks are much weathered and iron-stained.

On air-photographs the outcrops range in tone from very pale to dark, and on the south side of Nanny Goat Creek they locally show a fine-grained finger-print pattern. They can be distinguished from outcrops of adjacent sandstone formations as they form less positive topographic features.

Lithology. Rock types represented are acid porphyry, basalt, tuff, and minor greywacke, lithic sandstone, phyllite, shale, and siltstone; all are exposed in the type area. A prominent very steep to vertical cleavage is commonly developed (Fig. 16) approximately parallel to the bedding which trends northwest to northeast. This is probably an axial plane cleavage and indicates that the formation may be tightly folded, although no major folds have been recognized. However tight minor folds and contortions are common locally, as are zones of shearing and brecciation. Quartz veining is common throughout.

Acid porphyry crops out in the west part of the type area and westwards to the Ware Range, forming a series of low parallel strike ridges and hillocks (Fig. 15). It is also present on the south side of Nanny Goat Creek. The porphyry is speckled, with blebs of pale greyish clay or brown iron oxide in a pink, red, maroon, or mauve felsitic matrix. Many blebs are altered feldspar phenocrysts and others are xenoliths, vesicles or fiamme. Phenocrysts are mostly less than 2 mm across, and form up to 30 percent of the rock. Two types of altered feldspar, indicated by different colours, are visible in some specimens. Quartz and altered ferromagnesian phenocrysts are also commonly present, as are small xenoliths. A eutaxitic texture is apparent in several specimens and as no flow banding or autobrecciation of the type found in acid lava flows was seen, it is probable that some or all of the acid porphyry represents ash flow deposits.

Basalt mainly occurs as non-porphyritic lava flows that have quartz-filled amygdales. These lavas are very fine-grained and maroon to dark grey. Patchily porphyritic basalt, containing small pale phenocrysts of altered feldspar, is present locally, and is best exposed at the Wilson Creek waterholes (Fig. 18). It may be intrusive, as it does not show features such as vesicular tops indicative of lava flows. In both basalt types a fine-grained basaltic texture is generally discernible, although the original constituents have been replaced by secondary minerals, mainly clay and iron oxide.

Rocks considered to be tuff are well exposed at the Wilson Creek waterholes and in a large outcrop to the north. The tuff is mostly medium-grained and commonly appears massive and structureless except for prominent nearly vertical joints. Bedding is difficult to find except at a few localities, where it is indicated by thin beds and lenses of laminated fine to coarse tuff, greywacke, quartz sandstone, siltstone, shale, and phyllite. At such localities the prominent jointing is parallel to the bedding and regional cleavage. The tuff is mostly maroon to reddish brown, and has been recrystallized to a hornfelsic equigranular mosaic of white mica, quartz, iron oxides, and clay. Small detrital grains of tourmaline, rare pebbles of sandstone, and local lenses and interbeds of sedimentary rocks indicate the original clastic nature of the tuff. The recrystallization is considered to be the result of thermal metamorphism.

Non-volcanic rocks mostly less than 1 m thick are interbedded in the predominantly volcanic succession. Greywacke is the most common non-volcanic rock. It is poorly sorted, fine to coarse and consists of quartz, white mica, and altered feldspar grains, fine-grained lithic fragments, most of which are probably tuffaceous, minor detrital tourmaline, zircon, and opaque minerals, and a sericitic matrix. Secondary tourmaline needles, probably indicating thermal metamorphism, are developed in greywacke at the Wilson Creek waterholes. Lithic sandstone is generally medium-grained and, compared with the greywacke, is better sorted and has less matrix. Beds of shale, siltstone, and phyllite are mainly 2 to 15 cm thick. These rocks are micaceous and probably highly tuffaceous. The non-volcanic rocks are well exposed at the Wilson Creek waterholes, and a few hundred metres to the east, where they show tight minor folding about mainly vertical fold axes.

The regional cleavage, the presence of phyllitic rocks, and the micaceous nature of the non-volcanic rocks indicate that the formation has been affected by low-grade regional metamorphism, as well as by local thermal metamorphism.

Laterite overlies the Nanny Goat Creek Formation south of the Wilson Creek waterholes (where the outcrops are too small to show on the 1:250 000 geological map), south of Nanny Goat Creek, and on the east side of the Ware Range. The cappings consist of up to 2 m of pisolitic laterite over mottled and iron-stained deeply weathered bedrock. Concretions of dolomite are present in the mottled zone at the Wilson Creek waterholes.

Stratigraphic relationships and age. Field evidence indicates that the Nanny Goat Creek Formation is overlain unconformably by the Ware Range Sandstone to the west and the Supplejack Downs Sandstone to the south, and is probably intruded by the Winnecke Granophyre. However its contacts with these rock units are mostly concealed under Cainozoic deposits, and where they are exposed they are generally faulted.

The unconformable relationship with Ware Range Sandstone is evident on the east side of the Ware Range at 19°10'40"S, 130°02'30"E. Here Ware Range Sandstone dipping gently westward lies west and north of steeply cleaved and patchily brecciated amygdaloidal basalt. A faulted contact between the two formations is exposed 8 km to the north, where contorted phyllite capped by pisolitic laterite lies east of Ware Range Sandstone beds containing pebbles of volcanic rocks identical to those of the Nanny Goat Creek Formation.

The Nanny Goat Creek Formation is bounded on the south by hills of Supplejack Downs Sandstone. In the east the two formations are separated by a fault. In the west the contact may be an unconformity, as neither formation shows evidence of faulting, even within a few metres of each other. Here the Supplejack Downs Sandstone dips nearly vertically, younging to the south, and cuts obliquely across the cleavage and bedding of volcanic and sedimentary rocks of the Nanny Goat Creek Formation to the north. At this locality the Nanny Goat Creek Formation, but not the younger formation, is cut by quartz-hematite-tourmaline veins.

The intrusive relationship of the Winnecke Granophyre to the Nanny Goat Creek Formation is nowhere exposed, but is inferred from the evidence of thermal metamorphism and the close proximity of outcrops of the two units northeast of Wilson Creek. The Winnecke Granophyre is younger than the Nanny Goat Creek Formation as it is uncleaved and intrudes younger rocks (Mount Winnecke Formation).

From its lithology, steep dips, prominent cleavage, low-grade regional metamorphism and stratigraphic relationships, it is evident that the Nanny Goat Creek Formation can be correlated with the Mount Charles and Nongra Formations. Hence it is mapped as part of the Lower Proterozoic Tanami Group.

Outcrops of possible Nanny Goat Creek Formation (Ëlw?). Several outcrops mapped as possible Nanny Goat Creek Formation lie 14 to 28 km south of Nanny Goat Creek, from which they are separated by outcrops of Supplejack Downs Sandstone. They form similar terrain to the Nanny Goat Creek Formation, and, like this formation, consist of very steep to vertically dipping cleaved rocks which commonly show tight minor folds and contortions. The cleavage is parallel to the bedding, and trends north-south.

Rock types exposed are phyllite, banded chert, mudstone, siltstone, greywacke, lithic sandstone, and acid porphyry. Quartz-veining is very common. The greywacke and lithic sandstone are mostly medium to coarse, and consist of quartz grains, minor lithic grains, and detrital tourmaline and zircon in a fine-grained iron-stained sericitic matrix. Acid porphyry was seen at only one locality, 8 km southeast of Supplejack Downs homestead, where it is exposed near the base of a scree slope below a bluff of Supplejack Downs Sandstone. The porphyry is pale buff, strongly cleaved, and contains small quartz and altered feldspar phenocrysts set in a very fine mosaic of quartz and sericite.

At the acid porphyry locality and 6 km to the east-northeast the cleaved rocks are overlain unconformably by gently dipping Supplejack Downs Sandstone, which is mapped as Upper Proterozoic. They are probably also overlain by the Lower Cambrian Antrim Plateau Volcanics to the south and east, but contacts are concealed under laterite and Quaternary sand.

The stratigraphic relationships of the cleaved rocks, the lithologies represented, and the north-south bedding and cleavage trends indicate that these rocks belong to the Tanami Group and are possibly part of the Nanny Goat Creek Formation.

Nongra Formation (Els) (provisional new name)

The Nongra Formation is composed of low-grade metamorphic volcanic and sedimentary rocks that crop out in the south-central part of the Birrindudu Sheet area. The main outcrops lie between the Ware and Birrindudu Ranges. Other outcrops mapped as possible Nongra Formation from air-photo interpretation occur to the southwest, extending into the Tanami Sheet area east of Stake Range. It was in this southern area that Brown (1909) noted exposures of 'auriferous rock formation'.

The formation is named after Nongra Lake, 36 km north of the main outcrop and 47 km due north of the type locality, where the formation is perhaps best exposed.

Gently undulating terrain and low rounded hills and ridges are the dominant landforms on the Nongra Formation, and the only breakaway is that at the type locality. The maximum local relief is probably less than 20 m. Exposures are mostly rubbly and bouldery and occur on slopes, crests, and in shallow gullies. Much of the outcrop area is covered by Quaternary superficial deposits and by laterite.

On the air-photographs, outcrops of Nongra Formation capped by laterite or lateritic gravel are dark-toned, but otherwise they are medium to very light-toned, and generally show bedding trends.

The formation has very steep to vertical dips, strikes northwest to northeast, and has a prominent cleavage generally parallel to the bedding. Hence it is probably tightly folded about nearly vertical fold axes, though no fold closures have been seen either in the field or on air-photographs. Neither the top nor bottom of the formation is exposed, and its thickness is unknown.

Lithology Rock types in the exposures examined are phyllite, shale, siltstone, greywacke, lithic sandstone, banded chert, tuff, and acid porphyry. The sedimentary rocks are generally thinly interbedded. Quartz veining and local brecciation are common.

The phyllite, shale and siltstone are mainly maroon or grey; the phyllite commonly has rust spots, possibly after sulphides. The greywacke is poorly sorted, fine to coarse, and maroon, purplish, brownish, or dark grey. It is made up of quartz grains (which form about 60 percent of the rock), lithic fragments (which are probably mostly of volcanic rocks), and minor detrital tourmaline and other heavy mineral grains, contained in an abundant iron-stained sericitic matrix. In places the greywacke is strongly cleaved. Compared with greywacke, the lithic sandstone is paler, better sorted, contains a higher percentage of quartz grains, and is mainly medium-grained. The banded chert is pink and grey, and may be silicified thin-bedded siltstone.

Of the two volcanic rocks, the tuff is micaceous, medium to fine, thinly to thickly bedded, and strongly cleaved. It contains little or no quartz. The other volcanic rock, acid porphyry, was found at only one outcrop, 7 km west of the type locality. It consists of about 10 percent of phenocrysts of partly resorbed quartz, altered feldspar, and altered ferromagnesian minerals set in a grey felsitic groundmass. The porphyry is cleaved and quartz-veined. Under the microscope the groundmass is seen to be a fine mosaic of quartz, sericite, and clay in which a vague eutaxitic or flow-banding texture is preserved.

The Nongra Formation has been affected by low-grade regional metamorphism. This is indicated by the regional cleavage and the presence of abundant secondary white mica. The rocks probably belong to the lowermost part of the greenschist facies. The absence of green minerals may be due to the much-weathered nature of the exposed rocks or may reflect the very low grade of metamorphism.

On outcrops capped by laterite, the only indication of the underlying rock types is provided by scattered rock fragments in the surface lateritic gravel. Fragments of quartz-tourmaline veins in lateritic gravel at the most easterly exposure of the Nongra Formation indicate possible thermal metamorphism and metasomatism by a concealed granitic intrusion (Winnecke Granophyre?)

Stratigraphic relationships and age. The Nongra Formation is unconformably overlain by Ware Range Sandstone. This unconformity is inferred from exposures in the central part of the main outcrop area, where gently dipping Ware Range Sandstone forms low bluffs to the north of steeply dipping cleaved greywacke, tuff, and other rocks; and also from exposures 18 km to the west, where Ware Range Sandstone lies northwest of more steeply dipping greywacke, phyllite and chert. At the latter locality conglomerate beds in the basal Ware Range Sandstone contain pebbles of jasper, chert, vein quartz, and other rock types probably derived from the underlying Nongra Formation. The Nongra Formation is inferred to be unconformably overlain by Gardiner Formation and Lower Cambrian Antrim Plateau Volcanics east of the Stake Range.

From its lithology, steep dips, cleavage, and regional metamorphism, the Nongra Formation can be correlated with the Mount Charles, Killi Killi, and Nanny Goat Creek Formations. Hence it is mapped as part of the Lower Proterozoic Tanami Group.

Helena Creek Formation (Blh) (provisional new name)

The Helena Creek Formation crops out in the northeast part of the Birrindudu Sheet area, southwest of Hooker Creek. The outcrop area is 16 km long from north-northeast to south-southwest and up to 3 km wide, and is crossed by Helena Creek, after which the formation is named. Only three exposures of the formation have been examined, and a type locality has not yet been selected. Dips have not been measured, as no bedding was observed, and the thickness of the formation is unknown.

The outcrop area consists of low rounded rises in the north which become higher to the south and pass into branching ridges up to 30 m high with closely spaced prominent spurs. On air-photographs the outcrops are mainly dark-toned. Closely spaced trend lines striking north-northeast are visible in the central and northern parts.

Lithology. The only rock types seen were coarse maroon lithic sandstone and conglomerate, exposed at the northern end of the outcrop area, and a reddish maroon rock thought to be tuff exposed in the south. The lithic sandstone and conglomerate form rubbly exposures on a low rise. The sandstone is similar to some of that in the Nanny Goat Creek Formation at the Wilson Creek waterholes. It is made up of subangular grains of quartz, chert, jasper, quartzite, phyllite, and porphyritic acid volcanics enclosed in a mainly sericitic matrix that forms about 10 percent of the rock; a quartz overgrowth cement is also present. The conglomerate has a similar composition to the sandstone and is made up of pebbles generally less than 2 cm across enclosed in a medium-grained sandy matrix.

The rock mapped as tuff is well exposed on the bluff at the southern end of the main outcrop. Here it is a well jointed, massive, fine-grained, iron-stained aggregate of quartz and sericitic material with some flakes of a pale green chloritic mineral and minor detrital tourmaline. Quartz forms less than 50 percent of the rock. To the southeast the rock has been thermally metamorphosed to quartz-veined quartzitic hornfels. Compared with other rocks seen in the Birrindudu-Tanami area, the tuff is most like tuff in the Nanny Goat Creek and Nongra Formations.

Stratigraphic relationships and age. The Helena Creek Formation is intruded by the Winnecke Granophyre. Contacts between them are concealed, but the intrusive relationship is indicated by the occurrence of thermally metamorphosed tuff adjacent to granite outcrops in the south. To the west the Helena Creek Formation is bounded by a fault, and to the north and east it is covered by Quaternary deposits.

The rock types seen within the Helena Creek Formation are more comparable to those found within the Nanny Goat Creek Formation than to those in any of the other formations in the area, and indicate that the Helena Creek Formation is probably part of the Lower Proterozoic Tanami Group.

UPPER PROTEROZOIC
(CARPENTARIAN OR ADELAIDEAN)

Mount Winnecke Formation (Buw)

The Mount Winnecke Formation consists predominantly of folded sandstone and intercalated acid volcanics which crop out mainly in the southeast part of the Birrindudu Sheet area, east of the Ware Range. The outcrops extend southward into the northernmost part of the Tanami Sheet area. Two small outcrops of acid volcanics mapped as Mount Winnecke Formation also occur further south in the Tanami Sheet area, 15 km east-northeast of Supplejack Downs homestead and 17 km northeast of Tanami (Fig. 12).

The formation was named the Mount Winnecke Sandstone by Traves (1955) after Mount Winnecke (15°46'06"E, 130°19'50"S). However, as the formation is composed of acid volcanics as well as sandstone, Mount Winnecke Formation is considered a more appropriate name.

The type area is the structural basin north of Mount Winnecke, and the type section is on the north side of this structure, where the maximum known thickness of the formation, about 4800 m, is exposed. Traves (1955) did not select a type area.

The sandstone is generally more resistant to erosion than the volcanics and crops out as steep-sided strike ridges and plateaux up to 50 m high, whereas the volcanics form topographic depressions or low rounded hills and gently undulating terrain (Fig. 19). Tuffaceous beds associated with the volcanics are intermediate in their resistance to erosion and form depressions between ridges on non-tuffaceous sandstone and ridges between outcrops of acid volcanics. These topographic relationships are well displayed north of Winnecke Creek. Most of the Quaternary sand in the outcrop area is probably underlain by acid volcanics and tuffaceous beds.

The sedimentary and volcanic rocks generally have moderate to steep dips and have been folded into large anticlinal and synclinal structures which are most evident in the Winnecke Range (Fig. 21).

Lithology The main rock types of the Mount Winnecke Formation are lithic sandstone, tuffaceous sandstone and siltstone, and acid lava. Also present are conglomerate, laminated tuff, lapilli tuff, and minor mudstone and agglomerate.

The lithic sandstone is pale grey where freshly exposed but weathered surfaces have reddish, brownish, maroon, and purple tints and mottles due to iron staining. It is mainly poorly sorted, medium to coarse or gritty, and generally forms beds more than 1 m thick. Pebbly beds occur in many places. Current bedding is almost ubiquitous, flaggy bedding is rare, and ripple marks are very rare. Cross-cutting quartz veins generally less than 1 cm thick are very common, in places forming complex box-works. Surface silicification is widespread and small cappings of silcrete occur locally.

The lithic sandstone is made up of about 80 percent quartz and quartzite grains, 10 percent lithic grains and 10 percent matrix. The lithic grains and matrix are generally white and consist mainly of kaolin. Some of the white grains are altered acid volcanic fragments, and others may be altered feldspar grains. Heavy minerals include zircon and rare tourmaline.

With increasing content of volcanic clasts the lithic sandstone grades into tuffaceous sandstone, which is more susceptible to weathering. Laterite cappings are common on tuffaceous sandstone, and iron-staining is more pronounced, resulting in deep maroon and purple colours. Compared with lithic sandstone, tuffaceous sandstone is more poorly sorted and more commonly coarse-grained and gritty. It forms beds over 1 m thick, typified by current bedding, and much thinner beds, 1 to 10 cm thick, marked by ripple marks. The thin beds of tuffaceous sandstone are commonly interbedded with tuffaceous siltstone (Fig. 26). The best exposures of the thinly bedded tuffaceous rocks are in the banks of incised creeks, and the most extensive outcrops are northwest of Mount Winnecke.

The tuffaceous sandstone (Fig. 27) is made up of over 15 percent volcanic rock fragments, and less than 75 percent quartz grains in a fine matrix that forms over 10 percent of the total rock. Altered feldspar grains are visible in some thin sections. Shards of altered volcanic glass have not been recognized in thin sections. Mica is a common constituent of the tuffaceous sandstone and also of the commonly associated tuffaceous siltstone.

Conglomerate is not widespread in the Mount Winnecke Formation, and where present it is generally associated with tuffaceous beds and acid volcanics. It contains clasts, generally less than 10 cm across, of vein quartz, quartzite, lithic sandstone, and tuffaceous and volcanic rocks. Good exposures occur 7 km north of Mount Winnecke, where conglomerate is interbedded with mainly tuffaceous sandstone forming a scarp face on the western edge of a sandstone plateau, and 27 km south of Mount Winnecke, where conglomerate overlies a thick acid lava and is in turn overlain by lithic sandstone.

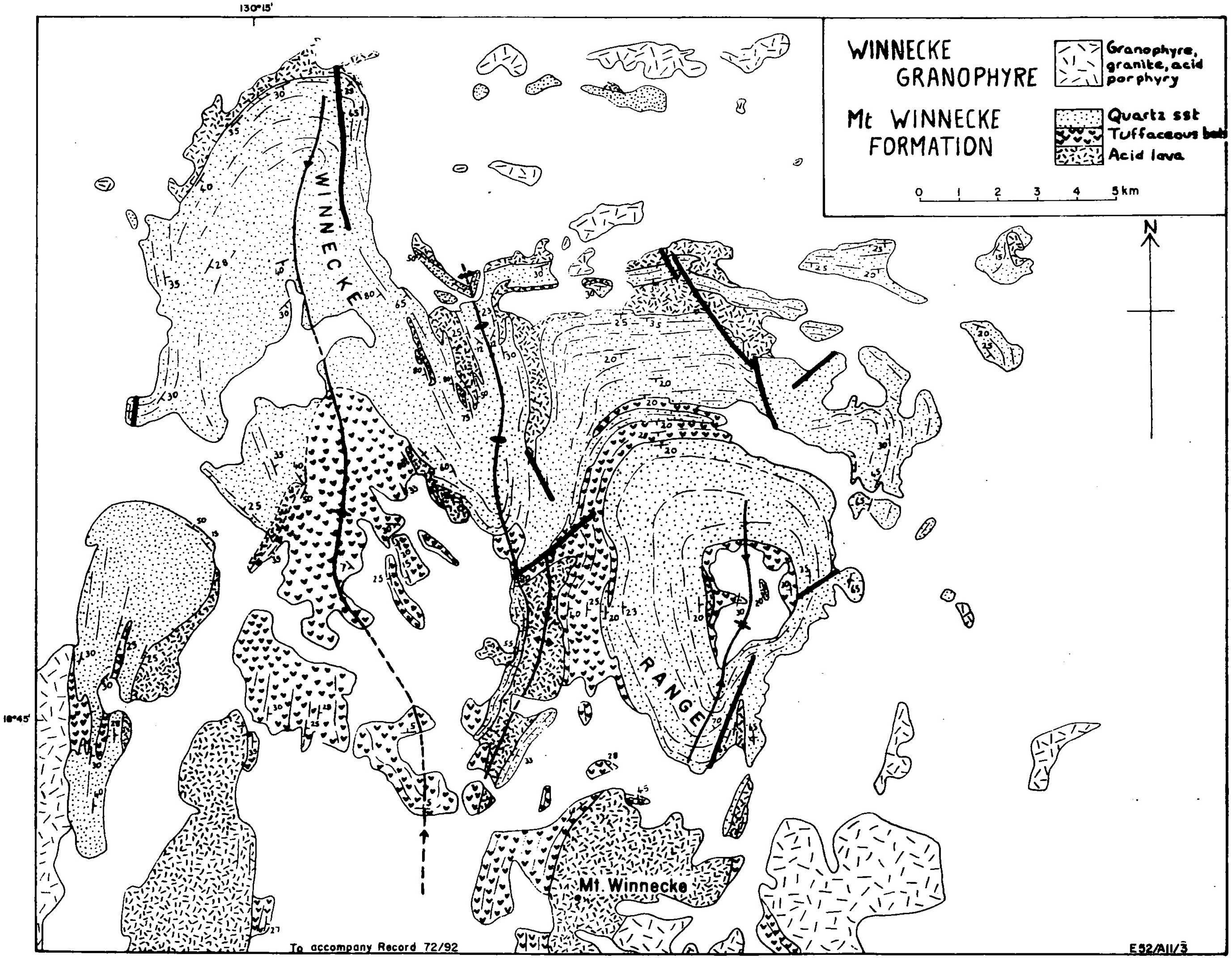

FIG 21–GEOLOGICAL MAP OF THE WINNECKE RANGE

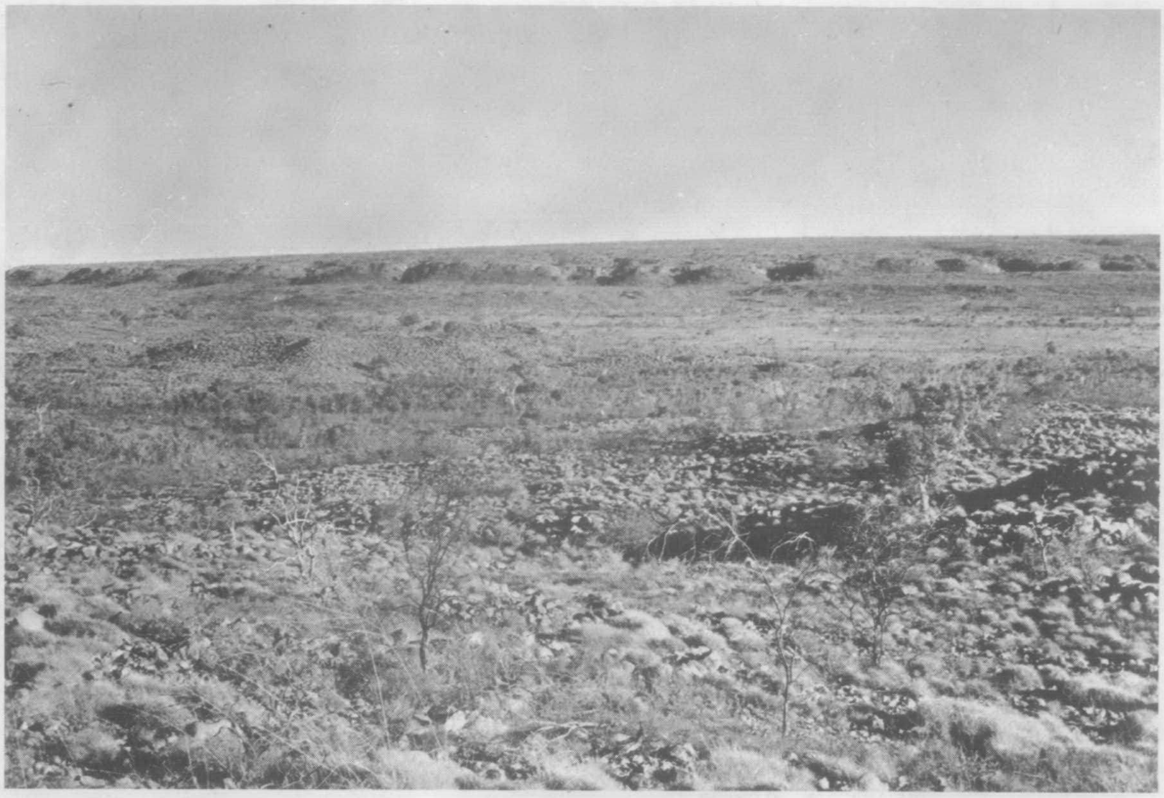

Fig 19 View south along part of the type section of the Mount Winnecke Formation. The depression between the sandstone rise in the foreground and the plateau-forming sandstone in the background is formed on mainly tuffaceous rocks. (Neg. GA/5734)

Fig 20 Stellate clusters of tourmaline on a joint surface in lithic sandstone close to the contact of the Mount Winnecke Formation and the Winnecke Granophyre west of Wilson Creek (Neg. GA/5690)

The acid lavas are exposed as pale buff or grey to deep maroon or purplish friable felsitic rocks. They are generally deeply weathered and relatively fresh surface samples can be obtained only from exposures of the interiors of the largest flows. Most of the lavas are porphyritic, containing up to 20 percent phenocrysts of feldspar and in most cases quartz. The phenocrysts are generally less than 1 cm across. The individual lava flows, like acid lavas elsewhere, are thick relative to their lateral extent, compared with basic lavas, and are dome-shaped. The thickest flow measured in the field was 200 m, but many are probably thicker. The interiors of the flows are massive and appear structureless, but their margins are blocky, due to autobrecciation, and are commonly scoriaceous. Many of the lavas also show contorted flow-banding at their edges (Fig. 23). The lavas pass laterally into bedded tuffaceous sedimentary rocks; this is well displayed in the northwest part of the type area.

Several specimens from acid lavas have been examined in thin section. Those that are porphyritic contain euhedral feldspar phenocrysts which in most specimens are completely pseudomorphed by clay or sericitic material (Figs 22 and 23). Where remnants of the original feldspars are preserved, they consist of either or both sodic plagioclase and alkali feldspar. Quartz phenocrysts are of the β-quartz type and show resorption features. Altered ferromagnesian phenocrysts and opaque microphenocrysts are also commonly present. The groundmass of the lavas probably consisted originally of microlites and glass or cryptocrystalline to microcrystalline quartz and feldspar, but now in most rocks it is a fine quartz mosaic. However, traces of the original texture can usually be discerned under ordinary light, where the outlines of the original microlites are indicated by dust particles or opaque material (Fig. 22). In a few of the freshest samples the groundmass consists of a fine mosaic of quartz and alkali feldspar with opaque granules and dust.

In scoriaceous lava the vesicles are infilled with quartz, celadonite, and, at one locality, diaspore and pyrophyllite. The latter two minerals are present in samples collected from the top of a non-porphyritic lava flow immediately underlying lithic sandstone 17 km south of Mount Winnecke. The diaspore is anhedral, unlike feldspar phenocrysts, and probably occupies small vesicles. Pyrophyllite in the same samples forms fine-grained mica-like aggregates associated with the diaspore, and is possibly an alteration product of the diaspore. The presence of both minerals indicates that the lava may once have contained alunite, a common sulphate mineral in hydrothermally altered acid lava. The two minerals were identified microscopically by W.B. Dallwitz, and by G.H. Berryman using X-ray diffraction.

The alteration of most of the acid lavas is due in part to surface weathering, but is probably due also to hydrothermal propylitization during and immediately after the extrusion of the acid magma.

Volcanic rocks associated with the lavas are medium to very fine tuff, lapilli tuff, and agglomerate. Medium to very fine tuff is well exposed on the northwest side of Mount Winnecke, overlying acid lava. Here, as elsewhere, the tuff is a very thinly bedded to laminated waterlaid deposit silicified in part to chert. Some of the beds show graded bedding. Where silicified the tuff is pale buff to greyish, otherwise it is maroon.

Lapilli tuff crops out 6 km south-southwest of Mount Winnecke (Figs 24 and 25) as nearly vertical maroon beds 1 to 2 m thick 'wrapped around' a core of quartzose to highly lithic and tuffaceous sandstone and conglomerate. The beds of lapilli tuff have poorly defined bedding planes. Each bed consists of unsorted fragments of non-porphyritic lava mostly less than 2 cm across, and probably represents a separate eruptive phase during a major eruption. The beds are interpreted as waterlaid deposits close to the eruptive site.

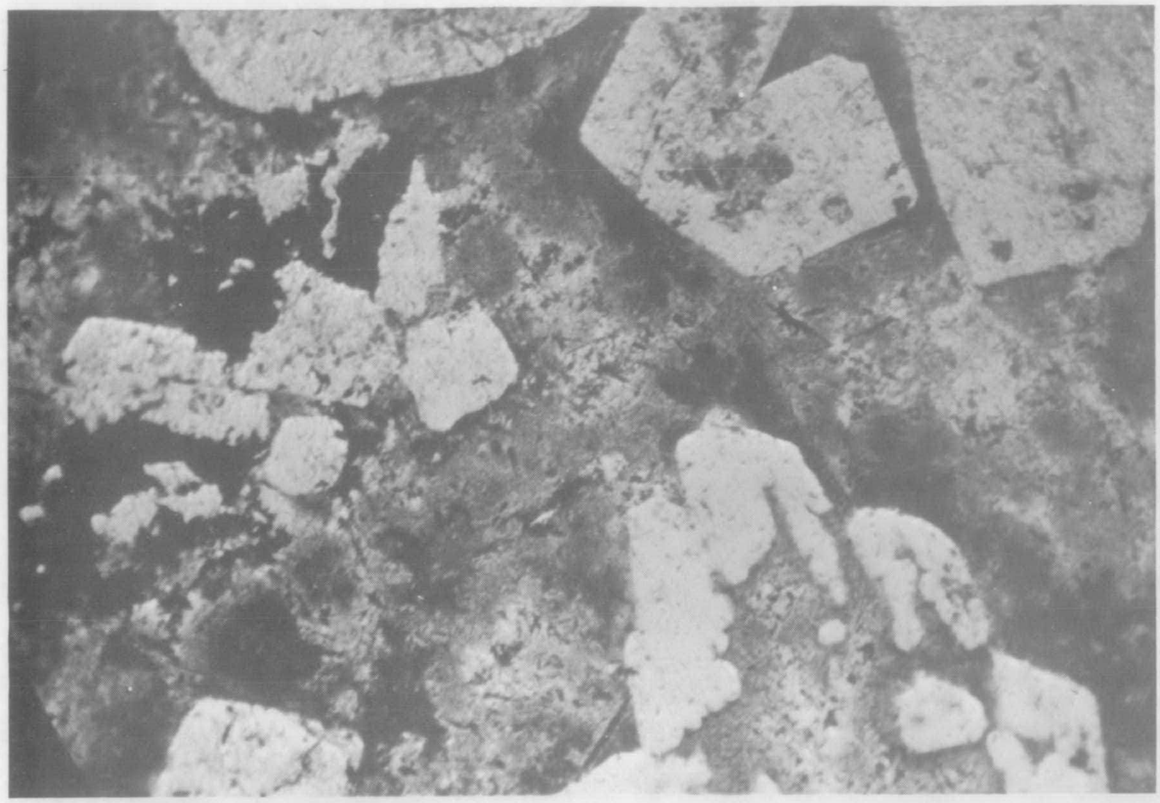

Fig 22 Photomicrograph of acid lava, Mount Winnecke Formation, showing euhedral phenocrysts of feldspar pseudomorphed by clay minerals. Some phenocrysts show resorption features. Crystallites visible in the groundmass are a primary feature of the originally glassy groundmass now recrystallized to a quartz mosaic. P.P.L., x 90 (Neg. M1293/2A)

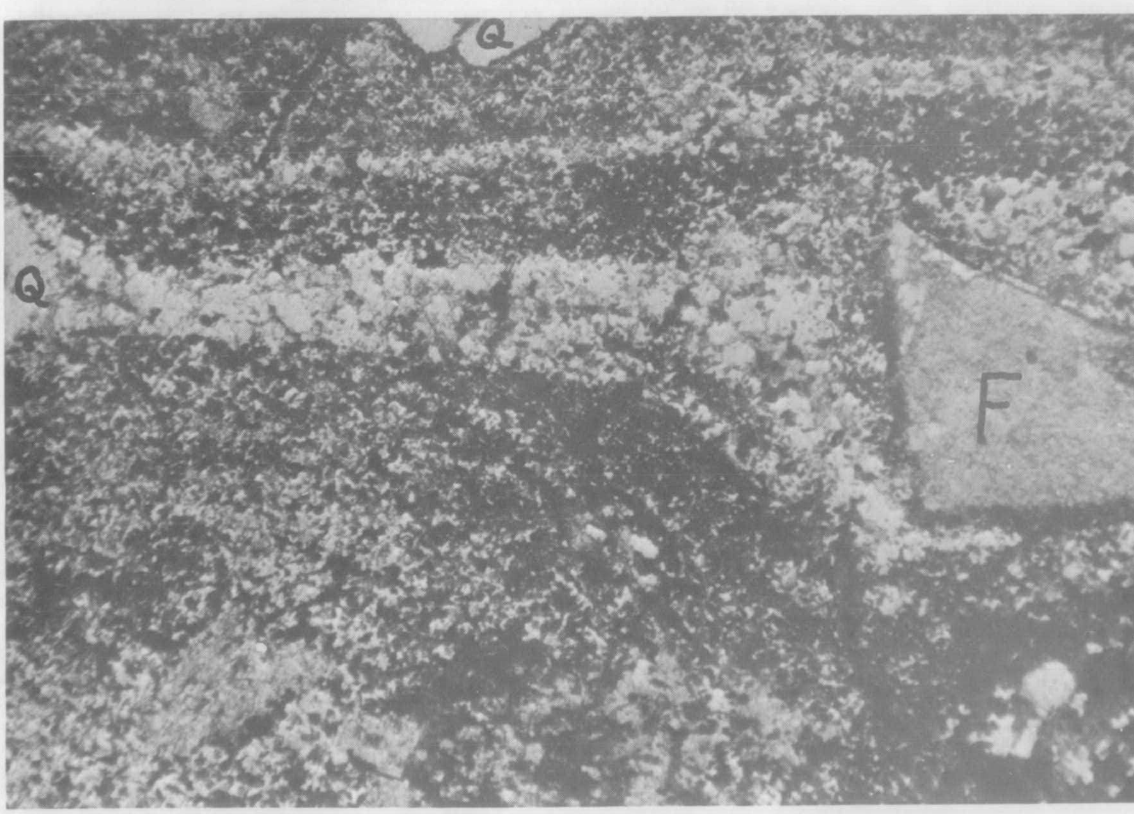

Fig 23 Photomicrograph of flow-banded acid lava, Mount Winnecke Formation, showing phenocrysts of altered feldspar (F) and partly resorbed quartz (Q) in a fine granular groundmass consisting mainly of quartz, iron oxide (opaque), and clay. P.P.L. x 90 (Neg. M1293/15A)

Fig 24 Steeply-dipping lapilli tuff of the Mount Winnecke Formation (Neg. GA/5728)

Fig 25 Lapilli tuff of the Mount Winnecke Formation. Close up of the beds shown in Fig 24. (Neg. GA/5745)

Agglomerate has been found only at one locality, a creek bed 15 km west-northwest of Mount Winnecke. It is made up of scattered fragments of sandstone and acid lava in a medium to fine tuffaceous matrix.

The following evidence indicates that most if not all of the acid volcanicity probably took place under water. Firstly the acid lava flows interfinger with current-bedded sandstone undoubtedly deposited in water. Secondly, where contacts are exposed, the acid lavas are directly overlain by waterlaid deposits, and not by air-fall pyroclastics as is commonly the case with sub-aerial acid lavas. Thirdly the tuffs associated with the acid lavas are waterlaid and not sub-aerial deposits. Fourthly, in spite of an abundance of fragmentary volcanic material, there appears to be a complete absence of ignimbritic rocks; such rocks would be expected unless the volcanic eruptions took place under water. Underwater eruptions could also help account for the highly altered nature of most of the acid lava, as the emission of acid magma into water would cause more extensive chilling than normal, leading to the formation of abundant hydrous volcanic glass that is especially susceptible to alteration by contemporaneous hydrothermal activity, metamorphism, and weathering.

Description of type area. Except for agglomerate, all the main rock types present in the formation are represented in the type area, the structural basin north of Mount Winnecke (Fig 21), and also in the type section on the north side of the basin. The type section is 9 km long and extends from 18°37'55"S, 130°21'20"E, the base of the exposed succession, to 18°42'40"S, 130°27'10"E. Within this section, which is described in Table 2, there is an almost completely exposed succession nearly 5 000 m thick (estimated from air-photographs) dipping south at 20° to 35°.

Table 2

TYPE SECTION OF THE MOUNT WINNECKE FORMATION

Thickness (m)	Top of section (southern end of section line)
200	Medium-grained tuffaceous sandstone dipping south beneath Quaternary sand. To west the sandstone overlaps onto scoriaceous and blocky, flow-banded, non-porphyritic, acid lava.
1 820	Mainly current-bedded, medium-grained lithic sandstone, generally well sorted. At base of unit, on northern edge of plateau, current-bedded, coarse to gritty sandstone containing well-rounded pebbles mainly of vein quartz and acid volcanic rocks overlies 15 m of medium to coarse lithic sandstone.
280	Thin-bedded tuffaceous sandstone and siltstone forming topographic depression; some interbeds of lithic sandstone.
140	Current-bedded, mainly coarse lithic sandstone forming low ridge.
140	Current-bedded, coarse and gritty tuffaceous sandstone forming depression.
1 220	Plateau-forming sandstone. Medium to coarse lithic sandstone, locally gritty and pebbly.
520	Acid lava containing feldspar phenocrysts, forms depression, with exposures confined to incised creeks; lateritic weathering profiles developed locally.
230	Medium to coarse current-bedded lithic sandstone; forms southern part of strike ridge.
250	Acid lava containing quartz and feldspar phenocrysts forms northern part of strike ridge. Sand plain to north.
Total 4 800	Base of exposed succession

<u>Descriptions of other areas</u>. Northwest of the type area a sequence of lithic sandstone and intercalated acid lava flows is well displayed on the western limb of a southerly-plunging anticline (Fig. 21). The lowest lava in the sequence forms part of a low ridge on the east side of the Tanami/Hooker Creek track. It contains phenocrysts of quartz and feldspar and is probably the same as that at the base of the sequence exposed in the type section. It is separated by about 350 m of mainly lithic sandstone from a group of younger acid lava flows that interfinger with sandstone to the south. Two further flows occur slightly higher in the succession, within a sequence of mainly lithic sandstone beds.

West of the Tanami/Hooker Creek track, at the northern end of Winnecke Range, acid lava underlies a thick sequence of lithic sandstone that has been folded to form a southerly plunging syncline. To the south, east of Pattie Creek, tuffaceous beds and some acid lavas crop out in the core of the syncline. To the west, outcrops of tuffaceous beds are separated from an older sequence of sandstone and volcanics by a sand plain. This older sequence, exposed on the west side of the track, consists of lithic sandstone with intercalations of tuffaceous sandstone, acid lava, and agglomerate. The beds here generally dip 25° to 30° east except in the south, where sandstones are irregularly contorted.

South of Winnecke Creek the sequence is dominated by acid lavas, both porphyritic and non porphyritic, but also includes some very thin-bedded to laminated tuff, lapilli tuff, and thin-bedded tuffaceous sandstone and siltstone. Here lithic sandstone is largely confined to the east, where it forms two parallel strike ridges trending north-south about 10 km apart. The sandstone of the west ridge directly overlies the autobrecciated top of a thick acid lava, and fragments of the lava are incorporated in the basal sandstone beds. The sandstone forming the east ridge has been strongly sheared and is schistose, with a schistosity developed parallel to the vertical bedding.

The most easterly outcrop of the formation is a synclinal ridge of lithic sandstone in the southeast corner of the Birrindudu Sheet area and the northeast corner of the Tanami Sheet area.

Acid lava mapped as Mount Winnecke Formation crops out at two localities farther south in the Tanami Sheet area. At one outcrop, 17 km northeast of Tanami, quartz feldspar porphyry forms isolated low mounds. Unlike nearby Lower Proterozoic rocks, the porphyry is uncleaved, and it is thought to overlie unconformably the Lower Proterozoic and to be overlain unconformably by sandstone of the Gardiner Formation. At the other locality, 15 km east-northeast of Supplejack Downs homestead, quartz feldspar porphyry underlies northerly dipping Supplejack Downs Sandstone.

The outcrops mapped as possible Mount Winnecke Formation 20 km west of Pattie Creek, in the Birrindudu Sheet area, consist of current-bedded lithic sandstone which has moderate to steep dips and appears to be folded into a northerly-trending syncline. It is faulted to the west against the Ware Range Sandstone, which dips consistently northeast at a low angle. The difference in bedding attitudes indicates that the sandstone east of the fault is probably older than that to the west and an unconformity may separate them. If so, the older sandstone can probably be correlated with the Mount Winnecke Formation.

Stratigraphic relationships, correlations and age. The Mount Winnecke Formation is intruded by the Winnecke Granophyre and is possibly faulted against the Ware Range Sandstone to the west. East of Supplejack Downs homestead it is overlain, possibly unconformably, by Supplejack Downs Sandstone. In the Black Hills area it is probably unconformable on Mount Charles Formation and is overlain, probably unconformably, by Gardiner Formation. The Mount Winnecke Formation is overlain unconformably by Cambrian rocks east of the Winnecke Range, but the unconformity was not seen in the field.

Contacts between the Mount Winnecke Formation and the Winnecke Granophyre are exposed east of the Tanami/Hooker Creek track south of Winnecke Creek, and on the west side of the track north of Winnecke Creek. At the first locality an irregular subhorizontal roof contact is exposed where lithic sandstone caps low hills of deeply weathered granophyre. At the sharp intrusive contact both the sandstone and the granophyre have been affected by greisenization, and the sandstone has been thermally metamorphosed and metasomatized to a tourmaline-bearing quartzitic hornfels (Fig. 20). The tourmaline commonly forms stellate clusters of crystals several centimetres long. Farther north, on the west side of the track, the intrusive contact dips steeply east, the granophyre cropping out to the west. The contact rocks exposed are altered granophyre, slightly hornfelsic but not metasomatized sandstone, and, in the most northern exposure, acid lava. Some shearing has taken place parallel to the contact, mainly affecting the granophyre. At both localities only sandstone within a few metres of the contact has been affected by thermal metamorphism.

North of the type area, low hills of Winnecke Granophyre occur in juxtaposition to low hills of Mount Winnecke Formation, but contacts between the two units were not seen. Here, north of Gum Creek, sandstone of the Mount Winnecke Formation is thermally metamorphosed to quartzite, but associated acid lava appears little affected.

The lack of much thermal metamorphism of the country rocks and the contact relationships indicate that the Winnecke Granophyre was intruded at a high level, and it is thought probable that the intrusive rocks forming the Winnecke Granophyre and the volcanics of the Mount Winnecke Formation were comagmatic, and hence are essentially of the same age.

The unconformable relationship between the Mount Winnecke Formation and Cambrian rocks to the east is evident from the flat-lying attitude of the Cambrian rocks, in comparison with the adjacent steeply dipping Mount Winnecke Formation.

The Mount Winnecke Formation is considered to be younger than the Lower Proterozoic rocks in the area, as it is less tightly folded and is essentially uncleaved. Similarly the formation is probably older than the Ware Range Sandstone to the west, from which it is separated by a major fault. The Ware Range Sandstone has shallower dips and is not intruded by the Winnecke Granophyre. From these considerations the Mount Winnecke Formation is tentatively correlated with the Whitewater Volcanics, which occur at the base of the Carpentarian sequence in the east Kimberley region (Dow & Gemuts, 1970). This age problem should be resolved when the Winnecke Granophyre and possibly some of the acid lavas of the Mount Winnecke Formation have been isotopically dated.

Winnecke Granophyre (Bgw)

Granophyre, granite, and intrusive acid porphyry are extensively exposed in the eastern part of the Birrindudu Sheet area, and outcrops extend south into the northeastern part of the Tanami Sheet area. These rocks are mapped as Winnecke Granophyre, a name proposed by Traves (1955) for granophyre cropping out in the upper reaches of Winnecke Creek and its tributaries. Granite and intrusive porphyry were previously recorded in the Winnecke Creek area by Jensen (1915). The unit is well exposed on the west side of the Tanami/ Hooker Creek track north of Winnecke Creek, at 18°46'S, 130°12'E, and this is selected as the type area. Over much of its outcrop area the Winnecke Granophyre is capped by laterite.

At most exposures the granite, granophyre, and porphyry are soft, friable, and much altered, mainly due to weathering. These exposures commonly occur in breakaways up to 10 m high below flat laterite-capped surfaces (Fig. 29) and, south of Winnecke Creek, on inselbergs rising up to 20 m above the sand plain (Fig. 28). The larger inselbergs have flat cappings of laterite which represent remnants of a former extensive laterite surface.

Fig 26 Exposure of gently-dipping tuffaceous sandstone and siltstone of the Mount Winnecke Formation (Neg. GA/5730)

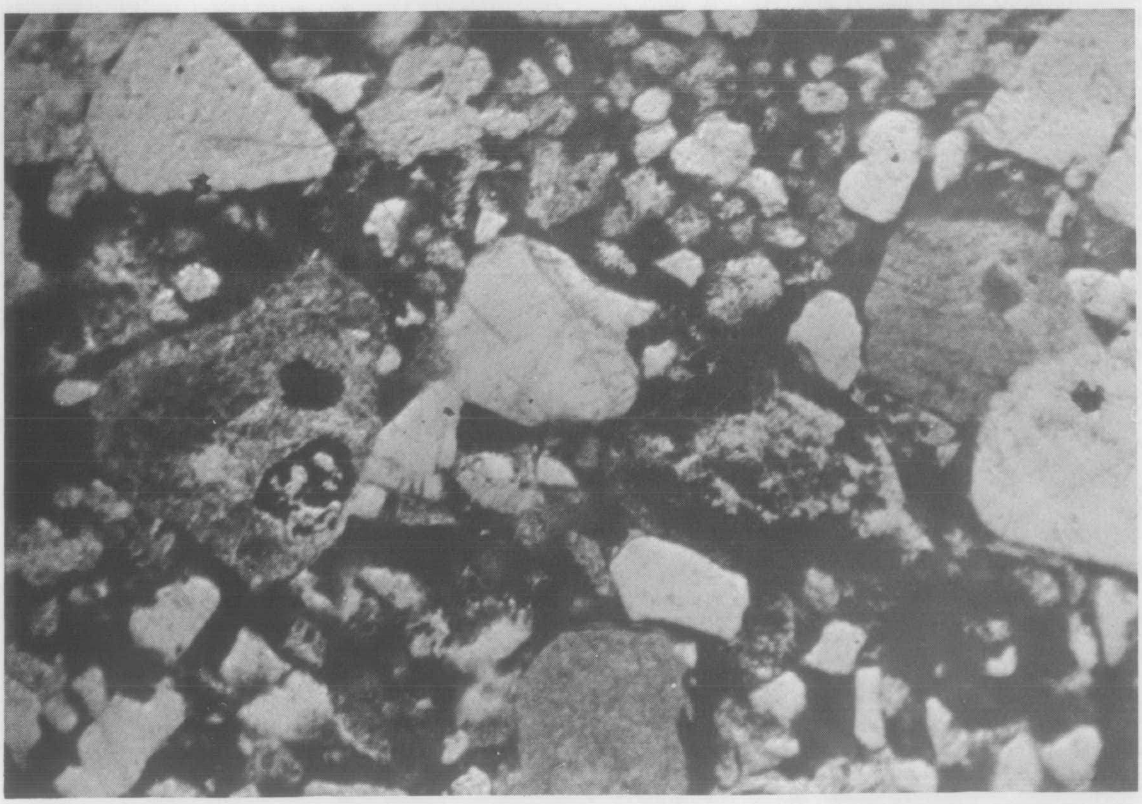

Fig 27 Photomicrograph of ironstained tuffaceous sandstone, Mount Winnecke Formation; showing poorly sorted grains of quartz and various rock fragments. P.P.L. x 90 (Neg. M1293/17A)

Fig 28 Inselbergs of Winnecke Granophyre in the northeast part of the Tanami Sheet area. (Neg. GA/5703)

Fig 29 Exposures of mainly lateritized Winnecke Granophyre in breakaways east of the Ware Range. (Neg. GA/5755)

The depth of weathering is very variable, and in places fresh unweathered granophyre, granite, and porphyry occur less than 5 m below the top of the laterite capping. Exposures of fresh rock consist of spheroidal boulders and smooth rounded surfaces forming mounds, low hillocks, and tors (Fig. 30). Such exposures of granophyre and to a lesser extent porphyry are extensively developed in the type area. Exposures of slightly altered granophyre are generally similar except that the boulders and surfaces of bare rock are angular rather than rounded.

On air-photographs the unweathered and slightly weathered exposures show up mainly as medium to dark-toned areas that commonly show strong jointing, whereas the much weathered exposures are typically light-toned and unjointed.

Granophyre and granite are shades of pink when fresh, and white, yellow, reddish brown, or maroon when weathered. Both contain biotite as the predominant primary ferromagnesian mineral. Phenocrysts of feldspar up to 1 cm long are commonly present in the granophyre, as also are small drusy cavities now unfilled with quartz, chlorite, epidote, and, in one sample, prehnite. Graphic textures are often visible in hand specimens. The granite is mostly non-porphyritic, though feldspar phenocrysts up to 3 cm long are present locally. Some of these phenocrysts poikilitically enclose groundmass minerals. Intrusive porphyry is associated with the granophyre and granite but is less widespread. It typically consists of 20 to 30 percent phenocrysts of quartz, pink and white feldspar, and dark ferromagnesian minerals set in a maroon to dark grey groundmass. Most of the phenocrysts are 5 to 10 mm long and are generally larger and form a higher percentage of the total rock than those in the porphyritic acid lavas of the Mount Winnecke Formation. However the distinction between the two is not always clear, and some of the porphyry mapped as Winnecke Granophyre, such as that in the southeast corner of the Birrindudu Sheet area, may be extrusive and part of the Mount Winnecke Formation.

Quartz veins and small xenoliths rich in biotite are common in all of the three main intrusive rock types, and greisens occur locally, mainly near intrusive contacts with the Mount Winnecke Formation.

In places the granophyre and granite are cut by dykes, some of which are offset along major joints or faults. These dykes are fine-grained and generally non-porphyritic. Some are of leucocratic microgranite and granophyre, but others are much darker and may be andesitic in composition. The latter commonly show flow-banding, and one such dyke, cutting sheared granite on the west side of the/Tanami Hooker Creek track north of Gum Creek, contains small slivers and rounded fragments of granite.

The granophyre and granite are locally sheared, and in some places schistose rocks are developed, as in Winnecke Creek 13 km northeast of Mount Winnecke. Similar rocks also form inselbergs 8 km south-southeast of Mount Winnecke. The shear planes are approximately vertical and, like the commonly associated quartz veins, mostly strike north-south.

Some of the large quartz veins cutting the Winnecke Granophyre are several metres wide and incorporate fragments of sheared granite and granophyre and also volcanic and sedimentary rocks presumably derived from the Mount Winnecke Formation. These large quartz veins are probably developed along faults.

Cross-sections of the laterite capping the Winnecke Granophyre are well exposed in the west in breakaways. Here pisolitic laterite 1 to 2 m thick overlies a zone generally more than 5 m thick of mottled and iron-stained much altered granitic rock. An underlying pallid zone is exposed in places, mainly in incised gullies. Cross-cutting quartz veins are preserved undisturbed within the laterite and in several places form ridges rising above the general laterite surface. Where quartz ridges are not developed, the presence of quartz veins is indicated by quartz rubble, which shows up as readily visible white patches on air-photographs. East of the western breakaways the lateritic weathering profile is generally incomplete, as the pisolitic upper zone is absent, and the cappings consist mainly of partly

Fig 30 Spheroidal boulders of fresh Winnecke Granophyre east of the Ware Range. (Neg. GA/5753)

Fig 31 Strongly weathered unnamed granite near Lake Buck. (Neg. GA/5691)

silicified mottled material. This forms low, smoothly rounded rises between broad drainage depressions. The laterite is covered by thin layers of wind-blown sand.

Lithology The granophyre consists essentially of quartz, variably turbid alkali feldspar, sodic plagioclase, and brown biotite. Quartz is mostly confined to the groundmass, but occurs as phenocrysts in some specimens (Fig. 32). The alkali feldspar is orthoclase in some specimens, microcline in others, and is commonly microperthitic: it is present both as euhedral phenocrysts and in the groundmass, where it is mostly in micrographic intergrowths with quartz. In some specimens alkali feldspar phenocrysts appear to be replaced by micrographic quartz and alkali feldspar. Part or complete alteration of alkali feldspar to kaolin is very common. Plagioclase, mostly in the form of euhedral phenocrysts of oligoclase - andesine, is generally subordinate to alkali feldspar, and typically is more altered, mainly to sericite and kaolin. Biotite is present as phenocrysts, as fine-grained crystal aggregates that may represent small xenoliths, and as small flakes in the groundmass. It shows secondary alteration to green mica, chlorite, iron oxide and, in much altered specimens, kaolin. Green hornblende and pseudomorphs possibly after fayalite occur with biotite in a specimen collected 19 km southwest of Mount Winnecke. Primary and secondary minerals present in minor amounts are allanite, apatite, clinozoisite, epidote, fluorite, leucoxene, opaque iron oxides, sphene, zircon, and undentified metamict minerals.

The granite is similar mineralogically to the granophyre, but is coarser-grained, mostly non-porphyritic, and has a predominantly granitic rather than graphic texture. However, small patches of graphic quartz and alkali feldspar are common and in places granite probably grades into granophyre. Alkali feldspar and plagioclase are present in about equal proportions, hence the granite is classified as biotite adamellite. The colour index is generally between 5 and 10.

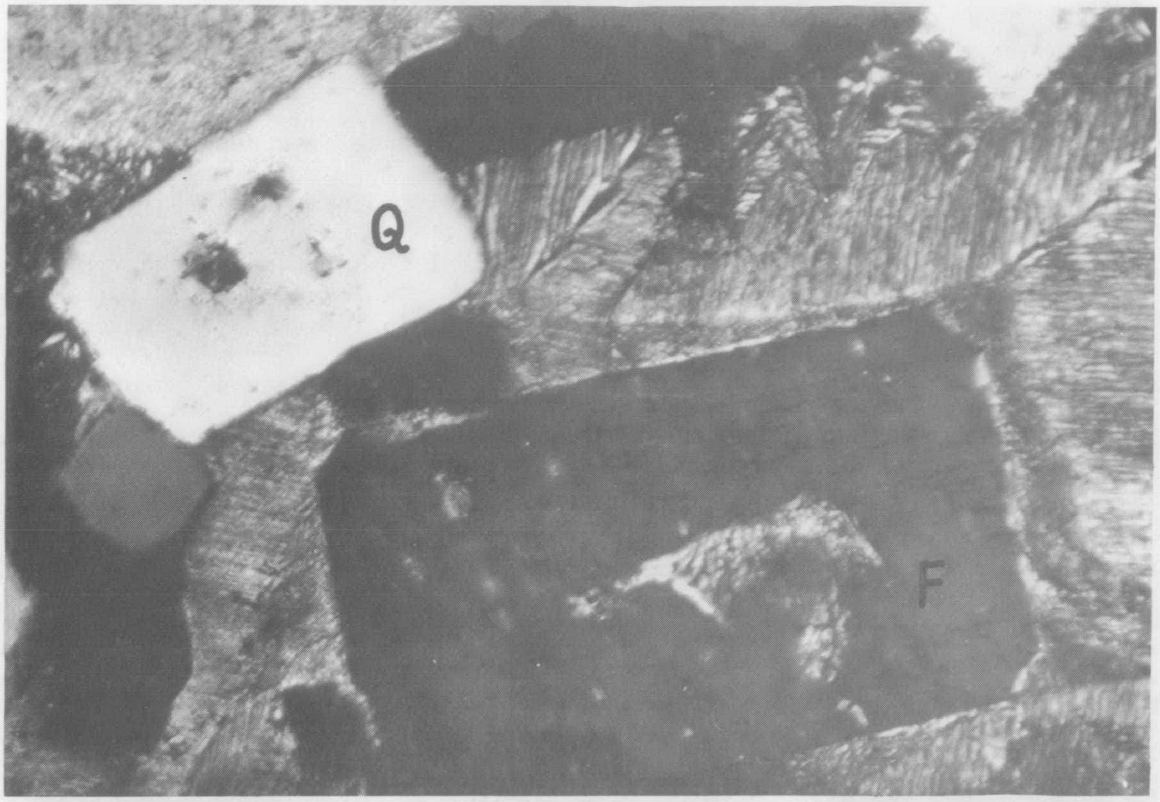

Fig 32 Photomicrograph of porphyritic granophyre; euhedral phenocrysts of quartz (Q) and partly resorbed alkali feldspar (F) in a very fine-grained micrographic network of quartz (white) and feldspar (dark). Winnecke Granophyre. C.N. x 250 (Neg. M1293/23)

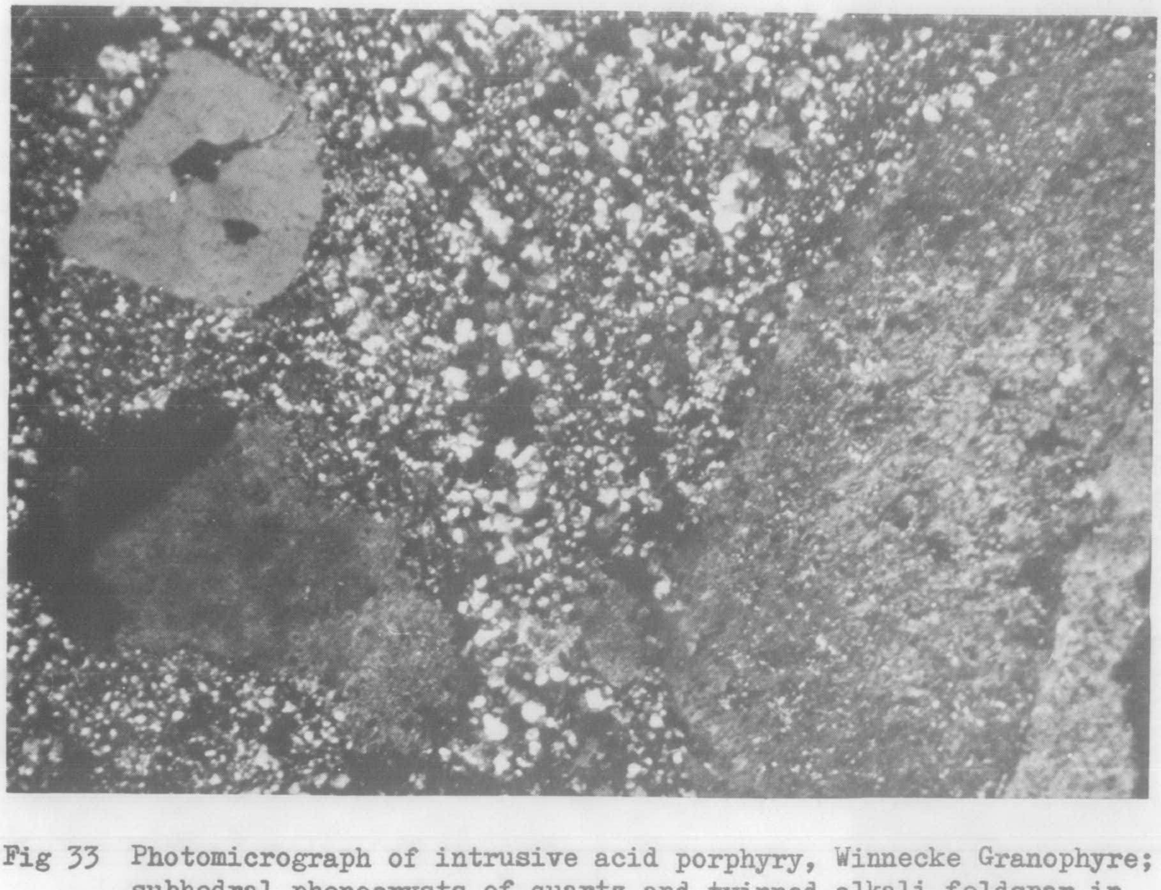

Fig 33 Photomicrograph of intrusive acid porphyry, Winnecke Granophyre; subhedral phenocrysts of quartz and twinned alkali feldspar in a micrographic groundmass. C.N. x 90 (Neg. M1293/5A)

The much altered granite and granophyre that are bleached white consist of primary quartz and secondary kaolin, in some specimens accompanied by sericite. The kaolin pseudomorphs the original feldspar and biotite.

The porphyry (Fig. 33) contains euhedral to subhedral phenocrysts of quartz, plagioclase ranging from albite to labradorite (An 50), orthoclase, biotite, and, in some specimens, blue tourmaline and hypersthene. Accessory and secondary minerals are similar to those in the granophyre. The phenocrysts are set in a fine to very fine-grained granitic and patchily graphic mosaic of quartz and alkali feldspar, with opaque granules, flakes of biotite or chlorite, and microphenocrysts of plagioclase.

Relationships and age. The Winnecke Granophyre intrudes the Mount Winnecke Formation and is overlain unconformably by the Antrim Plateau Volcanics. It probably intrudes the Helena Creek and Nanny Goat Creek Formations of Lower Proterozoic age in the north and south respectively, but contacts are concealed beneath Quaternary sand. A major fault separates the Winnecke Granophyre from the Ware Range Sandstone to the west.

The intrusive contacts with the Mount Winnecke Formation are exposed at several localities in the Birrindudu Sheet area. Irregular roof contacts can be seen on low hills 22 km southwest of Mount Winnecke: the contact rocks are affected by greisenization and tourmalinization, and the sandstone within a few metres of the underlying granophyre is thermally metamorphosed to quartzite. The granophyre here is deeply weathered, and is cut by fine-grained dyke rocks. Steeply dipping contacts between altered granophyre and slightly hornfelsic sedimentary rocks are exposed 18 km west-northwest of Mount Winnecke and a steep contact between unweathered intrusive porphyry and hornfelsic quartzite is exposed 8 km southeast of Mount Winnecke. Nowhere is the metamorphic aureole around the Winnecke Granophyre more than a few metres wide.

The field relationships and petrographic evidence indicate firstly, that the Winnecke Granophyre is probably made up of several separate high-level intrusions closely related to one another in time and space, and secondly that these intrusions were probably comagmatic with the acid volcanic rocks of the Mount Winnecke Formation. Hence the intrusive rocks are probably the same age as the Mount Winnecke Formation, which is tentatively considered to be lowermost Carpentarian. The Winnecke Granophyre may also be comagmatic with the unnamed granite cropping out to the south and west.

The Winnecke Granophyre is probably older than the Ware Range Sandstone and the succeeding Talbot Well Formation. The latter formation includes sandstone containing grains of granophyre that may be derived from the Winnecke Granophyre.

The contact between the Winnecke Granophyre and the overlying Lower Cambrian Antrim Plateau Volcanics is exposed on hills 20 km west of the 28-mile bore on Hooker Creek. At this locality weathered medium-grained granitic greisen is overlain by a basalt lava flow.

Unnamed granite (Bg)

Unnamed granitic rocks form the central parts of the Browns Range Dome southwest of Birrindudu and the Coomarie Dome northwest of Tanami, and also occur northeast of Tanami on the east side of Black Hills. The granitic rocks form flat to very gently undulating terrain, and are very poorly exposed, mostly being concealed beneath Quaternary sediments.

The granite of the Browns Range Dome is exposed near the northeast and southwest sides of the dome, in the Birrindudu and Tanami Sheet areas respectively, but is mostly concealed under Quaternary sand. Exposures of kaolinised granite on the north side of the dome were recorded by Davidson (1905) and Brown (1909). Where exposed, the granite consists of quartz, white mica, and white altered feldspar. It is mainly medium-grained, but is locally coarse to pegmatitic. Schistose varieties also occur in the southwest at the contact with schistose greywacke of the Killi Killi Formation and in the northeast where doubtful Killi Killi Formation is exposed. Northwest of this locality normal granite is overlain unconformably by younger sandstone of the Gardiner Formation. A few hundred metres south of the unconformity the granite is cut by several quartz veins and has some small patches of silcrete developed upon it. Low rises of granite capped by laterite have been photo-interpreted in the northeast and south.

The granite of the Coomarie Dome is not exposed but is known from numerous holes drilled in 1971. It is overlain by Quaternary sand mostly 1 to 3 m thick but ranging to more than 20 m thick locally, and also, in the west and east, by Tertiary travertine that in places is more than 10 m thick. The granite underlying the Cainozoic deposits is either lateritized and silicified to a reddish brown rock with bleached mottles, or is altered to yellowish brown clayey to sandy disaggregated granite. Relatively fresh granite was intersected at depths of 30 m to 80 m in a series of vertical holes drilled along two lines across the dome. The granite here is mainly medium-grained and non-porphyritic, and consists of quartz, pink feldspar largely altered to clay, and either or both muscovite and biotite; greisen, pegmatite, and quartz veins occur locally. At one drill hole, No. 25, 19 km northwest of Tanami, a gabbroic rock was intersected below 23 m of sand and was cored at 48 m. It consists of zoned plagioclase mostly altered to sericite, brown hornblende, clinopyroxene, orthopyroxene, brown biotite, opaque minerals, and some interstitial quartz.

The Coomarie Dome granite intrudes and has thermally metamorphosed Mount Charles Formation to the south and is overlain by unmetamorphosed shale and sandstone of the Gardiner Formation to the east, north, and west. A small outcrop of Mount Charles Formation capped by laterite 40 km north-west of Tanami may be a small roof pendant.

The granite east of the Black Hills was previously known from small outcrops northeast and east-northeast of Mount Charles (Roberts, 1968), and in 1971 was intersected to the south in drill holes Nos 54 to 61 and 63 to 65. At the surface exposures strongly weathered pink granite (Fig. 31) made up of quartz and altered feldspar and mica is associated with several major quartz veins trending west to northwest. In the drill holes the granite encountered is generally similar to that of the Coomarie Dome except that some is porphyritic. The least altered granite was in drill hole No. 60, 40 km east-northeast of Tanami, at a depth of 20 m. It consists of phenocrysts up to 5 mm long of plagioclase and microcline set in a medium-grained granitic groundmass of quartz, microcline, intensely pleochroic biotite, and accessory apatite, epidote, sphene, and zircon; the plagioclase is largely altered to sericite but the microcline is quite fresh. A medium-grained gabbroic rock occurs in drill hole No. 64, 53 km east-northeast of Tanami, underlying limestone at a depth of 24 m. In the core taken at 53 m the rock consists of plagioclase, mostly altered to sericite or clay, pale green to brown amphibole, brown biotite, accessory apatite, and minor interstitial quartz; unlike the gabbroic rock of the Coomarie Dome granite, it does not contain pyroxene.

In the west the granite has intruded and thermally metamorphosed basalt of the Mount Charles Formation, and in the east it is overlain by younger sediments that are possibly of Cambrian age and also by Tertiary travertine. It is not seen in contact with the Gardiner Formation.

The unnamed granitic rocks in the three areas are generally similar petrographically and are likely to be similar in age. They intrude rocks of the Lower Proterozoic Tanami Group, and in two of the areas they are overlain unconformably by the Gardiner Formation, which is Carpentarian or Adelaidean. In the other area, east of the Black Hills, the granite is unconformably overlain by sediments of probably Cambrian age. These relationships indicate that the unnamed granitic rocks may be Lower Carpentarian. If so they can probably be correlated with the Winnecke Granophyre.

Supplejack Downs Sandstone (Bus) (provisional new name)

Irregularly folded lithic sandstone and orthoquartzite cropping out in the northeast part of the Tanami Sheet area south of the Ware Range are mapped as the Supplejack Downs Sandstone. The name is derived from Supplejack Downs homestead, on the west side of the outcrop area. The formation forms narrow strike ridges and broad undulating to flat-topped ridges mostly less than 30 m high. The ridges are separated by sand plains. Vegetation is generally sparse on the ridges, and the formation is well exposed on steep slopes, in gullies, and on bluffs. On gentle slopes and crests exposures are mainly rubbly, commonly consisting of displaced small angular blocks and chips. Cappings of lateritic gravel and pisolitic laterite about 1 m thick are common on broad ridge crests, and small patches of iron-stained silcrete occur locally.

The formation has been folded to form irregular open and locally tight folds, and is affected by many faults, some of which are marked by quartz veins. Because of this, and because of the disconnected exposures, no succession has been established within the formation. For the same reasons the thickness of the formation is not known. The maximum thickness exposed is about 1300 m. A type section has been selected at the southern end of a strike ridge 11 km east of Supplejack Downs homestead.

Lithology. Where exposed, the formation consists of lithic sandstone, orthoquartzite, and minor shale and siltstone. However, the shale and siltstone are more readily eroded than the sandstone, and may underlie much of the area covered by sand plain. At the type section about 6 m of interbedded lithic sandstone and orthoquartzite are exposed, dipping 20^{o} northwest.

The sandstone is mostly pale pink or mauve to deep maroon and less commonly white to grey. It forms beds that are generally less than 1 m thick and are locally flaggy. Bedding planes are commonly undulating, and most beds show current bedding. Many weathered surfaces, especially on ridge crests, are silicified. Both the lithic sandstone and orthoquartzite are generally well sorted and medium-grained, but range from fine to coarse and in places contain small mudstone pellets. Some rare lenses of conglomeratic sandstone are present locally. Quartz veining is a characteristic feature, and there is much shearing and brecciation. This is normally steeply inclined to vertical but is locally horizontal, as along the northern edge of the outcrop area.

The orthoquartzite consists predominantly of quartz grains, lithic grains making up less than 5 percent of the rock. Some quartz grains are quite turbid and some contain small flecks of sericite; these grains may be pseodomorphs after feldspar. The orthoquartzite has a quartz overgrowth cement and little or no matrix. The lithic sandstone is similar to the orthoquartzite but has 5 to 20 percent of lithic grains, and locally contains over 10 percent of altered clayey matrix (mainly sericite and kaolin). Most of the lithic grains in both types of sandstone are white or pink in hand specimen and turbid in thin section, where they consist generally of a fine to very fine mosaic of quartz. Some contain tabular 'microphenocrysts' of quartz that may be pseudomorphing feldspar. These lithic grains are probably derived from acid volcanic rocks. Other lithic grains are of chert, phyllite, quartzite, and altered basalt. Heavy minerals present include relatively abundant blue and yellow tourmaline, minor zircon, and opaques.

Stratigraphic relationships and age. The Supplejack Downs Sandstone unconformably overlies the Lower Proterozoic Nanny Goat Creek Formation and is overlain unconformably by the Antrim Plateau Volcanics, which are Lower Cambrian. It also overlies acid porphyry mapped as Mount Winnecke Formation 15 km east-northeast of Supplejack Downs homestead, but it is not known whether this is a conformable contact. The relationships of the Supplejack Downs Sandstone to the Gardiner Formation to the west and the Ware Range Sandstone to the north is uncertain, as contacts are not exposed. The Supplejack Downs Sandstone dips consistently westwards in the west, and almost certainly underlies either conformably or, perhaps more likely, unconformably the Gardiner Formation.

The lithic grains in the sandstone may be derived from both the Nanny Goat Creek and Mount Winnecke Formations.

Contacts with the Nanny Goat Creek Formation are exposed along the northern edge of the outcrop area, where nearly vertical beds of the Supplejack Downs Sandstone cut across cleaved rocks of the older formation. The contact is faulted in the east but is probably an unconformity in the west. Southeast of Supplejack Downs homestead, vertically cleaved Lower Proterozoic rocks mapped as possible Nanny Goat Creek Formation pass under gently dipping beds of the Supplejack Downs Sandstone.

Antrim Plateau Volcanics unconformably overlie the Supplejack Downs Formation near Supplejack Downs homestead in the west and also northwest of the homestead near the Tanami/Hooker Creek track.

The stratigraphic relationships of the Supplejack Downs Formation indicate that it is younger than both the Lower Proterozoic Nanny Goat Creek Formation and the Carpentarian (?) Mount Winnecke Formation, and it is older than the Gardiner Formation, which is at the base of the Carpentarian or Adelaidean Birrindudu Group. Therefore the Supplejack Downs Sandstone is mapped as Upper Proterozoic, probably Carpentarian.

<u>BIRRINDUDU GROUP</u> (provisional new name)

The Birrindudu Group crops out extensively between Birrindudu homestead in the north and Tanami in the south. It is named after Birrindudu homestead and the Birrindudu Range to the southeast.

The group is made up of the Gardiner Formation and Ware Range Sandstone, which occur at the base, and the overlying Talbot Well Formation and Stake Range Beds. These stratigraphic units are grouped together as they form a conformable sequence consisting predominantly of current-bedded lithic sandstone. The maximum exposed thickness of the group is about 6 000 m, west of the Stake Range.

Stratigraphic relationships, age, and correlations

The Birrindudu Group lies with strong angular unconformity on the Lower Proterozoic Tanami Group, and is also unconformable on unnamed granite. Although contacts with the Supplejack Downs Sandstone, Winnecke Granophyre, and Mount Winnecke Formation in the east are not exposed, these units are probably also overlain unconformably by the group. The Birrindudu Group is itself overlain unconformably by flat-lying Lower Cambrian Antrim Plateau Volcanics, and by the Larranganni Beds, which are probably Cretaceous.

From its stratigraphic relationships, the Birrindudu Group is mapped as Upper Proterozoic, but whether it is Carpentarian or Adelaidean can be determined only when isotopic age data become available after the 1972 field season. Hence correlations with the East Kimberley and Victoria River regions are uncertain at present.

Gardiner Formation (Buf)

The Gardiner Formation comprises sandstone and associated conglomerate, shale, and siltstone, It is the most widespread of the Upper Proterozoic formations in the Birrindudu and Tanami Sheet areas and crops out extensively west of the Tanami/Hooker Creek track. Its outcrop in the Birrindudu Sheet area is limited to the vicinity of the Northern Browns Range (Fig. 3A). The formation extends west into the Billiluna and Gordon Downs Sheet areas, where it has been mapped as Gardiner Beds by Wells (1962a), Casey & Wells (1964), Gemuts & Smith (1968), and Dow & Gemuts (1969). The formation was named Gardiner Beds by Casey & Wells (1964) after the Gardiner Range, which extends about 15 km into the Tanami Sheet area from the Billiluna Sheet area to the west. Previously only the base of the unit was defined, but now the top as well as the base have been defined in the Birrindudu - Tanami area, and therefore the name of the unit has been upgraded to Gardiner Formation.

Outcrops are mostly discontinuous strike ridges which broaden into plateaux where the dips of beds approach horizontal or where the beds, as in the Pargee and Tanami Ranges, are gently folded. The outcrops are separated by sand plains. The maximum relief is about 100 m but the ridges are mostly much lower. The formation is well exposed on scarps (Figs 34 and 35).

On air-photographs the Gardiner Formation has a medium to light tone. Bedding traces are generally well marked and the jointed nature of most beds is readily visible.

Casey & Wells (1964) described a type section about 90 m thick at Larranganni Bluff, on the eastern margin of the Billiluna Sheet area, and they estimated a maximum exposed thickness for the unit

Pound, in the Stansmore Sheet area. In the area mapped the greatest thicknesses of Gardiner Formation are in the Stake Range area, where about 2 500 m is exposed, and on a strike ridge east of the Pargee Range, where the formation is over 2 600 m thick. However, precise measurement of thicknesses here and elsewhere is impossible because of the complex outcrop distribution and because the top and bottom of the sequence are not exposed in any one outcrop. Some thicknesses of exposed rock are given in the following table. They have been calculated from estimated average dips based on field measurements and distances measured on air-photographs.

TABLE 3

CALCULATED THICKNESSES OF THE GARDINER FORMATION

Locality	Dip	Thickness (m)	Comments
Northern Browns Range	10°	700	top not exposed
Southern Browns Range	10°	900	" " "
NW Stake Range	40°	1100	neither base nor top exposed
NE " "	20°	1400	base not exposed
Central Stake Range	50°	2500	base not exposed
Southern " "	50°	1900	" " "
SE of Stake Range	20°	1000	neither base nor top exposed
S of Stake Range	40°	1600	base not exposed
Crazy Dingo Range	25°	1400	top not exposed
E of Pargee Range	30°	2600	neither base nor top exposed
NE North Coomarie Range	10°	870	base not exposed
Central North Coomarie Range	40°	320	" " "
East Coomarie Range	70°	470	neither base nor top exposed
W of Black Hills	40°	800	" " " " "
West Tanami Range	20°	700	" " " " "
Talbot Hills	10°	430	" " " " "
South Supplejack Range	8°	350	" " " " "
Central " "	35°	700	base not exposed
North " "	50°	760	" " "
NW of " "	5°	300	base not exposed; some possible strike faulting.

<u>Structure</u>. The two most prominent structures affecting the Gardiner Beds are the Browns Range and Coomarie Domes. The doming took place after the Gardiner Formation was laid down. In the area between the domes the Gardiner Formation has been folded and faulted to form a complex pattern of basins, anticlines, and synclines.

Lithology. The Gardiner Formation consists predominantly of lithic sandstone, but conglomerate, orthoquartzite, and shale with thinly interbedded siltstone and fine sandstone are also present. Glauconitic sandstone occurs at several localities. Shale and siltstone, being more readily eroded than sandstone, may be concealed beneath the superficial deposits on the sand plains separating the sandstone outcrops.

The lithic sandstone is mostly medium-grained but ranges from fine to coarse. Most beds are over 1 m thick but some are much thinner and are flaggy (Figs 34 and 35). Current-bedding is almost ubiquitous (Figs 36 and 37) and ripple marks are locally abundant (Fig. 38). Scattered pebbles and conglomeratic lenses are common in places. The colour of beds ranges from white to pink, grey, and dark purple, mainly because of varying degrees of iron staining. In places the sandstone shows very fine colour banding which is unrelated to bedding.

In thin section the lithic sandstone is seen to consist of subangular to rounded grains of quartz and up to 30 percent lithic fragments, many of which are of acid and basic volcanic rocks. Small amounts of alkali feldspar grains are present in some thin sections. The sandstone has a quartz overgrowth cement and up to 10 percent matrix. Heavy minerals normally present include tourmaline and zircon.

Conglomerate (Figs 40 and 41) consists of well rounded pebbles and boulders, up to 30 cm long, of mainly fine to medium orthoquartzite and lithic sandstone, in a sandstone matrix. In places it includes pebbles of chert and conglomerate that could be derived from the Pargee Sandstone. Northeast of Tanami rare basalt pebbles were found in conglomerate. The conglomerate mostly occurs at or near the base of the Gardiner Formation, where it forms one or more layers several metres thick, interbedded with sandstone. Good exposures can be seen about 10 km northeast of Tanami on a strike ridge west of the Tanami/Hooker Creek track, in the southern part of the low range south-east of Mount Frederick, and at the southwest end of the West Pargee Range where it lies unconformably on Pargee Sandstone.

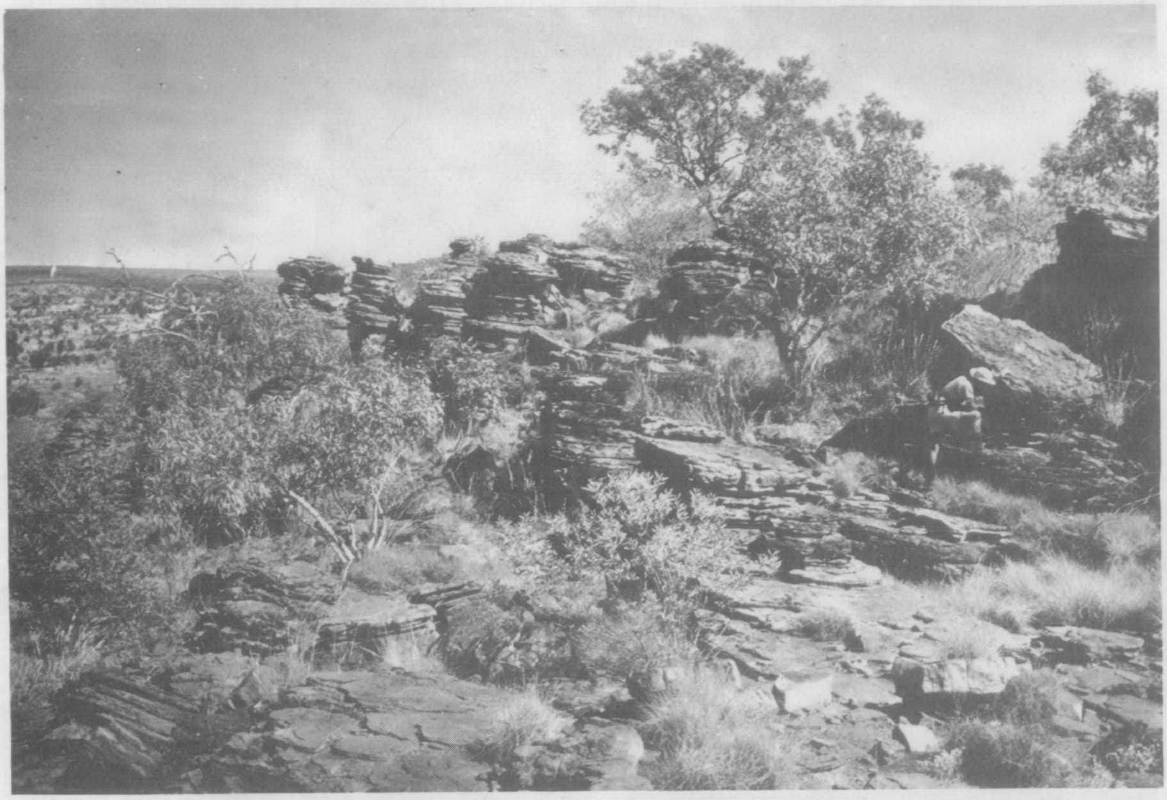

Fig 34 Flaggy current-bedded coarse lithic sandstone, Gardiner Formation. The beds which dip gently north form a scarp on the south side of Northern Browns Range. (Neg. GA/5743)

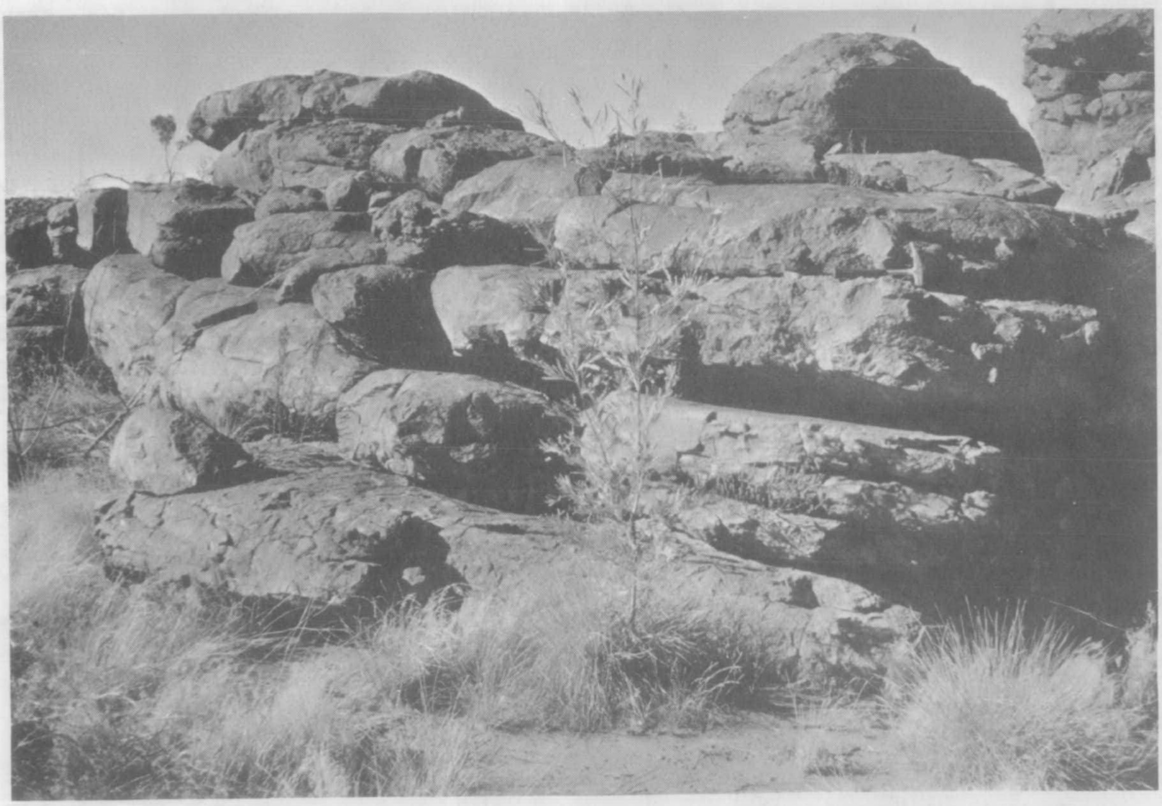

Fig 35 Gently dipping sandstone of the Gardiner Formation southeast of the Stake Range. (Neg. GA/5689)

Fig 36 Current-bedded sandstone of the Gardiner Formation, south scarp of the Crazy Dingo Range. (Neg. GA/5681)

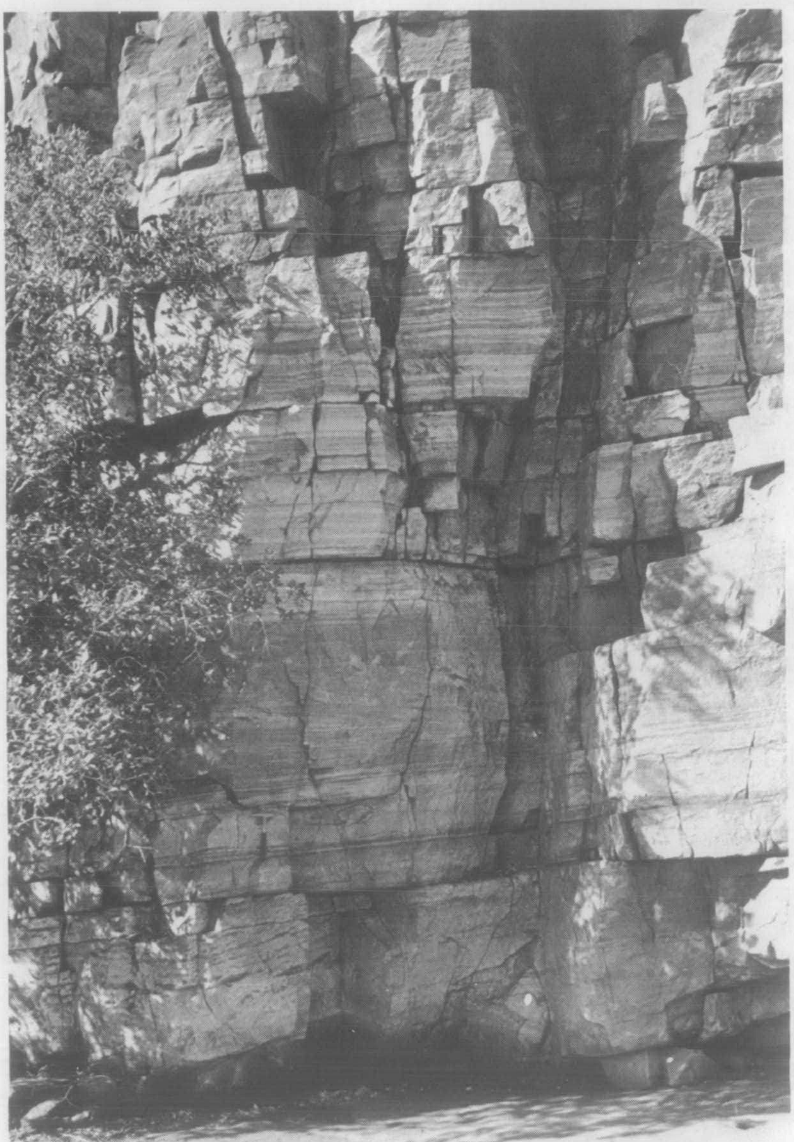

Fig 37 Moderately dipping sandstone of the Gardiner Formation, north side of the Crazy Dingo Range. (Neg. M/1288)

Fig 38 Ripple-marked bedding plane on sandstone, Gardiner Formation. (Neg. GA/5692)

Fig 39 Flat lying, thin-bedded, shale, siltstone, and fine sandstone near the base of the Gardiner Formation at Larranganni Bluff. (Neg. GA/5712)

Fig 40 Well rounded pebbles and cobbles, mainly of sandstone, in conglomerate near the base of the Gardiner Formation, north-east of Tanami. (Neg. GA/5714)

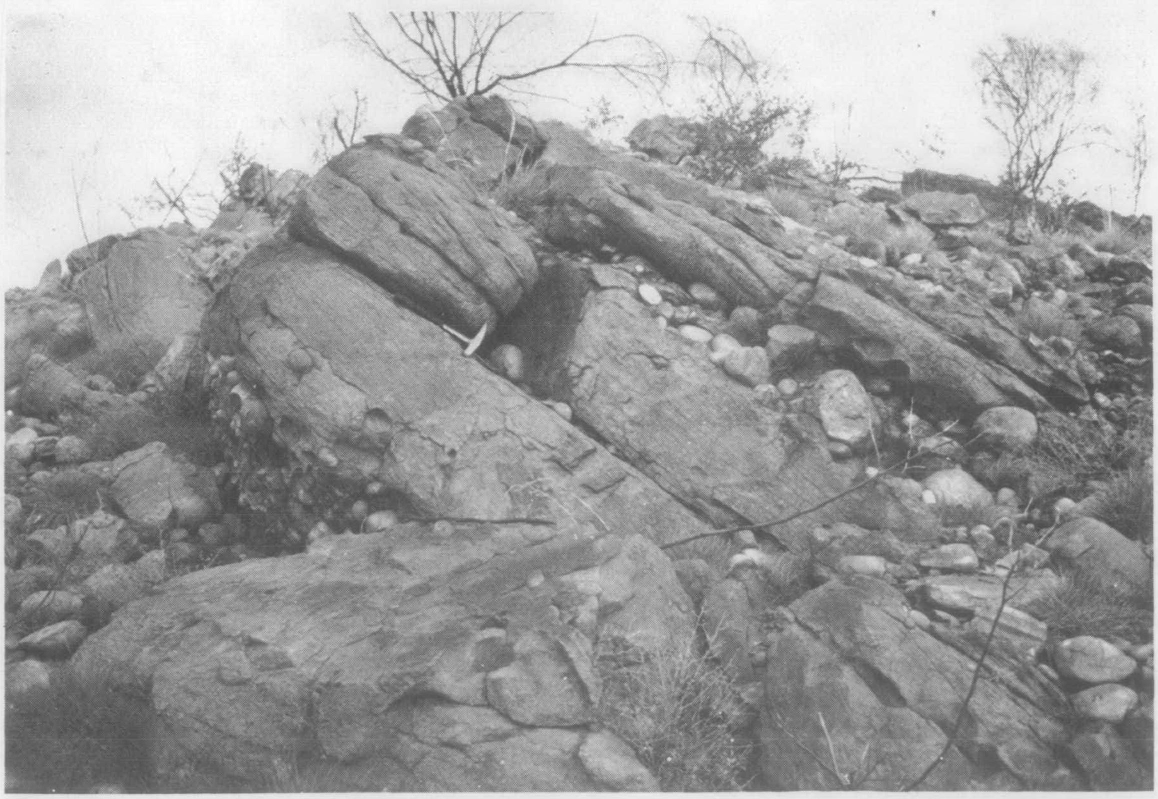

Fig 41 Conglomerate interbedded with current-bedded lithic sandstone of the Gardiner Formation, Supplejack Range. (GA/5754)

The orthoquartzite is mostly medium to coarse, white, pink or grey, and current-bedded. In thin section it is seen to consist of rounded grains of quartz, some of which have iron-stained rims, and a quartz-overgrowth cement. Little matrix is normally present, but an abundant sericitic matrix is present in one specimen which could be classified as quartz-rich greywacke.

Shale with thinly interbedded siltstone and fine sandstone is not well exposed except in bluffs where it is flat-lying and overlain by sandstone, as at Larranganni Bluff (Fig. 39), near Coomarie Spring, and southeast of the Stake Range at 19°20'S, 129°35'E. However, these rocks were intersected in several stratigraphic drill holes (Nos 1, 2, 15, 16, 40, 50, and 71) and probably underlie many of the sand-covered areas. Some of the shale is gypsiferous, as in drill hole No. 50. The shale and associated beds are mostly maroon but are also white, grey, green and mottled. In places they form sequences at least 80 m thick, as in drill hole No. 16. They occur mostly near the base of the formation, as on the Western Australia border at Larranganni Bluff where Casey & Wells (1964) reported 35 m of interbedded shale and sandstone overlying basal conglomerate, and in the Southern Browns Range where about 45 m of shale overlie basal conglomerate and orthoquartzite. Thin sandstone interbeds in the sequence near Coomarie Spring contain abundant grains of feldspar, mainly microcline, probably derived from the underlying granite, but elsewhere the sandstone interbeds are of lithic sandstone.

Glauconitic sandstone was found in the North and East Coomarie Ranges, Southern Browns Range, Crazy Dingo Range, and at several localities between the Gardiner and Supplejack Ranges. It generally occurs a few hundred metres below the top of the formation. In the North and East Coomarie Ranges glauconite as globular grains is mostly present in iron-stained, thin-bedded, medium to fine lithic sandstone though it also occurs in white orthoquartzite. At Coomarie Spring north-easterly-dipping iron-stained glauconitic sandstone is separated by some 80 m of shale, siltstone, and minor sandstone from overlying Talbot Well Formation, In the Southern Browns Range it is about 7 m thick and is overlain by at least 300 m of mainly lithic sandstone.

Correlations, stratigraphic relationships and age. Mapping of the Gardiner Formation involves correlation of many outcrops separated by Quaternary sand. The base of the formation is marked by an unconformity on Lower Proterozoic rocks, the top by the appearance of chert of the Talbot Well Formation. Many outcrops have been mapped as Gardiner Formation by reference to one of these boundaries; others by reference to regional structure and lithology.

The unconformity with Lower Proterozoic rocks is well exposed at Larranganni Bluff, at the southern end of the Gardiner Range. Here gently dipping sandstone and shale of the Gardiner Formation overlie steeply dipping cleaved metamorphics of the Killi Killi Formation. The same unconformity is also exposed on the northern edges of the Gardiner and Southern Browns Ranges.

Near Tanami, in the Tanami Range and the western Black Hills, the formation unconformably overlies the Lower Proterozoic Mount Charles Formation, but the unconformity is not exposed.

In the Pargee and West Pargee Ranges the Gardiner Formation is unconformable on Pargee Sandstone; the unconformity is exposed at several localities.

The contact of the Gardiner Formation with the overlying Talbot Well Formation is exposed in the Talbot Hills, along the northern edge of the North Coomarie Range, in the Supplejack Range and to the northwest, and north of the Pargee Range. The contact appears to be conformable, but the exposures are not good enough for this to be established with certainty.

In the Supplejack Range and near Coomarie Spring the Gardiner Formation is overlain unconformably by flat-lying Lower Cambrian Antrim Plateau Volcanics. This unconformity was intersected in stratigraphic holes north of Talbot Well. At Larranganni Bluff the formation is also overlain unconformably by Larranganni Beds, mapped as Cretaceous (?).

The Gardiner Formation is assigned to the Upper Proterozoic as it is strongly unconformable on rocks of the Tanami Group, mapped as Lower Proterozoic, and is unconformably overlain by the Lower Cambrian Antrim Plateau Volcanics. It may be correlated with the Speewah Group, of the Kimberley Region, which unconformably overlies the Whitewater Volcanics at the base of the Carpentarian sequence (Dow & Gemuts, 1969). However, it could also be correlated with younger Carpentarian or with Adelaidean rocks. One possibility is that the Gardiner Formation is equivalent to the Vaughan Springs Quartzite in the Ngalia Basin to the south and hence with the Heavitree Quartzite in the Alice Springs area. The Vaughan Springs Quartzite is Adelaidean and has been dated, using glauconite, at 1 280 m.y.

Ware Range Sandstone (Bur) (provisional new name)

The Ware Range Sandstone crops out in the northern part of the Tanami Sheet area and in the southern and central parts of the Birrindudu Sheet area. It forms Ware Range, after which it is named, the Northern Ware, Birrindudu, and Mana Ranges, and several lower unnamed hills and ridges.

Outcrops consist of strike ridges and plateau areas up to 100 m but generally less than 30 m high. Gently dipping beds commonly form tor-like masses. Good exposures occur along creeks and gullies. Silicification and small patches of silcrete are common on weathered surfaces.

On air-photographs the outcrops have pale tones. Bedding is mostly clearly shown, due to differential erosion of sandstone bands, and linear gullies and narrow shallow depressions indicate transverse joints. Large cross-cutting quartz veins in the southern part of Ware Range show up as prominent white lines.

The maximum known thickness of the Ware Range Sandstone is about 3 000 m. This is the calculated thickness on the east side of the Ware Range, where the base but not the top of the formation is exposed. About 2 170 m of section is present along the Birrindudu Range, underlying the succeeding Talbot Well Formation, but here the base is not exposed. Thicknesses of about 1 800 and 1 700 m are present at the southern end of the Northern Ware Range and in the Mana Range respectively. All thicknesses are calculated from dips measured in the field and distances measured on air-photographs.

The type section for the Ware Range Sandstone is in the Ware Range between Frog Valley and the fault bounding the range to the east; here the maximum thickness of 3 000 is exposed.

The formation has been folded into mostly broad anticlinal and synclinal structures, and dips range from gentle (less than 10°) to steep (over 45°). It has also been displaced by several major and many minor faults, some of which are marked by quartz veins.

Lithology. The main rock types are lithic sandstone and orthoquartzite. Minor conglomerate is present locally, mostly near the base of the formation, and thinly interbedded shale, siltstone and fine sandstone are exposed at a few localities, mainly near the top of the formation. Glauconitic sandstone has been found in the sequence exposed along the Northern Ware Range.

Lithic sandstone and orthoquartzite form beds that are commonly less than 1 m thick, although much thicker beds occur locally. In many exposures bedding planes are undulating. Current bedding is almost ubiquitous, and ripple marks are common locally. Rarely the bedding structures have been disturbed, apparently by later slumping. Mudstone pellets mostly about 1 cm across are present at many exposures. Quartz veining and zones of brecciation are common in the southern part of Ware Range, where some quartz veins over 1 m wide can be traced for several kilometres.

Both the lithic sandstone and orthoquartzite are mostly medium-grained and well sorted, and range from pink, white, mauve, or grey to deep maroon or purple. In many places the rocks have small black or, less commonly, maroon iron-stained spots and streaks. Subordinate coarse and very coarse lithic sandstone is less well sorted and in many places contains well rounded pebbles up to 10 cm across. Most pebbles are pink and grey sandstone but some are vein quartz or greenstone.

Orthoquartzite grades into lithic sandstone with increasing content of lithic grains, which form up to 30 percent of the total grains in some specimens of lithic sandstone. In hand specimen the lithic grains are characteristically dull white or pink and appear clayey or micaceous. Under the microscope they are seen to be mostly very fine to fine aggregates of quartz and clay minerals representing altered phyllite, shale, siltstone, and volcanic fragments; grains of chert and quartzite are also present. In one specimen a grain of partly altered feldspar was identified, and many specimens contain grains of turbid quartz that may be pseudomorphing feldspar. Both the lithic sandstone and orthoquartzite have a quartz overgrowth cement, and generally have little or no matrix. Matrix that is present consists of a fine-grained iron-stained aggregate mainly of quartz and sericite.

Conglomerate occurs near the base of the formation on the east side of the Ware Range, east of the Birrindudu Range and higher up in the succession in the Mana Range. In the first area it occurs on both sides of a major fault. On the east side of this fault, on the northern margin of the Tanami Sheet area, the conglomerate forms a ridge that is separated from the main range by a sandy depression. On the west side of the fault the conglomerate crops out on the scarp bounding the range. The conglomerate here and east of the Birrindudu Range is associated with current-bedded, pebbly, medium to coarse lithic sandstone, and contains well rounded to angular clasts of sandstone, quartzite, vein quartz, acid volcanics, basalt, mudstone, chert, and siltstone in a sandy matrix. Most clasts are probably derived from underlying Lower Proterozoic rocks. Two beds of conglomerate are exposed on the Mana Range. The upper bed is about 7 m thick and is near the top of the exposed sequence. The other bed, about 10 m below, is 3 m thick. Both beds contain well rounded clasts mainly of sandstone, quartzite, chert, and vein quartz.

The thinly interbedded shale, siltstone, and fine sandstone within the Ware Range Sandstone are more readily eroded than the coarser rocks, and form topographic depressions. Exposures occur in the banks of incised creeks in Frog Valley, in the valley 5 km to the southwest, and on the west side of the sandstone plateau at the southern end of the Ware Range. At these three localities the beds are probably at or close to the top of the formation. Similar beds also occur in the Northern Ware Range, where they are associated with a glauconitic sandstone band about 3 m thick. Individual beds are generally less than 3 cm thick. The fine sandstone is commonly micaceous.

In the type section the 3 000-m thick sequence consists predominantly of lithic sandstone and orthoquartzite. Conglomerate is present only in the east, at the base of the succession, where it is faulted against Nanny Goat Creek Formation. The conglomerate is associated with lithic sandstone dipping west at 43°. At the top of the sequence, in Frog Valley, thinly interbedded shale, siltstone, and fine-grained sandstone overlie lithic sandstone and orthoquartzite dipping 60° west.

In the sequence exposed in the central part of the Birrindudu Range about 2 170 m of lithic sandstone and orthoquartzite dip west at 40 to 60°. At the top of the succession about 100 m of medium orthoquartzite and thin bedded fine lithic sandstone underlie chert of the Talbot Well Formation.

Correlations, stratigraphic relationships, and age. The several outcrops mapped as Ware Range Sandstone are isolated from one another by areas covered by Quaternary sand. Correlations between the outcrops are based on lithology, regional structure, and stratigraphic relationships. The outcrops of the Northern Ware Range are clearly the northern extension of the Ware Range outcrop, and they lie on the easterly-dipping limb of a large anticline, in the core of which is exposed the Lower Proterozoic Nongra Formation. The sandstone forming the Birrindudu Range lies on the westerly-dipping limb of the same anticline, and hence can be correlated with the sandstone of the Ware Range. Sandstone east of the Birrindudu Range lies unconformably on the Nongra Formation.

A similar relationship is apparent to the south, where sandstone folded into a broad syncline forms the Mana Range, which is situated between outcrops of Nongra Formation to the northeast and southwest. Hence the sandstone of the Mana Range is also mapped as Ware Range Sandstone.

The Ware Range Sandstone unconformably overlies the Lower Proterozoic Nanny Goat Creek and Nongra Formations, and is overlain conformably by the Talbot Well Formation and unconformably by the Lower Cambrian Antrim Plateau Volcanics. A major fault separates it from the Winnecke Granophyre and Mount Winnecke Formation to the east. The Ware Range Sandstone is considered to be Upper Proterozoic, and is probably the lateral equivalent of the Gardiner Formation to the southwest, and hence may be unconformable on Supplejack Downs Sandstone; however, the contacts between these formations are not exposed and their relationships can only be inferred.

The unconformable relationship with Nanny Goat Creek Formation is exposed on the east side of the Ware Range southeast of Frog Valley, where gently dipping Ware Range Sandstone lies west and north of cleaved basalt of the Nanny Goat Creek Formation. The unconformity on Nongra Formation was observed west of the Northern Ware Range, at $18^{o}44'$S, $129^{o}52'$E, and east of the Birrindudu Range, at $18^{o}43'$S, $129^{o}41'$E. At these localities Ware Range Sandstone dipping at 5^{o} north and 37^{o} northwest respectively is exposed adjacent to vertically cleaved metasediments.

Ware Range Sandstone is overlain conformably by chert of the Talbot Well Formation on the west side of the Birrindudu Range. A similar relationship is inferred southwest of the Ware Range, where chert and other sedimentary rocks mapped as possible Talbot Well Formation crop out. Basalt of the Antrim Plateau Volcanics overlies the Ware Range Sandstone at the northern ends of the Birrindudu and Northern Ware Ranges.

The Ware Range Sandstone is mapped separately from the Upper Proterozoic Gardiner Formation at present as it consists almost entirely of sandstone, whereas the Gardiner Formation includes significant local thicknesses of shale, siltstone, and conglomerate. In addition, continuity between outcrops of the two formations cannot be readily recognized. However both formations have similar relationships to the underlying Nongra and overlying Talbot Well Formations, and have comparable styles of folding. They are therefore considered to be the same age, and may eventually be mapped as a single formation.

Talbot Well Formation (Put) (provisional new name)

In the Birrindudu Sheet area the Talbot Well Formation crops out along the western edge of the Birrindudu Range. In the Tanami Sheet area outcrops occur on the flanks of strike ridges of Gardiner Formation, such as along the North Coomarie and Supplejack Ranges, and in the centres of structural basins, such as northwest of the Supplejack Range and in the Talbot Hills.

The formation is mostly gently dipping to flat-lying, and forms low outcrops, many of which consist solely of surface rubble. The main rock type is stromatolitic chert (Fig. 42). Some outcrops have remnant cappings of laterite, and small patches of silcrete are present locally.

On air-photographs outcrops have a smooth pale tone with dark patches where laterite is present.

The maximum thickness is estimated at about 300 m. The type section is on the west side of the Supplejack Range, west-northwest of Supplejack Downs homestead.

Lithology The formation consists of chert, cherty sandstone, sandstone and siltstone with chert bands, mudstone, and limestone. Two drill holes intersected the formation northeast of Coomarie Spring. No. 30 penetrated chert and No. 31 penetrated medium-grained sugary orthoquartzite and interbeds of limestone about 2 cm thick.

The chert is mostly white to grey but is also maroon and greenish and may be mottled and streaky. It is commonly stromatolitic and probably represents silicified limestone or dolomite. The chert is locally massive or brecciated and bedding is nowhere well marked. In places, as in the Talbot Hills and northwest of the Supplejack Range, the chert is associated with flaggy fine lithic siltstone. The medium-grained cherty sandstone consists of loosely packed quartz grains in an abundant chert cement. At the western end of the North Coomarie Range it contains spherical grains of quartz which appear to be silicified oolites. Some quartz grains have white cores and clear rims, others the reverse.

At the type section an estimated thickness of about 300 m of rock is exposed. Here some 10 m of thin-bedded, flaggy, fine sandstone and thin-bedded shale, and siltstone at the base of the sequence are overlain by chert. Some of the basal sandstone has a chert cement and appears to be oolitic. The overlying chert is stromatolitic, commonly brecciated, and forms mostly bouldery outcrops. Undulating bedding is exposed locally. Thin sections of the chert show shapes of pellets, streaks, and rhombohedra preserved in microcrystalline silica.

In the outcrops mapped as 'doubtful Talbot Well Formation', southwest of the Ware Range, the rock types exposed are lithic sandstone; thin-bedded maroon shale, siltstone and fine sandstone; buff mudstone; mottled and streaky chert. The lithic sandstone commonly contains small cavities and locally has a chert cement. One specimen contains grains of quartz and alkali feldspar, granophyric quartz and feldspar, clasts of shale, siltstone, and quartzite, and detrital muscovite, biotite, tourmaline, and zircon.

Stratigraphic relationship and age. The Talbot Well Formation lies conformably between the Gardiner Formation below and the Stake Range Beds above, and it is part of the Upper Proterozoic Birrindudu Group. It is unconformably overlain by Lower Cambrian Antrim Plateau Volcanics west of Supplejack Downs homestead.

Fig 42 Rubbly exposure of stromatolitic chert (see structure near hammer handle) of the Talbot Well Formation, south Supplejack Range. (Neg. GA/5749)

Fig 43 Exposure of white weathered basalt, northeast of Supplejack Downs homestead. Antrim Plateau Volcanics. (Neg. GA/5752)

Stake Range Beds (Puk) (provisional new name)

The Stake Range Beds consist mainly of lithic sandstone. They crop out west and south of the Stake Range, north of the Coomarie Dome, and west of the Birrindudu Range. The maximum thickness exposed is about 2 500 m, in the syncline on the west side of the Stake Range. The selected type section is across the western limb of the syncline, at 19°15'S. The unit has not been given a formation name because its upper limit has not been defined.

On air-photographs the Stake Range Beds have a medium tone. Bedding trends are prominent.

Lithology. The Stake Range Beds consist of lithic sandstone and minor orthoquartzite, siltstone, and shale. The lithic sandstone is medium to fine-grained and buff or maroon. Much of the sandstone is flaggy, and some shows ripple marks, current bedding, and mud cracks. The flaggy beds commonly have micaceous partings. Small shale pellets are locally abundant in the sandstone, as also are red lithic grains. The orthoquartzite is medium-grained, current-bedded, and locally iron-stained. Siltstone and shale occur with lithic sandstone mainly as thin interbeds, but also as thin laminae in North Coomarie Range.

In the type section medium-grained sandstone containing red lithic grains and some shale pellets is overlain by ripple-marked and current-bedded fine to medium sandstone and minor interbedded shale.

Stratigraphic relationship and age The Stake Range Beds are inferred to be conformable on the under-lying beds of the Talbot Well Formation, but this cannot be demonstrated as contacts between them are not exposed. The Beds are unconformably overlain by the Lower Cambrian Antrim Plateau Volcanics west of the Birrindudu Range and north of the Coomarie Dome. They are the youngest unit of the Birrindudu Group.

UNDIVIDED LIMBUNYA GROUP (Ehu)

Outcrops of rocks mapped as undivided Limbunya Group in the adjoining Limbunya Sheet area (Sweet et al., 1971) extend southwards into the northern part of the Birrindudu Sheet area north of Birrindudu homestead. The rocks exposed are lithic sandstone and orthoquartzite that have been folded into northwesterly-trending synclines and anticlines. Dips range up to 35°. Similar sandstones crop out to the west, in the northwest corner of the Birrindudu Sheet area, where they show the same types of folds and trends, and they also are mapped as undivided Limbunya Group.

The undivided Limbunya Group forms strike ridges less than 20 m high, low mounds, and some gently undulating terrain. Exposures are commonly in the form of rocks protruding through the thin soil cover. On air-photographs the outcrops have pale to medium tones. The maximum thickness exposed is about 400 m.

Lithology. The predominant rock types are lithic sandstone and orthoquartzite. The only other rock types observed were in the northwest, where chert and chert-bearing conglomerate mapped as possibly Limbunya Group crop out at 18°02'S, 129°04'E, and 18°02'S, 129°07'E respectively.

Lithic sandstone is mainly pale to dark grey, maroon or purple, and medium to fine-grained. Current bedding is common, some sandstone shows ripple marks, and some contains small shale pellets. In places the bedding structures have been strongly disturbed, apparently by slumping. Most beds are over 1 m thick. Orthoquartzite is generally similar to the lithic sandstone, apart from containing a lower proportion of lithic grains. In the southwest, close to the Western Australia border, some orthoquartzite contains scattered, large, well rounded grains of quartz. Both the lithic sandstone and orthoquartzite have a quartz-overgrowth cement and little or no matrix.

The chert exposed in the northwest is stromatolitic, massive, and maroon to grey. It is probably silicified dolomite or limestone, and may represent an algal reef. The conglomerate to the east is bedded, dipping 15° northeast, and consists of rounded fragments of sandstone up to 25 cm across and smaller angular fragments of chert enclosed in a sandstone matrix.

Neither the chert nor the conglomerate was seen in contact with sandstone; they could belong to the Antrim Plateau Volcanics rather than the Limbunya Group.

Stratigraphic relationships and age. The undivided Limbunya Group is overlain unconformably by basalt belonging to the Lower Cambrian Antrim Plateau Volcanics. Patches of basalt too small to be mapped overlie sandstone at 18°02'S, 129°23'E and 18°13'S, 129°07'E. Also laterite and black and grey cracking clay that are probably developed on the basalt partly surround the main sandstone outcrops.

The Limbunya Group is considered by Sweet at al (1971) to be Carpentarian or Adelaidean. The outcrops of the group are isolated from those of other Upper Proterozoic rocks to the south, and the relationship of the Limbunya Group to the Birrindudu Group is not known.

UNNAMED UPPER PROTEROZOIC (Ɐu)

Small low outcrops of sandstone, siltstone, and shale east and north of the Talbot Hills, in the Tanami Sheet area, are mapped as unnamed Upper Proterozoic because they cannot be readily correlated with any named Upper Proterozoic formation. Cappings of laterite are developed on some outcrops, mainly on shale and siltstone.

Outcrops east of the Talbot Hills consist of low strike ridges of lithic sandstone and orthoquartzite rising above the sandy plain. The maximum thickness exposed is about 800 m. These rocks lie on the western and southern sides of a synclinal structure on the western margin of the Wiso Basin, and have dips of 10° to 90°. The lithic sandstone and orthoquartzite are mostly pale maroon, medium-grained, and current-bedded, and have a quartz overgrowth cement. Small shale pellets are common, and shearing and quartz veins occur locally. Near Lake Buck the sandstone probably overlies unnamed Proterozoic granite, and it is overlapped unconformably by flat-lying chert and minor sandstone mapped as probably Cambrian.

North of the Talbot Hills the unnamed Upper Proterozoic outcrops consist of flat-lying deep maroon medium lithic sandstone, maroon micaceous siltstone and shale, and strongly iron-stained rubbly orthoquartzite. These rocks are not seen in contact with other pre-Tertiary rocks and may possibly be Cambrian.

CAMBRIAN

Antrim Plateau Volcanics (Єla)

Basaltic lavas and minor pyroclastics and intercalated sedimentary rocks of the Antrim Plateau Volcanics crop out extensively in the East Kimberley, Victoria River and Daly River regions (Traves, 1955; Sweet et al., 1971) and extend into the Granites-Tanami area. They cover much of the northern part of the Birrindudu sheet area and continue southwards as mostly small isolated outcrops to the southern edge of the Tanami Sheet area east of Tanami and into The Granites Sheet area.

The volcanics were named Antrim Plateau Basalts by David (1932), after the Antrim Plateau, an area of hilly dissected country about 55 km east of Halls Creek, in the Gordon Downs Sheet area. The name was later modified to Antrim Plateau Volcanics by Traves (1955). A detailed account of the volcanics north of the Birrindudu Sheet area is given by Sweet et al. (1971). Basalt, the main rock type, is generally much weathered, and most outcrops are capped by laterite.

The main landforms developed on the volcanics are low, broad and often barely perceptible rises, many of which are partly bounded by breakaways. The volcanics also form mesas and buttes and undulating terrain, and they underlie extensive plains covered by black and grey cracking clay in the Birrindudu Sheet area. Mesas and buttes, in many cases with benched (stepped) sides, are well developed northeast of Hooker Creek, in the northeast corner of the area, where a plateau formed of flat-lying lava flows has been strongly dissected. Undulating terrain occurs where weathered basalt and cappings of laterite have been stripped by erosion to reveal fresh basalt below, such as near Supplejack Downs homestead; on this terrain the fresh basalt is generally exposed as loose rubble of subangular to rounded fragments lying on the surface.

On air-photographs the volcanics generally show up as dark tones, due to laterite cappings. Where the cappings are absent, the outcrops have pale to medium tones.

In the area mapped the Volcanics probably reach their maximum thickness northeast of Hooker Creek, where up to 30 m of basalt is exposed and the base of the volcanics lies at an unknown depth below. North of the Birrindudu Sheet area the Antrim Plateau Volcanics reach thicknesses of over 300 m (Sweet et al., 1971).

Lithology. The predominant rock type is tholeiitic basalt, which forms flat-lying lava flows in the Birrindudu Sheet area and probably also in the Tanami Sheet area to the south, where individual lava flows cannot be readily identified and the attitude of the basalt is not known. Flows northeast of Hooker Creek are up to 15 m thick. No basalt intrusions have been found. The upper and lower parts of the flows are vesicular and the centres are massive. The tops of the flows are locally scoriaceous and blistery. Pillow-like structures indicating possible sub-acqueous origin are developed in places, as at small outcrops east of the Stake Range (Fig. 44) and at the northern end of the Northern Ware Range. Most of the flows, however, are undoubtedly subaerial.

At most localities the basalt is strongly weathered to depths of 8 m or more and is capped by pisolitic laterite about 2 m thick. In places the laterite cap persists for much greater depths. North of Talbot Well, drill holes in basalt passed through over 20 m of weathered rock. Scaly nodular surfaces are characteristic of many weathered exposures (Fig. 43).

The weathered basalt is white to maroon, mauve, purple or reddish-brown, and is commonly mottled. Colour zoning of the weathered profile is commonly well displayed; for instance north of Supplejack Downs homestead white basalt up to 2 m thick overlies about 5 m of maroon, mauve, and white mottled basalt, below which fresh dark greyish basalt is exposed. A basaltic texture is generally identifiable in the weathered basalt, even where all the original constituents have been replaced. Secondary minerals are mainly quartz, opaline silica, kaolin, hematite, goethite and limonite; small grains of anatase were recognized in some specimens (G. Berryman, X.R.D. identification).

Scoriaceous basalt is generally black, even when weathered, and was probably originally glassy. Vesicles in the basalt are mostly infilled with quartz, celadonite, or white clay minerals. Large geodes, some over 50 cms across, occur in the basalt near Supplejack Downs homestead. Some are lined with agate, and some contain well shaped crystals of clear, smoky and mauve quartz. Euhedral zeolite crystals pseudomorphed by goethite and quartz occur in scoriaceous basalt 8 km north of Supplejack Downs homestead. Bright green quartz probably derived from a geode was found in basaltic rubble near Mila Waterhole, north of Birrindudu homestead.

When fresh the basalt is dark greyish, and consists of labradorite laths, augite, opaque minerals, and minor secondary sericite and clay minerals.

Stromatolitic chert (Fig. 45) and sandstone are interbedded with the basalt at several localities. Good exposures of chert were seen at the Savage Hills south of Supplejack Downs homestead, 15 km north of the homestead, and 25 km north of Birrindudu homestead. Two main types of sandstone crop out, one of which is thin-bedded to laminated, fine to coarse and appears to be tuffaceous; the other type, at the base of the volcanics 15 km north of Supplejack Downs homestead and near Coomarie Spring, is a very poorly sorted lithic sandstone or greywacke which, at the first locality, is associated with chert and also with pink and maroon sandstone that may belong to part of the underlying Supplejack Downs Sandstone.

Stratigraphic relationships and age. The Antrim Plateau Volcanics lie with angular unconformity on Upper and Lower Proterozoic formations and on Winnecke Granophyre, and they are overlain unconformably by Larrangajni Beds (Fig. 47) which are mapped as Cretaceous. The volcanics are not seen in contact with the Cambrian sedimentary rocks that crop out in the east.

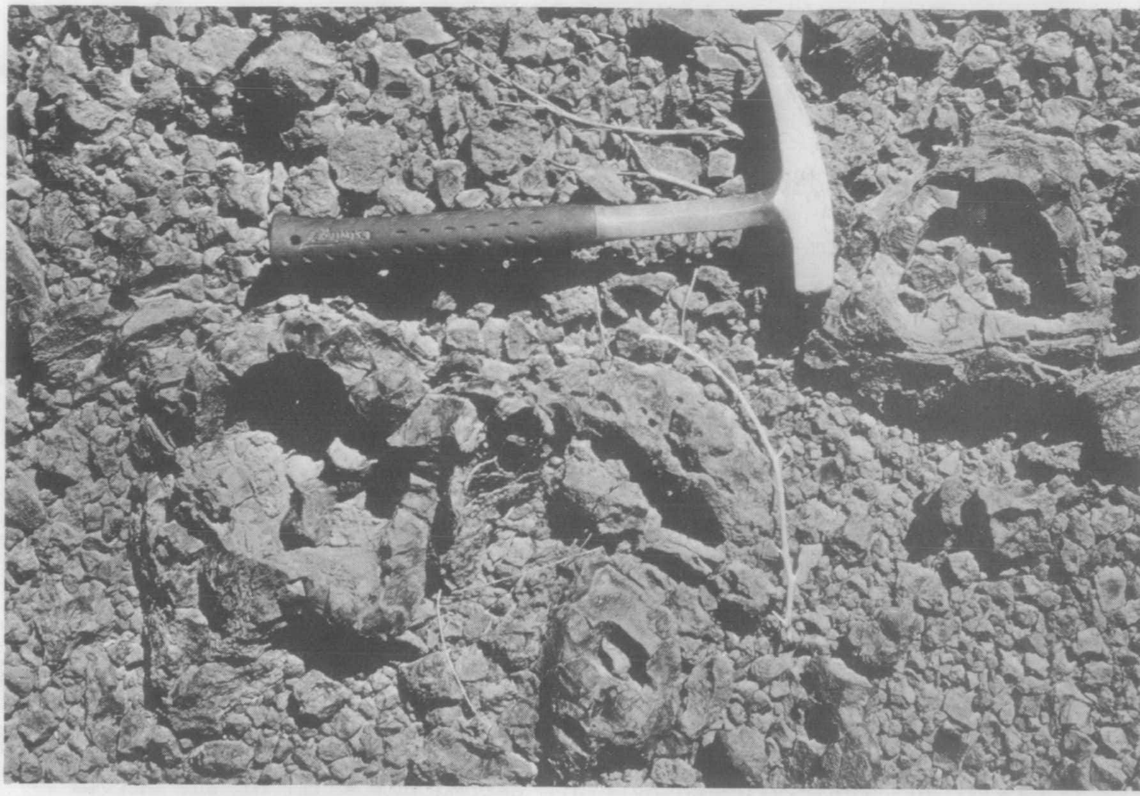

Fig 44 Pillow-like structure in basalt. Antrim Plateau Volcanics, east of Stake Range. (Neg. GA/5684)

Fig 45 Algal structures in chert in the Antrim Plateau Volcanics north of Birrindudu Homestead. (Neg. GA/5694)

However, north of the Birrindudu Sheet area the volcanics are overlain, probably disconformably, by Headleys Limestone (Sweet et al., 1971) and with slight angular unconformity by Montejinni Limestone (Randal & Brown, 1967). Both limestone formations are Middle Cambrian. From these relationships, and from stratigraphic evidence in the East Kimberley region, the Antrim Plateau Volcanics are considered to be probably Lower Cambrian (Sweet et al., 1971).

The unconformity on Proterozoic rocks is well exposed at the northern end of the Northern Ware Range, where basalt overlies Ware Range Sandstone; on the Supplejack Range 9 km north-northwest of Supplejack Downs homestead, where basalt overlies steeply dipping sandstone of the Gardiner Formation; south of Coomarie Spring, where basalt and basal sandstone overlie shale of the Gardiner Formation; and 20 km west of the 18-mile bore on Hooker Creek, where low hills of Winnecke Granophyre are capped by basalt of the Antrim Plateau Volcanics.

The unconformable relationship of the Larranganni Beds on Antrim Plateau Volcanics is exposed north of Supplejack Downs homestead, where a very irregular surface developed on basalt is partly covered by sandstone, siltstone, and conglomerate of the younger unit.

Unnamed Cambrian (Ꞓ)

Scattered low outcrops of flat-lying sedimentary rocks near the eastern edge of the area are mapped as unnamed Cambrian. The main outcrops are in the southeast, near Lake Buck. The rocks are mostly poorly exposed on low mounds, hills, and plateaux generally less than 10 m high, some of which are partly bounded by breakaways. Unnamed Cambrian rocks were also intersected in several stratigraphic holes drilled in 1971. The maximum thickness known is 67 m, the depth of drill hole No. 65, which ended in the unit.

Laterite cappings are common. On air-photographs these show up as smooth dark grey tones, but otherwise the outcrops are white to pale grey.

Lithology The unnamed Cambrian consists of sandstone, mudstone, chert, dolomite, and limestone. The rocks appear to be unfossiliferous.

Sandstone is exposed east of the Winnecke Range in the Birrindudu Sheet area and northeast of Wilson Creek and near Lake Buck in the Tanami Sheet area. Sandstone was also intersected in drill hole No. 62, east of the Black Hills. The most common type of sandstone exposed is a porous black to dark brown, medium to coarse, iron-stained orthoquartzite. White to pale buff orthoquartzite or quartz-rich, fine to medium, lithic sandstone, is exposed in breakaways at 19°00'S, 130°26'E. Cellular solution weathering at the surface may be an indication of a calcareous content. The sandstone in drill hole No. 62 is reddish brown and overlies a breccia (at 33 m) that may also be Cambrian. The breccia consists of angular fragments of brown mudstone in an abundant pale greyish matrix of the clay mineral palygorskite (X.R.D. determination by G. Berryman).

Mudstone is exposed southeast and northeast of Lake Buck, and was intersected in drill holes Nos 61, 62, 63, and 66. It is mainly purple or maroon.

Chert is present in the southeast corner of the Birrindudu Sheet area and more extensively near Lake Buck (Fig 46), where it is associated with limestone and dolomite. It also occurs in drill hole No. 61 at 14.5 to 16 m, overlying disaggregated granite. The chert is generally thinly banded, greyish, and is considered to be silicified calcareous mudstone or siltstone. On the northeast side of Lake Buck some of the chert shows well developed asymmetrical ripple marks.

Unnamed Cambrian limestone exposed near Lake Buck forms low rises slightly higher than travertine mapped as Tertiary. Dolomite was intersected in drill holes Nos 65 and 67, but was not identified in surface exposures. Both the limestone and dolomite are white to pale grey. The limestone contains chert, and in places it is capped by Tertiary travertine, which is locally silicified. Distinguishing between the Cambrian limestone and Tertiary travertine is often not possible either in the field or by air-photograph interpretation. In the Wiso Basin to the east Milligan et al. (1966) described some of the Cambrian limestone as 'travertinized'; the same may apply in the Tanami Sheet area. For instance, current-bedded travertine on the south side of Lake Buck, mapped as Tertiary, may in fact be Cambrian calcarenite.

Stratigraphic relationships, correlations and age. Near Lake Buck the unnamed Cambrian rocks lie on unnamed Proterozoic granite and overlap unconformably onto unnamed Upper Proterozoic rocks. They are presumed to have similar relationships to the Winnecke Granophyre and the Mount Winnecke Formation in the Birrindudu Sheet area. At the contact with the unnamed granite near Lake Buck, flat-lying banded chert and thin sandstone lie directly on much altered granite. The contact was intersected in drill holes 61, 63, and 64.

Rocks mapped as unnamed Cambrian were provisionally identified by Simpson (1971) as Merrina Beds because similar outcrops in the Winnecke Creek area were mapped as Merrina Beds by Milligan et al. (1966). Undifferentiated Lower Palaeozoic mapped in the southwest corner of the East Tanami Sheet area by the same workers has since been found to be at least partly Cambrian. However, no Cambrian fossils have been found in the Birrindudu-Tanami area, and correlations with formally named Cambrian rock units in the Wiso Basin to the east are uncertain. Therefore the rocks in the Birrindudu-Tanami area, although regarded as probably Cambrian, have not been formally named.

CRETACEOUS

Larranganni Beds (Kl) (provisional new name)

The Larranganni Beds consist predominantly of flat-lying white to grey silicified sandstone. They cap small scattered mesas and buttes up to 10 m high in the Tanami Sheet area but do not crop out in the Birrindudu Sheet area. The main exposures are north of Supplejack Downs homestead and on the south side of Larranganni Bluff, after which the unit is named. The beds reach their maximum thickness of about 8 m near Larranganni Bluff.

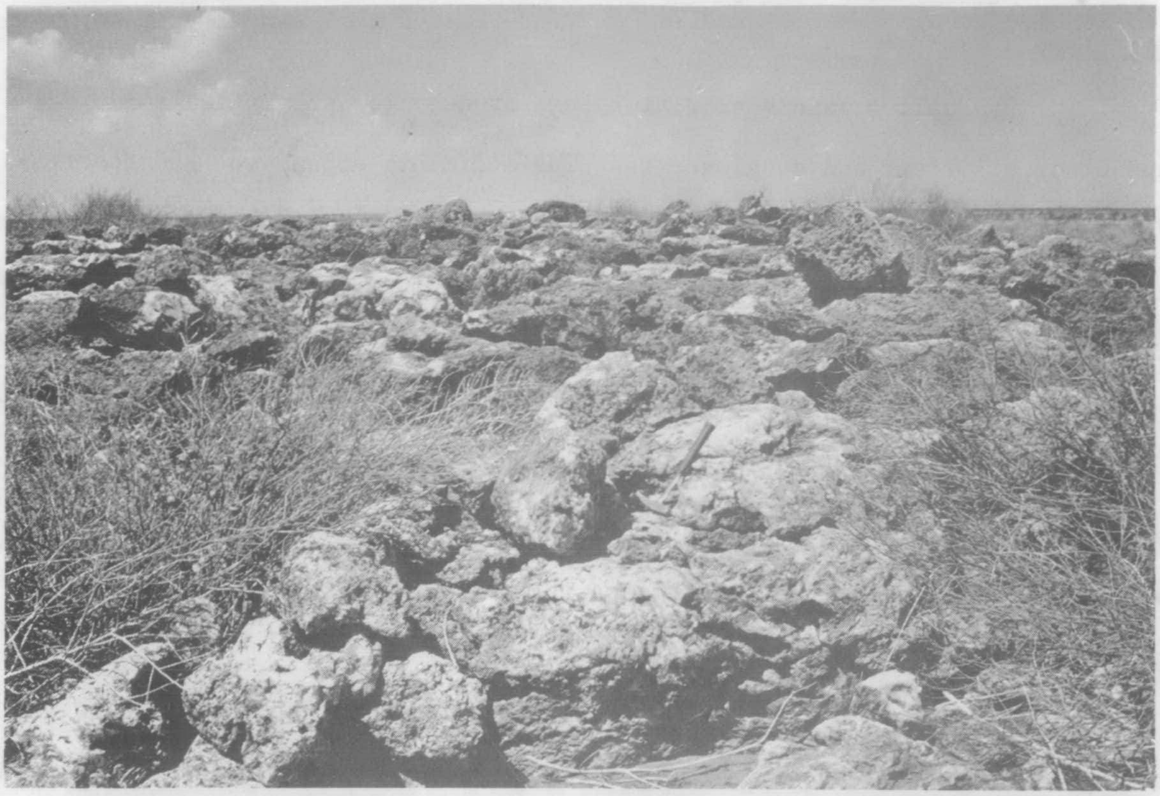

Fig 46 Exposure of chert (silicified limestone?) mapped as Cambrian; near Lake Buck. (Neg. GA/5710)

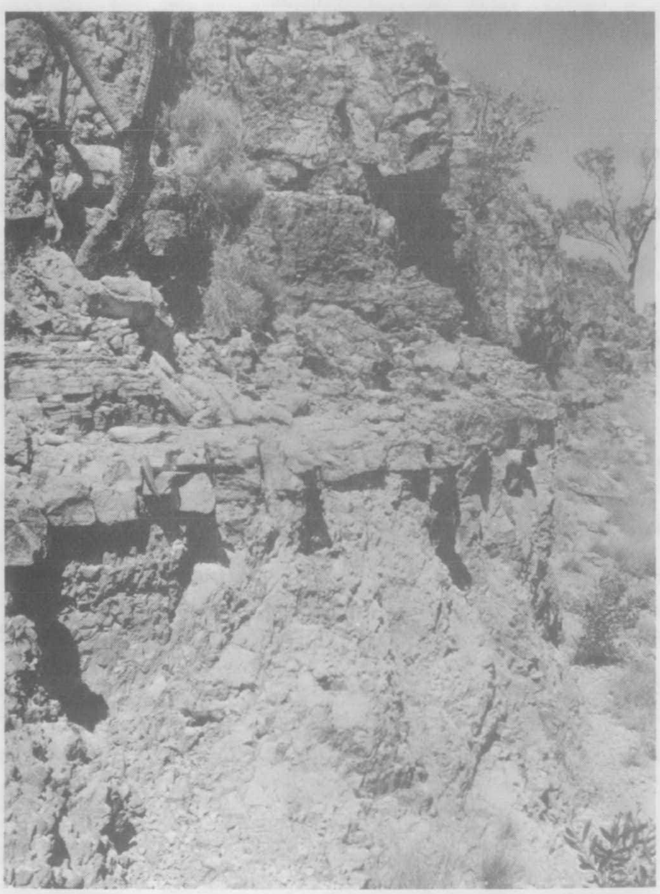

Fig 47 Flat-lying Larranganni Beds overlying white altered basalt of Antrim Plateau Volcanics, north of Supplejack Downs homestead. (Neg. GA/5757)

Lithology

The unit consists of flat-lying, crudely to well bedded sandstone and minor siltstone and conglomerate. The sediments appear to be unfossiliferous. The sandstone typically forms beds about 1 m thick, but the thickness is variable and lensing out is common. The siltstone is generally thin-bedded. The sandstone is white to pale grey, fine to coarse and commonly silicified. Sorting is variable and the grains, which are mainly quartz, tend to be poorly rounded. Cellular surfaces due to solution weathering are characteristic suggesting that the sandstone is partly calcareous. Near Larranganni Bluff well bedded sandstone (Fig. 48) passes laterally into crudely bedded, very poorly sorted conglomeratic sandstone.

Conglomerate crops out 7 km east-northeast of Supplejack Downs homestead, where it contains poorly sorted sub-angular to rounded pebbles and cobbles of various types of sandstone, and also chert, white altered basalt, a pale green porphyritic acid volcanic rock, and vein quartz; these are set in an abundant sandstone matrix.

Stratigraphic relationships, origin, and age. The Larranganni Beds lie unconformably on irregular surfaces of Killi Killi Formation and Gardiner Formation at Larranganni Bluff, on Gardiner Formation in the Supplejack Range, and on basalt of the Antrim Plateau Volcanics north of Supplejack Downs homestead. Cappings of Tertiary laterite and silcrete are common, pisolitic laterite up to 1 m thick being predominant in the Supplejack area, and silcrete in the western outcrops.

The beds are probably fluvial and lacustrine in origin. In the Supplejack Downs area current bedding is common, and at a locality 7 km east-northeast of the homestead conglomerate and sandstone show possible torrential bedding. Current bedding was not observed in the well bedded possibly lacustrine sandstone at Larranganni Bluff.

Fig 48 Flat-lying Larranganni Beds with silicified beds and silcrete capping; near Larranganni Bluff (in background). (Neg. GA/5717)

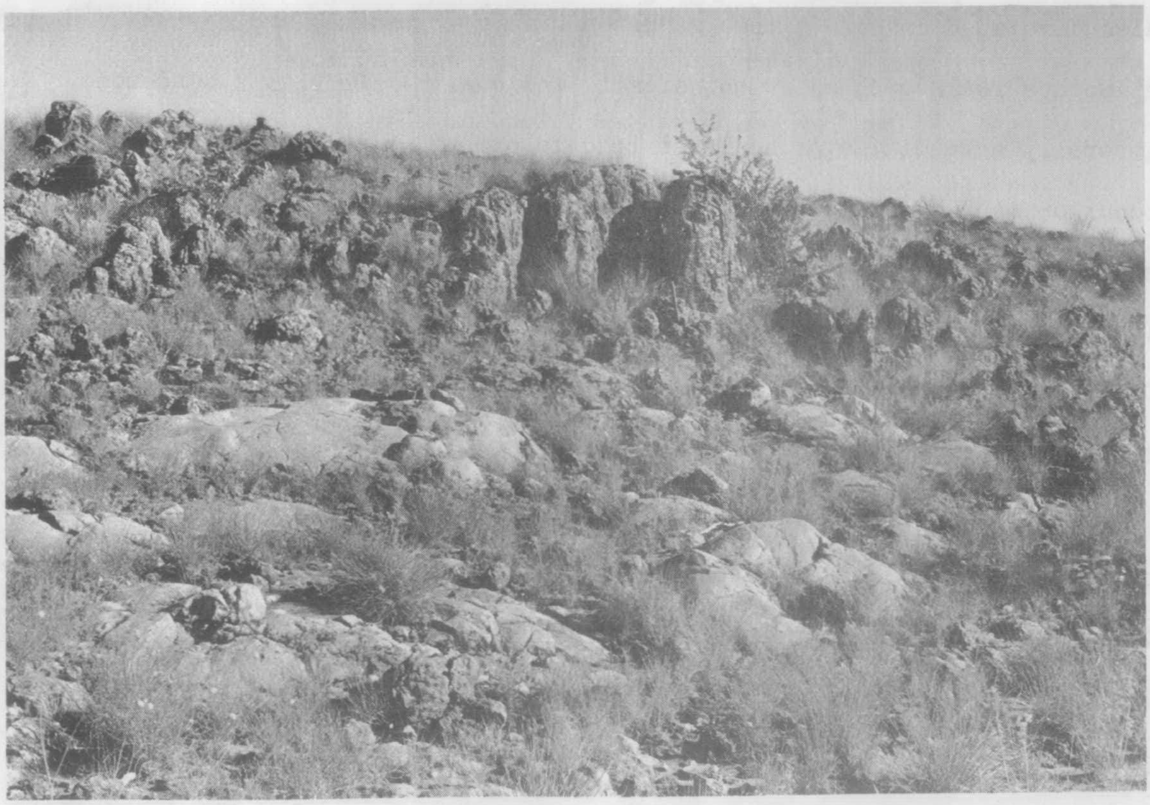

Fig 49 Silcrete north of the Crazy Dingo Range showing smooth rounded surfaces (in foreground) and columnar structure. (Neg. M/1327)

After the Larranganni Beds were laid down the area was subjected to a long period of erosion, and the beds now occur on topographic highs unrelated to the present drainage system. This, and the presence of Tertiary laterite and silcrete cappings, indicate that the beds may be pre-Tertiary, and they are tentatively correlated with Cretaceous beds of similar lithology which crop out in the Stansmore Sheet area to the southwest (Wells, 1962c).

TERTIARY

Laterite

Laterite is common throughout the area mapped, as cappings on rocks ranging in age from Lower Proterozoic to Cainozoic. The cappings form topographic highs with smooth to very gently undulating tops, and show up as dark tones on air-photographs. They mostly have gently sloping sides, commonly with shallow gullies, but many are partly bounded by breakaways.

The laterite is best developed on rocks relatively low in silica, such as basalt, phyllite, shale, mudstone, siltstone, and greywacke, but is also developed on some lithic sandstone, acid volcanics, and granite. Highly siliceous rocks such as orthoquartzite and quartz-rich lithic sandstone generally have little or no laterite development, although laterite cappings occur on many chert outcrops. Such cappings may have been formed on less siliceous rock types, such as shale or basalt, previously overlying the chert. Laterite is also associated with silcrete at outcrops north of Supplejack Downs homestead, where it was not possible to determine which of the two was the younger.

Complete lateritic profiles are present in many places, especially on basalt of the Antrim Plateau Volcanics, where the profiles are locally over 20 m thick. Similar thicknesses were penetrated in drill holes north of Talbot Well. On granite the profile is commonly less than 5 m thick. The profiles are well exposed in breakaways, where they mostly consist of a cemented pisolitic upper layer about 1 m thick, a central mottled zone 3 or more metres thick, and a lower white pallid zone. The pisolitic layer is deep reddish purple to black and is highly ferruginous, consisting largely of limonite and either or both goethite and hematite. The underlying zone is generally mottled reddish, maroon, purple, and white. Variations in the lateritic profile are common: a mottled zone commonly underlies the bleached zone in lateritized basalt, and only the pisolitic layer is generally present on sandstone. Another variation was observed 1 km southeast of Coomarie Spring (Figs 50 and 51) where an upper layer of normal pisolitic laterite 1 m thick overlies 3 m of layered pisolitic laterite developed on shale of the Gardiner Formation. Small lenses of iron-stained silcrete occur between the two layers of pisolitic laterite, and vertical pipes have been eroded in the lower layer of laterite.

As well as forming cappings on topographic highs, pisolitic laterite is also locally present bordering creeks, as near the Tanami/Hooker Creek track on the north side of Wilson Creek. At such localities, which are too small to be shown on the geological maps, the pisolitic laterite rests on Quaternary alluvium.

Age The lateritic cappings are remnants of a very gently undulating erosion surface. The youngest rocks on which they are formed are the Larranganni Beds mapped as Cretaceous (?), and perhaps silcrete mapped as Tertiary. Since the formation of the laterite considerable erosion has taken place, much more than is likely to have occurred in the area during the Quaternary. Hence the laterite cappings are considered to be Tertiary, and are correlated with the Tennant Creek erosion surface of Hays (1967). The pisolitic laterite on Quaternary alluvium is probably a sediment derived from older laterite.

Fig.50. Upper part of the lateritic profile developed on shale southeast of Coomarie Spring. Mottled and bleached shale exposed in the gully is overlain by about 3 m of layered pisolitic laterite capped by normal pisolitic laterite. (Neg. M1292/10A).

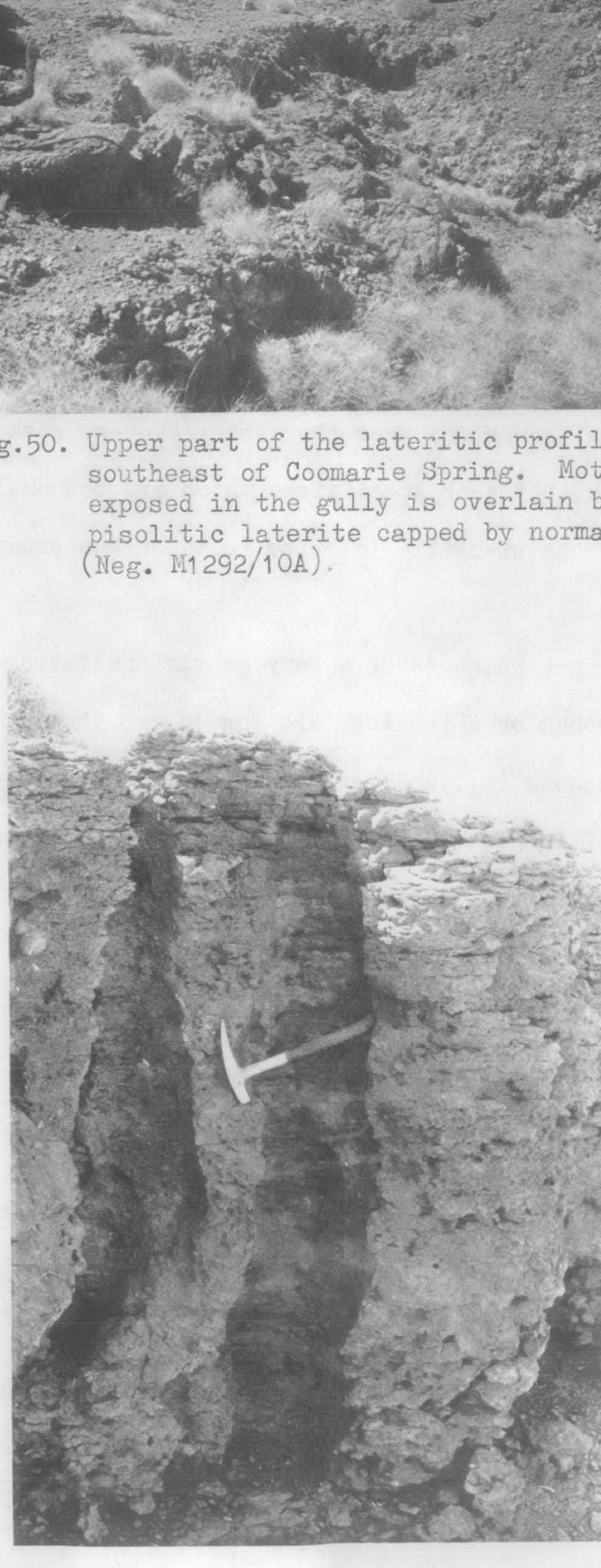

Fig.51. Vertical pipe in layered laterite, locality as for Fig 50. (Neg. 1292/13A).

Silcrete (Ts)

Patches of silcrete were observed in many parts of the area, but only rarely were they large enough to include on the geological maps. Silcrete is found on topographic rises, where it occurs mainly on Proterozoic sandstone but also on Larranganni Beds, Winnecke Granophyre, and quartz veins. At some localities it is associated with pisolitic laterite. Exposures (Fig 49) commonly consist of a veneer of silcrete cobbles and boulders on smoothly rounded weathered surfaces. Columnar structures are present in places (cf Senior & Senior, 1972).

The silcrete is a greyish to pale buff rock formed mainly of unsorted angular quartz grains set in a very fine to amorphous siliceous matrix. Locally it also includes fragments, some over 1 cm across, of chert and vein quartz.

Where the silcrete is associated with pisolitic laterite it is generally developed on slopes below remnant laterite cappings, and in such situations it appears to be younger than the laterite capping. However, in places it also occurs directly underlying pisolitic laterite, and such silcrete may be older than the laterite.

Travertine (Tt)

Occurrences of travertine are widespread in the Tanami Sheet area but rare in the Birrindudu Sheet area. On air-photographs travertine typically has a light tone and a cerebriform texture. It crops out in general topographic depressions, where it forms undulating terrain with low mounds and solution hollows. Travertine is most extensively developed in the southeast corner of the Tanami Sheet area near Lake Buck. Here it has been largely silicified and is difficult to distinguish from Cambrian chert. Some cross-bedded travertine was seen on the southern edge of Lake Buck.

The travertine is considered to be pre-Quaternary and is possibly an evaporite deposit in Tertiary drainage channels.

QUATERNARY

The Quaternary comprises the superficial deposits that cover most of the mapped area. They are grouped into four units.

<u>Black and grey residual soils</u> (Qb)

Extensive flat and generally treeless plains in the Birrindudu Sheet area are covered by black and grey residual soils that are probably several metres deep. These are heavy clay soils that crack widely and deeply when they dry out after each wet season (Stewart, 1970). They are developed on basalt of the Lower Cambrian Antrim Plateau Volcanics.

<u>Aeolian sand and piedmont sediments</u> (Qz)

Aeolian sand and piedmont deposits are the most widespread Quaternary sediments, and cover most of the plains separating outcrops of Cambrian and Proterozoic rocks. Aeolian sand is most evident in the eastern part of the Tanami Sheet area, where it forms groups of low longitudinal dunes. These dunes appear to be stable at present. Piedmont sediments consisting of sand and gravel are restricted to gentle slopes flanking residual hills and ridges.

<u>Alluvial and aeolian sand occupying drainage depressions</u> (Qs)

Barely perceptible drainage depressions mostly with no well defined drainage channels occur on the plains throughout the area. They are commonly dendritic, and are characterized on air-photographs by arcuate vegetation patterns. Sediments consisting mainly of sand are washed into these depressions during rainy periods, and wind-blown sand is deposited during dust storms.

<u>Alluvial and lacustrine sediments</u> (Qa)

Sand, silt and clay mapped as alluvium occur along the major creeks, and lacustrine deposits, mainly clay, occur in claypans (Fig. 52), salt pans, and in Nongra Lake (Fig. 53) and Lake Buck. The unit also includes floodout sediments of Sturt Creek. These were penetrated in a bore at Birrindudu homestead, where they consist of 21 m of green and white clay underlain by weathered basalt and overlain by 3 m of lateritic sand (Shields, 1965).

Fig 52 Claypan east of Stake Range (Neg. GA/5705)

Fig 53 Nongra Lake; looking southwards from the east side, June 1971. (Neg. M/1215)

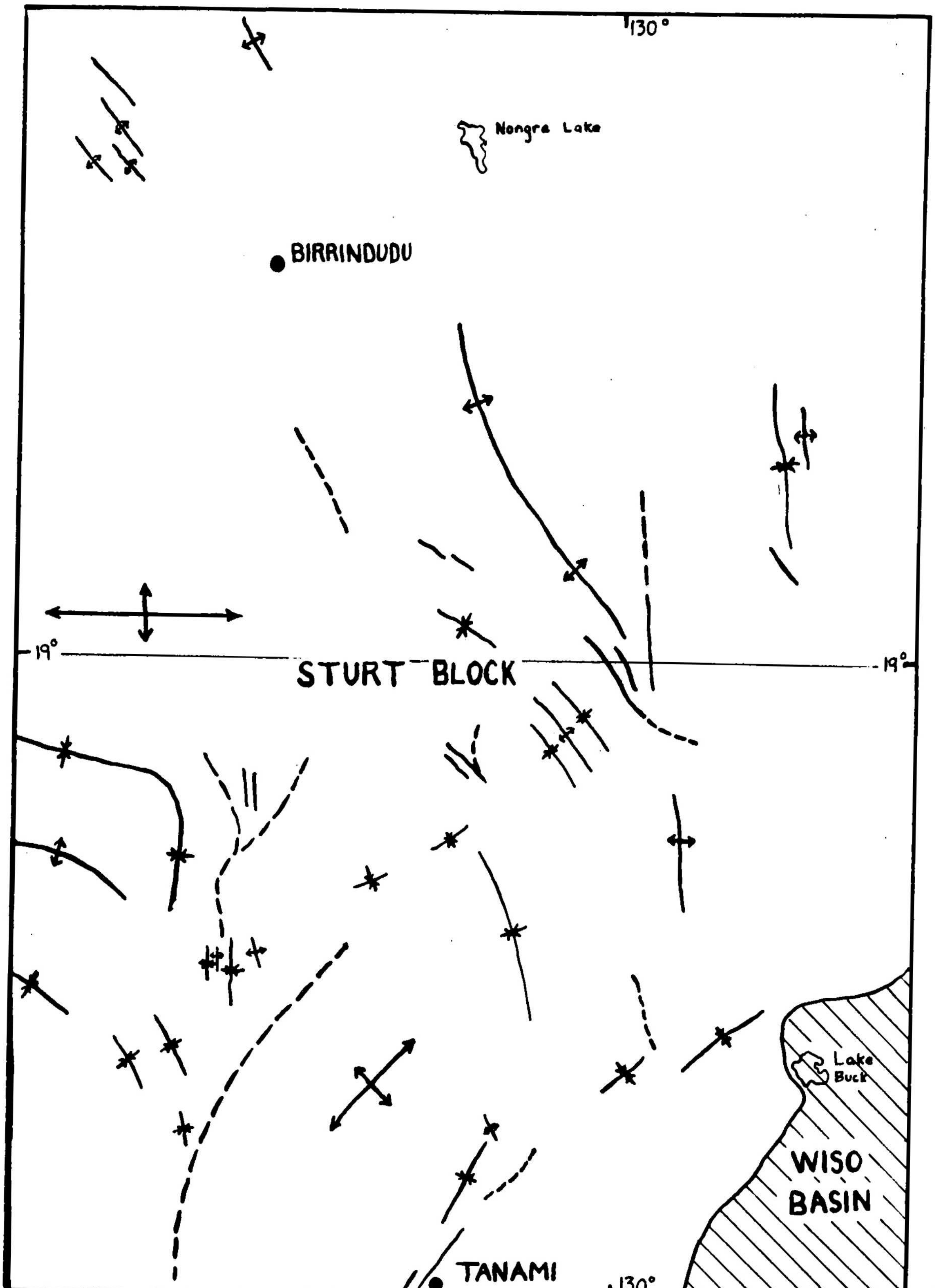

FIG. 54. STRUCTURAL SKETCH MAP.

STRUCTURE

The area forms parts of two major tectonic units, the Sturt Block which occupies most of the area mapped and the Wiso Basin in the extreme east. The Sturt Block was subject to at least two major periods of tectonic activity during the Proterozoic, one affecting only Lower Proterozoic rocks, the other affecting both Lower and Upper Proterozoic rocks, but it has been a stable area during the Phanerozoic and folded Proterozoic rocks are overlain by flat-lying Lower Cambrian rocks. The Wiso Basin consists of subhorizontal Cambrian marine sediments that thicken to the east.

The two tectonic units and the main structural features of the area are shown in Figure 54.

Folding

The Lower Proterozoic rocks have been tightly folded, possibly isoclinally, and they generally have a steep to vertical cleavage trending northwest to northeast. The cleavage is probably parallel to the axial planes of the folds. The tight folding and the development of the cleavage took place before deposition of the Upper Proterozoic. Because of the lack of marker beds within the Lower Proterozoic and generally poor exposures, only two major folds have been mapped. These are a syncline in Pargee Sandstone in the West Pargee Range, and a syncline in Mount Charles Formation to the southeast. Another fold closure may be located 20 km east-northeast of Tanami, where two gossan ridges converge. Tight minor folds can be seen at several exposures, as for instance between Tanami and the Tanami Range, and 100m east of the Wilson Creek waterholes. The variable trends of cleavage are probably due to folding during the Upper Proterozoic.

The Upper Proterozoic sedimentary rocks in the central and southern parts of the area form broad domes and anticlinal structures, with cores of older granite and Lower Proterozoic rocks, separated by broad synclinal structures and areas of irregular folding. Trends range from easterly in the west to northerly in the east. In the north the Upper Proterozoic Limbunya Group has been folded into synclines and anticlines with vertical fold axes trending north-west. The irregular pattern of folds is attributed to the area being at the intersection of major north and west trends.

Major folds affecting the Upper Proterozoic rocks include the following examples.

1. Browns Range and Coomarie Domes. These have cores of granite and Lower Proterozoic rocks and are flanked by outwardly dipping Gardiner Formation. The Browns Range Dome is elongated east-west and the Coomarie Dome northeast-southwest. The doming took place after the deposition of the Gardiner Formation and may be due to isostatic adjustment of the granite bodies after their intrusion.

2. Two broad synclines and one anticline between Browns Range Dome and Larranganni Bluff. These have gently sloping limbs and trend east southeast.

3. A syncline on the west side of Stake Range. This has a nearly vertical axis that swings eastwards from east-west to north-south.

4. A broad anticlinal structure in the central part of the Birrindudu Sheet area. This fold probably extends from Nongra Lake south and then southeast to the Ware Range.

5. The southeasterly-trending Mana Range syncline.

6. A complex synclinal basin on the west side of Supplejack Range. Between this structure and the Pargee Range to the southwest are a number of small folds with trends ranging from east-west to north-south.

7. Synclinal troughs on the north and northeast sides of Coomarie Dome.

8. Synclinal and anticlinal structures between Tanami and Coomarie Spring, on the southeast side of Coomarie Dome.

9. The circular Talbot Hills basin.

10. A probable syncline trending east-west east of the Talbot Hills, on the western margin of the Wiso Basin.

11. The northerly trending anticlinal and synclinal folds of the Mount Winnecke Formation. These may have been formed before the Birrindudu Group was deposited; if so they are older than the other Upper Proterozoic folds in the area and indicate a third major phase of tectonic activity.

Faulting

Faults are very common on the Sturt Block, where they displace Lower and Upper Proterozoic rocks, and undoubtedly many more are present than are shown on the geological maps. Most of the faulting probably took place after the folding of the Upper Proterozoic but before the Lower Cambrian. This is indicated by the cross-cutting relationships of the faults to the folded rocks, and the absence of faults which can be shown to displace the Lower Cambrian Antrim Plateau Volcanics. The volcanics were laid down on a highly irregular surface, and their present distribution can be accounted for without involving either subsequent faulting or folding.

Most faults mapped probably have displacements of less than a few hundred metres, and there appear to be relatively few major faults. However major faults are likely to form zones that are preferentially eroded, and hence may be concealed beneath superficial deposits. The faults mapped are mainly oblique to bedding trends, but strike faults occur in the Stake Range, and may also be present elsewhere, as for instance 30 km northwest of Supplejack Downs homestead, where the outcrop pattern indicates possible repetition of beds due to faulting. Several faults may be marked by large quartz veins such as occur in the Ware Range.

The faults show a wide range of trends, but perhaps the most common trend is west -northwest to northwest.

The main faults mapped in the area are listed below.

1. A fault on the east side of the Ware Range. This fault is downthrown to the west, and has brought Nanny Goat Creek Formation, Mount Winnecke Formation, and Winnecke Granophyre in the east alongside Ware Range Sandstone.

2. A fault along the contact between Ware Range Sandstone and Nongra Formation on the southwest side of the Northern Ware Range.

3. An inferred and concealed northerly-trending fault southwest of the Birrindudu Range. It accounts for the northeasterly dipping Gardiner Formation to the west cutting across northwesterly dipping Ware Range Sandstone to the east.

4. A fault southeast of the Ware Range. It is downthrown to the south and has brought Nanny Goat Creek Formation alongside Supplejack Downs Sandstone.

5. Two faults that join to form a 'Y' on the east side of the Stake Range. They are probably partly normal and partly tear faults.

6. A mostly concealed fault on the west side of the Coomarie Dome, downthrown to the east, that has brought westerly dipping Gardiner Formation alongside Lower Proterozoic rocks to the west.

GEOPHYSICAL SURVEYS

Airborne magnetic and radiometric surveys of the Tanami Sheet area were carried out by BMR in 1962 (Spence, 1964), and an airborne magnetic survey of the Birrindudu Sheet area was undertaken in 1967 (Taylor, in prep). Part of the Tanami Sheet area was also included in an airborne radiometric survey in 1961 (Mulder, 1961). The whole area mapped has been covered by a reconnaissance gravity survey (Whitworth, 1970; Flavelle, in prep.). In this Record a brief account only is given of the results of these surveys in relation to the findings of the 1971 geological survey.

The area has a complex magnetic anomaly pattern (Spence, 1964; Taylor, in prep.) with individual anomalies estimated to originate at depths ranging from near surface to over 2 000 m. Magnetic highs tend to coincide with areas of Lower Proterozoic rocks or areas that are probably underlain by Lower Proterozoic rocks at shallow depth. Granite is mainly indicated by magnetic lows. Areas of Upper Proterozoic rocks mostly have smooth featureless magnetic profiles. On Antrim Plateau Volcanics in the Birrindudu Sheet area magnetic anomalies, though not intense, change very markedly over short distances (Taylor, in prep.).

Radioactivity is generally low and fairly uniform throughout the whole area. Zones of relatively high intensity coicide with granite occurrences. Anomalies found in 1961 (Mulder, 1961) were mostly caused by surface laterite.

The regional gravity survey (Whitworth, 1970) revealed a series of intense short wave-length Bouguer anomalies showing a predominant north-northeast trend. As a result of the survey the northern part of the area was termed the Billiluna Gravity Plateau and the southern part the Coomarie Regional Gravity Complex. The suggestion by Flavelle (in prep) that the gravity highs may correspond to Lower Proterozoic rocks and the gravity lows to granite has been borne out by the 1971 geological survey.

ECONOMIC GEOLOGY

The only ore deposits that have been worked in the area are those of gold near Tanami. Copper minerals have been found at a few localitites, and the occurrence of uranium at the Killi Killi Hills indicates that the area lies in a uraniferous region.

Gold

Gold was discovered at Tanami in 1900 by Allan Davidson, and was exploited intermittently between 1904 and 1940. Descriptions of the deposits are included in published reports by Davidson (1905), Brown (1909), Gee (1911), and Hossfeld (1940). Lode, eluvial and alluvial gold were obtained. The total production is unknown, but may be about 2 500 ozs (Hossfeld, 1940, from an unpublished report by H.A. Ellis). The workings are now inaccessible, and the following account is based largely on the report by Hossfeld.

The reef gold occurs along two fracture zones trending northeast-southwest and dipping east. Most of the gold was obtained from small lenticular quartz bodies along a series of fissures, and from country rocks favourable to enrichment that are cut by the fissures. Some gold also came from quartz-jasper-hematite reefs. The country rocks are tightly folded thin-bedded fine-grained sedimentary rocks which are partly silicified to chert, minor greywacke, and intercalated basalt. They belong to the Lower Proterozoic Mount Charles Formation. The 'favourable country rocks', described by earlier workers as felsite, may be silicified fine-grained sedimentary rocks or basalt Alluvial and eluvial gold was found near the lodes.

Gold has also been recorded in the Lower Proterozoic Killi Killi Formation near Larranganni Bluff (Davidson, 1905).

Copper

Copper carbonates have been recorded in Lower Proterozoic rocks on the north side of the Southern Browns Range (Davidson, 1905; Phillips, 1959), and as rare smears in Lower Proterozoic amphibolite on the east side of the

Black Hills (Roberts, 1968). Phyllite containing 0.1 percent copper in the form of chalcopyrite was intersected in a diamond-drill hole put down by Enterprise Exploration Pty Ltd in 1962 (quoted by Roberts, 1968).

Uranium

At the Killi Killi Hills prospects, located just inside Western Australia, uranium is concentrated in xenotime in conglomerate at the base of the Gardiner Formation, directly overlying Lower Proterozoic rocks (Clark & Blockley, 1960; Prichard et al., 1960). The xenotime is probably detrital.

During the 1971 geological survey exposures throughout the mapped area and hand specimens of conglomerate and other rock types, including granite, were tested for radioactivity using an Austral Model GMIb geiger counter. However, except for the conglomerate at the Killi Killi Hills prospects, no significant anomalies were found. Only one specimen other than the conglomerate gave more than twice background values. This was the core, consisting mainly of palygorskite, from drill hole No. 62, east of the Black Hills, The absence of anomalies over exposures may be due at least in part to the rocks having been leached during weathering; the area should not be considered unprospective for uranium.

Water Supply

Occurrences of surface water have been described in the section on Topography and Drainage, in the Introduction to this Record.

Underground water is tapped by several bores in both Sheet areas, those in the Tanami Sheet area being listed in Kingdom et al (1967). There are bores with wind pumps on Birrindudu and Supplejack Downs properties, along Hooker Creek, and at Tanami. The bore at Tanami is the deepest in the area; it reached water at a depth of about 40 m, and was continued to over 100 m. Supplies of water can be expected at shallow depth below most travertine outcrops in the area.

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APPENDIX

Stratigraphic drilling 1971

A total of 85 shallow stratigraphic holes were drilled in the Tanami Sheet area to obtain information on bedrock in areas covered by superficial deposits. Holes were drilled along the following lines, mostly at intervals of about 3 km: north-south and east-west across the Coomarie Dome; along the Tanami/Hooker Creek track between Coomarie Spring and the Supplejack Downs turn-off, and along two short east-west lines 5 and 17 km north of Talbot Well; along a line east from the Black Hills near Mount Charles; along a track to the Black Hills 16 km northnortheast of Tanami; and along the Tanami-Billiluna road from the Tanami Range to south of Mount Frederick. Positions of all holes drilled are shown on the Preliminary Edition of the Tanami Geological Sheet. Drill logs are given below.

During the drilling of each hole, cuttings were taken at intervals of 1.5 m. In most holes when hard bedrock was reached, cores up to .5 m long were collected. The maximum depth drilled was 82 m, and the average was about 15 m. The drilling was done by a BMR team led by E. Lodwick using a mobile Mayhew drilling rig.

Stratigraphic hole 1

0 - 4.5 m	cuttings:	maroon shale
4.5 - 30.5 m	cuttings:	paler maroon and mottled shale
30.5 - 30.7 m	core :	gently dipping (about 18°) banded and mottled maroon and pale greenish-grey shale. Gardiner Formation

Stratigraphic hole 2

0 - 6 m	cuttings:	lateritic sand
6 - 35.4 m	cuttings:	maroon shale
35.4 - 35.6 m	core :	flat-lying maroon shale with pale greenish grey bands and mottles. Gardiner Formation

Stratigraphic hole 3

0 - 3.7 m	cuttings:	lateritic sand
3.7 - 3.9 m	core :	travertine, partly silicified
3.9 - 7.5 m	cuttings:	pale brown to grey clay
7.5 - 30.5 m	cuttings:	pale brown to grey clay
30.5 - 32.9 m	cuttings:	maroon sandstone
32.9 - 33.0 m	core :	silicified maroon medium lithic sandstone. Gardiner Formation

Stratigraphic hole 4

0 - 4.5 m	cuttings:	laterite
4.5 - 29 m	cuttings:	disaggregated granite
29 - 30.5 m	cuttings:	brown clay
30.5 - 32.0 m	cuttings:	disaggregated granite
32.0 - 32.3 m	core :	reddish brown medium micaceous granite. Unnamed granite

Stratigraphic hole 5

0 - 4.5 m	cuttings:	laterite
4.5 - 6.7 m	cuttings:	altered granite
6.7 - 7.1 m	core :	mottled lateritized and silicified medium granite. Unnamed granite

Stratigraphic hole 6

0 - 3 m	cuttings:	laterite
3 - 5.5 m	cuttings:	lateritized granite
5.5 - 5.8 m	core :	mottled lateritized and silicified medium granite. Unnamed granite.

Stratigraphic hole 7

0 - 3 m	cuttings:	laterite
3 - 4.9 m	cuttings:	lateritized granite
4.9 - 5.0 m	core :	mottled lateritized and silicified medium granite. Unnamed granite

Stratigraphic hole 8

0 - 3.5 m	cuttings:	laterite
3.5 - 11.5 m	cuttings:	pale lateritized granite
11.5 - 12.2 m	core :	lateritized medium granite. Unnamed granite.

Stratigraphic hole 9

0 - 3	m cuttings:	reddish brown sand	
3 - 6	m cuttings:	laterite sandstone	
6 - 9	m cuttings:	partly silicified sand	
9 - 35	m cuttings:	weathered granite	
35 - 48.7	m cuttings:	disaggregated granite	
48.7 - 51.8	m core :	medium-grained micaceous granite.	Unnamed granite

Stratigraphic hole 10

0 - 8.2	m :	laterite	
8.2 - 8.5	m :	lateritized granite.	Unnamed granite

Stratigraphic hole 11

0 - 3	m cuttings:	red-brown sand	
3 - 7.6	m cuttings:	granitic sand	
7.6 - 7.9	m core :	mottled granite.	Unnamed granite.

Stratigraphic hole 12

0 - 1.5	m cuttings:	ferruginous sand	
1.5 - 29.3	m cuttings:	disaggregated granite	
29.3 - 29.4	m core :	pink medium-grained biotite granite.	Unnamed granite.

Stratigraphic hole 13

0 - 3.5	m cuttings:	laterite	
3.5 - 14	m cuttings:	travertine	
14 - 43.3	m cuttings:	disaggregated granite	
43.3 - 43.6	m core :	medium-grained greisenous granite.	Unnamed granite.

Stratigraphic hole 14

0 - 12	m cuttings:	laterite	
12 - 14.6	m cuttings:	iron-stained sand	
14.6 - 14.9	m core :	white medium sandstone containing maroon shale fragments.	Gardiner Formation?

Stratigraphic hole 15

0 - 6	m cuttings:	laterite	
6 - 9	m cuttings:	bleached shale	
9 - 25.9	m cuttings:	maroon shale	
25.9 - 26.2	m core :	flat-lying maroon and pale greenish grey shale.	Gardiner Formation.

Stratigraphic hole 16

0 - 5	m cuttings:	lateritized shale	
5 - 29.6	m cuttings:	grey and maroon shale	
29.6 - 29.9	m core :	flat-lying maroon and grey shale, siltsone, and fine sandstone	
29.9 - 81	m cuttings:	maroon and grey shale.	Gardiner Formation.

Stratigraphic hole 17

0 - 3	m cuttings:	laterite	
3 - 11.0	m cuttings:	lateritized granite	
11.0 - 11.3	m core :	weathered granite.	Unnamed granite.

Stratigraphic hole 18

0 - 5 m cuttings: laterite
5 - 79.2 m cuttings: yellowish brown disaggregated granite.
79.2 - 80.8 m core : medium-grained weathered biotite granite. Unnamed granite.

Stratigraphic hole 19

0 - 5 m cuttings: laterite
5 - 9.1 m cuttings: lateritized granite
9.1 - 9.8 m core : silicified weathered granite. Unnamed granite.

Stratigraphic hole 20

0 - 5 m cuttings: laterite
5 - 6.7 m cuttings: yellowish brown weathered granite.
6.7 - 7.0 m core : silicified weathered granite. Unnamed granite.

Stratigraphic hole 21

0 - 6.7 m cuttings: laterite
6.7 - 7.0 m core : lateritic granitic breccia.

Stratigraphic hole 22

0 - 6 m cuttings: laterite
6 - 11.9 m cuttings: yellowish brown granite.
11.9 - 12.2 m core : silicified weathered medium-grained granite. Unnamed granite.

Stratigraphic hole 23

0 - 9 m cuttings: laterite
9 - 51.8 m cuttings: disaggregated granite
51.8 - 52.1 m core : quartz-veined greisen. Unnamed granite.

Stratigraphic hole 24

0 - 4 m cuttings: laterite
4 - 10.7 m cuttings: weathered granite.
10.7 - 11.0 m core : weathered medium granite. Unnamed granite.

Stratigraphic hole 25

0 - 7.5 m cuttings: lateritic gravel
7.5 - 23 m cuttings: reddish brown sand
23 - 30.5 m cuttings: pale olive-brown and green weathered gabbro.
30.5 - 30.8 m core : greenish yellow weathered gabbro.
30.8 - 48.5 m cuttings: gabbro
48.5 - 48.8 m core : gabbric rock consisting of mainly biotite, clinopyroxene, orthopyroxene and hornblende. Unnamed granite.

Stratigraphic hole 26

0 - 4.5 m cuttings: laterite
4.5 - 6.0 m cuttings: maroon travertine
6.0 - 15.2 m cuttings: yellow-brown granite
15.2 - 15.5 m core : altered pink granite. Unnamed granite.

Stratigraphic hole 27

0 - 6.0 m cuttings: laterite
6.0 - 9.0 m cuttings: red-brown siltstone?
9.0 - 11.0 m cuttings: maroon tuff or basalt?
11.0 - 11.3 m core : maroon mudstone or tuff. Mount Charles Formation.

Stratigraphic hole 28

0 - 6.0 m cuttings: laterite
6.0 - 10.7 m cuttings: chert fragments
10.7 - 10.75m core : maroon and pale grey brecciated silicified mudstone. Talbot Well Formation

Stratigraphic hole 29

0 - 7.5 m cuttings: laterite
7.5 - 11.6 m cuttings: travertine
11.6 - 12.2 m core : travertine?

Stratigraphic hole 30

0 - 6.0 m cuttings: laterite
6.0 - 7.5 m cuttings: chert
9.1 - 9.2 m core : breccia containing chert and maroon mudstone fragments. Talbot Well Formation.

Stratigraphic hole 31

0 - 20 m cuttings: mudstone
20 - 26.5 m cuttings: white sandstone
26.5 - 27.0 m core : white, flat-lying, medium quartz sandstone. Talbot Well Formation?

Stratigraphic hole 32

0 - 4.6 m cuttings: laterite
4.6 - 4.7 m core : maroon medium quartz sandstone. Talbot Well Formation?

Stratigraphic hole 33

0 - 3.7 m cuttings: laterite
3.70- 3.73 m cuttings: breccia containing red-brown mudstone and brown micaceous sandstone fragments. Talbot Well Formation?

Stratigraphic hole 34

0 - 7.5 m cuttings: laterite
7.5 - 9.0 m cuttings: reddish-brown basalt
9.0 - 15.5 m cuttings: brown mudstone
15.5 - 15.8 m core : maroon fine to medium lithic sandstone. Antrim Plateau Volcanics/unnamed Upper Proterozoic.

Stratigraphic hole 35

0 - 21.0 m cuttings: lateritic profile
21.0 - 21.3 m core : maroon altered basalt. Antrim Plateau Volcanics.

Stratigraphic hole 36

0 - 4.5 m cuttings: laterite
4.5 - 4.9 m core : lateritized basalt
4.9 - 10.7 m cuttings: basalt
10.7 - 11.0 m cuttings: pale grey basalt. Antrim Plateau Volcanics

Stratigraphic hole 37

0 - 4.6 m cuttings: laterite
4.6 - 4.9 m core : lateritized basalt
4.9 - 11.6 m cuttings: basalt. Antrim Plateau Volcanics

Stratigraphic hole 38

0 - 9.0 m cuttings: laterite
9.0 - 13.5 m cuttings: mottled, lateritized basalt
13.5 - 26.0 m cuttings: grey and maroon basalt. Antrim Plateau Volcanics
26.0 - 29.0 m cuttings: pale grey and maroon mudstone
29.0 - 29.2 m core : brown, flat-lying mudstone and pale grey medium lithic sandstone. Gardiner Formation

Stratigraphic hole 39

0 - 9.5 m cuttings: laterite
9.5 - 9.8 m core : maroon basalt. Antrim Plateau Volcanics

Stratigraphic hole 40

0 - 4.5 m cuttings: laterite
4.5 - 26.0 m cuttings: basalt. Antrim Plateau Volcanics
26.0 - 38.1 m cuttings: maroon and grey shale, mudstone
38.1 - 38.6 m core : maroon and grey shale, mudstone. Gardiner Formation

Stratigraphic hole 41

0 - 4.5 m cuttings: laterite
4.5 - 7.5 m cuttings: lateritized basalt
7.5 - 9.1 m cuttings: grey basalt
9.1 - 9.4 m core : massive dark grey basalt. Antrim Plateau Volcanics

Stratigraphic hole 42

0 - 7.5 m cuttings: laterite
7.5 - 9.1 m cuttings: grey basalt
9.1 - 9.4 m cuttings: greyish maroon basalt. Antrim Plateau Volcanics

Stratigraphic hole 43

0 - 1.5 m cuttings: laterite
1.5 - 12.2 m cuttings: grey basalt
12.2 - 12.5 m cuttings: dark greyish maroon altered amygdaloidal basalt, calcite in amygdales. Antrim Plateau Volcanics

Stratigraphic hole 44

0 - 9.0 m cuttings: laterite
9.0 - 34.7 m cuttings: brown mudstone
34.7 - 35.1 m core : gently dipping maroon and pale grey mudstone. Unnamed Upper Proterozoic

Stratigraphic hole 45

0 - 4.5 m cuttings: cemented laterite
4.5 - 7.6 m cuttings: lateritized basalt
7.6 - 7.9 m core : maroon basalt. Antrim Plateau Volcanics

Stratigraphic hole 46

0 - 13.0 m cuttings: reddish brown basalt
13.0 - 13.3 m core : maroon basalt. Antrim Plateau Volcanics

Stratigraphic hole 47

0 - 4.5 m cuttings: laterite
4.5 - 24.4 m cuttings: mottled weathered basalt
24.4 - 24.7 m core : grey basalt. Antrim Plateau Volcanics

Stratigraphic hole 48

0 - 12.0 m cuttings: lateritized mudstone.
12.0 - 16.5 m cuttings: mudstone
16.5 - 16.7 m core : gently dipping maroon and pale grey mudstone. Unnamed Upper Proterozoic

Stratigraphic hole 49

0 - 11.0 m cuttings: laterite
11.0 - 24.5 m cuttings: bleached mudstone
24.5 - 25.3 m cuttings: maroon mudstone
25.3 - 25.6 m core : maroon mudstone. Upper Proterozoic

Stratigraphic hole 50

0 - 9.0 m cuttings: laterite
9.0 - 15.0 m cuttings: grey sticky clay
15.0 - 33.5 m cuttings: maroon and grey shale and mudstone
33.5 - 33.7 m core : grey shale and pale medium quartz sandstone. Gardiner Formation

Stratigraphic hole 51

0 - 3.0 m cuttings: laterite
3.0 - 31.7 m cuttings: weathered granite
31.7 - 32.0 m core : reddish brown altered granite, fine to medium, contains quartz, pink feldspar, and white mica. Unnamed granite.

Stratigraphic hole 52

0 - 11.0 m cuttings: lateritized granite
11.0 - 43.3 m cuttings: weathered granite
43.3 - 43.6 m core : pink fine to medium granite and pegmatite vein. Unnamed granite

Stratigraphic hole 53

0 - 2.4 m cuttings: laterite
2.4 - 7.6 m cuttings: dark grey basalt or amphibolite. Mount Charles Formation

Stratigraphic hole 54

0 - 3.0 m cuttings: laterite
3.0 - 16.8 m cuttings: dark grey amphibolite or basalt with calcite veins
16.8 - 17.1 m core : dark grey basalt or amphibolite. Mount Charles Formation

Stratigraphic hole 55

0 - 4.5 m	cuttings:	laterite
4.5 - 12.0 m	cuttings:	lateritized basalt
12.0 - 21.5 m	cuttings:	brown and purple altered basalt. Mount Charles Formation
21.5 - 42.7 m	cuttings:	disaggregated granite
42.7 - 42.8 m	core :	disaggregated granite. Unnamed granite

Stratigraphic hole 56

0 - 4.5 m	cuttings:	laterite
4.5 - 9.0 m	cuttings:	altered basalt. Mount Charles Formation
9.0 - 21.5 m	cuttings:	amphibolite.
21.5 - 24.7 m	cuttings:	granite
24.7 - 25.0 m	core :	medium-grained, aphyric, pink leucocratic granite. Unnamed granite

Stratigraphic hole 57

0 - 30.5 m	cuttings:	very weathered granite
30.5 - 30.8 m	core :	mottled medium-grained altered granite. Unnamed granite

Stratigraphic hole 58

0 - 7.6 m	cuttings:	lateritzed granite
7.6 - 7.9 m	core :	mottled altered granite. Unnamed granite

Stratigraphic hole 59

0 - 3.0 m	cuttings:	laterite
3.0 - 4.3 m	cuttings:	weathered granite
4.3 - 4.57m	core :	medium-grained granite. Unnamed granite

Stratigraphic hole 60

0 - 3.0 m	cuttings:	laterite
3.0 - 5.5 m	cuttings:	limestone. Tertiary travertine
5.5 - 20.0 m	cuttings:	weathered granite
20.0 - 20.3 m	core :	aphyric medium-grained biotite granite. Unnamed granite

Stratigraphic hole 61

0 - 6.0 m	cuttings:	laterite
6.0 - 14.5 m	cuttings:	chocolate-brown mudstone
14.5 - 16.0 m	cuttings:	chert. Cambrian or Tertiary
16.0 - 39.6 m	cuttings:	disaggregated granite
39.6 - 39.62m	core :	weathered granite. Unnamed granite

Stratigraphic hole 62

21.3 - 21.6 m	core :	ferruginous, cellular sandstone
21.6 - 33.5 m	cuttings:	sandstone and mudstone
36.6 - 36.7 m	core :	Palygorskite breccia, radioactive anomaly. Probably Cambrian

Stratigraphic hole 63

0 - 4.5 m	cuttings:	laterite
4.5 - 26.0 m	cuttings:	pale mudstone. Cambrian?
26.0 - 62.5 m	cuttings:	weathered granite or greisen
62.5 - 62.8 m	core :	medium-grained greisen or granite containing quartz and mica. Unnamed granite

Stratigraphic hole 64

12.0 - 24.5 m cuttings: limestone. Cambrian or Tertiary
24.5 - 53.3 m cuttings: weathered gabbro
53.3 - 53.9 m core : altered gabbro. Unnamed granite

Stratigraphic hole 65

0 - 1.5 m cuttings: sand
1.5 - 21.5 m cuttings: maroon limestone
21.5 - 67.1 m cuttings: pale mudstone and clay
67.1 - 67.4 m core : medium dolomitic sandstone. Cambrian

Stratigraphic hole 66

0 - 3.0 m cuttings: sand
3.0 - 10.7 m cuttings: pale grey clay
10.7 - 12.0 m cuttings: maroon mudstone
12.0 - 30.0 m cuttings: clay
30.0 - 30.3 m highly altered ferruginous rock. Cambrian?

Stratigraphic hole 67

0 - 4.6 m cuttings: laterite
4.6 - 4.7 m core : white cellular dolomite. Cambrian

Stratigraphic hole 68

0 - 15.0 m cuttings: laterite
15.0 - 43.6 m cuttings: altered basalt?
43.6 - 43.9 m core : dark grey altered basalt or amphibolite.
Mount Charles Formation

Stratigraphic hole 69

0 - 1.0 m cuttings: sand
1.0 - 49.0 m cuttings: weathered shale and siltstone
49.0 - 49.3 m core : purple shale, mudstone and siltstone.
Mount Charles Formation

Stratigraphic hole 70

0 - 4.5 m cuttings: sand
4.5 - 35.1 m cuttings: shale
35.1 - 35.7 m core : cleaved and contorted, brown and maroon micaçeous siltstone mudstone, thin sandstone dipping 45° - 70°.
Mount Charles Formation

Stratigraphic hole 71

0 - 2.0 m cuttings: laterite
2.0 - 7.6 m cuttings: mudstone
7.6 - 7.9 m core : flat lying maroon and pale grey shale, siltstone, and mudstone
7.9 - 44.5 m cuttings: mudstone
44.5 - 47.2 core : flat-lying maroon micaceous mudstone.
Gardiner Formation

Stratigraphic hole 72

0 - 15.0 m cuttings: laterite
15.0 - 31.1 m cuttings: weathered amphibolite
31.1 - 31.4 m core : dark blue-grey amphibolite. Mount Charles Formation

Stratigraphic hole 73

0 - 2.5 m cuttings: sand
2.5 - 4.6 m cuttings: travertine
4.6 - 4.9 m core : travertine. Tertiary travertine

Stratigraphic hole 74

0 - 9.0 m cuttings: laterite
9.0 - 62.2 m cuttings: altered granite
62.2 - 62.5 m core : granitic greisen and vein quartz.
Unnamed granite

Stratigraphic hole 75

0 - 5.2 m cuttings: sand
5.2 - 5.5 m core : cemented ferruginous sand, possibly granitic

Stratigraphic hole 76

0 - 7.5 m cuttings: laterite
7.5 - 42.1 m cuttings: weathered amphibolite
42.1 - 42.4 m core : amphibolite. Mount Charles Formation

Stratigraphic hole 77

0 - 7.5 m cuttings: laterite
7.5 - 27.5 m cuttings: yellow-brown phyllite
27.5 - 56.2 m cuttings: reddish-brown phyllite
56.2 - 56.4 m core : grey cleaved phyllite. Mount Charles Formation

Stratigraphic hole 78

0 - 5.2 m cuttings: laterite
5.2 - 5.5 m core : ferruginous breccia with phyllite fragments.
Mount Charles Formation

Stratigraphic hole 79

0 - 4.5 m cuttings: laterite
4.5 - 36.6 m cuttings: yellow-brown shale, possibly tuffaceous
36.6 - 36.9 m core : maroon cleaved phyllitic tuff. Mount Charles Formation

Stratigraphic hole 80

0 - 6.0 m cuttings: laterite
6.0 - 16.8 m cuttings: weathered tuff
16.8 - 17.1 m core : maroon tuff. Mount Charles Formation

Stratigraphic hole 81

0 - 3.7 m cuttings: laterite
3.7 - 3.8 m core : maroon medium lithic sandstone. Mount Charles Formation

Stratigraphic hole 82

0 - 35.0 m	cuttings:	yellow-brown weathered mudstone or tuff	
35.0 - 56.4 m	cuttings:	red-brown weathered mudstone or tuff	
56.4 - 57.9 m	cuttings:	grey mudstone or tuff. Mount Charles Formation?	

Stratigraphic hole 83

0 - 12.0 m	cuttings:	laterite
12.0 - 21.5 m	cuttings:	pale cemented sand
21.5 - 38.1 m	cuttings:	red-brown mudstone
38.1 - 39.6 m	cuttings:	maroon mudstone. Killi Killi Formation

Stratigraphic hole 84

0 - 8.5 m	cuttings:	red sand
8.5 - 9.1 m	cuttings:	maroon sandstone
9.1 - 9.3 m	core :	pale maroon, medium lithic sandstone. Killi Killi Formation

Stratigraphic hole 85

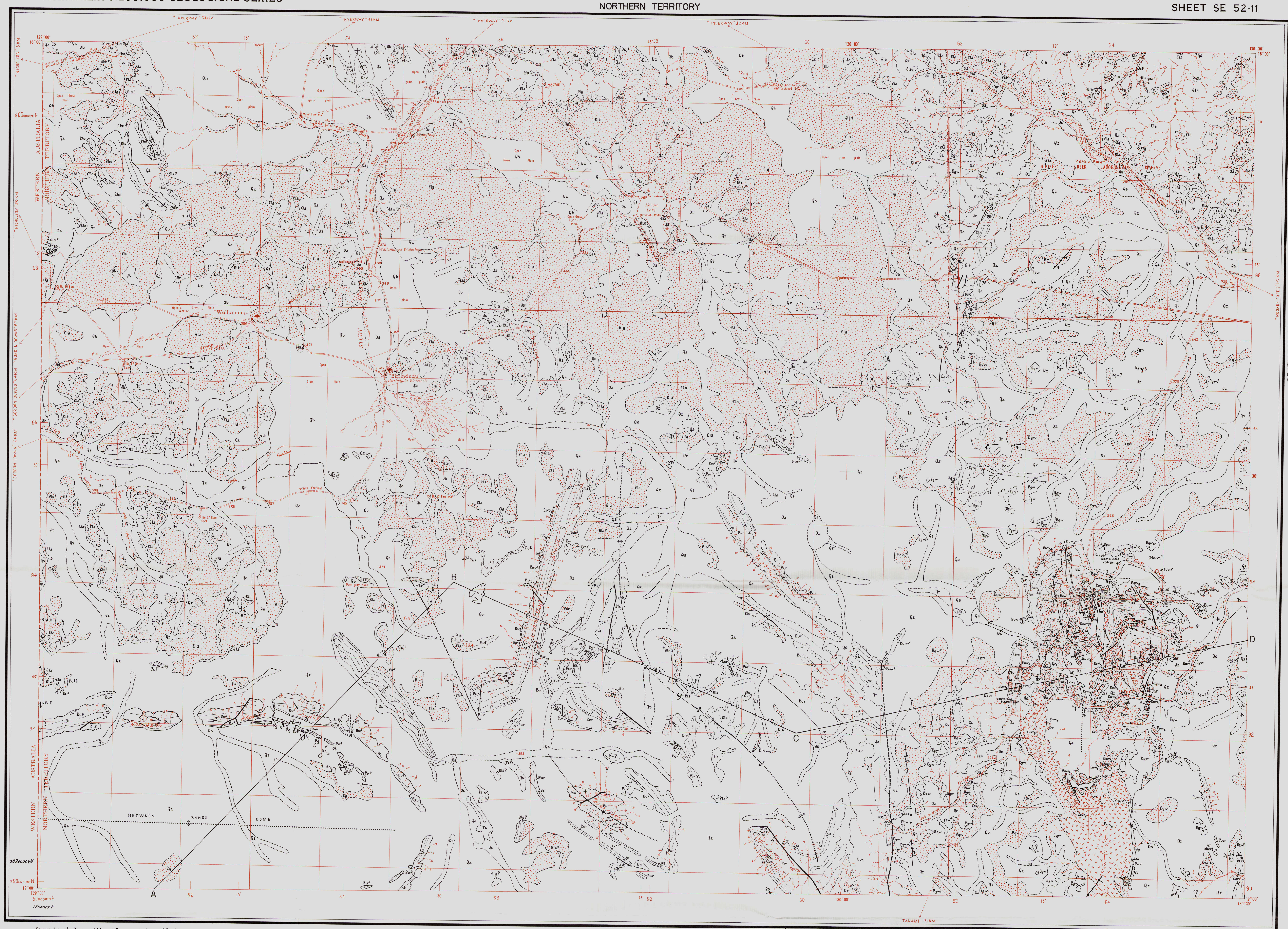
0 - 1.0 m	cuttings:	sand
1.0 - 36.6 m	cuttings:	reddish weathered tuff
36.6 - 36.9 m	core :	maroon to brown tuff or greywacke. Killi Killi Formation

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

BIRRINDUDU

NORTHERN TERRITORY

SHEET SE 52-11



Reference

CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay: alluvial and lacustrine
			Qs	Sand: alluvial and aeolian
			Qz	Sand, gravel: aeolian and piedmont deposits
			Qb	Black and grey soil
	TERTIARY		Tt	Travertine
			Ts	Silcrete
			(dotted pattern)	Laterite capping
PALAEOZOIC	CAMBRIAN		€	Orthoquartzite, lithic sandstone, chert
		Antrim Plateau Volcanics	€la	Tholeiitic basalt, minor tuffaceous sandstone, lithic sandstone and stromatolitic chert
PROTEROZOIC	UPPER PROTEROZOIC (CARPENTARIAN OR ADELAIDEAN)	Limbunya Group	Ƥhu	Lithic sandstone, orthoquartzite, minor chert and conglomerate
		Birrindudu Group: * Stake Range Beds	Ƥuk	Lithic sandstone, orthoquartzite
		Birrindudu Group: * Talbot Well Formation	Ƥut	Stromatolitic chert, lithic sandstone
		Birrindudu Group: * Ware Range Sandstone	Ƥur	Lithic sandstone, orthoquartzite, minor conglomerate, shale and siltstone; Glauconitic sandstone
		Birrindudu Group: Gardiner Formation	Ƥuf	Lithic sandstone, orthoquartzite
			Ƥg	Medium to coarse muscovite granite
		Winnecke Granophyre	Ƥgw	Biotite granophyre, biotite adamellite, intrusive acid porphyry
		Mount Winnecke Formation	Ƥuw	Lithic sandstone, minor conglomerate
			Ƥuwt	Tuffaceous sandstone, siltstone and conglomerate; minor laminated tuff, lapilli tuff, acid lava
			Ƥuwa	Porphyritic and non-porphyritic acid lava
	LOWER PROTEROZOIC	Tanami Group: * Helena Creek Formation	Ƥlh	Lithic sandstone, conglomerate, tuff
		Tanami Group: * Nongra Formation	Ƥls	Phyllite, shale, siltstone, greywacke, lithic sandstone banded chert, tuff, extrusive acid porphyry

* Name not yet approved

Geological Boundary

Anticline, showing plunge

Syncline

Fault

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

10 Strike and dip of strata

Vertical strata

Horizontal strata

65 Overturned strata

Dip < 15° } air-photo interpretation

Trend line } air-photo interpretation

80 Strike and dip of foliation

Dyke; q-quartz

Bore

Bore with windpump

WH Waterhole

Swamp

Highway

Road

Vehicle track

Landing ground

"Birrindudu" Homestead

Yd Yard

Fence

Astronomical station

·420 Elevation in metres, accurate

pd Position doubtful

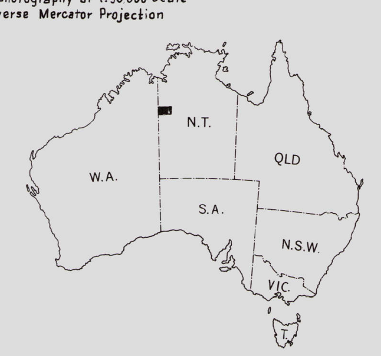
* Name not yet approved by State Authority

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister of National Development. Base map compiled by the Division of National Mapping from aerial photography at 1:50,000 Scale
Transverse Mercator Projection

NOTE ON GRID COORDINATES

Brown lines with black italic numbers (numbers shown only at SW corner of map and change of zone), indicate the 10,000 yard grid, Zone 4 (Australia Series), CLARKE 1858 SPHEROID. Transverse Mercator Projection

Brown numbered ticks (with larger upright numbers), inside the neatline are 20,000 metre intervals of the superimposed Australian Map Grid, Zone 52 AUSTRALIAN NATIONAL SPHEROID. Transverse Mercator Projection



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3°30'E 4°E 4°30'E

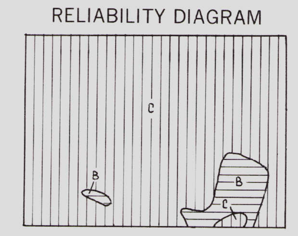
ANNUAL CHANGE 1'W

Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES

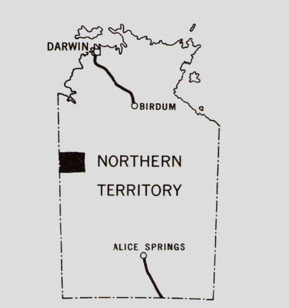
5 0 5 10 MILES

RELIABILITY DIAGRAM

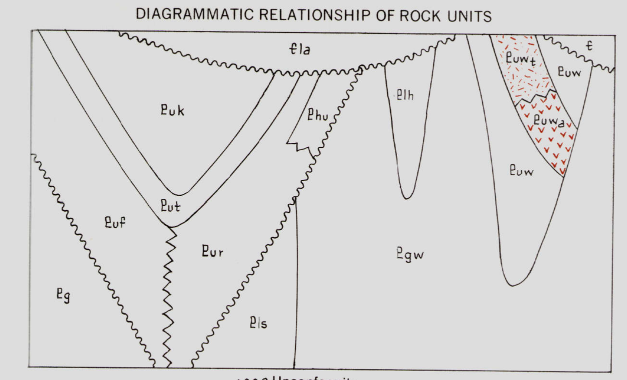


Geology B Detailed reconnaissance: numerous traverses, and air-photo interpretation
C General reconnaissance: few traverses, and air-photo interpretation

Geology 1971 by D.H. Blake, P.A. Smith
Compiled 1972 by D.H. Blake
Cartography by Geological Branch BMR
Drawn by D. Green

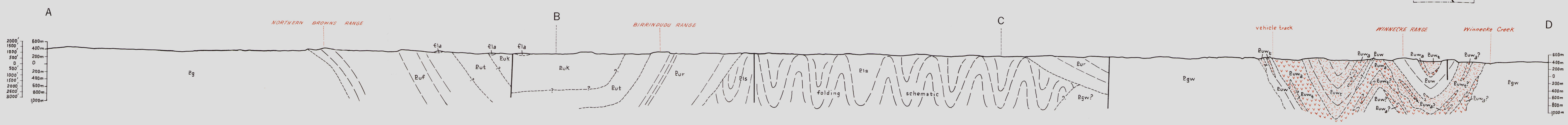


DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Section

Cainozoic sediments omitted
Scale: V/H = 4



PRELIMINARY EDITION 1972

SUBJECT TO AMENDMENT

BIRRINDUDU

SHEET SE 52-11

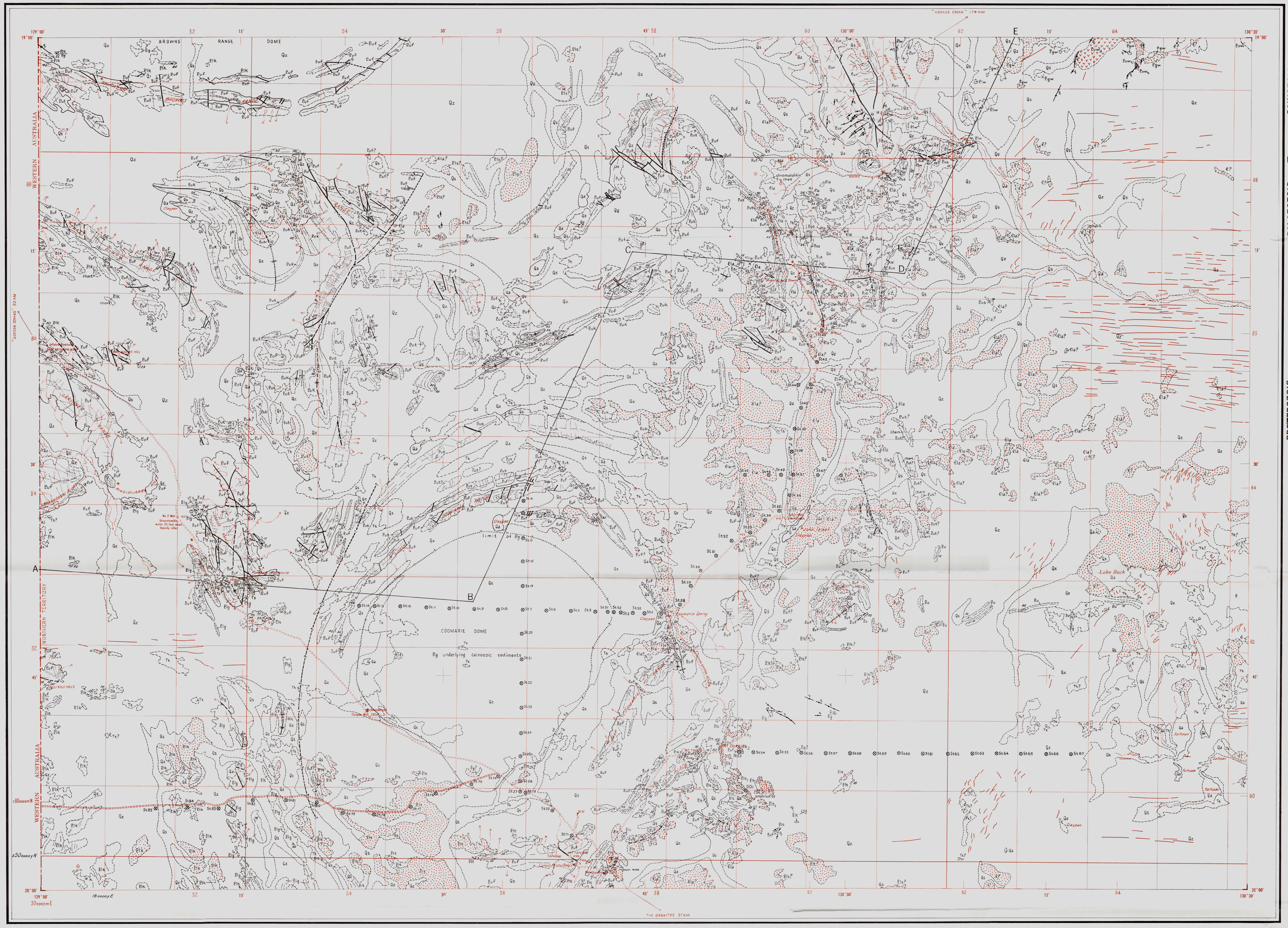
MERCURY-WALCH

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

TANAMI

NORTHERN TERRITORY

SHEET SE 52-15



Reference

CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay: alluvial and lacustrine
			Qs	Sand: alluvial and aeolian
			Qz	Sand, gravel: aeolian and piedmont deposits
	TERTIARY		Tt	Travertine, partly silicified
			Ts	Silcrete
				Laterite capping
MESOZOIC ?	CRETACEOUS	*Larranganni Beds	Kl	Sandstone, siltstone, conglomerate
PALAEOZOIC	CAMBRIAN		Є	Orthoquartzite, lithic sandstone, mudstone, chert, dolomite, limestone
		Antrim Plateau Volcanics	Єla	Tholeiitic basalt, minor tuffaceous sandstone, lithic sandstone and stromatolitic chert
PROTEROZOIC			Pu	Lithic sandstone, orthoquartzite, siltstone, shale
	UPPER PROTEROZOIC (CARPENTARIAN OR ADELAIDEAN)	Birrindudu Group: *Stake Range Beds	Puk	Lithic sandstone, minor orthoquartzite, siltstone and shale
		Birrindudu Group: *Talbot Well Formation	Put	Stromatolitic chert, cherty sandstone, lithic sandstone, siltstone, mudstone, limestone
		Birrindudu Group: *Ware Range Sandstone	Pur	Lithic sandstone, orthoquartzite, minor conglomerate, shale and siltstone
		Birrindudu Group: Gardiner Formation	Puf	Lithic sandstone, orthoquartzite, conglomerate, shale and siltstone; Glauconitic sandstone
		*Supplejack Downs Sandstone	Pus	Lithic sandstone, orthoquartzite, minor shale and siltstone
			Pg	Medium to coarse biotite and muscovite granite; minor gabbroic rocks
		Winnecke Granophyre	Pgw	Biotite granophyre, biotite granite, intrusive acid porphyry
		Mount Winnecke Formation	Puw	Lithic sandstone
			Puwt	Tuffaceous sandstone, siltstone and conglomerate
			Puwa	Porphyritic and non-porphyritic acid lava
	LOWER PROTEROZOIC	Tanami Group: *Nongra Formation	Pls	Phyllite, shale, greywacke, chert, extrusive acid porphyry
		Tanami Group: *Nanny Goat Creek Formation	Plw	Extrusive acid porphyry, non-porphyritic and porphyritic basalt, tuff, greywacke, lithic sandstone, phyllite, shale, siltstone
		Tanami Group: *Mount Charles Formation	Plt	Banded chert, partly silicified shale and siltstone, basalt, greywacke, phyllite, jaspilite, gossanous ironstone
			Plt₁	Phyllite, phyllitic siltstone and greywacke, gossanous ironstone
			Plt₂	Basalt, amphibolite
		Tanami Group: *Pargee Sandstone	Plg	Lithic sandstone, orthoquartzite, conglomerate, greywacke
		Tanami Group: *Killi Killi Formation	Plk	Greywacke, lithic sandstone, phyllite, shale, siltstone, chert, jaspilite, tuff, extrusive acid porphyry, orthoquartzite, minor conglomerate

*Name not yet approved

Geological boundary
Anticline
Syncline
Fault

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

Strike and dip of strata
Unmeasured strike and dip of strata
Strike and dip of strata, facing not known
Vertical strata
Horizontal strata
Overturned strata
Trend line; Joint pattern — air-photo interpretation
Strike and dip of foliation
Strike and dip of cleavage
Vertical cleavage
Dyke; q-quartz

Mine, abandoned (gold)
Sta — BMR stratigraphic hole
DD1 — Diamond drill hole (Enterprise Exploration Co Pty Ltd)
Bore with windpump
WH — Waterhole
Spring
Sand dunes
Vehicle track
Landing ground
"Supplejack Downs" — Homestead
Yd — Yard
Trigonometrical station
Astronomical station
425 — Elevation in metres, accurate
* Name not yet approved by State Authority

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of Nation Development. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Division of National Mapping from aerial photography at 1:50,000 Scale
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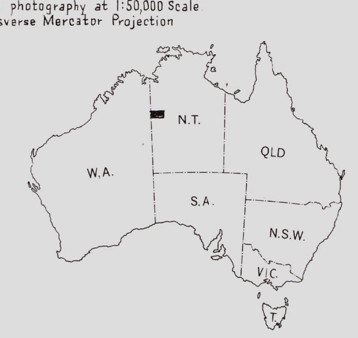

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ANNUAL CHANGE 55″W

Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES
5 0 5 10 15 MILES

Section
Cainozoic sediments omitted
Scale V/H = 4

Geology 1971 by D.H. Blake, I.M. Hodgson, P.A. Smith
Compiled 1972 by D.H. Blake, I.M. Hodgson, P.A. Smith
Cartography by Geological Branch, BMR
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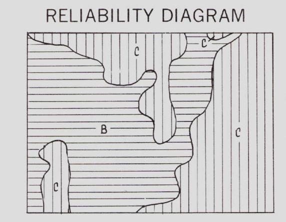
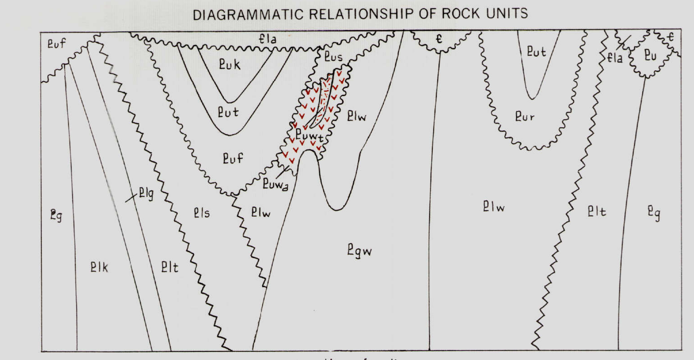
RELIABILITY DIAGRAM

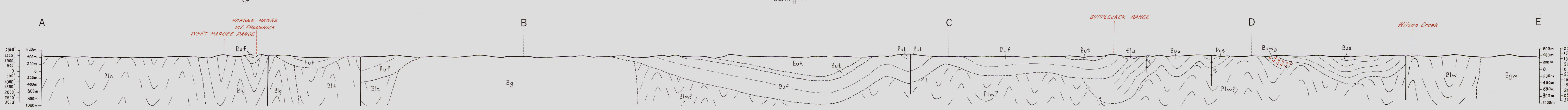


Geology B Detailed reconnaissance: numerous traverses, and air-photo interpretation
C General reconnaissance: few traverses, and air-photo interpretation

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Unconformity



PRELIMINARY EDITION 1972

SUBJECT TO AMENDMENT

TANAMI

SHEET SE 52-15

MERCURY-WALCH