REPORT 174

Geology of the Birrindudu and Tanami 1:250 000 Sheet Areas, Northern Territory

by

D. H. BLAKE, I. M. HODGSON, AND P. A. SMITH

DEPARTMENT OF MINERALS AND ENERGY
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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. Also present are minor outcrops of Tertiary calcrete and silcrete and terrestrial sediments of possible Cretaceous age.

The oldest rocks are those of the Tanami complex of Archaean? age. They comprise tightly folded and cleaved low-grade regionally metamorphosed sediments and volcanics which can probably be correlated with the Halls Creek Group in the Kimberleys. They crop out in several basement inliers in both Sheet areas, and are intruded and thermally metamorphosed by the Lower Proterozoic Winnecke Granophyre and three unnamed granite bodies. The Winnecke Granophyre also intrudes the Mount Winnecke Formation, which consists of folded sandstone and acid volcanics that are probably comagmatic with the granophyre. The Tanami complex and the Lower Proterozoic rocks, which also include the Pargee Sandstone and Supplejack Downs Sandstone, together make up The Granites-Tanami Block. They are unconformably overlain by the Carpentarian Birrindudu Group, a sequence composed mainly of sublithic and quartz arenite, some of which is glauconitic, with some shale, siltstone, conglomerate, and stromatolitic chert. The Birrindudu Group has been affected by broad doming and irregular folding. The basal unit of the group, the Gardiner Sandstone, may be correlated with the Speewah Group or Mount Parker Sandstone, or both, in the Kimberleys, and with part of the Limbunya Group in the Victoria River region. The 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. Laterite is developed on many pre-Tertiary rocks, especially the Antrim Plateau Volcanics, granite, and Tanami complex.

Of economic interest are gold-bearing quartz veins at Tanami, and uranium-bearing conglomerate at the base of the Gardiner Sandstone in the Killi Killi Hills on the western edge of the Tanami Sheet area.

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°S and 20°S and longitudes 129°E and 130°30′E. The western boundary is the Western Australian 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 (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.

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 Gardner Range, but this part is now overgrown and has been replaced by a new track running west from Tanami to Halls Creek via Billiluna homestead. Most of the tracks are suitable only for four-wheel-drive vehicles. Travel cross-country off formed tracks is relatively easy, the main hazards being grass seeds, which clog up radiators, short sharp stakes, which cause numerous punctures, and a paucity of landmarks, which makes navigation difficult.

Habitation is restricted to Birrindudu homestead in the northwest and Supplejack Downs homestead to the southeast. Both properties are used for cattle raising. Each homestead has an airstrip suitable for light aircraft, and there is an unmaintained airstrip at Tanami. Most of the area is ideal for survey by helicopter as there are virtually unlimited landing sites.

Halls Creek, the nearest town (population about 600), is connected by regular flights with Derby, Kununurra, and Alice Springs. Three nearby homesteads, Gordon Downs, Nicholson, and Inverway, and Hooker Creek Native Reserve, also have scheduled air services.

Climate and vegetation

The following notes on climate and vegetation are based largely 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 to the west and Wave Hill to the northeast. For the period from 1931 to 1960

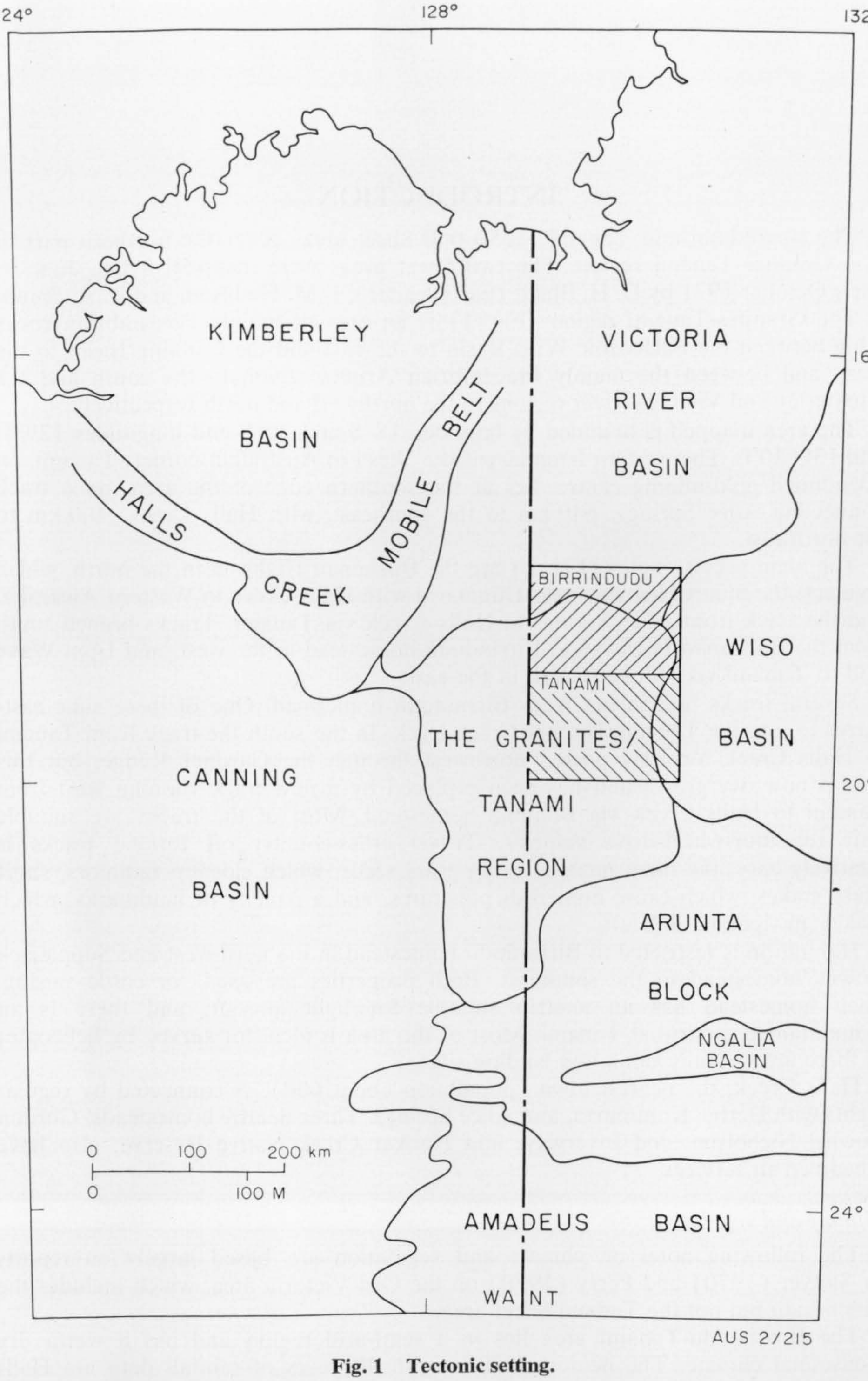

Fig. 1 Tectonic setting.

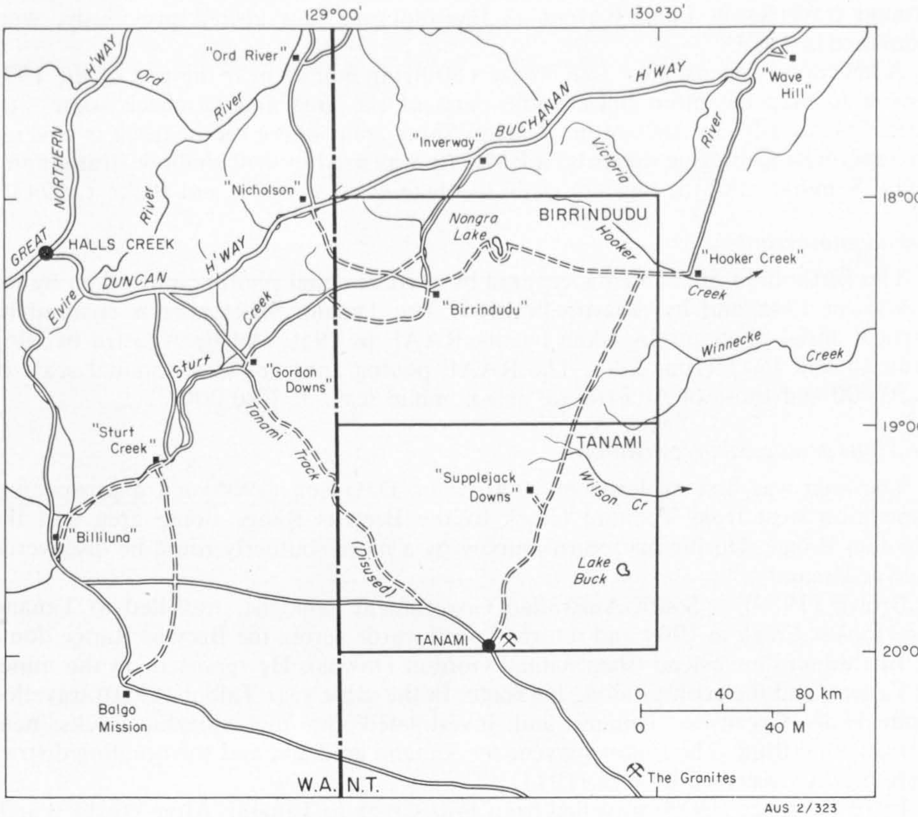

Fig. 2 Locality map.

the mean annual rainfall at Wave Hill was 484 mm and at Halls Creek 424 mm. At both stations almost all the rain falls in the period from December to March, although at Halls Creek at least one wet day can be expected each month. Extrapolating the data from these two stations the average annual rainfall in the area mapped is estimated to decrease from about 450 mm in the northwest to about 300 mm in the south.

The temperature at Halls Creek reaches a maximum of over 38°C in October, November, and December, and also in March. Similar maximum temperatures can be expected in the Birrindudu/Tanami area. 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 consists typically of low savannah, the main tree being snappy gum (*Eucalyptus brevifolia*), with extensive grasslands, mainly of Mitchell grass, on clay plains. 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

Most of the field work was undertaken in 1971, with the help of 1 :250 000 photo-geological maps prepared by Simpson (1971), and was mainly carried out by ground traverses in Land Rovers. A few outcrops, not visited previously, were examined in 1973.

A helicopter was used for four weeks (80 flying hours) near the end of the 1971 season to map the more inaccessible parts of the area and to check some sites visited previously. In parts of the Tanami Sheet area, where the bedrock is covered by superficial Cainozoic deposits, a BMR rig was used to drill shallow stratigraphic holes. Summaries of the logs are given in Blake et al. (1972), and Blake (1974).

Aerial photographs

The Birrindudu Sheet area is covered by vertical aerial photographs taken by the RAAF in 1948 and by Adastra in 1967. The Tanami Sheet area is covered by vertical aerial photographs taken by the RAAF in 1950 and by Adastra in 1967 (run 1) and 1971 (runs 2-8). The RAAF photographs are at a nominal scale of 1:50 000 and those of Adastra are at a nominal scale of 1:80 000.

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 Gardner 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 returned northwards across the Browns Range dome to Birrindudu homestead (then named Gordon Downs). 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 the Tanami goldfield and surrounding district were briefly described by Gee (1911).

In 1914 Jensen (1915) travelled from Pine Creek to Tanami. After World War I, Terry (1932) made several journeys to The Granites-Tanami region, and in 1928 prospected the area near Larranganni Bluff. The Aerial Geological and Geophysical Survey of Northern Australia carried out a survey of the mines at Tanami in 1937-38 (Hossfeld, 1940). The Birrindudu Sheet area was included in the reconnaissance geological survey of the Ord-Victoria region by Traves (1955).

In 1959 a geological reconnaissance of part of the Tanami Sheet area was made by Phillips for Enterprise Exploration Pty Ltd and this was followed by more detailed work in the Black Hills area (Phillips, 1961, 1962). Roberts (1968) carried out geological mapping and geochemical sampling in the same area for Anaconda Aust. Inc. in 1968.

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, or possibly lower near Lake Buck in the southeast. It can be divided into four main topographic divisions (Fig. 3): the Sturt Plateau, the dissected plateau margin to the east, the Victoria River Plains and Terraces in the northeast, and the low-level plains east of the dissected plateau margin.

Sturt Plateau

Most of the area mapped is part of the Sturt Plateau (Traves, 1955; Paterson, 1970; Simpson, 1971), a flat to very gently undulating surface from which rise ancient monadnocks. These form low ranges generally less than 30 m high that have accordant or subaccordant summits. Most of the ranges are strike ridges and

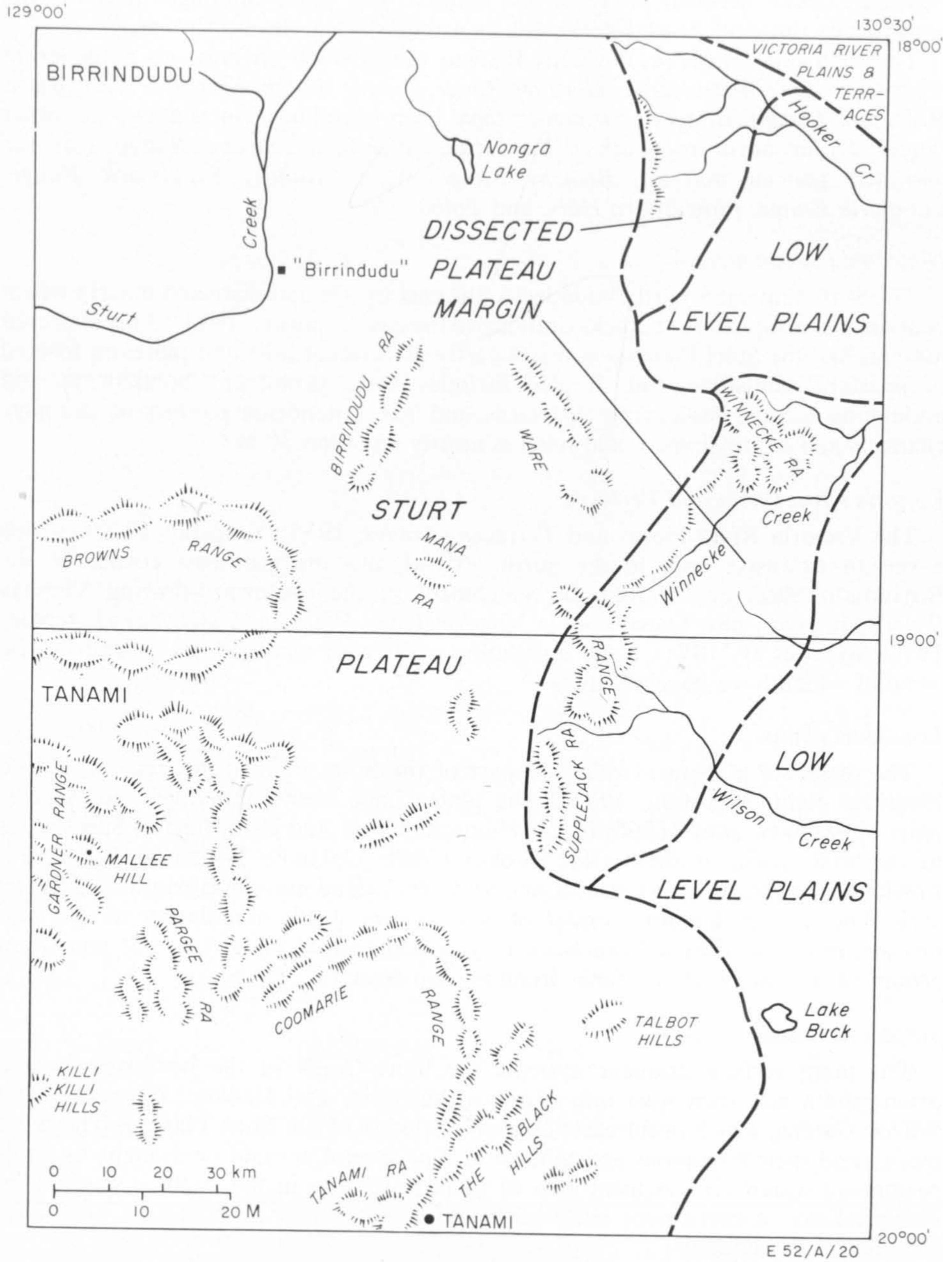

Fig. 3 Topographic subdivisions.

plateaux formed mainly of highly resistant Precambrian sandstones. The ranges are incised by drainage channels which pass on to outwash fans on narrow flanking piedmont slopes. The channels disappear in the surrounding plains. Low breakaways are common locally. Barely perceptible drainage depressions, some with small claypans, occur between many of the ranges. The main drainage lines on the plateau are those of Sturt Creek and its tributaries in the northwest.

The following ranges on the Sturt Plateau were named on previous maps (from north to south): *Ware Range, Gardner Range, Pargee Range, Killi Killi Hills, Black Hills,* and *Tanami Range*. New names have been introduced for some of the other ranges (from north to south): *Birrindudu Range, Winnecke Range* (on the dissected plateau margin), *Browns Range, Mana Range, Supplejack Range, Coomarie Range, Pingidijarra Hills,* and *Talbot Hills*.

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 margin, like the Sturt Plateau, consists partly of residual hills and plateaux formed of resistant sandstone, but it also includes some prominent breakaways and undulating terrain descending eastwards and has a dendritic pattern of drainage channels and depressions. Local relief is mostly less than 30 m.

Victoria River Plains and Terraces

The Victoria River Plains and Terraces (Traves, 1955; Simpson, 1971), which cover an extensive area to the north, extend into the northeast corner of the Birrindudu Sheet area, within the catchment of the northward-flowing Victoria River. This unit, also known as the Victoria River Plains and Benches (Paterson, 1970; Sweet et al., 1971), is an undulating plain with scattered mesas and buttes, some of which have benched sides.

Low-level plains

The dissected plateau margin and part of the Sturt Plateau pass eastward into low-level plains (Simpson, 1971). The plains have been subdivided into several units by Milligan et al. (1966) in the Winnecke Creek and East Tanami Sheet areas to the east; parts of them (the Hooker Creek Uplands, Winnecke Tableland, Lowland Dunefields, and Hanson-Lander Plains) extend into the Birrindudu-Tanami area. The low-level plains consist of flat to very gently 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, Winnecke, and Wilson Creeks, which drain eastwards off the edge of the Sturt Plateau. The main creeks and their tributaries are ephemeral, but several contain permanent to semi-permanent waterholes. A local area of inland drainage in the north is centred on Nongra Lake, a permanent body of brackish water that fluctuates in area both seasonally and annually.

In addition to the waterholes along the larger creeks, the Jellebra Rockholes northwest of Mount Frederick and Camel Waterholes on the east side of the Tanami Range contain more or less permanent supplies of water. 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 northern part of the Northern Territory Hays (1967) has recognized four main erosion surfaces. The oldest and highest, the Ashburton Surface, which is considered by Hays to be Cretaceous, is represented in the Birrindudu-Tanami area by the accordant to subaccordant summits of residual ridges and plateaux 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. It is represented by widespread cappings of laterite on low rises to the west of the low-level plains. The younger Wave Hill and Koolpinyah Surfaces have not been recognized in the mapped area.

Rock nomenclature

In this Report the Precambrian sandstones are classified according to Pettijohn, Potter, & Siever (1972): quartz arenite, in which at least 95 percent of the detrital grains are quartz, quartzite, or chert; sublithic arenite, in which 5 to 25 percent of the grains are rock fragments and feldspar; lithic arenite, in which over 25 percent of the grains are rock fragments and feldspar; greywacke, which contains more than 15 percent matrix; glauconitic sandstone; tuffaceous sandstone. The arenites characteristically have a cement of quartz that forms overgrowths in optical continuity with the detrital quartz grains.

The grainsizes used to classify the sandstones are as follows: fine, 0.125 to 0.25 mm; medium, 0.25 to 0.5 mm; coarse, 0.5 to 1 mm; and very coarse, 1 to 2 mm. The bedding thickness terms used for sedimentary rocks are: laminated, less than 1 cm; thin-bedded, 1 to 50 cm; medium-bedded, 50 cm to 2 m; and thick-bedded, over 2 m.

For igneous rocks the classification of Hatch, Wells, & Wells (1961) is used where practicable, but because many of the fine-grained rocks are extensively altered, and chemical analyses are lacking, general terms such as acid porphyry and acid lava are used instead of rhyolite or rhyodacite. If the grainsize of the 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; and if over 3 cm as pegmatitic.

Terms describing metamorphic facies are as defined by Turner & Verhoogen (1960). Phyllite and phyllitic rocks are distinguished from shale and other sedimentary rocks by the presence of white mica along cleavage planes.

Many of the rocks have been deeply weathered as a result of intense lateritization and silicification during the Cainozoic Era and are difficult to identify in the field and laboratory.

ARCHAEAN?

TANAMI COMPLEX (NEW NAME)

The Tanami complex, named after the abandoned gold mining settlement of Tanami, comprises the oldest known rocks in the area (see Table 1 for summary of stratigraphy). The complex consists of tightly folded sedimentary and volcanic rocks which are commonly cleaved. The general absence of green minerals such as chlorite may be due to intense weathering or may reflect a very low metamorphic grade.

The complex forms the basement throughout the Birrindudu-Tanami area, and crops out in several inliers in both Sheet areas. It comprises the Mount Charles, Killi Killi, Nanny Goat Creek, Nongra, and Helena Creek Beds, each of which contains volcanics and greywacke.

The Tanami complex crops out to the west in the adjoining Gordon Downs, Billiluna, and Lucas Sheet areas, where it was mapped as part of the Halls Creek Group (Gemuts & Smith, 1968; Dow & Gemuts, 1969) and as Halls Creek Metamorphics (Casey & Wells, 1964; Wells, 1962a,b), and also to the south in The Granites Sheet area (Blake et al., 1973). The rocks now mapped as Mount Charles Beds were called the Tanami Metamorphic Series by Jensen (1915), who described them as 'highly metamorphic (probably Precambrian) mineral-bearing rocks . . . over a wide area around Tanami' (p. 14) that consist largely of metamorphosed and metasomatized volcanic rocks with laminated quartzite, jasper, jasperoid schist, and slate (p. 17). The name Tanami complex is preferred to Tanami Metamorphic Series because most of the rocks have undergone only minor metamorphism (cf. Halls Creek Group, Dow & Gemuts, 1969).

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

The group is overlain unconformably by the Lower Proterozoic* Supplejack Downs Sandstone, the Carpentarian Birrindudu Group, and the Lower Cambrian Antrim Plateau Volcanics, and probably also by the Lower Proterozoic Mount Winnecke Formation. It is intruded by the Winnecke Granophyre and by unnamed granitic bodies, all of which are probably Lower Proterozoic or early Carpentarian.

The lithology, structure, and metamorphism of the Tanami complex are similar to those of the Halls Creek Group in the East Kimberley region of Western Australia, and the complex is probably the stratigraphic equivalent of this group, which is considered to be possibly Archaean (Dow & Gemuts, 1969; Gellatly, 1971).

Killi Killi Beds
(new name)

The Killi Killi Beds comprise low-grade regionally metamorphosed sedimentary and volcanic rocks that crop out in the western part of the Tanami Sheet area, mainly south and southeast of the Killi Killi Hills, after which the formation is named. The beds extend westwards into the Lucas and Billiluna Sheet areas, where they were mapped by Casey & Wells (1964) as Halls Creek Metamorphics, and also southwards into The Granites Sheet area.

Rocks now mapped as Killi Killi Beds were observed first by Davidson (1905), who recorded quartz-veined ironstone in metamorphic rocks near Larranganni Bluff, a locality which was later described by Talbot (1910) and Phillips (1959).

*As used in this Report, the Lower Proterozoic ranges from about 2300 to about 1800 m.y., and the Carpentarian from about 1800 to about 1400 m.y.

TABLE 1. SUMMARY OF STRATIGRAPHY

Age	*Unit and Map Symbol*	*Maximum Thickness (m)*	*Main Rock Types*	*Stratigraphic Relationships*	*Remarks*
QUATERNARY	Qa	20+	Sand, silt, clay; minor evaporites	Superficial veneer on older units	Fluvial and lacustrine sediments
	Qs	?	Sand, silt	Superficial veneer on older units	Alluvial and aeolian sediments in drainage depressions
	Qz	?	Sand, local gravel	Superficial veneer on older units	Mainly aeolian; includes sand and gravel on piedmont slopes flanking residual hills and ridges
	Qb	?	Grey clay	Superficial veneer, mainly on Cla	Residual soil development on Cla. Birrindudu Sheet only
TERTIARY	Tt	?	Calcrete, partly silicified to chert	Superficial veneer	Formed along Tertiary drainage lines. In SE not reliably distinguished from Cambrian limestone and chert
	Ts	3	Silcrete	Superficial veneer on Kl and Proterozoic rocks	Small patches common, rarely large enough to show on map
	Stipple	20+	Laterite	Veneer on pre-Tertiary units	Widespread cappings on mid-Tertiary erosion surface
CRETACEOUS?	Larranganni Beds Kl	8	Sandstone, probably partly calcareous; minor siltstone and conglomerate	Unconformable on Atk, Pdg, and Cla	Tanami Sheet area only. Terrestrial water-laid deposits
			MAJOR UNCONFORMITY		
CAMBRIAN	Unnamed Cambrian C	67+	Quartz arenite, sublithic arenite, mudstone, chert, limestone, dolomite	Unconformable on Pg and Pdg, and probably also on Plw and Pgw	Restricted to W edge of Wiso Basin. Flat-lying
	Antrim Plateau Volcanics Cla	30+	Tholeiitic basalt, tuffaceous sandstone, lithic arenite, stromatolitic chert	Unconformable on Precambrian rock units; overlain unconformably by Kl	Flat-lying terrestrial lava flows. Widespread in both Sheet areas. Extensively lateritized
			MAJOR UNCONFORMITY		

TABLE 1—*continued*

Age		*Unit and Map Symbol*	*Maximum Thickness (m)*	*Main Rock Types*	*Stratigraphic Relationships*	*Remarks*
CARPENTARIAN		Undivided Limbunya Group Phu	400	Sublithic arenite, quartz arenite	Overlain unconformably by Cla	Restricted to NW part of Birrindudu Sheet area; folded into NW-trending synclines and anticlines
CARPENTARIAN	BIRRINDUDU GROUP	Coomarie Sandstone Pdk	2500	Sublithic arenite	Conformable on Pdt; overlain unconformably by Cla	Main outcrops in synclinal structures in Tanami Sheet area
CARPENTARIAN	BIRRINDUDU GROUP	Talbot Well Formation Pdt	300	Stromatolithic chert, cherty sandstone, siltstone, mudstone, limestone	Conformable on Pdg; overlain conformably by Pdk and unconformably by Cla	Main outcrops in Tanami Sheet area. Mostly gently dipping
CARPENTARIAN	BIRRINDUDU GROUP	Gardiner Sandstone Pdg	3000	Sublithic arenite, conglomerate, quartz arenite, shale, siltstone, glauconitic sandstone	Unconformable on Tanami complex, Plw, and Pg, and probably on Pls; overlain conformably by Pdt and unconformably by Cla, C, and Kl	Extensive outcrops in both Sheet areas. Affected by broad and tight folding. Uraniferous basal conglomerate at Killi Killi Hills
				MAJOR UNCONFORMITY		
LOWER PROTEROZOIC		Unnamed granite Pg	—	Medium to coarse biotite and muscovite granite	Intrudes At, Atk, and Atc; overlain by Pdg and C	Forms central parts of Browns Range and Coomarie domes; also forms an intrusion E of Black Hills. Possibly comagmatic with Pgw
LOWER PROTEROZOIC		Winnecke Granophyre Pgw	—	Biotite granophyre, biotite adamellite, biotite-quartz-feldspar porphyry	Intrudes Ath and Plw, probably also Atw; overlain by Cla	Probably comagmatic with acid volcanics of Mount Winnecke Formation and possibly also with Pg
LOWER PROTEROZOIC		Supplejack Downs Sandstone Pls	1300+	Sublithic arenite, quartz arenite	Unconformable on Atw and possibly on Plw; overlain unconformably by Cla and probably also by Pdg	Tanami Sheet area only. Irregularly folded
LOWER PROTEROZOIC		Mount Winnecke Formation Plw	4800	Sublithic arenite, tuffaceous sandstone and siltstone, porphyritic and non-porphyritic acid lavas	Intruded by Pgw; overlain unconformably by Pdg, C, and possibly by Pls	Folded into major anticlines and synclines. Acid volcanism probably subaqueous
LOWER PROTEROZOIC		Pargee Sandstone Plg	1500+	Sublithic arenite, quartz arenite, conglomerate, greywacke	Unconformable on Atk and Atc; unconformably overlain by Pdg	Tanami Sheet area only. Steeply dipping and tightly folded
				MAJOR UNCONFORMITY		

TABLE 1—*continued*

Age		*Unit and Map Symbol*	*Maximum Thickness (m)*	*Main Rock Types*	*Stratigraphic Relationships*	*Remarks*
ARCHAEAN?	TANAMI COMPLEX	Undivided Tanami complex At	?	Mica schist, chert, conglomerate	Intruded by Pg; unconformably overlain by Pdg	NW part of Tanami Sheet area only. Some copper mineralization
		Helena Creek Beds Ath	?	Lithic arenite, greywacke, phyllite, tuff, conglomerate	May be lateral equivalent of Atn and Atw; intruded by Pgw	NE part of Birrindudu Sheet area only
		Nongra Beds Atn	1000+	Phyllitic shale, siltstone, and greywacke, sublithic arenite, banded chert, tuff, extrusive acid porphyry	Unconformably overlain by Pdg and Cla; may be intruded by granite	Crops out in both Sheet areas. Steep to vertical dips; cleaved
		Nanny Goat Creek Beds Atw	1000+	Extrusive acid porphyry, basalt, tuff, greywacke, sublithic arenite, phyllite, shale, siltstone	Unconformably overlain by Pls and Pdg, and probably by Plw; probably intruded by Pgw	Tanami Sheet area only. Steeply dipping, generally cleaved
		Mount Charles Beds Atc	1000+	Phyllite, phyllitic siltstone and greywacke, chert, basalt; gossanous ironstone	Intruded by Pg and overlain unconformably by Plg, Pdg, and Plw	Tanami Sheet area only. Steeply dipping and tightly folded; cleaved. Host for gold mineralization at Tanami
		Killi Killi Beds Atk	3000+	Phyllitic greywacke, lithic sandstone, shale, mudstone, tuff, acid porphyry	Intruded by Pg; overlain unconformably by Plg, Pdg, and Kl	Tanami Sheet area only. Steeply dipping and tightly folded; cleaved

The land surface developed on the beds is generally broadly undulating, but includes scattered steep rocky hills and ridges up to 15 m high (Fig. 6). On the tops of undulations the beds are commonly exposed as low ribs of rock protruding through the superficial Cainozoic cover sediments.

On aerial photographs the Killi Killi Beds commonly have a closely spaced light and dark banded pattern with wavy trends reflecting bedding. The margins of outcrop areas are usually poorly defined. Deeply weathered outcrops have a light smooth pattern, and several outcrops are capped with laterite which shows up as smooth dark grey areas.

The Killi Killi Beds are probably several thousand metres thick, but their thickness is unknown because of tight folding and scattered outcrops. The best exposures are in the adjoining Billiluna Sheet area, where the reference area is located (Blake et al., 1973).

Lithology

The beds comprise greywacke, sublithic and lithic arenites, shale, mudstone, siltstone, tuff, acid porphyry, ironstone, and minor orthoquartzite. Low-grade regional metamorphism in the medium and fine-grained rocks is indicated by the widespread development of secondary mica and a very steep to vertical cleavage or schistosity which is generally subparallel to the bedding. Gossans are developed locally. Cross-cutting quartz veins abound, and some large veins form low ridges or mounds; many of the veins contain specular hematite.

Phyllitic to schistose 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 set in an abundant sericitic matrix. Sericite is also present with clay minerals as an alteration product of lithic fragments and possibly of feldspar grains. Sericitic 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 at and to the south of the Killi Killi Hills. Fine-grained brownish maroon greywacke containing about 10 percent quartz grains was intersected beneath 2 m of sand in BMR Tanami No. 85.

The sublithic and lithic arenites, which are commonly interbedded with the greywacke, are medium to coarse-grained. Sublithic arenite predominates south of Larranganni Bluff. Conspicuous clasts of red chert are common in the medium-bedded mainly lithic arenite interbedded with siltstone and acid porphyry on the south side of the Pingidijarra Hills. This arenite is more resistant to weathering and forms strike ridges up to 3 m high. It is grey, cross-bedded, and poorly sorted and the lithic grains are partly altered to kaolin; some chlorite, blue-grey tourmaline, and rare zircon are present.

Phyllitic shale, mudstone, and siltstone are commonly interbedded with greywacke and arenite. They are generally maroon, brown, or black, owing to iron-staining, but are also shades of grey. Some of the siltstone is probably tuffaceous. Maroon phyllitic mudstone was intersected below 21 m of Cainozoic sand in BMR Tanami No. 83.

Acid volcanic rocks are interbedded with greywacke and arenite on the south side of the Pingidijarra Hills and 9 km north of Jellebra Rockholes. Purple and purplish brown non-porphyritic tuff at the first locality shows well developed spheroidal weathering, and consists of sericitic blebs in a fine-grained silicified groundmass. The blebs, which may be altered pumice fragments, are associated with shard-like siliceous material. Acid porphyry is present at both localities; it contains up to 30 percent phenocrysts of white euhedral to subhedral feldspar and subordinate mica and glassy quartz set in a purplish felsitic groundmass. Both the feldspar and mica are pseudomorphed by clay minerals and turbid quartz. Pseudomorphs after pyroxene were observed in one specimen. The groundmass consists of a fine mosaic of recrystallized quartz with sericite and iron oxides. The porphyry is probably a pyroclastic deposit, as it forms bands only a few metres thick, much thinner than normal acid lavas, and does not show lava flow features such as flow banding, and associated scoria and breccia.

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 arenite. One bed close to the Western Australia border consists of white ellipsoidal chert pods in dark brown to black jaspilite: the pods range from 1 to 2 cm long and are elongated parallel to the bedding. An isolated low rounded ridge about 3 m high, 8 km southeast of Larranganni Bluff, is formed of steeply dipping finely laminated cherty ironstone.

The formation contains a few thin beds of quartz arenite. White coarse-grained medium-bedded quartz arenite with a ferruginous matrix is interbedded with tuff and porphyry at the Pingidijarra Hills. Fine-grained grey to reddish brown quartz arenite showing small-scale cross-bedding crops out 9 km north of Jellebra Rockholes; it has a sericitic matrix and contains scattered mica flakes and a little detrital tourmaline. Medium-grained quartz arenite underlies 8 m of sand in BMR Tanami No. 84.

Folding and metamorphism

The Killi Killi Beds have been tightly folded. Several tight small folds were observed in the field, and the closures on several large folds are visible on the aerial photographs. The consistent steep dip and a cleavage, which is generally subparallel to the bedding indicate that the folding may be isoclinal.

The low-grade regional metamorphism probably accompanied the folding. Its effects, however, have been largely obscured by silicification, ferruginization, and other weathering effects.

Stratigraphic relationships

The Killi Killi Beds are unconformably overlain by the Carpentarian Gardiner Sandstone and, in The Granites Sheet area to the south, by the Lower Proterozoic Pargee Sandstone. The Pargee Sandstone contains abundant detrital chert, some of which may have been derived from the Killi Killi Beds. The unconformable relationship between steeply dipping Killi Killi Beds and gently dipping Gardiner Sandstone is well exposed in the Killi Killi Hills, the Pingidijarra Hills, south of Larranganni Bluff, and 2 km north of Jellebra Rockholes (Fig. 7).

Mount Charles Beds
(new name)

The Mount Charles Beds are low-grade metasediments and metavolcanics that crop out in the Tanami Sheet area, mainly in the south between longitudes 129°15′E and 130°00′E. The reference area is the vicinity of Mount Charles (19°50′00″S, 129°50′40″E), after which the formation is named, in the northern part of the Black Hills. The beds were described but not named by Roberts (1968), and had been previously described in less detail by Brown (1909), Jensen (1915), and Hossfeld (1940). Jensen included the beds in his 'Tanami Metamorphic Series'.

The Mount Charles Beds form low rounded hills and strike ridges, many of which are covered by laterite and lateritic gravel. Some of the hills in the Black Hills area are surmounted by prominent steep-sided rocky ridges several metres high (Fig. 9). Bedding, where discernible on aerial photographs, generally does not show the wavy trends characteristic of the Killi Killi Beds.

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

Gold-bearing lodes were found in the Mount Charles Beds at Tanami by Davidson (1905) in 1900 and were worked spasmodically up to 1940.

Lithology

The Mount Charles Beds comprise phyllite, phyllitic siltstone and greywacke, chert, jaspilite, lithic to sublithic arenite, basalt, amphibolite, and gossanous bands. Following Roberts (1968), three main lithological units have been mapped, characterized respectively by chert, phyllite, and basic volcanics. Quartz veins are common in all three units.

Unit 1, which is the most widespread, consists predominantly of banded chert (Fig. 8) with thin interbeds of laminated and partly silicified shale and siltstone. Also present are basalt, some thin beds of fine greywacke and lithic to sublithic arenite, and jaspilite. The unit is well developed along the Black Hills west of Mount Charles, at Tanami, southeast and northwest of the Pargee Range, and west of the Tanami Range. The beds are commonly contorted, and tight to isoclinal minor folds and crenulations are common. Cleavage is not as well developed as in unit 2.

Intercalations of basalt are common at Tanami, and are present at all the abandoned mine workings examined. The basalt may be the rock type described by Brown (1909) as diorite and by Hossfeld (1940) as possible tuff. It is maroon to purple, much weathered, and consists mainly of hematite, kaolinite, and variable amounts of quartz. The original fine-grained basaltic texture can usually be recognized both in hand specimen and thin section. Small amygdales and micro-phenocrysts are present locally. The best exposures were seen in the sides of a recently bulldozed costean at Tanami, where basalt is intercalated with folded thinly interbedded shale, siltstone, and fine lithic arenite. The basalt is somewhat sheared, but otherwise massive; it is not known whether it is extrusive or intrusive.

Gossanous rocks are present locally but are less widespread than in unit 2, and do not form such prominent topographic features. They consist mainly of kaolinite, quartz, hematite, goethite, and limonite.

Unit 2 is well exposed at Mount Charles and along the Black Hills to the south and southeast (Fig. 4). It consists of phyllite, phyllitic siltstone and greywacke, and gossanous bands. A prominent cleavage is generally developed roughly parallel to the steep to vertical bedding, which trends north to northwest. The phyllitic rocks are thinly bedded to laminated, and range from yellow-brown to maroon and grey. They are locally altered to chert and quartzite. Limonitic spots, which are particularly common in the phyllite, probably represent altered pyrite crystals. The greywacke is medium to fine-grained and locally shows cross-bedding. It consists of quartz grains (generally less than 50% of the rock), fine-grained lithic fragments, white mica, iron oxide, and minor detrital tourmaline enclosed in an abundant sericitic matrix. Cellular gossanous bands form the prominent rocky ridges of the Black Hills, including Mount Charles (Fig. 9) and Mount Twigg. The gossans are similar in composition to those of unit 1, and are interbedded with the phyllitic rocks and, on Mount Charles, with conformable bands of medium-grained kaolinite, up to 8 cm thick, which appear to pass along strike into chert. The gossans are stratified and some are known from drilling to overlie black carbonaceous pyritic shales at depth (Phillips, 1962).

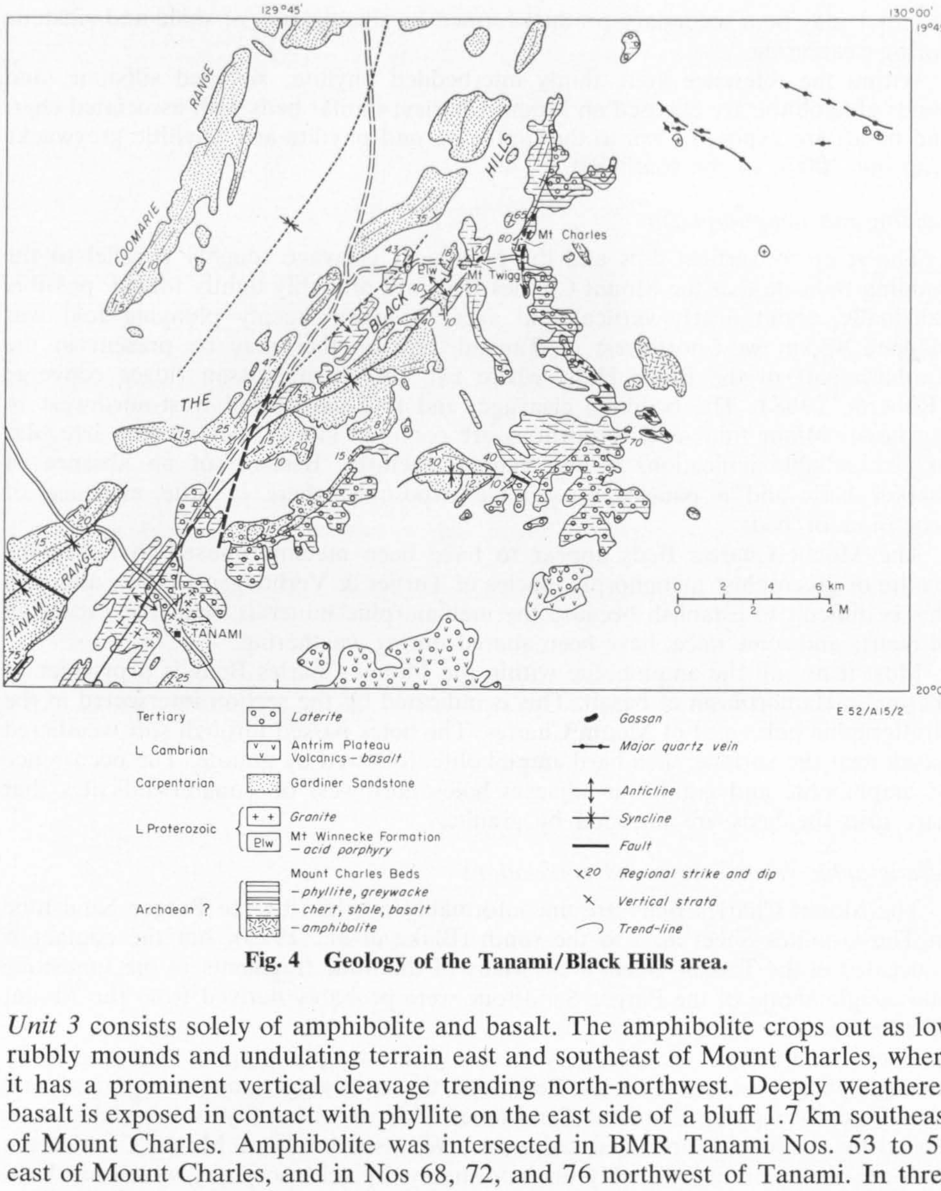

Fig. 4 Geology of the Tanami/Black Hills area.

Unit 3 consists solely of amphibolite and basalt. The amphibolite crops out as low rubbly 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 intersected in BMR Tanami Nos. 53 to 56 east of Mount Charles, and in Nos 68, 72, and 76 northwest of Tanami. In three of the holes east of Mount Charles, basalt passes down into amphibolite which rests on granite at a depth of about 16 m. In the holes northwest of Tanami the amphibolite persists to a depth of at least 30 m. The amphibolite is generally fine-grained, dark greenish or grey, and consists of an aggregate of green to blue-green amphibole, altered turbid feldspar, opaque granules, and minor interstitial quartz. A basaltic texture is preserved in places, and most if not all of the amphibolite represents basalt that has been thermally metamorphosed by the underlying granite.

Other stratigraphic holes, besides those in amphibolite, have intersected the Mount Charles Beds: BMR Tanami Nos. 69 and 70 west of Mount Twigg, and Nos. 77 to 82 northwest and west of Tanami. All these holes, even where close to exposures of unit 1, passed through only phyllite, phyllitic siltstone, and greywacke, which are the common rock types in unit 2. This indicates that much of the chert in unit 1 may be a secondary product formed by silicification of shale and siltstone during weathering.

Within the reference area, thinly interbedded phyllite, silicified siltstone, and bands of kaolinite are exposed on Mount Charles; similar beds with associated chert and basalt are exposed 1 km to the southeast, and phyllite and phyllitic greywacke crop out 300 m to the southwest.

Folding and metamorphism

The steep to vertical dips and the prominent cleavage roughly parallel to the bedding indicate that the Mount Charles Beds are 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 may be present in the southern part of the Black Hills, where two prominent gossan ridges converge (Roberts, 1968). The bedding, cleavage, and 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 Mount Charles Beds appear to have been metamorphosed to either the zeolite or greenschist metamorphic facies of Turner & Verhoogen (1960), although this is difficult to establish because the metamorphic minerals, with the exception of quartz and some mica, have been altered during weathering.

Most if not all the amphibolite within the Mount Charles Beds is a product of thermal metamorphism of basalt. This is indicated by the section intersected in the stratigraphic holes east of Mount Charles. The holes passed through soft weathered basalt near the surface, then hard amphibolite, followed by granite. The occurrence of amphibolite and granite in adjacent holes northwest of Tanami indicates that here also the beds are intruded by granite.

Stratigraphic relationships and correlations

The Mount Charles Beds are unconformably overlain by the Pargee Sandstone in The Granites Sheet area to the south (Blake et al., 1973), but the contact is concealed in the Tanami Sheet area. Many of the lithic fragments in the sandstone and conglomerate of the Pargee Sandstone were probably derived from the Mount Charles Beds.

There is a major unconformity between the steeply dipping and regionally metamorphosed Mount Charles Beds and the overlying unmetamorphosed and mostly gently dipping Gardiner Sandstone. This unconformity is invariably concealed by Cainozoic superficial sediments. West-southwest of Mount Charles the beds are also overlain, probably unconformably, by acid porphyry which has been mapped as part of the Mount Winnecke Formation.

The Mount Charles Beds are probably stratigraphically equivalent to the Killi Killi Beds, from which they are distinguished by the higher proportion of chert and fine-grained sediments and the presence of only minor greywacke, and are probably also equivalent to other units of the Tanami complex. Unlike the other units, the Mount Charles Beds do not contain acid volcanics.

Nanny Goat Creek Beds
(new name)

The Nanny Goat Creek Beds comprise steeply dipping and generally cleaved low-grade metasediments and metavolcanics that crop out in the northeastern part of the 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 beds are named.

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

The Nanny Goat Creek Beds form gently undulating terrain and a few small flat-topped low plateaux. Some rocky hillocks and strike ridges generally less than 3 m high are present on gentle rises. The plateaux are capped by laterite and partly bounded by breakaways. Most exposures are rubbly, but the beds are well exposed in creeks, especially at the waterholes in Wilson Creek (Fig. 10), 9 km southeast of where the creek crosses the Tanami/Hooker Creek track. Exposed rocks are much weathered and ironstained.

On aerial 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 form less positive topographic features than the adjacent sandstone formations.

Lithology

The beds comprise acid porphyry, basalt, tuff, and minor greywacke, sublithic arenite, phyllite, shale, and siltstone, all of which are exposed in the reference area. A prominent steep to vertical cleavage is commonly developed roughly parallel to the bedding, which trends northwest to northeast. No major folds have been mapped, but tight minor folds and contortions are common locally, as also are zones of shearing and brecciation. Quartz-veining is common throughout.

Acid porphyry crops out in the western part of the reference area and westwards to the Ware Range as a series of low parallel strike ridges and hillocks (Fig. 11). It is also present on the south side of Nanny Goat Creek. Blebs of pale greyish clay or brown iron oxide set in a pink, red, maroon, or mauve felsitic matrix give the porphyry a speckled appearance. Many of the blebs are altered feldspar phenocrysts; others are xenoliths, vesicles, and possible fiamme. The phenocrysts are generally less than 2 mm across, and locally form up to 30 percent of the rock. Some specimens contain altered phenocrysts of both pale grey and pale pink feldspar. Phenocrysts of quartz and altered ferromagnesian minerals and small xenoliths are also commonly present. The presence of a eutaxitic texture in some specimens and the absence of flow banding and autobrecciation suggest that some or all of the acid porphyry may be ash-flow deposits.

Most of the basalt forms non-porphyritic lava flows containing quartz-filled amygdales. The lavas are very fine-grained, and range from maroon to dark grey. Some basalt contains small pale phenocrysts of altered feldspar, as at Wilson Creek waterholes, where the basalt may be intrusive. Both types of basalt have a fine-grained basaltic texture, although the original constituents have been completely replaced by clay and iron oxide.

Altered tuff is well exposed at the Wilson Creek waterholes and in a large outcrop to the north. The tuff commonly appears massive, but bedding is indicated locally by thin beds and lenses of laminated fine to coarse tuff, greywacke, sublithic arenite, and phyllitic siltstone and shale. Prominent close jointing in the tuff is parallel to the bedding and regional cleavage. The tuff is mostly maroon to reddish brown, and generally consists of a medium-grained recrystallized equigranular mosaic of white mica, quartz, iron oxides, and clay. The presence of small detrital grains of tourmaline, rare pebbles of sandstone, and local lenses and interbeds of sedimentary rocks indicate the clastic nature of the tuff. The recrystallization is attributed to thermal metamorphism.

Individual beds of greywacke, sublithic arenite, and phyllitic shale and siltstone within the volcanic succession are generally less than 1 m thick. The greywacke is poorly sorted, fine to coarse, and consists of quartz, white mica, altered feldspar grains, fine-grained tuffaceous lithic fragments, and minor detrital tourmaline, zircon, and opaque minerals set in a sericitic matrix. Needles of secondary tourmaline, probably indicating thermal metamorphism, are present in greywacke at the Wilson Creek waterholes. The sublithic arenite is generally medium-grained and better sorted than the greywacke. Phyllitic shale and siltstone, which form beds 2 to 15 cm thick, 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 micaceous rocks, and the local recrystallization and development of tourmaline indicate that the Nanny Goat Creek Beds have been affected by both low-grade regional metamorphism and local thermal metamorphism.

The Nanny Goat Creek Beds are capped with laterite south of the Wilson Creek waterholes (where the outcrops are too small to show on the 1:250 000 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 grading down into mottled and ironstained deeply weathered bedrock. Concretions of dolomite are present in the mottled zone at the Wilson Creek waterholes.

Stratigraphic relationships

The Nanny Goat Creek Beds are overlain unconformably by the Carpentarian Gardiner Sandstone to the west and the Lower Proterozoic Supplejack Downs Sandstone to the south, and are probably intruded by the Lower Proterozoic Winnecke Granophyre. Most of the contacts are concealed by Cainozoic cover rocks, and where exposed they are generally faulted.

The unconformity between the Gardiner Sandstone and the Nanny Goat Creek Beds is evident on the east side of the Ware Range (19°10′40″S, 130°02′30″E). Here Gardiner Sandstone dips gently westward to the west and north of steeply cleaved and patchily brecciated amygdaloidal basalt. A faulted contact between the two units is exposed 8 km to the north, where contorted phyllite capped by pisolitic laterite lies adjacent to Gardiner Sandstone that contains pebbles of volcanic rocks similar to those in the Nanny Goat Creek Beds.

In the south the Nanny Goat Creek Beds are bounded by hills of Supplejack Sandstone. In the east these units are separated by a fault, but in the west the contact is probably an unconformity. In the west the Supplejack Downs Sandstone dips nearly vertically, younging to the south, and cuts obliquely across the cleavage and bedding of the volcanic and sedimentary rocks of the Nanny Goat Creek Beds to the north. The Nanny Goat Creek Beds are cut by quartz-hematite-tourmaline veins, which do not extend up into the Supplejack Downs Sandstone.

The contact between the Winnecke Granophyre and the Nanny Goat Creek Beds is not exposed, but the intrusive relationship is inferred from the evidence for thermal metamorphism of the Nanny Goat Creek Beds, such as hornfelsic textures and development of tourmaline needles. Unlike the Nanny Goat Creek Beds, the Winnecke Granophyre is uncleaved.

Outcrops of possible Nanny Goat Creek Beds (Atw?)

Several outcrops 14 to 28 km south of Nanny Goat Creek have been mapped as possible Nanny Goat Creek Beds. They have a similar topographic expression to the Nanny Goat Creek Beds, and also consist of steep to vertically dipping cleaved rocks with tight minor folds and contortions; the cleavage is generally parallel to the bedding, and trends north-south. The outcrops are separated from the main outcrop area by outcrops of Supplejack Downs Sandstone.

They consist of phyllitic to schistose mudstone, siltstone, greywacke, lithic arenite, acid porphyry, and chert. Quartz-veining is common. The greywacke and lithic arenite are generally medium to coarse, and consist of quartz grains, lithic grains, and detrital tourmaline and zircon set in a fine-grained ironstained sericitic matrix. Acid porphyry is exposed 8 km southeast of Supplejack Downs homestead, where it crops out 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 cleaved rocks are overlain unconformably by northerly dipping Supplejack Downs Sandstone. They are probably also overlain by the Lower Cambrian Antrim Plateau Volcanics to the south and east, where contacts are concealed under laterite and Quaternary sand.

The stratigraphic relationships of the cleaved rocks, their lithology, and the northerly trend of the bedding and cleavage indicate that these rocks probably belong to the Nanny Goat Creek Beds.

Nongra Beds
(new name)

The Nongra Beds are low-grade metamorphosed 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 Beds have been photo-interpreted to the southwest. These outcrops extend into the Tanami Sheet area southeast of the Browns Range, where Brown (1909) noted exposures of 'auriferous rock formation'.

The unit is named after Nongra Lake, 36 km north of the main outcrop area. In the reference area (19°42′50″S, 129°43′10″E), 48 km southeast of Birrindudu homestead, phyllitic rocks, chert, lithic to sublithic arenite, and acid porphyry crop out on a low ridge; the dip is steep to vertical and the strike north-south.

Gently undulating terrain and low rounded hills and ridges, with a relief of less than 20 m, are the dominant landforms on the Nongra Beds. Exposures are mostly rubbly and bouldery. Much of the outcrop area is covered by laterite, but the nature of the underlying rocks is commonly indicated by rock fragments in the surface gravel.

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

The beds have steep to vertical dips, strike northwest to northeast, and have a prominent cleavage, which is generally parallel to the bedding. They are probably tightly folded about nearly vertical fold axes, although no fold closures have been found. Neither the top nor bottom of the Nongra Beds is exposed, and the thickness is therefore unknown.

Lithology

The beds consist of phyllitic shale, siltstone, greywacke, and sublithic arenite, with minor banded chert, tuff, and acid porphyry. The sedimentary rocks are generally thinly interbedded. Quartz-veining and local brecciation are common.

The phyllitic shale and siltstone are mainly maroon or grey; rust spots, possibly after sulphides or garnet, are common. The greywacke is poorly sorted, fine to coarse, and maroon, purplish, brownish, or dark grey. It consists of quartz grains (about 60% of the rock), lithic fragments (most of which are probably volcanic), and minor detrital tourmaline and other heavy mineral grains, set in an abundant ironstained sericitic matrix. Compared with the greywacke, the sublithic arenite is paler and better sorted, 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 contains little or no quartz. The other volcanic rock (acid porphyry) was found only in the reference area. It contains about 10 percent phenocrysts of quartz, which is partly resorbed, and altered feldspar and ferromagnesian minerals set in a grey felsitic groundmass composed of a fine mosaic of quartz, sericite, and clay showing a vague eutaxitic or flow-banded texture.

Low-grade regional metamorphism of the Nongra Beds 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.

Stratigraphic relationships

The Nongra Beds are unconformably overlain by Gardiner Sandstone. An unconformable relationship can be inferred from the field evidence in the central part of the main outcrop area, where gently dipping Gardiner Sandstone forms low bluffs to the north of steeply dipping cleaved greywacke, tuff, and other rocks, and also 18 km to the west, where Gardiner Sandstone crops out to the northwest of more steeply dipping greywacke, phyllite, and chert. At the latter locality conglomerates in the basal part of the Gardiner Sandstone contain pebbles of jasper, chert, vein quartz, and other rock types that were probably derived from underlying Nongra Beds. Southeast of the Browns Range the Nongra Beds are inferred to be unconformably overlain by Lower Cambrian Antrim Plateau Volcanics.

The presence of fragments of quartz-tourmaline veins in lateritic gravel overlying the most easterly outcrop of the Nongra Beds indicates possible thermal metamorphism and metasomatism by a concealed granitic intrusion (Winnecke Granophyre?).

Helena Creek Beds
(new name)

The Helena Creek Beds crop out in the northeastern part of the Birrindudu Sheet area, southwest of Hooker Creek. The outcrop area is crossed by Helena Creek, after which the unit is named. The reference area (between 18°16′30″S, 130°08′00″E, 18°16′20″S, 130°10′00″E, and 18°18′00″S, 130°09′00″E) is south of the Hooker Creek/Nongra Lake track, 35 km east of Nongra Lake, where massive closely jointed tuff, thin-bedded to laminated tuff, porphyry, and quartz-veined quartzite crop out. As neither the top nor base are exposed, the thickness of the Helena Creek Beds is unknown.

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

Lithology

Medium to thin-bedded grey to maroon lithic arenite, greywacke, conglomerate, and phyllite are exposed in the northern part of the outcrop area, thin-bedded to laminated grey tuff and acid porphyry in the southeast, and reddish maroon massive tuff and quartz-veined quartzitic hornfels in the southwest. The lithic arenite and greywacke consist of subangular grains of quartz, chert, jasper, quartzite, phyllite, and porphyritic acid volcanics enclosed in a sericitic matrix; some quartz overgrowth cement is also commonly present. The conglomerate has a similar composition and consists of pebbles, generally less than 2 cm across, enclosed in a medium-grained sandy matrix.

Massive tuff is well exposed in the bluff at the southern end of the main outcrop. It is well jointed and fine-grained, and consists of an ironstained aggregate of quartz, and sericite, flakes of a pale green chloritic mineral, and a few grains of detrital tourmaline. Quartz forms less than 50 percent of the rock.

Stratigraphic relationships

The Helena Creek Beds are intruded by the Winnecke Granophyre and are overlain unconformably by the Cambrian Antrim Plateau Volcanics. The contacts, however, are concealed by Quaternary deposits. The intrusive relationship with the Winnecke Granophyre is indicated by the occurrence of quartzitic hornfels adjacent to granite in the south.

The lithology and deformation of the Helena Creek Beds are similar to those of the Nanny Goat Creek Beds, and indicate that the Helena Creek Beds are part of the Archaean? Tanami complex.

Undivided Tanami complex

Outcrops of undivided Tanami complex are restricted to the southern part of the Browns Range dome in the northwest corner of the Tanami Sheet area. They consist of mica schist, banded chert, and sheared conglomerate. The presence of mica schist and some copper carbonates and pyrite were recorded here by Davidson (1905). The mica schist has been formed by regional and thermal metamorphism of greywacke and possibly lithic arenite. Sheared conglomerate, consisting of deformed pebbles in a schistose matrix (Fig. 12), is exposed at one locality (19°02'S, 129°09'E). The schist and chert are cut by quartz and quartz-tourmaline veins.

The undivided Tanami complex is intruded by granite in the north, the contact being marked by a shear zone over 100 m wide; in the south it is overlain by southerly dipping Gardiner Sandstone.

LOWER PROTEROZOIC

Pargee Sandstone

(new name)

The Pargee Sandstone crops out in the western half of the Tanami Sheet area as a north-northwesterly belt up to 8 km wide. 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 Gardiner Sandstone. The largest outcrop, to the west of Mount Frederick, consists of a low range, where the maximum thickness of about 1500 m is exposed. South of the range strike ridges of Pargee Sandstone continue to the southern edge of the Tanami Sheet area.

On aerial photographs the Pargee Sandstone has a smooth medium tone; the trace of the bedding and also joints, along which gullies have developed, are clearly visible.

The type section extends for 800 m along a gully (between 19°38′20″S, 129°12′30″E and 19°38′30″S, 129°12′15″E) in the low range west of the Pargee Range, where 700 m of current-bedded medium to coarse arenite with interbeds of conglomerate, dipping 70° southwest, is exposed.

Lithology

The main rock types are silicified sublithic and lithic arenites, quartz arenite, conglomerate, and greywacke. Most of the arenite is medium-bedded and fine to coarse-grained, although some is pebbly to conglomeratic (Fig. 13). Current-bedding is almost ubiquitous, and ripple marks are locally common. The arenites are commonly pink, purple, maroon, and reddish brown due to ironstaining. They consist mainly of rounded to subangular quartz grains, with up to 30 percent turbid and lithic grains, and have a quartz overgrowth cement. The boundaries of the quartz grains are outlined by dust and ironstaining. The turbid grains are composed of diffuse mosaics of quartz, some of which are pseudomorphing feldspar. The lithic grains include chert, jasper, and volcanic rocks.

Conglomerate generally forms beds about 1 m thick interbedded with the arenites. Five conglomerate beds are present in a sequence about 25 m thick on the southwest side of Mount Frederick. The conglomerate consists mainly of pebbles or granules (as on the east side of Mount Frederick) of jasper, yellow and greenish chert, vein quartz, and lithic and quartz arenites set in a silicified sandstone matrix.

Greywacke is also interbedded with the arenites. It is dark grey to maroon, medium to fine-grained, poorly sorted, and contains clear and turbid quartz grains in about equal proportions, and subordinate lithic grains. Most of the grains are angular to subangular and very few are well rounded. The turbid quartz grains are similar to those in the arenites, and are generally better rounded than the clear grains; one grain was found to be composed of a micrographic intergrowth of clear primary quartz and turbid secondary quartz pseudomorphing alkali feldspar. Iron oxide forms patches in the matrix and is also present as discrete grains. A fine-grained matrix of variably ironstained quartz and sericite forms about 20 percent of the rock; some quartz overgrowth cement is also present.

Stratigraphic relationships and age

In the Pargee Range area the Pargee Sandstone is steeply dipping and tightly folded, and is unconformably overlain by less steeply dipping Gardiner Sandstone, the basal formation of the Carpentarian Birrindudu Group. A conglomerate composed of boulders of Pargee Sandstone is locally present at the base of the Gardiner Sandstone (Fig. 14). In The Granites Sheet area the Pargee Sandstone rests unconformably on the Archaean? Killi Killi and Mount Charles Beds (Blake et al., 1973). The chert and jasper grains in the Pargee Sandstone may have been derived from the Mount Charles Beds. The Pargee Sandstone is tentatively correlated with the Mount Winnecke Formation and Supplejack Downs Sandstone, and is probably Lower Proterozoic.

Mount Winnecke Formation
(Traves, 1955, amended)

The Mount Winnecke Formation consists predominantly of folded sandstone and intercalated acid volcanics which crop out mainly to the east of the Ware Range in the southeastern part of the Birrindudu Sheet area and northernmost part of the Tanami Sheet area. Two small outcrops of acid volcanics mapped as Mount Winnecke Formation also occur farther south, the first 15 km east-northeast of Supplejack homestead and the second 17 km northeast of Tanami (Fig. 4).

The sequence was called the Mount Winnecke Sandstone by Traves (1955) after Mount Winnecke (130°19′50″S, 15°46′06″E), but as the formation contains acid volcanics as well as sandstone the name has been amended to Mount Winnecke Formation.

The type section is across the north side of a structural basin north of Mount Winnecke, where a thickness of about 4800 m is exposed. Traves (1955) did not nominate a type section or 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 depressions or low rounded hills and gently undulating terrain. The tuffs form depressions between ridges of 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 anticlines and synclines, particularly in the Winnecke Range (Fig. 5).

Lithology

The formation is composed mainly of sublithic arenite, tuffaceous sandstone and siltstone, and acid lava, with some conglomerate, laminated tuff and lapilli tuff, and minor mudstone and agglomerate.

The unweathered sublithic arenite is pale grey, but weathered surfaces are variably ironstained. It is mainly poorly sorted, medium to very coarse, and generally forms beds over 1 m thick. Gritty and pebbly beds are widespread. Cross-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 common, and in places form complex networks. Surface silicification is widespread and small cappings of silcrete occur locally.

The arenite is generally composed 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 fragments of acid volcanic rocks; others may be grains of altered feldspar. Heavy minerals present include zircon and rare tourmaline.

With an increase in the proportion of fragments of volcanic rock the sublithic arenite grades into tuffaceous sandstone, which is more susceptible to weathering. Laterite cappings are common on the tuffaceous sandstone, and the pronounced ironstaining gives rise to deep maroon and purple colours. Compared with the

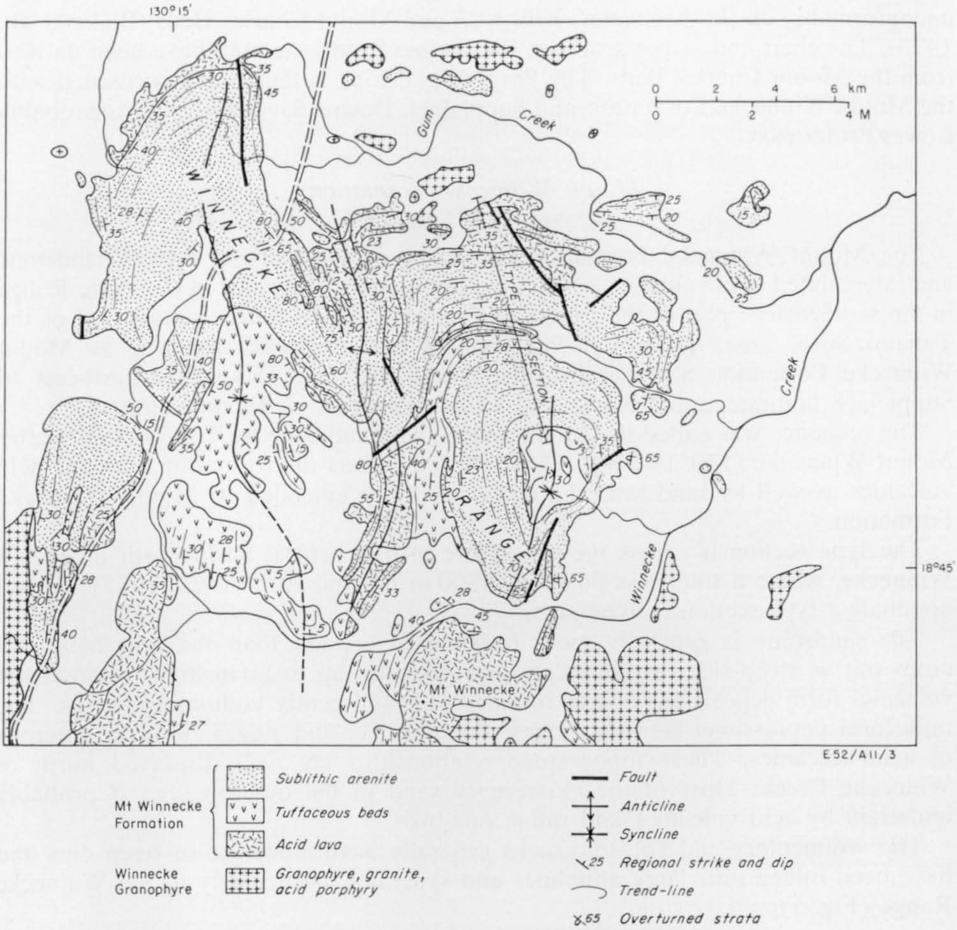

Fig. 5 Geology of the Winnecke Range.

sublithic arenite the tuffaceous sandstone is more poorly sorted and more commonly coarse-grained and gritty. It forms beds over 1 m thick, typified by cross-bedding, and much thinner beds, from 1 to 10 cm thick, which generally show ripple marks. The thin beds of tuffaceous sandstone are commonly interbedded with tuffaceous siltstone. 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 contains over 15 percent volcanic rock fragments, and over 10 percent matrix. Altered feldspar grains are visible in some specimens, but no shards of altered volcanic glass have been identified. Mica is common in the tuffaceous sandstone and associated tuffaceous siltstone.

Conglomerate is not widespread in the Mount Winnecke Formation and, where present, is generally associated with tuffaceous beds. It contains clasts, generally less than 10 cm across, of vein quartz, quartzite, sublithic arenite, and tuffaceous and volcanic rocks. Conglomerate is well exposed 7 km north of Mount Winnecke, where it is interbedded with tuffaceous sandstone in a scarp on the western edge of a sandstone plateau, and 27 km south of Mount Winnecke, where it lies between a thick flow of acid lava below and sublithic arenite above.

The acid lavas are pale buff or grey to deep maroon or purplish. They are generally deeply weathered, and relatively fresh specimens can be obtained only from the interiors of the largest flows. Most of the lavas contain up to 20 percent phenocrysts of feldspar, and in most cases some quartz, set in a felsitic matrix. The phenocrysts are generally less than 1 cm across. Individual flows are dome-shaped. The thickest flow measured was 200 m, but many are probably thicker. The interiors of the flows are massive and appear to be structureless, but the margins are blocky, owing to autobrecciation, and are commonly scoriaceous. Contorted flow banding is common on the edges of many of the flows (Fig. 15). The lavas pass laterally into bedded tuffaceous sedimentary rocks, as can be seen in the northwest part of the Winnecke Range.

The porphyritic varieties contain euhedral feldspar phenocrysts, which are generally pseudomorphed by clay or sericitic material (Figs 15, 16). The few remnants of the original feldspars preserved consist of sodic plagioclase or alkali feldspar, or both. Quartz phenocrysts are of the β-quartz type and show resorption features. Altered phenocrysts of ferromagnesian minerals and opaque microphenocrysts are commonly present. The groundmass probably consisted originally of microlites and glass or cryptocrystalline to microcrystalline quartz and feldspar, but in most specimens it now consists of a fine mosaic of quartz. However, in some specimens the original microlites are outlined by dust particles or opaque material (Fig. 16). In a few of the least-altered specimens, the groundmass consists of a fine mosaic of quartz and alkali feldspar with opaque granules and dust.

In the scoriaceous lava the vesicles are infilled with quartz, celadonite and, at one locality, diaspore* and pyrophyllite*. Diaspore and pyrophyllite are present in the top of a non-porphyritic lava flow immediately below a sublithic arenite 17 km south of Mount Winnecke. The diaspore is anhedral, and probably occupies small vesicles. The fine-grained micaceous aggregates of pyrophyllite are possibly an alteration product of the diaspore. The presence of both minerals indicates that the lava may once have contained alunite, which is common in hydrothermally altered acid lava.

The alteration of most of the acid lavas is partly due to surface weathering, and probably partly due to hydrothermal propylitization during and immediately after extrusion.

Medium to very fine tuff, lapilli tuff, and agglomerate are interbedded with the acid lavas. Medium to very fine tuff overlying acid lava is well exposed on the northwest side of Mount Winnecke. The tuff is a thin-bedded to laminated waterlaid deposit that has been partly altered to chert. Some of the beds show graded bedding. Where silicified the tuff is pale buff to greyish; elsewhere it is maroon.

Lapilli tuff crops out 6 km south-southwest of Mount Winnecke (Figs 17, 18) as nearly vertical beds, from 1 to 2 m thick, around a core of sublithic arenite, quartz arenite, tuffaceous sandstone, and conglomerate. The lapilli tuff consists of unsorted fragments of maroon non-porphyritic lava, most of which are less than 2 cm across, and was probably laid down under water, close to the eruptive site.

Agglomerate is exposed in a creek bed 15 km west-northwest of Mount Winnecke. It consists of scattered fragments of sandstone and acid lava set in a medium to fine tuffaceous matrix.

The following field evidence indicates that most if not all the volcanity was subaqueous. Firstly, the acid lava flows interfinger with cross-bedded sandstone that was undoubtedly deposited in water. Secondly, the acid lavas are overlain by waterlaid deposits, and not by air-fall pyroclastics. Thirdly, the tuffs associated with the acid lavas were laid down under water. Fourthly, in spite of an abundance of

*Microscopic identification by W. B. Dallwitz; X-ray diffraction identification by G. H. Berryman.

fragmentary volcanic material, ignimbritic rocks appear to be completely absent; such rocks might be expected if the volcanic eruptions were subaerial. The high degree of alteration of most of the acid lavas may be due in part to an abundance of hydrous volcanic glass formed by rapid chilling underwater: such glass is particularly susceptible to hydrothermal alteration and to any subsequent metamorphism and weathering.

Type section

All the main rock types, except agglomerate, are represented in the type section (Table 2) across the north side of the structural basin north of Mount Winnecke (Fig. 5). The type section is 9 km long (18°37′55″S, 130°21′20″E to 18°42′40″S, 130°27′10″E), and comprises a sequence estimated to be nearly 5000 m thick 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	TUFFACEOUS SANDSTONE, dipping south beneath Quaternary sand. To west along strike the sandstone overlaps onto scoriaceous and blocky flow-banded non-porphyritic acid lava
1820	SUBLITHIC ARENITE, cross-bedded, medium-grained, generally well sorted. Forms plateau. At base of unit, on northern edge of plateau, cross-bedded coarse to gritty arenite containing well rounded pebbles of vein quartz and acid volcanic rocks overlies 15 m of medium to coarse sublithic arenite
280	TUFFACEOUS SANDSTONE AND SILTSTONE with some interbeds of sublithic arenite. Forms topographic depression
140	SUBLITHIC ARENITE, cross-bedded, coarse. Forms low strike ridge
140	TUFFACEOUS SANDSTONE, cross-bedded, coarse and gritty. Forms depression
1220	SUBLITHIC ARENITE, medium to coarse, locally gritty and pebbly. Forms plateau
520	ACID LAVA containing feldspar phenocrysts. Forms depression; exposures confined to incised creeks. Some lateritic weathering profiles
230	SUBLITHIC ARENITE, medium to coarse, cross-bedded. Forms southern part of strike ridge
250	ACID LAVA containing quartz and feldspar phenocrysts. Exposed on north side of strike ridge. Sand plain to north
Total 4800	Base of exposed succession (northern end of section line)

Other areas

A sequence of sublithic arenite and intercalated acid lava flows is well exposed on the western limb of a southerly plunging anticline in the western part of the Winnecke Range (Fig. 5). The lowest lava can be traced east along strike to the lava at the base of the type section.

West of the Tanami/Hooker Creek track, at the northwest end of the Winnecke Range, acid lava underlies a thick sequence of sublithic arenite in a southerly plunging syncline. Tuffaceous beds and some acid lavas crop out to the south, in the core of the syncline, and to the southwest, on the western limb of the same syncline.

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

The most easterly outcrop mapped is a synclinal ridge of sublithic arenite 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 of these, 17 km northeast of Tanami, quartz-feldspar porphyry forms isolated low mounds. Unlike the nearby metamorphic rocks of the Mount Charles Beds, the porphyry is uncleaved; it is probably unconformable on the metamorphics and unconformably overlain by Gardiner Sandstone. At the other locality, 15 km east-northeast of Supplejack Downs homestead, quartz-feldspar porphyry underlies, possibly unconformably, northerly dipping Supplejack Downs Sandstone.

Outcrops of cross-bedded sublithic arenite 20 km west of Pattie Creek, in the Birrindudu Sheet area, have been mapped as possible Mount Winnecke Formation. The arenite has moderate to steep dips and appears to form a northerly trending syncline. It is faulted to the west against sublithic arenite and quartz arenite of the Gardiner Sandstone, which dips gently northeast.

Stratigraphic relationships, correlations, and age

The Mount Winnecke Formation is intruded by Winnecke Granophyre and is possibly faulted against Gardiner Sandstone to the west. East of Supplejack Downs homestead it is overlain, possibly unconformably, by Supplejack Downs Sandstone. In the Black Hills area it probably rests unconformably on Mount Charles Beds and is overlain, probably unconformably, by Gardiner Sandstone. East of the Winnecke Range, Cambrian rocks are inferred to rest unconformably on the Mount Winnecke Formation.

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, with sublithic arenite capping low hills of deeply weathered granophyre. At the sharp intrusive contact both the arenite and granophyre have been affected by greisenization, and the arenite nearby has been thermally metamorphosed to a tourmaline-bearing quartzitic hornfels. The tourmaline commonly forms stellate clusters of crystals several centimetres across (Fig. 19). Farther north, on the west side of the track, the intrusive contact dips steeply east, and the granophyre crops 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 the effects of thermal metamorphism are restricted to within a few metres of the contacts.

North of Gum Creek, sandstone of the Mount Winnecke Formation is thermally metamorphosed to quartzite, but the associated acid lava appears to be only slightly altered.

The types of instrusive rocks and the lack of significant thermal metamorphism indicate that the Winnecke Granophyre is a high-level intrusion. Both it and acid lavas of the Mount Winnecke Formation have been dated by the Rb-Sr method at 1800 m.y. (late Lower Proterozoic) by R. W. Page. They are probably comagmatic, as they are similar petrographically as well as in age.

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

The Mount Winnecke Formation is younger than the Tanami complex as it is less tightly folded and is essentially uncleaved and not affected by regional metamorphism. It is tentatively correlated with the Lower Proterozoic Whitewater Volcanics of the Kimberley region.

Supplejack Downs Sandstone
(new name)

The Supplejack Downs Sandstone consists of a sequence of irregularly folded sublithic arenite and quartz arenite which crops out in the northeastern part of the Tanami Sheet area to the south of the Ware Range. 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, less than 30 m high, 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. The exposures on gentle slopes and crests are mainly rubbly. Some of the broad ridge crests are capped by lateritic gravel and pisolitic laterite about 1 m thick, and small patches of ironstained silcrete occur locally.

The formation forms irregular open folds and local tight folds, and is displaced by faults, some of which are marked by quartz veins. The maximum thickness exposed is about 1300 m. The type section (19°16′50″S, 130°02′45″E) is across the southern end of a strike ridge 11 km east of Supplejack Downs homestead, where about 6 m of sublithic arenite and quartz arenite dip west at 15° to 20°.

Lithology

The outcrops consist of sublithic arenite, quartz arenite, and minor shale and siltstone, but much of the sand-covered area between outcrops may be underlain by the less resistant shale and siltstone.

The arenites are generally pale pink or mauve to deep maroon, and less commonly white to grey. They generally form beds less than 1 m thick, and are locally flaggy. The bedding planes are commonly undulating, and cross-bedding is common. Many of the weathered surfaces, especially on ridge crests, are silicified. Both the sublithic arenite and quartz arenite are generally well sorted and medium-grained, but range from fine to coarse, and in places contain small shale pellets. Rare lenses of conglomeratic sandstone are present locally. Quartz-veining is characteristic, and shearing and brecciation are common. The shear planes are generally steeply inclined, but are locally horizontal along the northern edge of the outcrop area.

The sublithic arenite commonly has up to 10 percent altered clayey matrix (mainly sericite and kaolin), whereas the quartz arenite has little or no matrix. Both have a quartz overgrowth cement. Some of the quartz grains are turbid and some contain small flecks of sericite — they may be pseudomorphs after feldspar. Most of the lithic grains are white or pink in hand specimen and turbid in thin section, and consist of a fine to very fine mosaic composed mainly of quartz. Some of the grains contain tabular microphenocrysts of quartz which may be pseudomorphs after feldspar, and were probably derived from acid volcanic rocks. Grains of chert, phyllite, quartzite, and altered basalt are also present. The heavy minerals include relatively abundant blue and yellow tourmaline, minor zircon, and iron oxide.

At the type section sublithic arenite is interbedded with quartz arenite, both of which are medium-bedded and medium-grained. Some beds contain small shale pellets.

Stratigraphic relationships and age

The Supplejack Downs Sandstone rests unconformably on the Archaean? Nanny Goat Creek Beds and is overlain unconformably by the Lower Cambrian Antrim Plateau Volcanics. It also overlies, possibly unconformably, acid porphyry mapped as Mount Winnecke Formation 15 km east-northeast of Supplejack Downs homestead, and is probably overlain unconformably to the west by the Carpentarian Gardiner Sandstone, although the contact is not exposed. The lithic grains in the sandstone may have been derived from the Nanny Goat Creek Beds and Mount Winnecke Formation.

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

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

The field relationships indicate that the Supplejack Downs Sandstone is probably about the same age as, or slightly younger than, the Mount Winnecke Formation, and hence it is probably late Lower Proterozoic.

Winnecke Granophyre
(Traves, 1955)

The extensive outcrops of granophyre, adamellite, and intrusive acid porphyry in the eastern part of the Birrindudu Sheet area and outcrops of similar rocks in the northeastern part of the Tanami Sheet area are mapped as Winnecke Granophyre. Traves (1955) gave this name to granophyre cropping out in the upper reaches of Winnecke Creek and its tributaries, where granite and intrusive porphyry had been recorded previously by Jensen (1915). The unit is well exposed on the west side of the Tanami/Hooker Creek track to the north of Winnecke Creek (at 18°46′S, 130°12′E), and this locality has been selected as the type area.

The exposed granophyre, adamellite, and porphyry are commonly soft and friable, mainly because of weathering. Most of the exposures occur in breakaways up to 10 m high below flat laterite-capped surfaces and, south of Winnecke Creek, on laterite-capped inselbergs rising up to 20 m above the sand plain (Fig. 20). The depth of weathering is variable, and in places fresh rock crops out less than 5 m below the top of the laterite capping. The unaltered rocks crop out as spheroidal boulders and smooth rounded mounds, low hillocks, and tors (Fig. 21); the outcrops of slightly altered granophyre and adamellite are similar, except that the boulders and surfaces of bare rock are more angular.

On aerial photographs the unweathered and slightly weathered rocks 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.

The fresh granophyre and adamellite are pink, but the weathered rocks range from white to yellow, reddish brown, or maroon. Biotite is the main ferromagnesian constituent. The granophyre commonly contains phenocrysts of feldspar up to 1 cm long, and small druses filled with quartz, chlorite, epidote, and, in one specimen, prehnite. A graphic texture is often recognizable in hand specimen. The adamellite is generally non-porphyritic, though feldspar phenocrysts up to 3 cm long are present locally. Some of the phenocrysts are poikilitic. Porphyry is associated with the granophyre and adamellite, but is less widespread. It generally contains 20 to 30 percent phenocrysts of quartz, pink and white feldspar, and ferromagnesian minerals set in a maroon to dark grey microgranitic to felsitic groundmass. The phenocrysts range from 5 mm to 1 cm long, and are generally larger and more abundant than those in the porphyritic acid lavas of the Mount Winnecke Formation. However, the intrusive porphyry cannot always be distinguished from acid lavas, and some of the porphyry mapped as Winnecke Granophyre, such as that in the southeast corner of the Birrindudu Sheet area, may be part of the Mount Winnecke Formation.

Quartz veins and small xenoliths rich in biotite are common in the granophyre, adamellite, and porphyry, and greisens occur locally, mainly near intrusive contacts with the Mount Winnecke Formation.

In places the granophyre and adamellite are cut by aplitic and andesitic? dykes, some of which are offset along major joints or faults. The aplitic dykes consist of leucocratic microgranite and granophyre. The andesitic? dykes are dark grey, fine-grained, and commonly flow-banded; one dyke cutting sheared adamellite on the west side of the Tanami/Hooker Creek track north of Gum Creek contains small slivers and rounded fragments of adamellite.

The granophyre and adamellite are locally sheared and cut by quartz veins, and in Winnecke Creek, 13 km northeast of Mount Winnecke, schistose rocks have been developed. The granitic rocks forming the inselbergs 8 km south-southeast of Mount Winnecke are also schistose. The shear planes are roughly vertical and, like the associated quartz veins, trend north-south.

Some quartz veins cutting the Winnecke Granophyre are several metres wide and enclose fragments of sheared adamellite and granophyre, and also fragments of volcanic and sedimentary rocks that were presumably derived from the Mount Winnecke Formation. These large veins probably mark fault lines.

Much of the Winnecke Granophyre is capped by laterite. The cappings are well exposed in the west in breakaways, where pisolitic laterite 1 to 2 m thick overlies a zone of mottled and ironstained altered granitic rock 5 m or more thick. An underlying pallid zone is exposed in places in gullies. Cross-cutting quartz veins are preserved within the laterite; some of them form small ridges. East of the breakaways most of the pisolitic upper zone has been partly or completely removed by erosion, leaving low smoothly rounded rises of partly silicified mottled material between broad drainage depressions.

Lithology

The granophyre consists of quartz, variably turbid alkali feldspar, sodic plagioclase, and brown biotite. Quartz phenocrysts are present in some specimens (Fig. 22). The alkali feldspar is orthoclase or microline and is commonly microperthitic; it forms euhedral phenocrysts and is present in the groundmass in micrographic intergrowths with quartz. In some specimens the alkali feldspar phenocrysts appear to have been partly or wholly replaced by micrographic quartz and alkali feldspar (Fig. 22). Alteration of the alkali feldspar to kaolin is common. Sodic plagioclase (oligoclase-andesine) is present as euhedral phenocrysts; it is generally subordinate to alkali feldspar, and is more altered to sericite and kaolin. Biotite forms phenocrysts, fine-grained aggregates that may represent small xenoliths, and small flakes in the groundmass. Some of the biotite has been altered 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. Minor amounts of allanite, apatite, clinozoisite, epidote, fluorite, leucoxene, opaque iron oxides, sphene, zircon, and unidentified metamict minerals have also been recorded.

The adamellite is similar in mineral composition to the granophyre, but is coarser grained, mostly non-porphyritic, and predominantly granitic rather than graphic in texture. Small patches of graphic quartz and alkali feldspar are common, and in places the adamellite may grade into granophyre. Alkali feldspar and plagioclase are present in about equal proportions, and the colour index is generally between 5 and 10.

The bleached granophyre and adamellite consist of quartz and kaolin pseudomorphs after feldspar and biotite. Some specimens also contain sericite.

The porphyry (Fig. 23) 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. The accessory and secondary minerals are similar to those in the granophyre. The phenocrysts are set in a fine to very fine-grained granitic and patchy 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 Beds of the Tanami complex in the north and south respectively, but the contacts are concealed by Quaternary sand. A major fault separates the Winnecke Granophyre from the Gardiner Sandstone to the west.

The Winnecke Granophyre has been dated isotopically at 1800 m.y. (late Lower Proterozoic) by R. W. Page, using the whole rock Rb^{87}/Sr^{87} method.

The irregular roof of the Winnecke Granophyre is exposed in low hills 22 km southwest of Mount Winnecke. The contact rocks of the Mount Winnecke Formation have been greisenized and tourmalinized, and the sandstone within a few metres of the underlying granophyre has been thermally metamorphosed to quartzite. The granophyre 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 north-west 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, distribution of outcrops, and the types of rocks present indicate that the Winnecke Granophyre probably consists of several separate but closely related high-level intrusions that are probably comagmatic with the acid volcanic rocks of the Mount Winnecke Formation. It may also be comagmatic with and similar in age to the unnamed granite cropping out to the south and west.

A contact between the Winnecke Granophyre and the Lower Cambrian Antrim Plateau Volcanics is exposed in the hills 20 km west of the 28-mile bore on Hooker Creek, where medium-grained greisenised granite is overlain by basalt lava.

Unnamed Granite

Unnamed granitic rocks, largely concealed by Quaternary sediments, are present in the central parts of the Browns Range and Coomarie domes and east of the Black Hills.

Within the Browns Range dome small outcrops of granite are present in the northwestern and southwestern parts of the Tanami and Birrindudu Sheet areas respectively; exposures of kaolinized granite were recorded by Davidson (1905) and Brown (1909) on the north side of the dome. The exposed granite is mainly medium-grained, but is locally coarse to pegmatitic; it consists of quartz, white mica, and white altered feldspar. Schistose granite is present in the southwest, in contact with schistose greywacke mapped as undivided Tanami complex, and also in the northeast. West-northwest of the latter locality unsheared granite is overlain by Gardiner Sandstone. A few hundred metres south of the unconformity the granite is cut by several quartz veins and is capped with small patches of silcrete. 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 was penetrated in numerous stratigraphic holes drilled in 1971. It is overlain by Quaternary sand, generally from 1 to 3 m thick but thickening in places to more than 20 m, and in the west and east by Tertiary calcrete up to 10 m thick. The granite immediately below the Cainozoic sediments is either lateritized and silicified to a reddish brown rock with bleached mottles, or is altered to yellowish friable granite. Relatively fresh granite is present at depths of 30 to 80 m. It is mainly medium-grained and non-porphyritic, and consists of quartz, pink feldspar largely altered to clay, and muscovite or biotite, or both; greisen, pegmatite, and quartz veins were present in some holes. In BMR Tanami No. 25, 19 km northwest of Tanami, a gabbroic rock was intersected below 23 m of sand and was cored at 48 m. The core is medium-grained and consists of zoned plagioclase, mostly altered to sericite, brown hornblende, clinopyroxene, orthopyroxene, brown biotite, opaque minerals, and some interstitial quartz.

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

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

In the west, the Black Hills granite has intruded and thermally metamorphosed basalt of the Mount Charles Beds, and in the east it is overlain by younger sediments of possible Cambrian age, and also by Tertiary travertine. It is not seen in contact with the Gardiner Sandstone.

The unnamed granitic rocks in the three areas are generally similar in composition, and are probably similar in age. They intrude rocks of the Archaean? Tanami complex, and in two of the areas they are overlain unconformably by the Carpentarian Gardiner Sandstone. These relationships indicate that the unnamed granitic rocks are probably Lower Proterozoic, and may be correlated with the Winnecke Granophyre.

CARPENTARIAN

BIRRINDUDU GROUP (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 comprises the Gardiner Sandstone at the base, the Talbot Well Formation, and the Coomarie Sandstone. The sequence is conformable and consists mainly of cross-bedded sublithic arenite. The group reaches a maximum known thickness of about 6000 m between the Browns Range and Pargee Range.

Stratigraphic relationships, age and correlation

The Birrindudu Group lies unconformably on the Tanami complex, on unnamed granite, and probably also on the Supplejack Downs Sandstone, Winnecke Granophyre, and Mount Winnecke Formation. It is itself overlain unconformably by the flat-lying Lower Cambrian Antrim Plateau Volcanics, and by the Cretaceous? Larranganni Beds.

The isotopic age of glauconite from the Gardiner Sandstone indicates that the group is Carpentarian. It may be stratigraphically equivalent to the Limbunya Group of the Victoria River region (Sweet et al., 1971), and to the Mount Parker Sandstone and Bungle Bungle Dolomite of the East Kimberley region (Dow & Gemuts, 1969).

Gardiner Sandstone
(Casey & Wells, 1964, amended)

The Gardiner Sandstone is the oldest and most widespread formation of the Birrindudu Group in the Birrindudu and Tanami Sheet areas, and crops out extensively west of the Tanami/Hooker Creek track. It extends westwards into the Billiluna and Gordon Downs Sheet areas, where it was mapped as Gardiner Beds (Wells, 1962a; Casey & Wells, 1964; Gemuts & Smith, 1968; Dow & Gemuts, 1969). The sequence was called the Gardiner Beds by Casey & Wells (1964) after the Gardner Range, incorrectly spelt as 'Gardiner' on Western Australian maps, which extends eastwards into the Tanami Sheet area from the Billiluna Sheet area. The name has been amended to Gardiner Sandstone as both the top and bottom are now defined.

The sandstone crops out in discontinuous strike ridges, up to 100 m high, which broaden into plateaux where the beds are approximately horizontal or where they are gently folded, as in the Pargee, Tanami, and Ware Ranges. The outcrops are separated by sand plains. Good exposures occur on scarps (Fig. 25). Many exposed surfaces are silicified and some are covered by small patches of silcrete.

On aerial photographs the Gardiner Sandstone has a medium to light tone. The trace of the bedding is generally clearly visible on the photographs, and joints are indicated by linear gullies and lines of vegetation. Cross-cutting quartz veins in the southern part of the Ware Range show up as prominent white lines.

The type section is at Larranganni Bluff (Casey & Wells, 1964) on the eastern margin of the Billiluna Sheet area; it is about 90 m thick. The maximum known thickness is about 3000 m, on the east side of the Ware Range. The thicknesses exposed at various localities are given in Table 3. They have been calculated from dips measured in the field and from distances measured on aerial photographs.

Structure

The Gardiner Sandstone dips outwards off the Browns Range and Coomarie domes and also outwards from the core of a broad anticline in the central part

TABLE 3

CALCULATED THICKNESSES OF THE GARDINER SANDSTONE

Locality	*Average Dip*	*Thickness (m)*	*Comments*
N Part of Browns Range	10°	700	Base but not top exposed
S Part of Browns Range	10°	900	Base but not top exposed
Range SE of Browns Range	50°	2500	Top but not base exposed
Gardner Range NW of Mallee Hill	25°	1400	Base but not top exposed
E of the Pargee Range	30°	2600	Neither base nor top exposed
N Part of Coomarie Range	10°	870	Top but not base exposed
E Part of Coomarie Range	70°	470	Neither base nor top exposed
W of Black Hills	40°	800	Neither base nor top exposed
Talbot Hills	10°	430	Neither base nor top exposed
Central Part of Supplejack Range	35°	700	Top but not base exposed
E Side of Ware Range	40°	3000	Base but not top exposed
N Part of Ware Range	12°	1800	Base but not top exposed
Birrindudu Range	45°	2170	Top but not base exposed
Mana Range	30°	1700	Base but not top exposed

of the Birrindudu Sheet area. Between the domes and the major anticline the Gardiner Sandstone has been folded and faulted into a complex pattern of basins, anticlines, and synclines. In the Ware Range, in the northeast, the formation forms broad anticlines and synclines and is cut by several major faults and many minor faults, some of which are defined by quartz veins over 1 m wide and 1 km long.

Lithology

The Gardiner Sandstone consists predominantly of sublithic arenite, with some conglomerate, quartz arenite, and thinly interbedded shale, siltstone, and fine arenite. Glauconitic sandstone occurs at several localities.

The sublithic arenite is generally medium-grained, but ranges from fine to coarse, and is locally pebbly. Most of the lithic grains are dull white or pink, and appear to be clayey or micaceous. Most of the beds are about 1 m thick, but some are thinner and have a flaggy parting (Fig. 25). Cross-bedding is almost ubiquitous, and ripple marks are abundant in places (Figs 26, 27). Undulating bedding planes are common in the Ware and Gardner Ranges. Scattered pebbles and conglomerate lenses are present locally. The arenite ranges from white to pink, grey, and dark purple, according to the intensity of ironstaining. In places it shows fine colour banding unrelated to bedding, and in the Ware Range some small black spots and streaks are present. Zones of brecciation occur along fault lines.

The sublithic arenite is composed of subangular to rounded grains of quartz and up to 25 percent lithic fragments, many of which were derived from acid and basic volcanic rocks. Some specimens contain grains of alkali feldspar and many contain grains of turbid quartz that may be pseudomorphing feldspar. Heavy minerals present include tourmaline and zircon. The arenite has a quartz overgrowth cement and up to 10 percent matrix.

One or more layers of conglomerate, up to several metres thick, commonly occur at or near the base of the Gardiner Sandstone, and some lenses are also present higher in the sequence. Good exposures can be seen on a strike ridge west of the Tanami/Hooker Creek track about 10 km northeast of Tanami (Fig. 28); in the southern part of the low range southeast of Mount Frederick; unconformable on the Pargee Sandstone 5 km southwest of Mount Frederick; in the Pingidijarra Hills; on the Supplejack Range (Fig. 29); on the Mana Range, where there is a conglomerate bed about 6 m thick near the top of the exposed sequence and another bed, about 3 m thick, 10 m below; and on either side of a major fault along the east side of the Ware Range, on the northern margin of the Tanami Sheet area. At the latter locality, east of the fault, the conglomerate forms a west-facing scarp. It contains angular to rounded pebbles and cobbles of acid volcanics, chert, and quartzite, many of which were probably derived from the underlying Tanami complex. Conglomerate at the base of the formation is formed largely of locally derived rock fragments. At most other localities the conglomerate is composed mainly of well rounded pebbles and boulders, up to 30 cm across, of fine to medium quartz arenite, sublithic arenite, and vein quartz set in a sandstone matrix. In places, pebbles of chert and conglomerate, which were possibly derived from the Pargee Sandstone, are present, and 10 km northeast of Tanami pebbles of basalt, probably derived from the Mount Charles Beds, were found in the conglomerate.

The quartz arenite is generally medium to coarse, white, pink, or grey, and cross-bedded. It consists of rounded grains of quartz, some of which have ironstained rims, and a quartz-overgrowth cement. It generally contains little or no matrix. The thinly interbedded shale, siltstone, and fine arenite are poorly exposed, except in cliffs where they are overlain by sublithic arenite and quartz arenite, as at Larranganni Bluff, southeast of Coomarie Spring, northeast of the Pargee Range (at 19°20′S, 129°35′E), in the southern part of the Browns Range, in the banks of incised creeks in Frog Valley (Ware Range), and on the north side of the Gardner Range north of Mallee Hill. They were also intersected in several stratigraphic holes in the Tanami Sheet area (BMR Tanami Nos 1, 2, 15, 16, 40, 50, and 71) and, as they are less resistant to erosion than thicker bedded arenite and conglomerate, they probably underlie many of the sand-covered areas between the sandstone outcrops. Some of the shale is gypsiferous, as in BMR Tanami No. 50. The shale, siltstone, and fine arenite are generally maroon, but locally white, grey, green, and mottled. In places they form sequences at least 80 m thick, as in BMR Tanami No. 16. They occur mainly near the base of the formation, as at Larranganni Bluff, where Casey & Wells (1964) reported a thickness of 35 m overlying basal conglomerate, and in the southern part of the Browns Range, where about 45 m of shale overlies basal conglomerate and quartz arenite, but are also present higher in the formation, as in the Ware Range area and near Coomarie Spring. Thin arenite interbeds in BMR Tanami No. 50 near Coomarie Spring contain abundant grains of feldspar, mainly microline, which was probably derived from the granite of the Coomarie dome.

Glauconitic sandstone is exposed in the Coomarie Range, the southern part of the Browns Range, in the Gardner Range north of Mallee Hill, at several localities between the Gardner and Supplejack Ranges, and in the northern part of the Ware Range. It generally occurs a few hundred metres below the top of the Gardiner Sandstone. The glauconite forms globular grains in ironstained thin-bedded medium to fine sublithic arenite, but is also present in quartz arenite. At Coomarie Spring the glauconitic sandstone is separated from overlying Talbot Well Formation by about 80 m of shale, siltstone, and minor arenite. In the southern part of the Browns Range it is about 7 m thick and is overlain by at least 300 m of sublithic arenite.

Stratigraphic relationships

The Gardiner Sandstone rests with marked angular unconformity on older rocks and is overlain conformably by chert of the Talbot Well Formation.

The unconformity with the Archaean? Tanami complex is well exposed at Larranganni Bluff, at the southern end of the Gardner Range, where gently dipping Gardiner Sandstone rests on steeply dipping cleaved metamorphics of the Killi Killi

Beds. The unconformity on Killi Killi Beds is also exposed on the northern edge of the Gardner Range and in the Killi Killi Hills.

In the Tanami Range and in the Black Hills, the formation rests unconformably on the Mount Charles Beds, but the contact is not exposed.

The unconformity with Nanny Goat Creek Beds is exposed on the east side of Ware Range southeast of Frog Valley, where gently dipping Gardiner Sandstone lies west and north of cleaved basalt. The unconformity with the Nongra Beds can be seen northwest of the Ware Range (at 18°44'S, 129°52'E), and east of the Birrindudu Range (at 18°43'S, 129°41'E), where the Gardiner Sandstone dips at 5° north and 37° northwest respectively adjacent to vertically cleaved metasediments.

On the southern side of the Browns Range dome the base of the Gardiner Sandstone is well exposed; it rests unconformably on undivided Tanami complex.

A major fault separates the Gardiner Sandstone from the Winnecke Granophyre and Mount Winnecke Formation east of the Ware Range.

In the Pargee Range and the range to the west, the Gardiner Sandstone is seen to be unconformable on the Pargee Sandstone. On the north side of the Browns Range dome and the east and north sides of the Coomarie dome it rests on unnamed granite.

The conformable contact between the Gardiner Sandstone and the overlying Talbot Well Formation is exposed along the northern edge of the Coomarie Range, in the Supplejack Range and to the northwest, north of the Pargee Range, and on the west side of the Birrindudu Range. A similar relationship is inferred southwest of the Ware Range.

In the Supplejack Range, near Coomarie Spring, and at the northern ends of the Birrindudu and Ware Ranges, the Gardiner Sandstone is overlain unconformably by flat-lying Antrim Plateau Volcanics. This unconformity was intersected in stratigraphic holes north of Talbot Well. At Larranganni Bluff the Gardiner Sandstone is overlain unconformably by the Cretaceous? Larranganni Beds.

Near Lake Buck silicified arenite mapped as Gardiner Sandstone? probably rests on unnamed granite and is overlapped unconformably by flat-lying chert and minor arenite mapped as Cambrian.

Age and correlations

Seven samples of glauconitic sandstone from the Gardiner Sandstone have been dated by the K-Ar method (AMDL Rep. 3437/73). One of the samples was collected at Coomarie Spring in the Tanami Sheet area, and the others from the adjoining Billiluna, Lucas, and The Granites Sheet areas. The age determinations indicate that the Gardiner Sandstone has an age of between 1400 and 1600 m.y. The formation is younger than the Winnecke Granophyre and Mount Winnecke Formation, and hence is early Carpentarian.

The Gardiner Sandstone may be correlated with the Speewah Group of the Kimberley region, which rests unconformably on the Lower Proterozoic Whitewater Volcanics (Dow & Gemuts, 1969). It may also be correlated with the Mount Parker Sandstone, which is unconformable on the Archaean? Halls Creek Group in the East Kimberley region (Dow & Gemuts, 1969), and with the Limbunya Group of the Victoria River region (Sweet et al., 1971).

Talbot Well Formation
(new name)

The Talbot Well Formation crops out along the western edge of the Birrindudu Range, and more extensively in the Tanami Sheet area, where exposures occur on the sides of strike ridges of Gardiner Sandstone, such as along the northern part of the Coomarie Range and along the Supplejack Range, and in the centres of structural basins, such as northwest of the Supplejack Range. The name is derived from Talbot Well (19°33′50″S, 129°55′20″E) in the Tanami Sheet area.

The formation is mostly gently dipping to flat-lying, and forms low rubbly outcrops consisting mainly of chert (Fig. 30). Some of the outcrops are capped by laterite, and small patches of silcrete are present locally.

On aerial photographs the outcrops generally have a smooth pale tone, with dark patches indicating the presence of laterite.

The maximum thickness of the formation is estimated at about 300 m. The type section is on the west side of the Supplejack Range (19°16′45″S, 129°54′00″E), west-northwest of Supplejack Downs homestead.

Lithology

The formation consists of chert, cherty arenite, siltstone, mudstone, limestone, quartz arenite, and sublithic arenite.

Most of the chert is white to grey, but some is 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 is poorly bedded. In places, as northwest of the Supplejack Range, the chert is associated with flaggy siltstone.

The cherty arenite is medium-grained and consists of loosely packed quartz grains set in an abundant chert cement. Locally, as at the western end of the Coomarie Range, it contains spherical grains of quartz representing silicified ooliths. Some of the ooliths have white turbid cores and clear rims; in others the order is reversed.

At the type section the sequence is about 200 m thick and consists of about 10 m of thinly interbedded shales, siltstone, and flaggy mainly sublithic arenite, dipping northwest at 10°, overlain by about 200 m of stromatolitic chert. These beds rest conformably on quartz arenite of the Gardiner Sandstone. Some of the basal arenite has a chert cement and appears to be oolitic. The overlying stromatolitic chert is commonly brecciated, and forms bouldery outcrops; undulating bedding is exposed locally.

Two stratigraphic holes intersected the formation between Coomarie Spring and Talbot Well. BMR Tanami No. 30 penetrated chert and No. 31 penetrated medium-grained sugary quartz arenite and interbeds of limestone about 2 cm thick.

Outcrops mapped as possible Talbot Well Formation southwest of the Ware Range consist of sublithic arenite, thin-bedded maroon shale, siltstone, and fine arenite, buff mudstone, and mottled and streaky chert. The sublithic arenite commonly contains small cavities and locally has a chert cement; one specimen contains grains of quartz, alkali feldspar, shale, siltstone, quartzite, and detrital muscovite, biotite, tourmaline, and zircon.

Chert cropping out in the Talbot Hills was first mapped as Talbot Well Formation (Blake et al., 1972), but is now known to belong to the Antrim Plateau Volcanics.

Stratigraphic relationships

The Talbot Well Formation lies conformably between the Gardiner Sandstone below and the Coomarie Sandstone above, and is part of the Carpentarian Birrindudu Group. It is unconformably overlain by the Antrim Plateau Volcanics west of Supplejack Downs homestead. Conformity with Coomarie Sandstone is inferred from the concordance of bedding trends.

Coomarie Sandstone
(new name)

The Coomarie Sandstone consists mainly of sublithic arenite. It crops out north of the Coomarie Range, after which the formation is named, and also between the Pargee and Browns Ranges, and west of the Birrindudu Range. The thickest known section is about 2500 m in the syncline south of the Browns Range; this estimate is based on dip measurements and photo-interpretation. The type section is across the western limb of the syncline between longitudes 129°12′10″E and 129°13′10″E.

On aerial photographs the Coomarie Sandstone has a medium tone, and bedding trends are generally prominent.

Lithology

The formation consists of sublithic arenite, and minor quartz arenite, siltstone, and shale. The sublithic arenite is flaggy, and some shows ripple marks, cross-bedding, and mud cracks. The flaggy beds commonly have micaceous partings. Small shale pellets and red lithic grains are locally abundant. The quartz arenite is medium-grained, cross-bedded, and locally ironstained. Siltstone and shale occur interbedded with sublithic arenite.

In the type section about 170 m of medium-grained sublithic arenite, containing red lithic grains and some shale pellets, dips east at 10°, and is separated by a sand plain 700 m wide from an overlying more steeply dipping sequence, about 500 m thick, of ripple-marked and cross-bedded fine to medium arenite and minor interbedded shale.

Stratigraphic relationships

The Coomarie Sandstone is inferred to be conformable on the Talbot Well Formation, and is the youngest unit of the Birrindudu Group. The formation is unconformably overlain by the Antrim Plateau Volcanics west of the Birrindudu Range and north of the Coomarie dome.

UNDIVIDED LIMBUNYA GROUP

The 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. They consist mainly of sublithic arenite and quartz arenite, which have been folded into northwesterly trending synclines and anticlines. The dip ranges up to 35°. They also crop out to the west, in the northwest corner of the Birrindudu Sheet area.

The undivided Limbunya Group forms strike ridges less than 20 m high, low mounds, and some gently undulating terrain. On aerial photographs the outcrops are pale to medium-toned. The maximum thickness exposed is about 400 m.

Lithology

The sequence consists of sublithic arenite and quartz arenite with chert (at 18°02′S, 129°04′E) and chert-bearing conglomerate (at 18°02′S, 129°07′E) in the northwest.

The sublithic arenite and quartz arenite are mainly pale to dark grey, maroon or purple, and medium to fine-grained. Cross-bedding is common, and some of the arenite shows ripple marks and some contains small shale pellets. In places the bedding has been strongly disturbed, apparently by slumping. Most of the beds are over 1 m thick. The arenites have a quartz-overgrowth cement and little or no matrix. In the southwest, close to the Western Australia border, some of the quartz arenites contain scattered large well rounded grains of quartz.

The chert exposed in the northwest is stromatolitic, massive, and maroon to grey, and was formed by silicification of dolomite or limestone. The conglomerate nearby is bedded, and dips northeast at 15°; it 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 and both 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 arenite at two localities (18°02′S, 129°23′E and 18°13′S, 129°07′E). The main arenite outcrops are partly surrounded by laterite and grey clay that are probably developed on the basalt.

The Limbunya Group can probably be correlated with the Gardiner Sandstone of the Birrindudu Group, and hence is probably early Carpentarian. However, since the outcrops are isolated from those of the Gardiner Sandstone to the south, the relationship between the Limbunya and Birrindudu Groups is not certain.

CAMBRIAN

(Traves, 1955)

Antrim Plateau Volcanics

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 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 amended 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). The basalt is generally much weathered and most of the outcrops are capped by laterite.

The main landforms developed on the volcanics are low broad rises, many of which are partly bounded by breakaways. The volcanics also form mesas and buttes and undulating terrain, and underlie extensive plains covered by grey clay in the Birrindudu Sheet area. Many of the mesas and buttes are benched, such as those northeast of Hooker Creek, in the northeast corner of the area, where a plateau formed of flat-lying lava flows has been deeply dissected. In the undulating terrain, such as that near Supplejack Downs homestead, the weathered basalt and cappings of laterite have been stripped off by erosion to reveal fresh basalt below. In this terrain subangular to rounded fragments of basalt are generally found lying on the surface.

On aerial photographs the volcanics generally have a dark tone owing to laterite cappings. Where the cappings are absent, the outcrops have a pale to medium tone.

The maximum thickness of the volcanics exposed in the area mapped is about 30 m, northeast of Hooker Creek. To the north of the Birrindudu Sheet area the Antrim Plateau Volcanics are over 300 m thick (Sweet et al., 1971).

Lithology

The predominant rock type is tholeiitic basalt, which forms flat-lying lava flows. In places, such as northeast of Hooker Creek, the flows are up to 15 m thick. The upper and lower parts of the flows are vesicular and the centres are massive; the tops are locally scoriaceous and blistery. Pillow-like structures, indicating extrusion under water, are present in the basalt southeast of the Browns Range (Fig. 32) and at the northern end of the Ware Range. Most of the flows, however, are subaerial. No associated intrusives have been found.

The basalt is generally intensely weathered to a depth of 8 m or more and is capped by pisolitic laterite about 2 m thick. In places the weathering persists to much greater depths, and north of Talbot Well some of the stratigraphic holes passed through over 20 m of weathered basalt. Scaly nodular surfaces ('popcorn' weathering) are characteristic of many weathered exposures.

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, as for example north of Supplejack Downs homestead, where white basalt up to 2 m thick overlies about 5 m of maroon, mauve, and white mottled basalt, resting on fresh dark greyish basalt. The basaltic texture has generally been preserved in the weathered basalt, even where all the original constituents have been replaced. The altered basalts consist mainly of quartz, opaline silica, kaolin, hematite, goethite, and limonite; small grains of anatase have been recognized in some specimens (G. H. Berryman, X-ray diffraction identification).

Where scoriaceous, the basalt is generally black, even when weathered. Most of the vesicles in the basalt have been infilled with quartz, celadonite, or white clay minerals. Large geodes, some over 50 cm across, occur in the basalt near Supplejack Downs homestead; some are lined with agate, and some contain well shaped crystals of glassy, smoky, and mauve quartz. Euhedral zeolite crystals pseudomorphed by goethite and quartz are present 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.

Where unweathered the basalt is dark grey, and consists of labradorite laths, augite, opaque minerals, and minor sericite and clay minerals.

In places stromatolitic chert (Fig. 32) and sandstone are interbedded with the basalt. Good exposures of chert were seen in hills 9 km and 28 km south-southeast of Supplejack Downs homestead, 15 km north of the homestead, and 25 km north of Birrindudu homestead. Two main types of sandstone crop out: the first type is thin-bedded to laminated, fine to coarse, and probably tuffaceous; the second type, which is exposed at the base of the volcanics 15 m north of Supplejack Downs homestead and near Coomarie Spring, is a very poorly sorted lithic arenite or greywacke which at the first locality is associated with chert and also with pink and maroon arenite that may belong to part of the underlying Supplejack Downs Sandstone.

Stratigraphic relationships and age

The Antrim Plateau Volcanics rest with angular unconformity on the Tanami complex, the Winnecke Granophyre, and the Birrindudu Group, and are overlain unconformably by the Larranganni Beds (Fig. 33). The volcanics are not seen in contact with the Cambrian sedimentary rocks of the Wiso Basin to the east, but north of the Birrindudu Sheet area they are overlain, probably disconformably, by the Headleys Limestone (Sweet et al., 1971) and with slight angular unconformity by the Montejinni Limestone (Randal & Brown, 1967), both of which 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 with the Proterozoic rocks is well exposed at the northern end of the Ware Range; on the Supplejack Range 9 km north-northwest of Supplejack Downs homestead, where the basalts overlie the Gardiner Sandstone; east of Talbot Well and in the Talbot Hills, where basalt and chert overlie Gardiner Sandstone; south of Coomarie Spring, where basalt and basal sandstone overlie shale of the Gardiner Sandstone; 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.

North of Supplejack Downs homestead an irregular erosional surface on the basalt is partly overlain by flat-lying sandstone, siltstone, and conglomerate of the Larranganni Beds.

Unnamed Cambrian

Scattered low outcrops of generally poorly exposed flat-lying sedimentary rocks near the eastern edge of the area have been mapped as unnamed Cambrian. The main outcrops are in the southeast, near Lake Buck. The rocks form 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 east of the Black Hills. A thickness of over 65 m was intersected in BMR Tanami No. 65.

Laterite cappings are common, and show up as smooth dark grey tones on the aerial photographs, but otherwise the outcrops are white to pale grey.

Lithology

The rocks exposed are sandstone, mudstone, chert, dolomite, and limestone.

Sandstone crops out 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 BMR Tanami No. 62 east of the Black Hills. The most common type of sandstone is a porous black to dark brown medium to coarse ironstained quartz arenite. White to pale buff fine to medium quartz arenite or sublithic arenite is exposed in breakaways 15 to 20 km south of the Winnecke Range. It has pitted weathered surfaces indicating that it may be partly calcareous.

The sandstone in BMR Tanami No. 62 is reddish brown and overlies a breccia (at 33 m), also possibly Cambrian, which consists of angular fragments of brown mudstone set in an abundant pale greyish matrix of the clay mineral palygorskite (X-ray diffraction determination by G. H. Berryman).

The mudstone exposed southeast and northeast of Lake Buck and intersected in BMR Tanami Nos 61 to 63 and 66 is mainly purple or maroon.

Chert is present in the southeast corner of the Birrindudu Sheet area and more extensively near Lake Buck (Fig. 34), where it is associated with limestone and dolomite. It overlies disaggregated granite in BMR Tanami No. 51 at 14.5 to 16 m. The chert is generally thinly banded, greyish, and may be silicified calcareous mudstone or siltstone. On the northeast side of Lake Buck some of the chert shows well developed asymmetrical ripple marks.

Limestone mapped as unnamed Cambrian near Lake Buck forms low rises slightly higher than calcrete mapped as Tertiary. Dolomite was intersected in BMR Tanami Nos 65 and 67, but was not found at the surface. Both the limestone and dolomite are white to pale grey. The limestone is locally capped by Tertiary calcrete, some of which is silicified. In places it is impossible to distinguish between the Cambrian limestone and Tertiary calcrete either in the field or by photo-interpretation. In the Wiso Basin to the east, Milligan et al. (1966) described some of the Cambrian limestone as 'travertinized', and cross-bedded calcrete on the south side of Lake Buck, mapped as Tertiary, may in fact be 'travertinized' Cambrian calcarenite.

Stratigraphic relationships, correlations, and age

Near Lake Buck the unnamed Cambrian rocks lie on unnamed granite and overlap unconformably onto Gardiner Sandstone?. They are presumed to have similar relationships to the Winnecke Granophyre and the Mount Winnecke Formation in the Birrindudu Sheet area. At the contact exposed near Lake Buck, flat-lying banded chert and thin arenite beds rest directly on weathered granite. The contact was intersected in three stratigraphic holes; in BMR Tanami Nos 61 and 63, mudstone overlies granite and in No. 64 limestone overlies weathered gabbroic rock.

The rocks mapped as unnamed Cambrian were deposited on the western margin of the Palaeozoic Wiso Basin. They were provisionally identified by Simpson (1971) as Cambrian Merrina Beds, because similar outcrops in the Winnecke Creek area were mapped as Merrina Beds by Milligan et al. (1966). Outcrops mapped as undivided Lower Palaeozoic in the southwest corner of the East Tanami Sheet area by the same workers have since been found to be at least partly Cambrian. However, no Cambrian fossils have been found in the Birrindudu-Tanami area, and correlations with the known Cambrian rock units in the Wiso Basin to the east are uncertain.

CRETACEOUS

Larranganni Beds
(new name)

The Larranganni Beds consist mainly of flat-lying white to grey silicified sandstone capping small scattered mesas and buttes up to 10 m high in the Tanami Sheet area. The main exposures are north of Supplejack Downs homestead and on the south side of Larranganni Bluff, after which the beds are named. The beds are up to 8 m thick in the reference area, 0.5 km south of Larranganni Bluff.

Lithology

The beds consist of flat-lying sandstone with minor siltstone and conglomerate. The sandstone commonly forms beds about 1 m thick, but in places the thickness is variable and lensing is common. The siltstone is generally thin-bedded. The sandstone is white to pale grey, fine to coarse, and is commonly silicified, resembling silcrete. Sorting is variable, and the grains, which consist mainly of quartz, tend to be poorly rounded. Weathered surfaces are commonly porous and pitted, probably through solution weathering, and indicate that the sandstone may have been partly calcareous. Near Larranganni Bluff, in the reference area, steeply dipping Killi Killi Beds are unconformably overlain by 8 m of well to poorly bedded flat-lying sandstone, capped by silcrete (Fig. 35), which passes laterally into crudely bedded very poorly sorted conglomeratic sandstone.

Conglomerate crops out 7 km east-northeast of Supplejack Downs homestead. It contains subangular 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 set in an abundant sandstone matrix.

Stratigraphic relationships, origin, and age

The Larranganni Beds lie unconformably on irregular surfaces of Killi Killi Beds and Gardiner Sandstone near Larranganni Bluff, on Gardiner Sandstone in the Supplejack Range, and on basalt of the Antrim Plateau Volcanics north of Supplejack Downs homestead (Fig. 33). They are commonly capped by Tertiary laterite and silcrete; pisolitic laterite cappings up to 1 m thick are predominant in the Supplejack area, and silcrete cappings predominate in the western outcrops.

The beds are probably partly fluvial and partly lacustrine. In the Supplejack Downs area cross-bedding is common, and at one locality, 7 km east-northeast of the homestead, conglomerate and sandstone show high-angle cross-bedding of possible torrential type. Cross-bedding was not observed in the well bedded sandstone at Larranganni Bluff, which may be lacustrine.

After the Larranganni Beds were laid down the area was subjected to a long period of erosion, and the outcrops are not related 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 the Cretaceous Hazlett Beds in the Stansmore Sheet area to the southwest (Veevers & Wells, 1961).

TERTIARY

Laterite

Laterite is common throughout the area as cappings on rocks ranging in age from Archaean? to Cainozoic. The cappings have smooth to very gently undulating tops, and are dark-toned on aerial photographs. Most of the cappings have gently sloping sides, commonly with shallow gullies, but many are partly bounded by breakaways.

The laterite is best developed on rocks such as basalt, phyllite, shale, mudstone, siltstone, and greywacke, but is also developed on some of the sandstones, acid volcanics, and granites. On the highly siliceous rocks, such as quartz arenite and most sublithic arenite, there is generally little or no laterite, although laterite cappings occur on many chert outcrops. The cappings on chert may have been formed on less siliceous rocks, such as shale or basalt, which previously overlay the chert. Laterite is associated with silcrete at outcrops north of Supplejack Downs homestead, but the age of the laterite relative to the silcrete is unknown.

Complete lateritic profiles are present in many places, especially on basalt of the Antrim Plateau Volcanics, where they are locally over 20 m thick. On granite, the profile is commonly less than 5 m thick. The profiles are well exposed in breakaways, where they generally consist of a cemented pisolitic upper layer about 1 m thick, a central mottled zone 3 m or more thick, and a lower pallid zone. The pisolitic layer is deep reddish purple to black and consists mainly of limonite and goethite or hematite, or both. The underlying zone is generally mottled reddish, maroon, purple, and white. Variations are common: a mottled zone commonly underlies the pallid zone in lateritized basalt, and only the pisolitic layer is generally present on sandstone. Another variation was observed 1 km southeast of Coomarie Spring, where an upper layer of pisolitic laterite 1 m thick overlies 3 m of layered pisolitic laterite developed on mottled and bleached shale of the Gardiner Sandstone. Small lenses of ironstained silcrete occur between the two layers of pisolitic laterite, and vertical pipes have been eroded in the layered laterite (Fig. 36).

In addition to the cappings on elevated areas, pisolitic laterite is also locally present along some creeks, as on the north side of Wilson Creek near the Tanami/Hooker Creek track. In these occurrences, 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 gently undulating erosion surface. The youngest rocks on which they are formed are the Larranganni Beds, mapped as possibly Cretaceous, and perhaps Tertiary silcrete. As there has been much more erosion since the formation of the laterite than is likely to have occurred during the Quaternary, the laterite cappings are regarded as Tertiary, and are correlated with the Tennant Creek erosion surface of Hays (1967). The pisolitic laterite on Quaternary alluvium is a Quaternary sediment derived from older laterite.

Silcrete

Patches of silcrete are present in many parts of the area, but only rarely are they large enough to be shown on the geological maps. Most of the silcrete occurs on hills and ridges, and is less than 3 m thick. It is formed on Proterozoic sandstone, Larranganni Beds, Winnecke Granophyre, and quartz veins, and at some localities it is associated with pisolitic laterite. Exposures (Fig. 37) commonly consist of a veneer of cobbles and boulders of silcrete on smoothly rounded weathered rock surfaces. Columnar structures are present in places (cf. Senior & Senior, 1972).

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

Where the silcrete is associated with pisolitic laterite it is generally developed on slopes below the laterite cappings, and in such situations may be the younger; but, in places it is also present under the pisolitic laterite, where it may be older than the laterite.

Calcrete

Calcrete is widespread in the Tanami Sheet area but rare in the Birrindudu Sheet area. On aerial photographs the calcrete typically has a light tone and a cerebriform texture. It crops out as low rises in broad shallow depressions, and forms undulating terrain with low mounds and solution hollows. The most extensive exposures are in the southeast corner of the Tanami Sheet area near Lake Buck, where much of the calcrete is silicified and is difficult to distinguish from Cambrian chert. Some cross-bedded calcrete was noted on the southern edge of Lake Buck.

The calcrete is considered to be pre-Quaternary and is probably a subsurface deposit formed in Tertiary drainage depressions.

QUATERNARY

Most of the area mapped is covered by superficial deposits, which are grouped into four units:

Residual Grey Clay

The extensive flat and generally treeless plains in the Birrindudu Sheet area are covered by grey residual soils that are probably several metres deep. They consist of heavy clay that cracks widely and deeply when it dries out after each wet season (Stewart, 1970). The clay is developed on basalt of the Antrim Plateau Volcanics.

Aeolian Sand and Piedmont Sediments

Aeolian sand covers most of the plains separating outcrops of Cambrian and Proterozoic rocks. In the eastern part of the Tanami Sheet area, it forms groups of low longitudinal dunes, which appear to be stable at present. Piedmont sand and gravel are restricted to gentle slopes flanking residual hills and ridges.

Alluvial and Aeolian Sand and Silt occupying Drainage Depressions

Barely perceptible drainage depressions with no well defined drainage channels occur throughout the area. Sand and silt are deposited in the depressions by sheet wash during rainy periods and are mixed with wind-blown sand and silt deposited during dust storms.

Fluvial and Lacustrine Sediments

Fluvial sand, silt, and clay are present on flood plains of major drainage channels, and lacustrine deposits, mainly clay, are present in claypans and in Nongra Lake and Lake Buck. The lacustrine clay is commonly gypsiferous. Evaporite minerals, mainly halite and gypsum, form thin deposits in salt lakes in the southeastern part of the Tanami Sheet area and also around the margins of claypans and lakes. The fluvial deposits include the floodout sediments of Sturt Creek, near Birrindudu homestead. These were penetrated in a bore, where they consisted of 21 m of green and white clay, resting on weathered basalt, and overlain by 3 m of lateritic sand (Shields, 1965).

STRUCTURE

Most of the area forms parts of two major tectonic units — The Granites-Tanami Block and the Birrindudu Basin. Two other tectonic units are also represented — the Victoria River Basin in the north and the Wiso Basin in the extreme east. The area underwent at least three major periods of tectonic activity before the close of the Proterozoic, but it has been stable during the Phanerozoic, and the folded Proterozoic rocks are overlain by flat-lying Lower Cambrian rocks.

The tectonic units and the main structural features are shown in Figure 38.

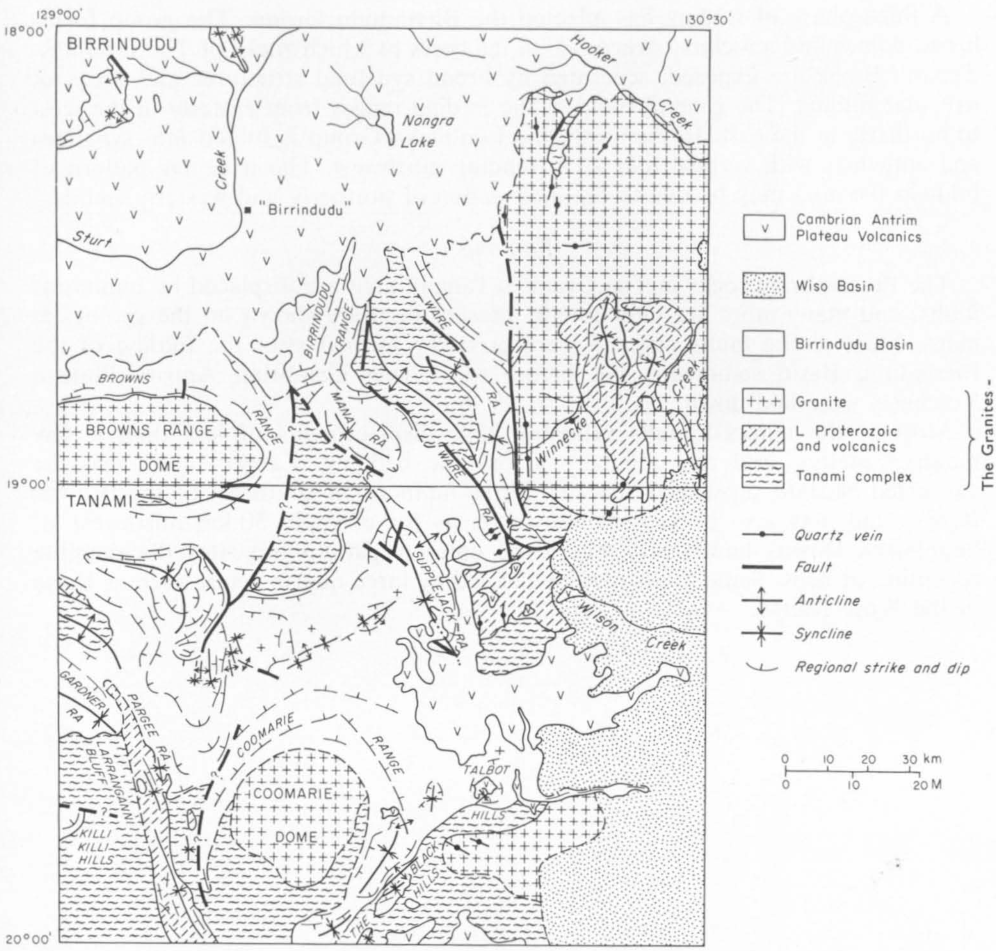

Fig. 38 Structure.

Folding

The Archaean rocks of the Tanami complex have been tightly folded, possibly isoclinally. They generally have a steep to vertical cleavage trending between northwest and northeast, probably parallel to the axial planes of the folds. Tight minor folds can be seen at several localities, as for example between Tanami and the Tanami Range, and 100 m east of the Wilson Creek waterholes. A major fold has been mapped in the Tanami complex south of the Pargee Range, and another may be present 20 km east-northeast of Tanami, where two gossan ridges converge. Other large folds may be present, but are difficult to identify because of a lack of marker beds within the Tanami complex and the widely scattered exposures. The variable cleavage trends are probably due to later folding, and the larger folds mapped in the Tanami complex may be younger and unrelated to the cleavage. The tight folding associated with the cleavage took place before the deposition of the Lower Proterozoic Pargee Sandstone, Supplejack Downs Sandstone, and Mount Winnecke Formation. These formations were folded into major synclines and anticlines during a later period of tectonism before the Carpentarian sediments of the Birrindudu Group were laid down.

A third phase of folding has affected the Birrindudu Group. The group forms broad domes and anticlinal structures, in the cores of which rocks of The Granites-Tanami Block are exposed, separated by broad synclinal structures and areas of irregular folding. The general trend of the folding ranges from easterly in the west to northerly in the east. In the north, the Limbunya Group is folded into synclines and anticlines with vertical fold axes trending northwest. The irregular pattern of folds in the area may be due to the intersection of northerly and westerly trends.

Faulting

The Precambrian rocks in The Granites-Tanami area are displaced by numerous faults, and many more are undoubtedly present than are shown on the geological maps. Most of the faults mapped were probably formed after the folding of the Birrindudu Basin sediments, but before the Lower Cambrian Antrim Plateau Volcanics were laid down.

Most of the mapped faults probably have displacements of less than a few hundred metres, and cut obliquely across the bedding. Larger faults may be concealed beneath superficial deposits. Strike faults occur southeast of the Browns Range, and may also be present elsewhere, as for example 30 km northwest of Supplejack Downs homestead, where the outcrop pattern indicates the possible repetition of beds. Some faults may be defined by large quartz veins, such as those in the Ware Range.

GEOPHYSICAL SURVEYS

The Bureau of Mineral Resources made airborne magnetic and radiometric surveys of the Tanami Sheet area in 1962 (Spence, 1964) and an airborne magnetic survey of the Birrindudu Sheet area in 1967. 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.). A brief account is given here of some of the results of these surveys.

The area has a complex magnetic anomaly pattern (Spence, 1964), and individual anomalies are estimated to originate at depths ranging from near surface to over 2000 m. The magnetic highs tend to coincide with areas of rocks of the Tanami complex or areas that are probably underlain by the Tanami complex at shallow depth. Granite is mainly indicated by magnetic lows. The Carpentarian Birrindudu Group generally has smooth featureless magnetic profiles. The magnetic anomalies on the Antrim Plateau Volcanics in the Birrindudu Sheet area change markedly over short distances, but are not intense (Taylor, R. J. pers. comm.).

Radioactivity is generally low and fairly uniform throughout the whole area. Zones of relatively high intensity are associated with granites. Most of the anomalies found in 1961 (Mulder, 1961) are related to surface laterite.

The regional gravity survey (Whitworth, 1970) revealed a series of intense short-wave-length Bouguer anomalies with a predominant north-northeasterly trend. The northern part of the area forms part of the Billiluna Gravity Plateau and the southern part belongs to the Coomarie Regional Gravity Complex. The suggestion by Flavelle (in prep.) that the gravity highs may correspond to metamorphic rocks and the gravity lows to granite is supported by the present geological survey.

ECONOMIC GEOLOGY

The gold deposits near Tanami are the only ore deposits that have been worked in the area. Copper minerals have been found at a few localities, and uranium is present in the Killi Killi Hills.

Gold

Gold was discovered at Tanami in 1900 by Davidson, and was exploited intermittently between 1904 and 1951. The deposits have been described by Davidson (1905), Brown (1909), Gee (1911), and Hossfeld (1940). Lode, eluvial, and alluvial gold were obtained. The total production is unknown, but may have been over 70 kg (Hossfeld, 1940, from an unpublished report by H. A. Ellis). The workings are now inaccessible, and the following account is based largely on Hossfeld's report.

The reef gold occurs along two fracture zones trending northeast and dipping southeast. 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, partly altered to chert, with minor greywacke and intercalated basalt. They belong to the Archaean? Mount Charles Beds. The favourable country rocks, which were described as felsite by earlier workers, may be silicified fine-grained sedimentary rocks or basalt. Alluvial and eluvial gold were found near the lodes.

Gold has also been recorded in the Archaean? Killi Killi Beds near Larranganni Bluff (Davidson, 1905).

Copper

Copper carbonates have been recorded in rocks of the Tanami complex on the north side of the Browns Range in the Tanami Sheet area (Davidson, 1905; Phillips, 1959), and as rare smears in amphibolite in the Mount Charles Beds 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 drill hole put down by Enterprise Exploration Pty Ltd in 1962 in the Black Hills, northeast of Tanami (Phillips, 1962).

Uranium

At the Killi Killi Hills prospects, just inside Western Australia in the Billiluna Sheet area, uranium is concentrated in xenotime in conglomerate at the base of the Gardiner Sandstone, which rests directly on Archaean? Killi Killi Beds (Clark & Blockley, 1960; Prichard et al., 1960; Blake et al., 1973). The origin of the xenotime is uncertain.

During the 1971 geological survey numerous exposures and specimens of conglomerate and other rock types were tested for radioactivity with an Austral Model GMIb geiger counter. With the exception of 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 value: this was the core, consisting mainly of palygorskite, from BMR Tanami No. 62, east of the Black Hills. The general absence of anomalies may be due partly to leaching of the rocks during weathering, and the area should not be considered unprospective for uranium.

Water Supply

Occurrences of surface water have been briefly described in the Introduction. Groundwater is tapped by several bores in both Sheet areas, and those in the Tanami Sheet area are listed in Kingdom et al. (1967). Bores with wind pumps are in use on the 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 the main calcrete outcrops in the area.

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*Available for reference at Geological Survey of Western Australia, Perth.
†Available for reference at Department of Mines, Darwin, and Bureau of Mineral Resources, Canberra.

Fig. 6 Steeply dipping Killi Killi Beds (K) overlain to the north by gently dipping Gardiner Sandstone (G). The escarpment in the background is Larranganni Bluff.

Fig. 7 Steeply dipping Killi Killi Beds (dark toned) overlain unconformably by gently dipping Gardiner Sandstone (pale toned), 2 km north of Jellebra Rockholes, Gardner Range.

Fig. 8 Steeply dipping black and white chert of the Mount Charles Beds, 6 km southeast of Mount Frederick, Pargee Range.

Fig. 9 Ridge of steeply dipping gossanous beds of the Mount Charles Beds, looking north from Mount Charles.

Fig. 10 Aerial view of waterholes (left centre of photograph) on Wilson Creek east of the Tanami/Hooker Creek track. The lineament (l) is the trace of a fault between Nanny Goat Creek Beds (left) and Supplejack Downs Sandstone (right).

Fig. 11 Cleaved acid porphyry of the Nanny Goat Creek Beds on the east side of the Ware Range.

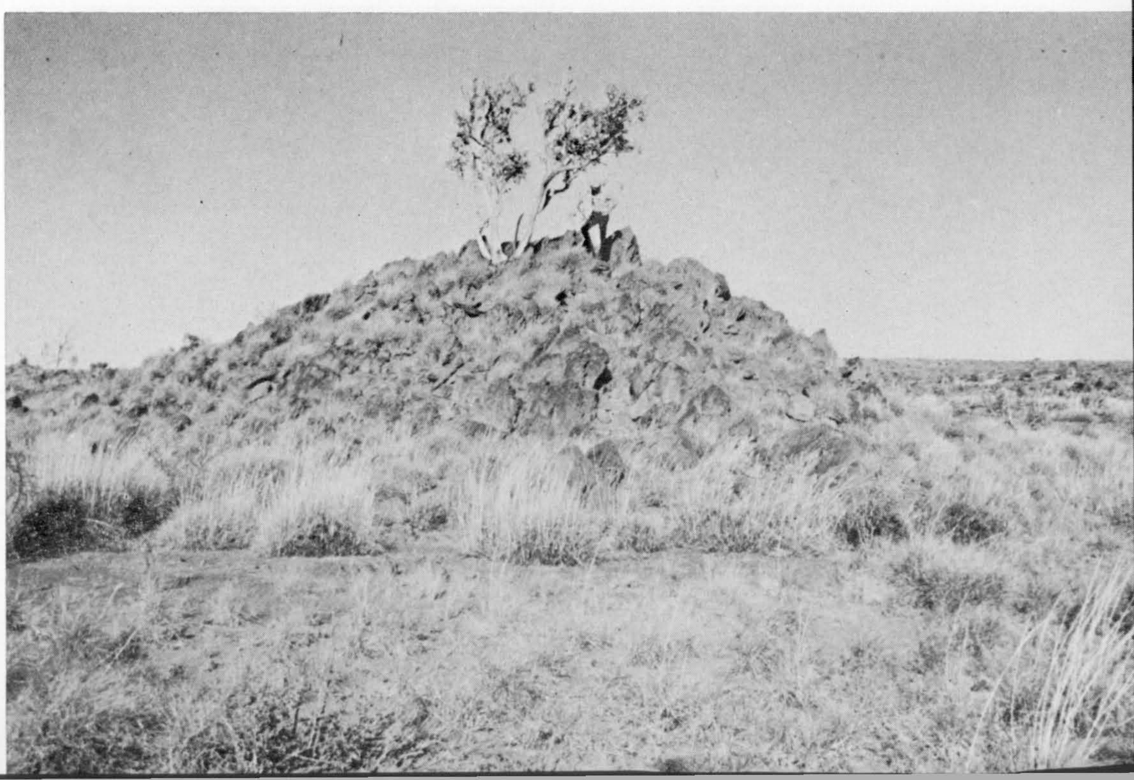


Fig. 12 Deformed conglomerate of undivided Tanami complex on the south side of the Browns Range dome.

Fig. 13 Steeply dipping conglomeratic sublithic arenite within the Pargee Sandstone, west of the Pargee Range.

Fig. 14 Boulders of Pargee Sandstone in conglomerate at the base of the Gardiner Sandstone, north-east of Mount Frederick, Pargee Range.

Fig. 15 Flow-banded acid lava of the Mount Winnecke Formation 22 km north of Mount Winnecke. Phenocrysts of altered feldspar (F) and of partly resorbed quartz (Q) are set in a fine granular groundmass composed mainly of quartz, iron oxide, and clay. Plane polarized light, X90.(71490242B).

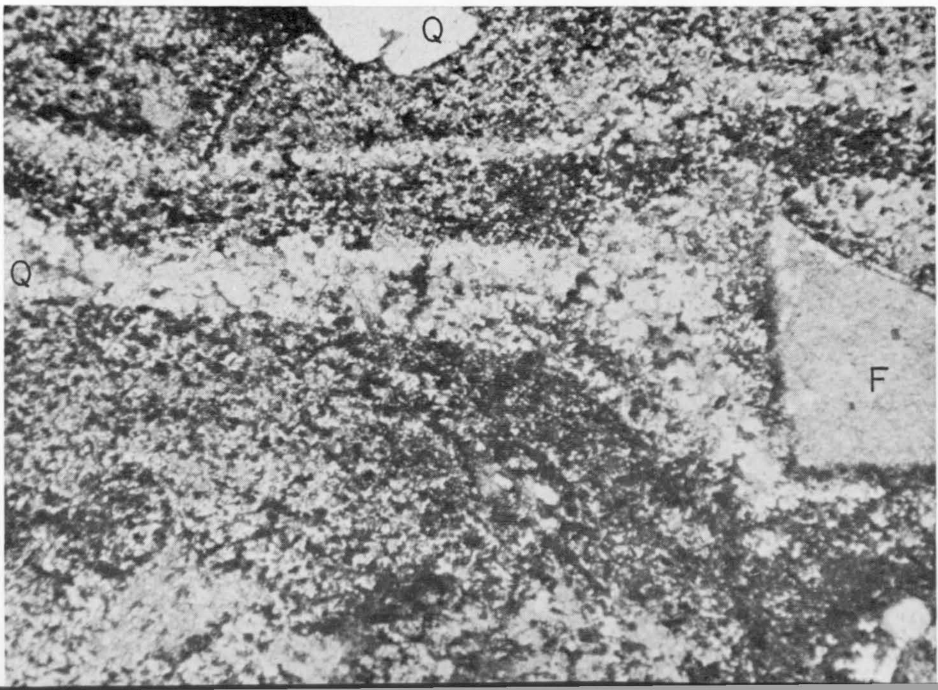


Fig. 16 Acid lava of the Mount Winnecke Formation, 17 km north of Mount Winnecke. The rock is composed of euhedral and partly resorbed phenocrysts of feldspar, pseudomorphed by clay minerals, set in a quartz mosaic formed by recrystallization of a glassy groundmass. Some of the crystallites in the original glass are still visible. Plane polarized light, X 90 (71490116).

Fig. 17 Steeply dipping lapilli tuff of the Mount Winnecke Formation, 6 km south-southeast of Mount Winnecke.

Fig. 18 Lapilli tuff of the Mount Winnecke Formation. Same locality as Figure 16.

Fig. 19 Stellate clusters of tourmaline on a joint plane in sandstone close to the contact between the Mount Winnecke Formation and the Winnecke Granophyre, 22 km west-southwest of Mount Winnecke.

Fig. 20 Inselbergs of Winnecke Granophyre in the northeast part of the Tanami Sheet area.

Fig. 21 Spheroidal boulders of unaltered Winnecke Granophyre east of the Ware Range.

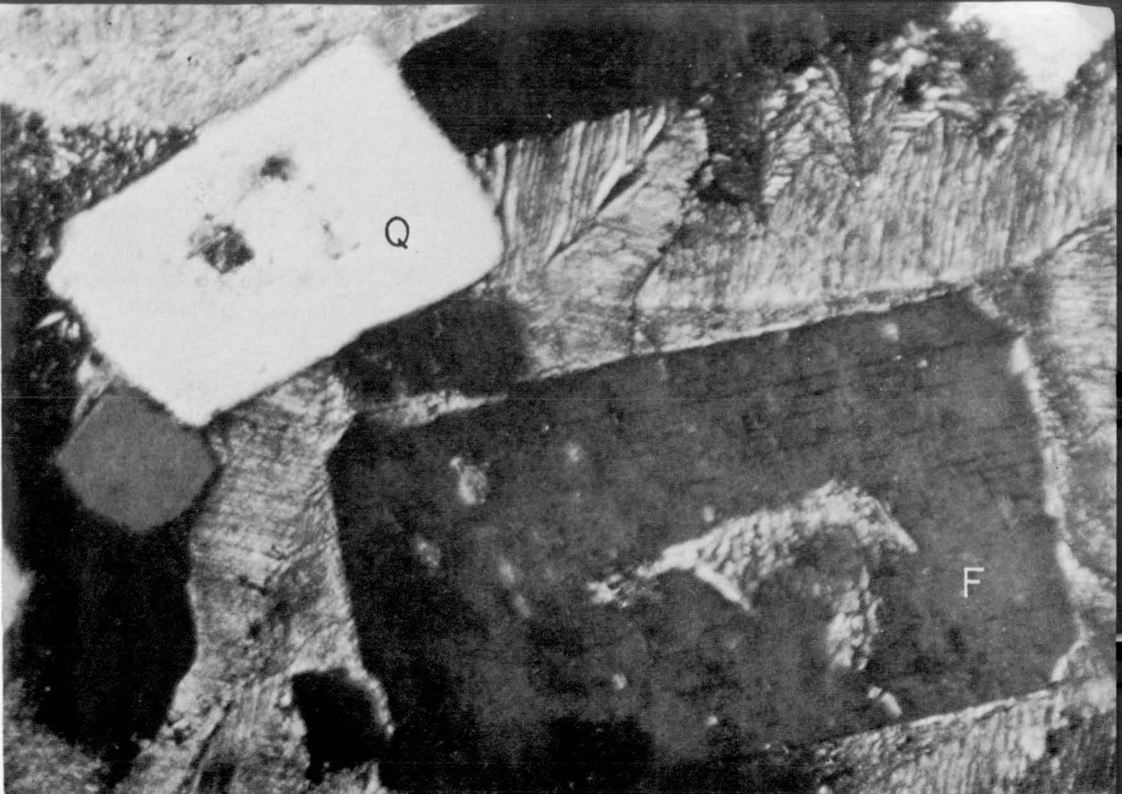
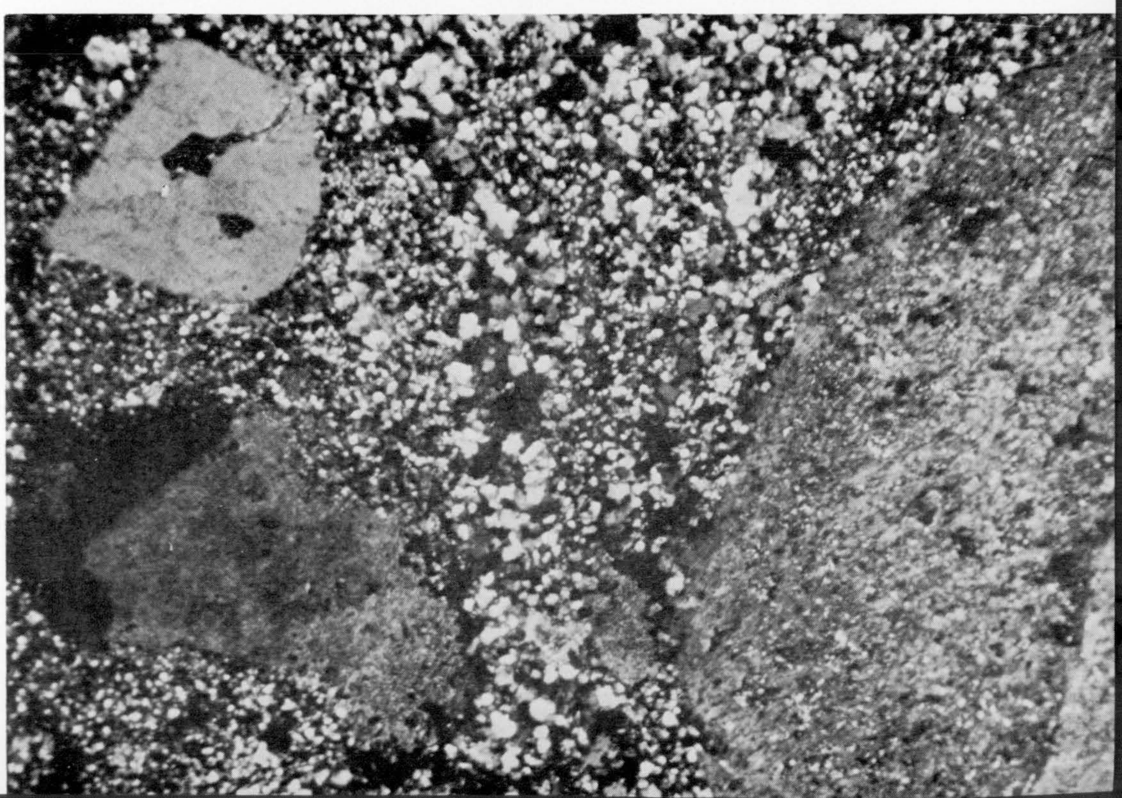


Fig. 22 Porphyritic Winnecke Granophyre, 13 km west-southwest of Mount Winnecke. The rock consists of euhedral phenocrysts of quartz (Q) and partly resorbed alkali feldspar (F) set in a fine granophyric intergrowth of quartz (white) and feldspar (dark). Polarized light, X 250 (71490337).

Fig. 23 Acid porphyry of the Winnecke Granophyre, 15 km west of Mount Winnecke. The rock contains subhedral phenocrysts of quartz and twinned alkali feldspar set in a micrograpitic groundmass. Polarized light, X90. (71490215).



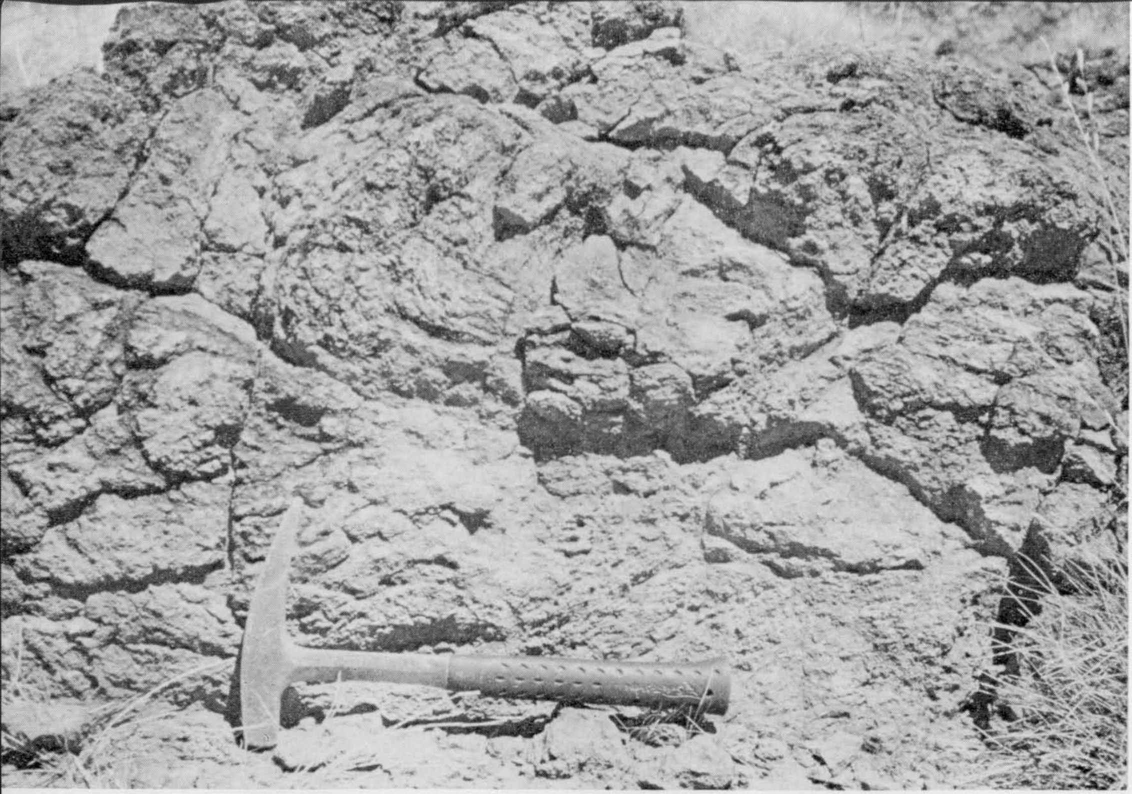


Fig. 24 Weathered unnamed granite near Lake Buck.

Fig. 25 Flaggy cross-bedded coarse sublithic arenite of the Gardiner Sandstone in a scarp on the north side of the Browns Range dome.

Fig. 26 Banded Gardiner Sandstone, Gardner Range north of Mallee Hill.

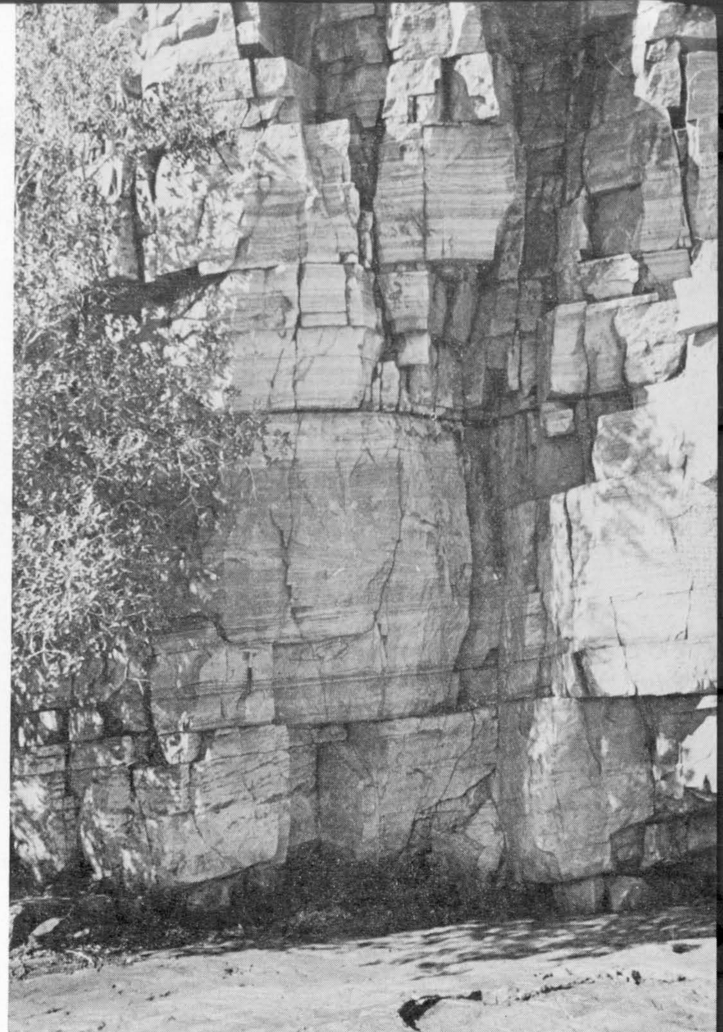


Fig. 27 Ripple-marked bedding plane in the Gardiner Sandstone 26 km west-northwest of Coomarie Spring.

Fig. 28 Well rounded pebbles and cobbles, mainly of sandstone, in conglomerate near the base of the Gardiner Sandstone, 10 km northeast of Tanami.

Fig. 29 Conglomerate interbedded with cross-bedded sublithic arenite within the Gardiner Sandstone, Supplejack Range.

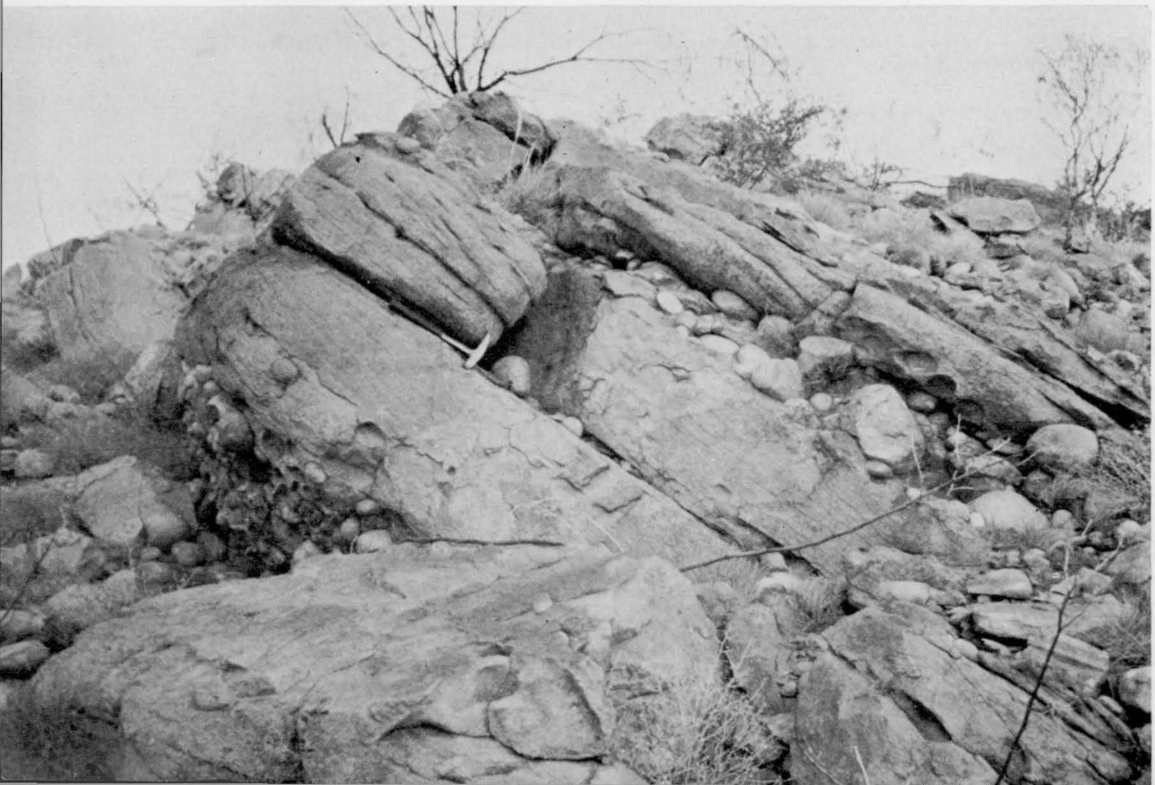


Fig. 30 Rubbly stromatolitic chert (see structure near hammer) of the Talbot Well Formation, on the southwest side of the Supplejack Range.

Fig. 31 Pillow-like structures in basalt of the Antrim Plateau Volcanics southeast of the Browns Range.

Fig. 32 Algal structures in chert within the Antrim Plateau Volcanics 23 km north of Birrindudu homestead.

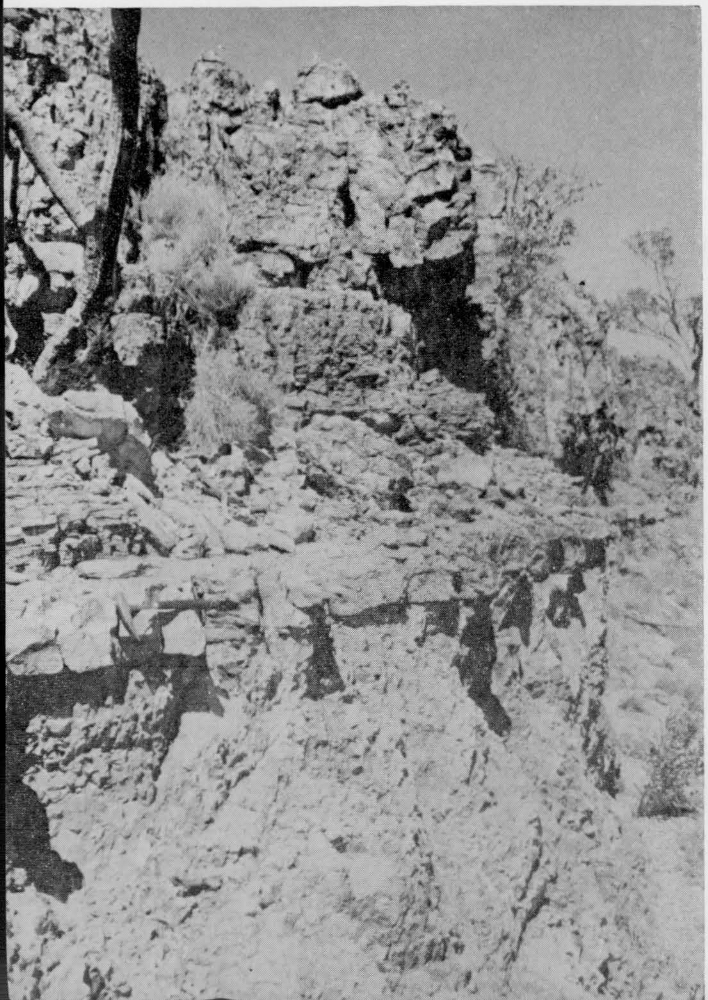


Fig. 33 Altered basalt of the Antrim Plateau Volcanics overlain by flat-lying Larranganni Beds north of Supplejack Downs homestead.

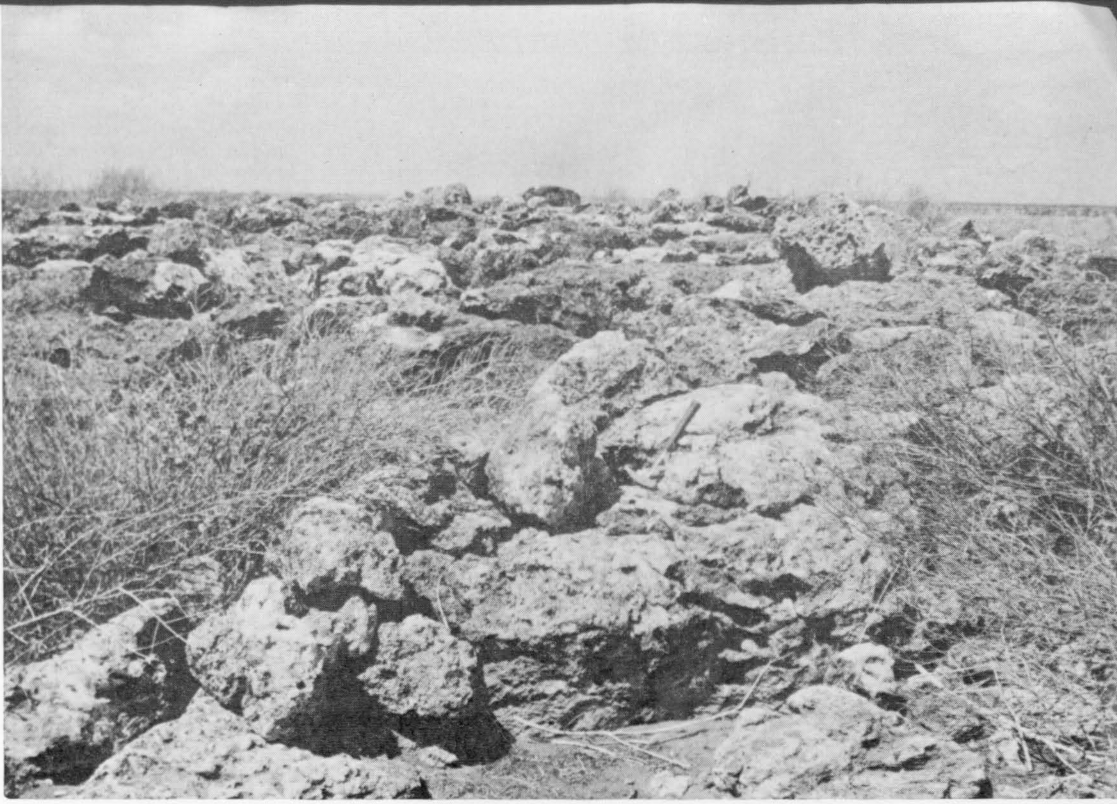


Fig. 34 Chert (silicified limestone?) mapped as unnamed Cambrian near Lake Buck.

Fig. 35 Silicified flat-lying Larranganni Beds capped by silcrete. The escarpment in the background is Larranganni Bluff.

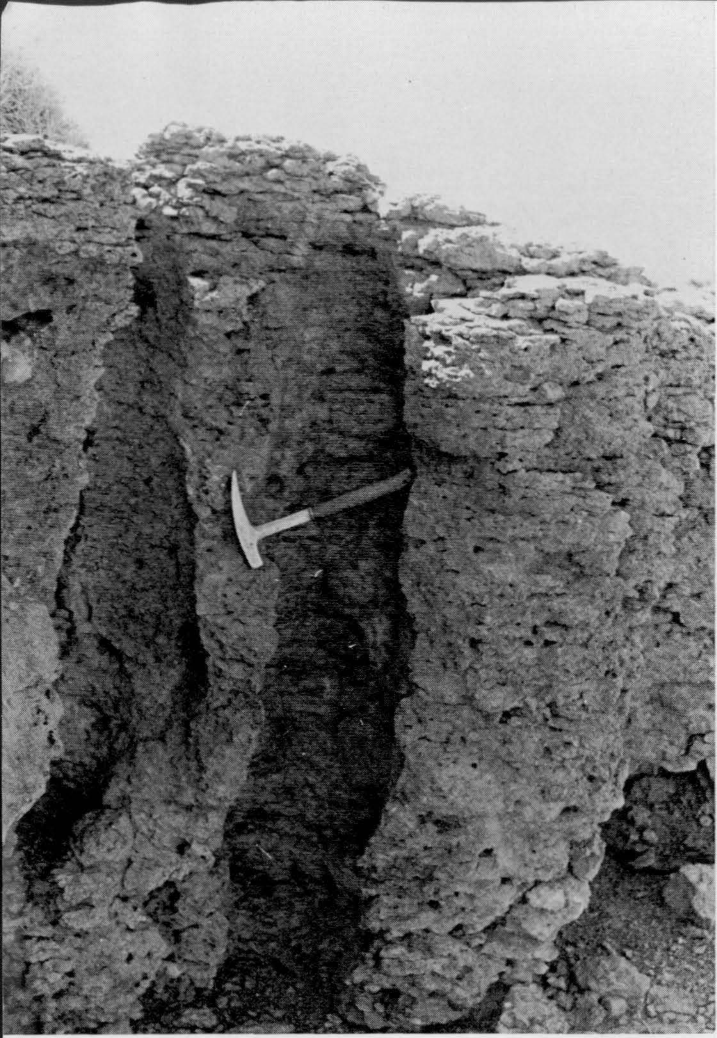


Fig. 36 Vertical pipe in layered laterite developed on shale within the Gardiner Sandstone southeast of Coomarie Spring.

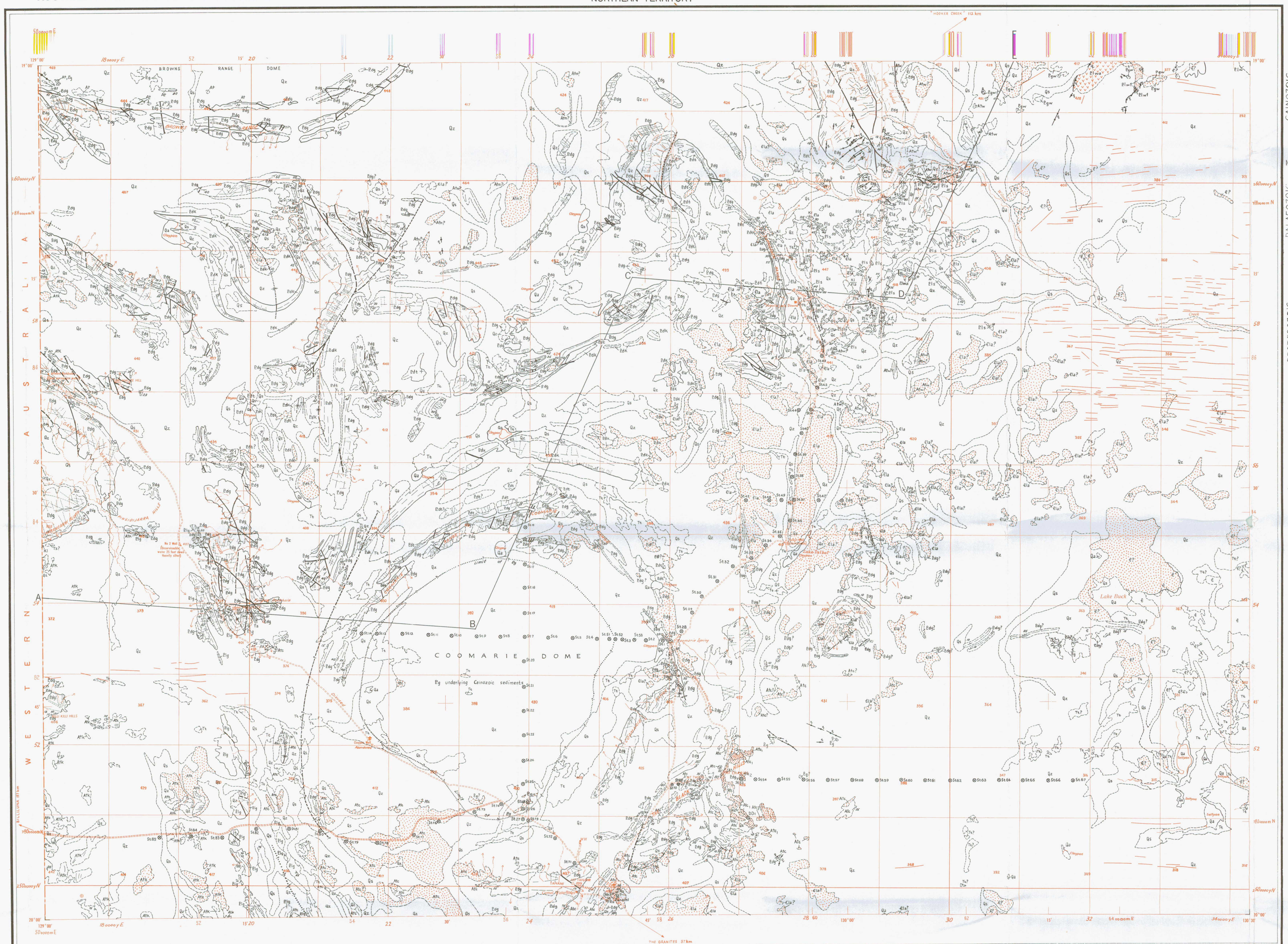
Fig. 37 Silcrete showing smooth rounded surfaces (foreground) and columnar structures. Three kilometres north of Jellebra Rockholes, Gardner Range.

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

TANAMI

NORTHERN TERRITORY

SHEET SE 52-15



Reference

Geological boundary

Anticline

Syncline

Fault

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

Strike and dip of strata

Strike and dip of strata, dip not measured

Strike and dip of strata, facing not known

Vertical strata

Horizontal strata

Strike and dip of overturned strata

Trend line } airphoto interpretation

Joint pattern } airphoto interpretation

Strike and dip of cleavage

Vertical cleavage

Sample locality for age determination (number refers to data in Explanatory Notes)

Quartz vein

Mine, abandoned

Au Gold

Drill hole; St - Stratigraphic hole (BMR Tanami 1-85)
DD1 - Diamond drill hole (Enterprise Exploration Co. Pty Ltd)

Bore with windpump

WH Waterhole

Spring

Ephemeral stream

Sand dunes

Vehicle track

Landing ground

"Supplejack Downs" Homestead

Yd Yard

Trigonometrical station

Astronomical station

520 Elevation in metres, accurate

425 Elevation in metres, approximate

Gravity station
Bouguer anomaly (milligals)
Isogal

Gravity anomaly - relative high

Gravity anomaly - relative low

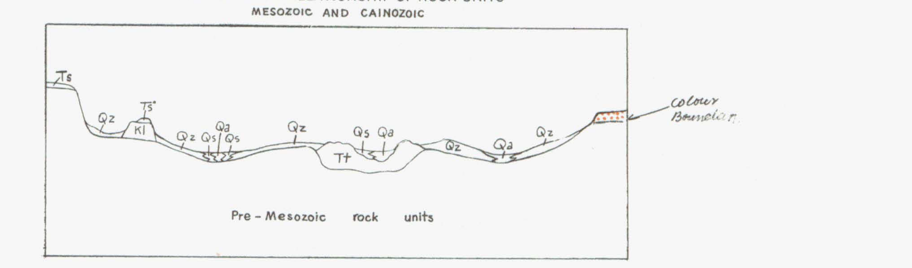
Bouguer anomalies are based on the 1965 observed gravity values at isogal gravity base stations in and near the area. For the calculation of Bouguer anomalies 2.2 g/cm³ has been adopted as an average rock density

Reference

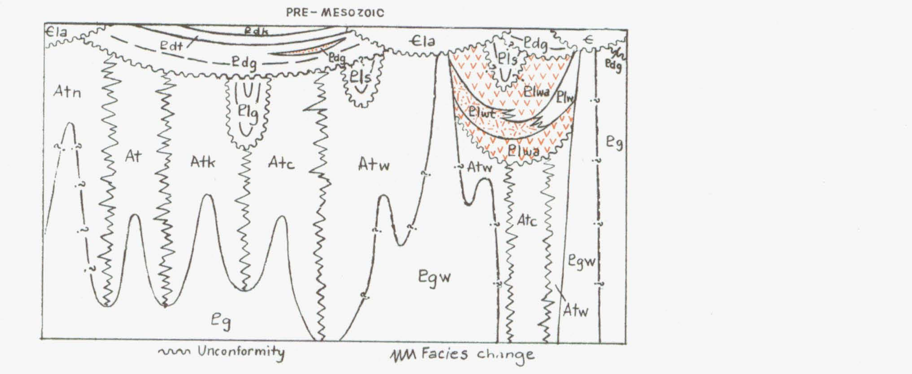
CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay, minor gypsum and halite: fluvial and lacustrine
			Qs	Sand, silt: alluvial and aeolian
			Qz	Sand, gravel: aeolian and piedmont deposits
	TERTIARY		Tt	Calcrete, partly silicified
			Ts	Silcrete
				Laterite capping
MESOZOIC	CRETACEOUS ?	Larranganni Beds	Kl	Sandstone, siltstone, conglomerate
PALAEOZOIC	CAMBRIAN		Є	Quartz arenite, sublithic arenite, mudstone, chert, limestone, dolomite
		Antrim Plateau Volcanics	Єla	Tholeiitic basalt; minor tuffaceous sandstone, lithic arenite and stromatolitic chert
PROTEROZOIC	CARPENTARIAN (Birrindudu Group)	Coomarie Sandstone	Pdk	Sublithic arenite, minor quartz arenite, siltstone and shale
		Talbot Well Formation	Pdt	Stromatolitic chert, cherty arenite, siltstone, mudstone, limestone, quartz arenite, sublithic arenite
		Gardiner Sandstone	Pdg	Glauconitic sandstone; Sublithic arenite, quartz arenite, conglomerate, shale and siltstone
	LOWER PROTEROZOIC		Pg	Medium to coarse biotite and muscovite granite; minor gabbroic rocks
		Winnecke Granophyre	Pgw	Biotite granophyre, biotite adamellite, intrusive acid porphyry
		Supplejack Downs Sandstone	Pls	Sublithic arenite, quartz arenite, minor shale and siltstone
		Mount Winnecke Formation	Plw	Sublithic arenite
			Plwt	Tuffaceous sandstone, siltstone, and conglomerate
			Plwa	Porphyritic and non-porphyritic acid lava
		Pargee Sandstone	Plg	Sublithic and lithic arenite, quartz arenite, conglomerate, greywacke
ARCHAEAN ?	(Tanami Complex)		At	Mica schist, chert, conglomerate
		Nongra Beds	Atn	Phyllite, shale, siltstone and greywacke; sublithic arenite, banded chert, tuff, intrusive acid porphyry
		Nanny Goat Creek Beds	Atw	Extrusive acid porphyry, non-porphyritic and porphyritic basalt, tuff, greywacke, sublithic arenite, phyllite, shale, siltstone
		Mount Charles Beds	Atc	Banded chert, partly silicified shale and siltstone, greywacke, lithic to sublithic arenite, basalt and jaspilite; gossanous bands
			Atc₁	Phyllite, phyllitic siltstone and greywacke; gossanous bands
			Atcs	Amphibolite, basalt
		Killi Killi Beds	Atk	Phyllitic greywacke, sublithic and lithic arenite, shale, mudstone, siltstone, tuff, acid porphyry, ironstone, and minor quartz arenite

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

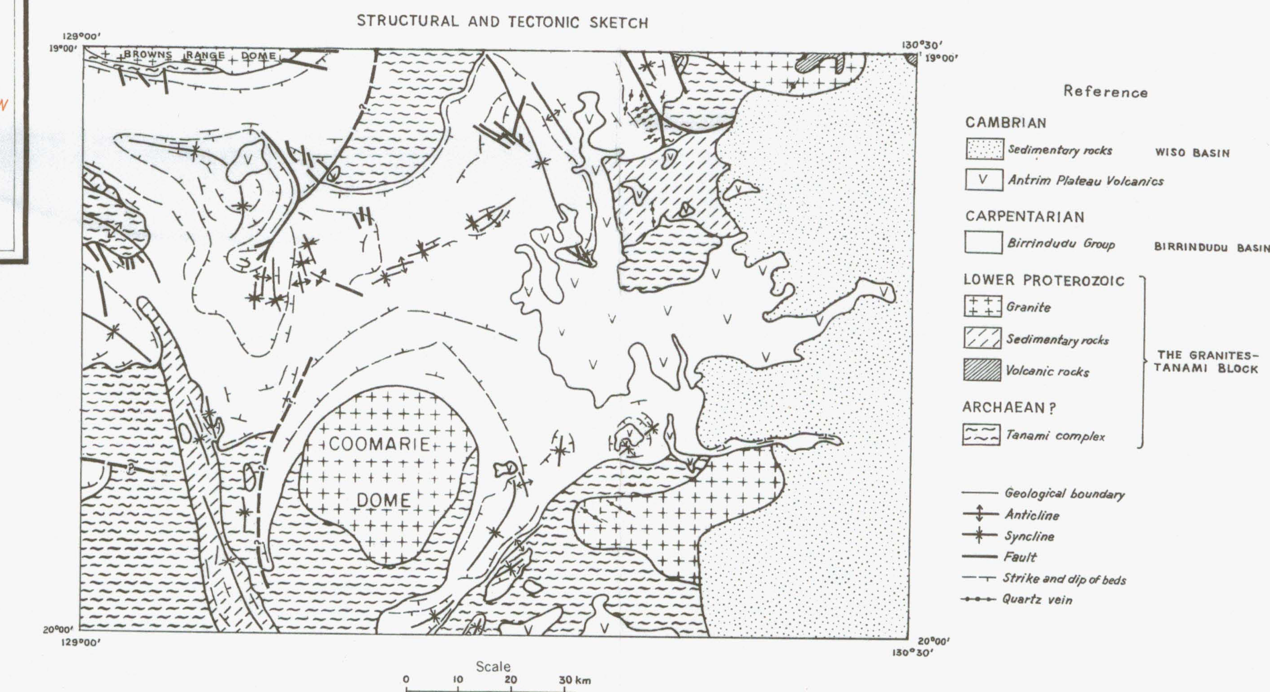
MESOZOIC AND CAINOZOIC



PRE-MESOZOIC



STRUCTURAL AND TECTONIC SKETCH



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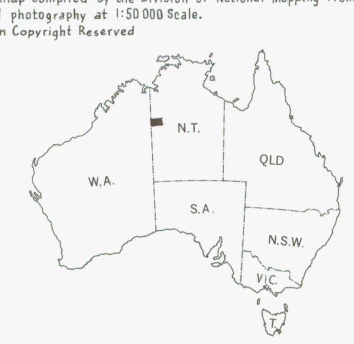
Base map compiled by the Division of National Mapping from aerial photography at 1:50 000 Scale.



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MOUNT RAMSAY SE 52-9	GORDON DOWNS SE 52-10	BIRRINDUDU SE 52-11	WINNECKE CREEK SE 52-12	SOUTH LAKE WOODS SE 53-9
MOUNT BANNERMAN SE 52-13	BILLILUNA SE 52-14	TANAMI SE 52-15	TANAMI EAST SE 52-16	GREEN SWAMP WELL SE 53-13
CORNISH SF 52-1	LUCAS SF 52-2	THE GRANITES SF 52-3	MOUNT SOLITAIRE SF 52-4	LANDER RIVER SF 53-1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

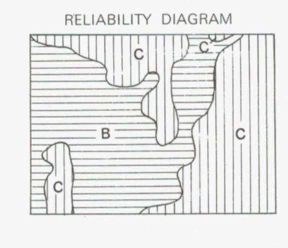
Scale 1:250 000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

GREY NUMBERED LINES ARE 20 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20 000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM



Geology B Detailed reconnaissance: numerous traverses, and airphoto interpretation
C General reconnaissance: few traverses, and airphoto interpretation

Gravity Reconnaissance

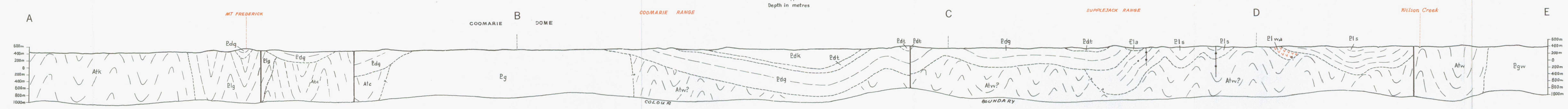
Geology 1971 by D.H. Blake, I.M. Hodgson, P.A. Smith
Compiled 1972 by D.H. Blake, I.M. Hodgson, P.A. Smith
Gravimetry 1965 by Geophysical Branch, BMR
Cartography by Geological Branch, BMR
Printed by: Mercury-Walch Pty Ltd., Hobart, Australia

Section

Cainozoic units omitted

Scale: $\frac{V}{H} = 4$

Depth in metres



FIRST EDITION 1974

TANAMI

SHEET SE 52-15

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Darwin, N.T.

BIRRINDUDU

NORTHERN TERRITORY

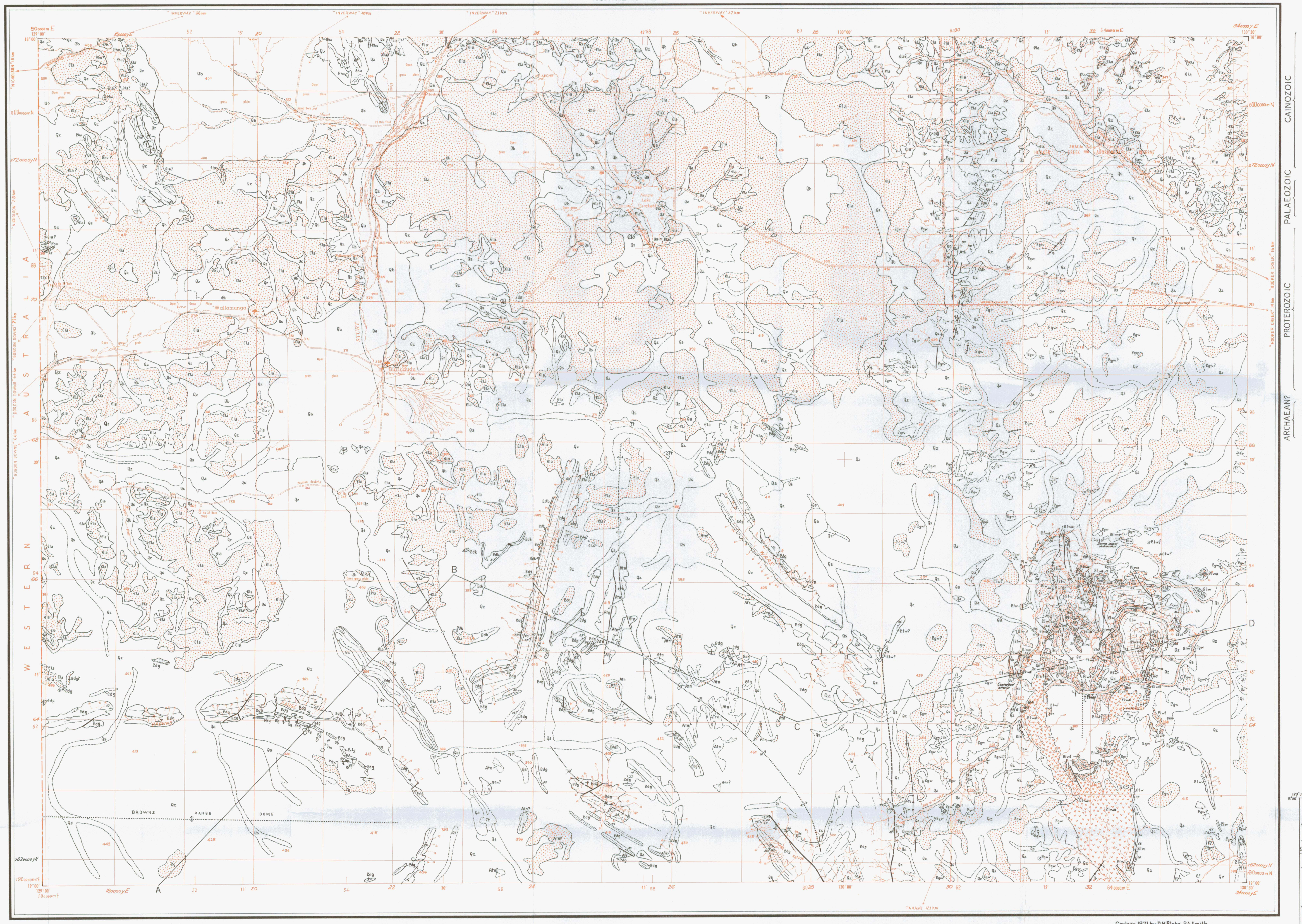
Reference

- Geological boundary
- Anticline, showing plunge
- Syncline
- Fault

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

- Strike and dip of strata
- Vertical strata
- Horizontal strata
- Overturned strata
- Dip < 15° } airphoto interpretation
- Trend line } airphoto interpretation
- Strike and dip of foliation
- Sample locality for age determination (number refers to data in Explanatory Notes)
- Quartz vein
- Bore
- Windpump
- Waterhole
- Swamp
- Ephemeral stream
- Highway
- Road
- Vehicle track
- Landing ground
- "Birrindudu" Homestead
- Yd Yard
- Fence
- Astronomical station
- ·398 Elevation in metres, accurate
- ·380 Elevation in metres, approximate
- pd Position doubtful
- Gravity station
- Bouguer anomaly (milligals)
- Isogal
- Gravity anomaly – relative high
- Gravity anomaly – relative low

Bouguer anomalies are based on the 1965 observed gravity values at isogal gravity stations in and near the area. For the calculation of Bouguer anomalies 2·2g/cm³ has been adopted as an average rock density

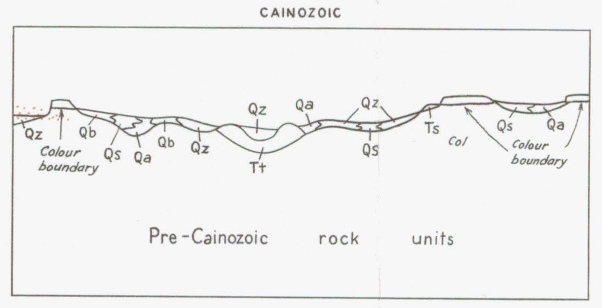


Reference

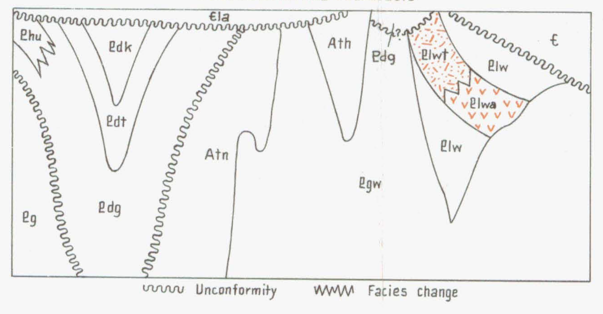
CAINOZOIC	QUATERNARY		Qa	Sand, silt, clay: fluvial and lacustrine
			Qs	Sand, silt: alluvial and aeolian
			Qz	Sand, gravel: aeolian and piedmont
			Qb	Residual grey clay
	TERTIARY		Tt	Calcrete, partly silicified
			Ts	Silcrete
				Laterite capping
PALAEOZOIC	CAMBRIAN		Є	Quartz arenite, sublithic arenite, chert
		Antrim Plateau Volcanics	Єla	Tholeiitic basalt; minor tuffaceous sandstone, lithic arenite, stromatolitic chert
PROTEROZOIC	CARPENTARIAN	Limbunya Group	Ƥhu	Sublithic arenite, quartz arenite; minor stromatolitic chert and conglomerate
		Birrindudu Group: Coomarie Sandstone	Ƥdk	Sublithic arenite, quartz arenite
		Birrindudu Group: Talbot Well Formation	Ƥdt	Stromatolitic chert, sublithic arenite
		Birrindudu Group: Gardiner Sandstone	Ƥdg	Glauconitic arenite; Sublithic arenite, quartz arenite; minor conglomerate, shale, siltstone
	LOWER PROTEROZOIC		Ƥg	Medium to coarse muscovite granite
		Winnecke Granophyre	Ƥgw	Biotite granophyre, biotite adamellite, intrusive acid porphyry
		Mount Winnecke Formation	Ƥlw	Sublithic arenite; minor conglomerate
			Ƥlwt	Tuffaceous sandstone, siltstone and conglomerate; minor laminated tuff, lapilli tuff, acid lava
			Ƥlwa	Porphyritic and non-porphyritic acid lava
ARCHAEAN?		Tanami complex: Helena Creek Beds	Ath	Greywacke, tuff, phyllite, conglomerate, lithic arenite, acid porphyry
		Tanami complex: Nongra Beds	Atn	Phyllitic shale, siltstone, greywacke, sublithic arenite, banded chert, micaceous tuff, extrusive acid porphyry

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS

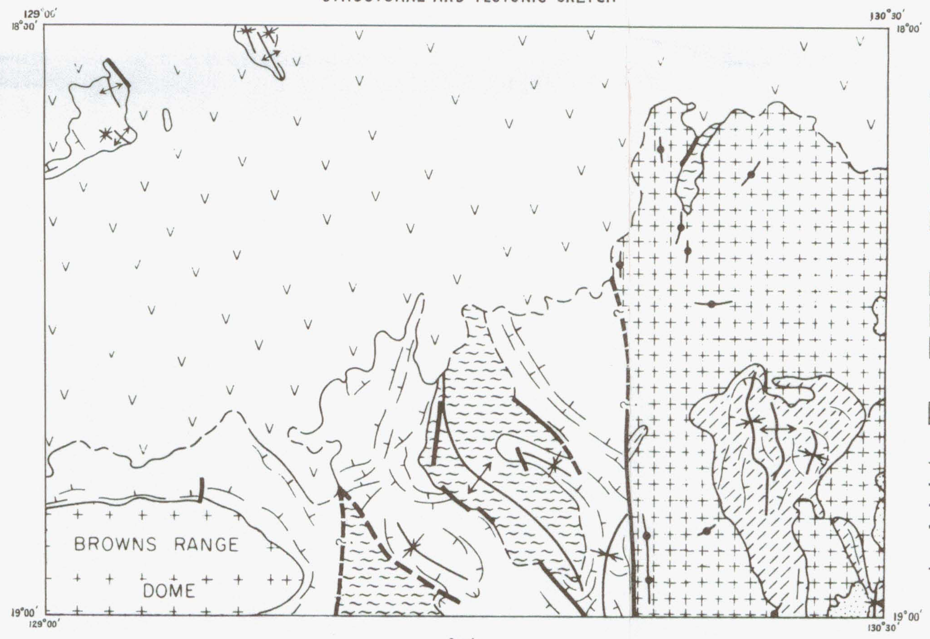
CAINOZOIC



PRECAMBRIAN AND PALAEOZOIC



STRUCTURAL AND TECTONIC SKETCH



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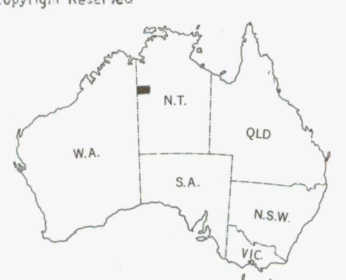
Base map compiled by the Division of National Mapping from aerial photography at 1:50 000 scale.



INDEX TO ADJOINING SHEETS

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CORNISH SF 52-1	LUCAS SF 52-2	THE GRANITES SF 52-3	MOUNT SOLITAIRE SF 52-4	LANDER RIVER SF 53-1

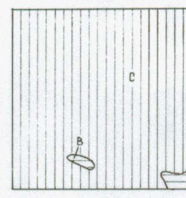
Scale 1:250 000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

GREY NUMBERED LINES ARE 20 000 METRE INTERVALS OF THE AUSTRALIAN MAP GRID, ZONE 52
GREY TICKS WITH ITALIC NUMBERS INDICATE THE 20 000 YARD GRID, ZONE 4 (AUSTRALIA SERIES)
TRANSVERSE MERCATOR PROJECTION

RELIABILITY DIAGRAM



Geology B Detailed reconnaissance: numerous traverses and airphoto interpretation
C General reconnaissance: few traverses and airphoto interpretation
Gravity Reconnaissance

Geology 1971 by D.H.Blake, P.A.Smith
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Gravimetry 1965, 1967 by Geophysical Branch, BMR
Cartography by Geological Branch, BMR
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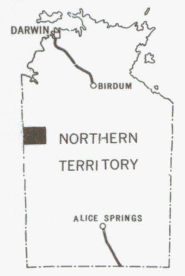
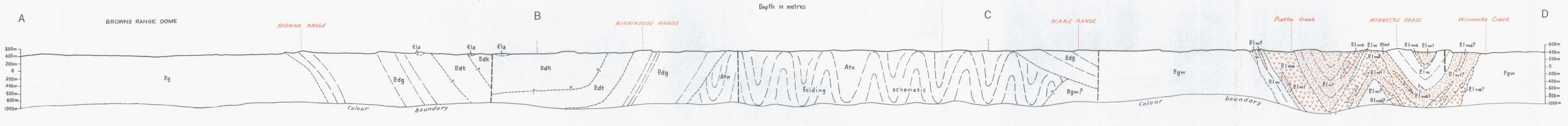


Section

Cainozoic sediments omitted
Scale: $\frac{V}{H} = 4$
Depth in metres



FIRST EDITION 1974

BIRRINDUDU

SHEET SE 55-11

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