BMR Bulletin
197

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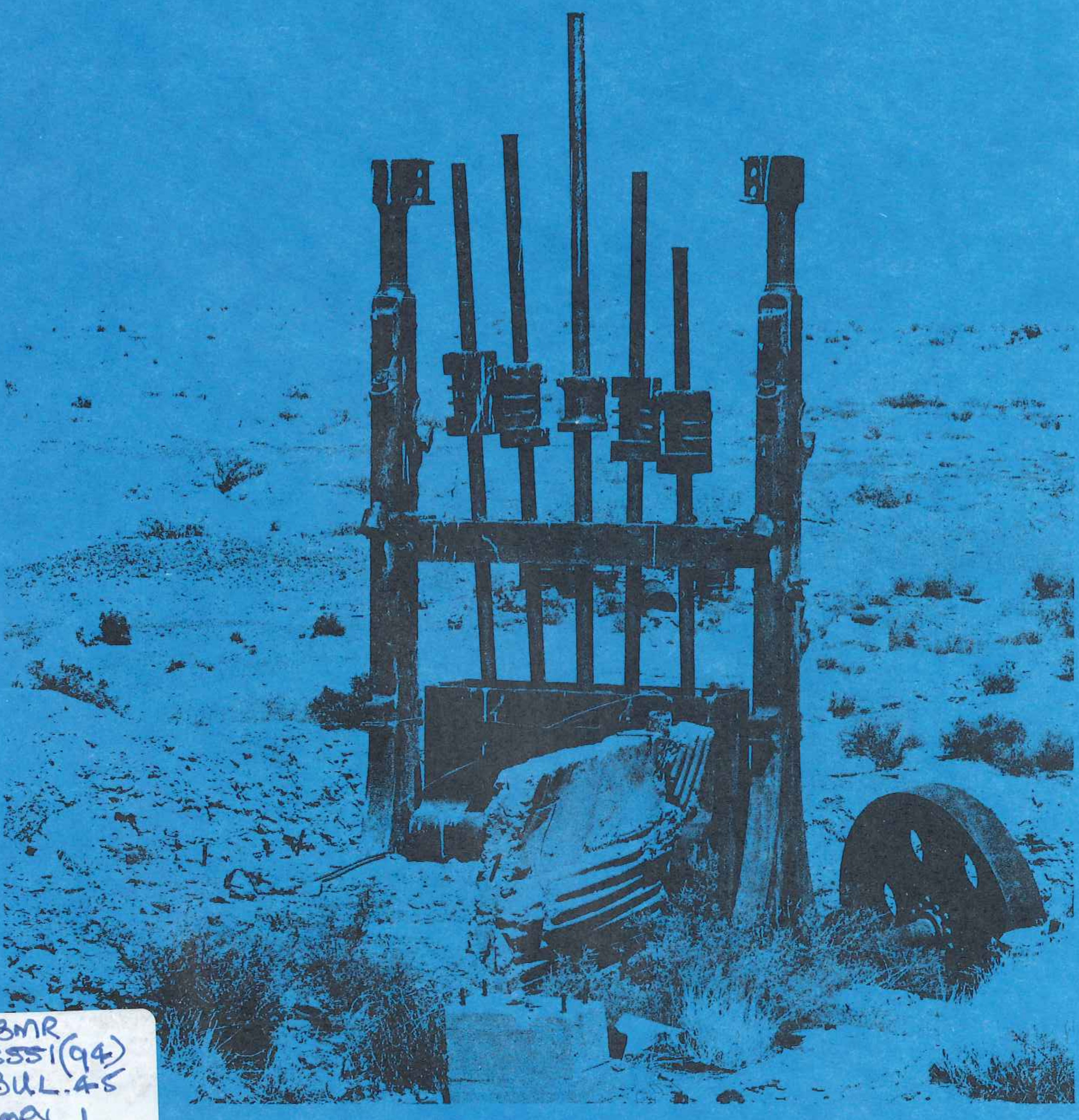

DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN 197

Geology of The Granites—Tanami Region, Northern Territory and Western Australia

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*Geological Survey of Western Australia

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ABSTRACT

The Granites-Tanami region, in the northwest of central Australia, is an area of mainly Precambrian rocks, largely covered by superficial Cainozoic sediments. It comprises parts of seven major Precambrian tectonic units—The Granites-Tanami Block, Halls Creek Province, and Arunta Block, which together form the basement, and the Birrindudu, Amadeus and Ngalia Basins, and an unnamed basin in the northwest. The basement units comprise Early Proterozoic and Carpentarian metasediments, metavolcanics, unmetamorphosed sedimentary and volcanic rocks, and granites. Isotopic data indicate ages of between 1820 and 1700 m.y. for the voicanics and granites in The Granites-Tanami Block, and about 1520 m.y. for those of the Arunta Block to the south. Marked angular unconformities separate the basement rocks from the overlying basin sedimentary rocks, which are predominantly clastic. The Birrindudu Basin contains both Carpentarian (about 1560 m.y.) and Adelaidean (about 900 m.y.) sediments. Those of Carpentarian age are correlated with sediments in the unnamed basin, and those of Adelaidean age are correlated with sediments of the Amadeus and Ngalia Basins to the south. Adelaidean sediments are also present in the unnamed basin. Phanerozoic rocks in The Granites-Tanami region are generally flat-lying, and overlie the Precambrian rocks with marked angular unconformity. All are probably non-marine. They include basalt lavas of the Early Cambrian Antrim Plateau Volcanics, and younger unfossiliferous Palaeozoic and minor probably Mesozoic sediments. Gold and minor copper in The Granites-Tanami Block, and uranium and associated rare earths in the Birrindudu Basin are the only known occurrences of possibly economic mineralisation in the region.

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INTRODUCTION

The Granites-Tanami region is an area of mainly Precambrian rocks largely covered by superficial Cainozoic sediments in the northwest of central Australia. It lies between the mainly Precambrian Kimberley region (Kimberley Basin and Halls Creek Province) and Victoria River Basin to the northwest and north respectively, and the Arunta Block to the south and southeast, and is flanked by Phanerozoic rocks of the Canning Basin to the west and the Wiso Basin to the east (Fig. 1). The western part is on the margin of the Great Sandy Desert, and the eastern part is in the Tanami Desert.

The region as described in this Bulletin is covered by all or parts of ten 1:250 000 map sheets—Birrindudu, Tanami, The Granites, Highland Rocks, and Lake Mackay in the Northern Territory, and Gordon Downs, Billiluna, Lucas, Stansmore, and Webb in Western Australia. These extend from 18°S to 23°S, and from 127°30′E to 130°30′E. Most of Lucas Sheet area is part of Balwina Aboriginal Reserve; most of Stansmore and Webb Sheet areas forms part of the Central Australia Aboriginal Reserve; Highland Rocks and Lake Mackay Sheet areas are in Lake Mackay Aboriginal Reserve; the northeast part of Birrindudu Sheet area is in Hooker Creek Aboriginal Reserve; and the eastern part of The Granites Sheet area is in the Tanami Wildlife Sanctuary (Fig. 2).

Most of the region is uninhabited, and there are few roads or tracks, except in the northwest (Fig. 2). There are no towns and only six homesteads—Balgo, Mongrel Downs, Supplejack Downs, Sturt Creek, Gordon Downs, and Birrindudu—all of which are on stations engaged in raising beef cattle. In addition, there is a motel at Rabbit Flat, between the abandoned gold mining settlements of Tanami and The Granites. Balgo Mission and Billiluna, Carranya, and Lake Gregory homesteads lie close to, but just west of the region, Ruby Plains homestead and Halls Creek township lie to

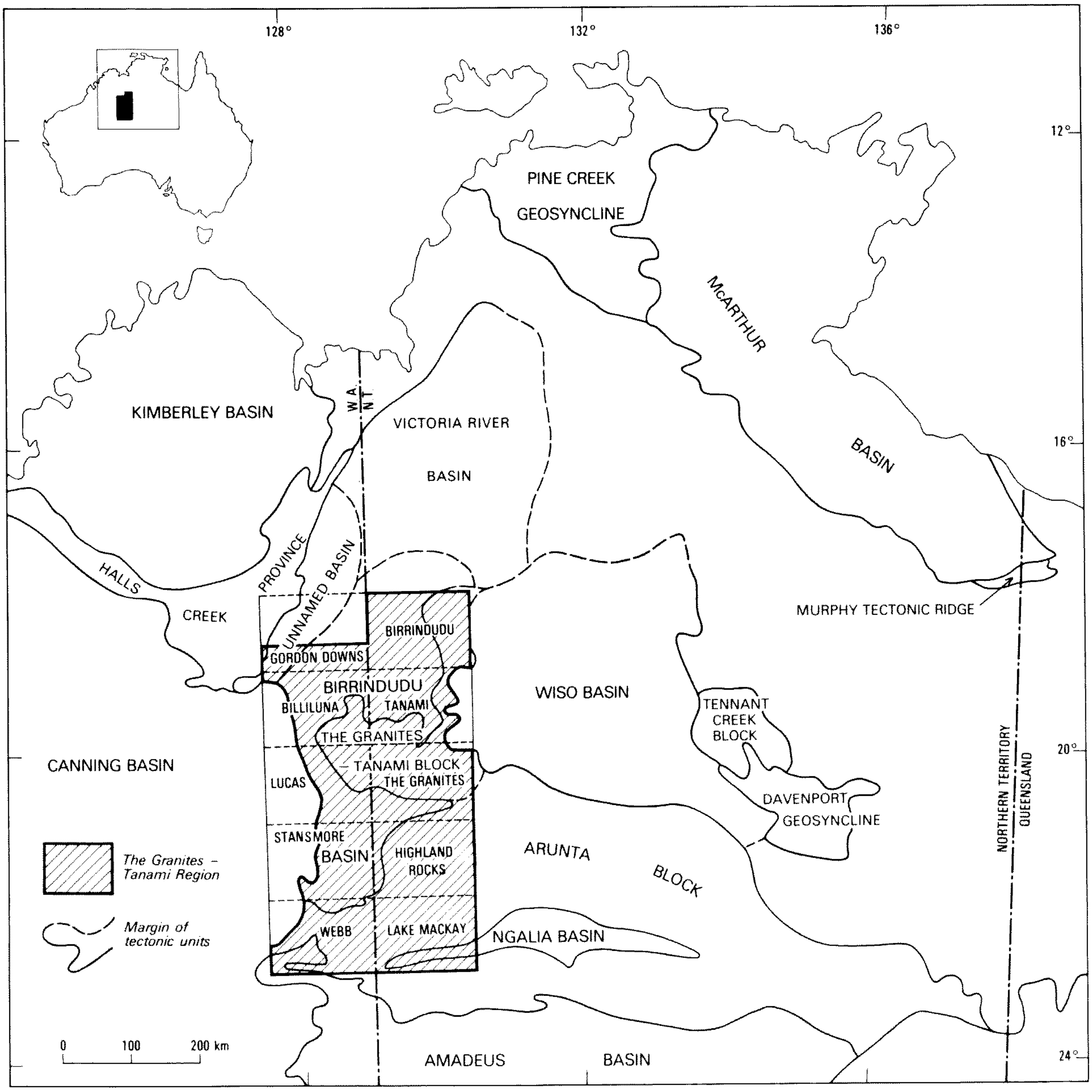

Fig. 1. Regional setting of The Granites-Tanami region.

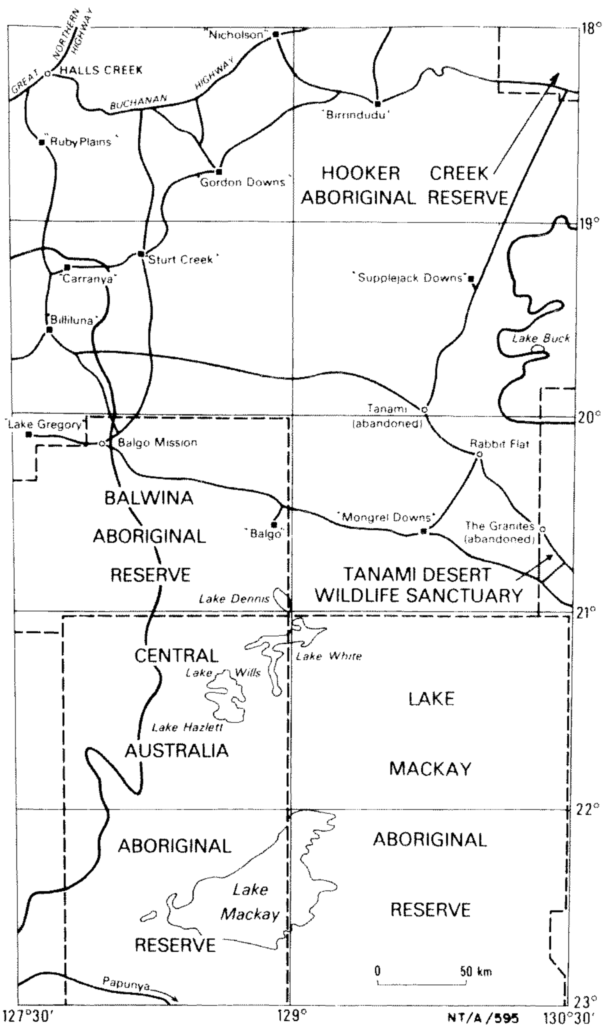

Fig. 2. Main access routes and reserves.

the northwest. Sturt Creek, Gordon Downs, and Birrindudu stations were once known as Denison Downs, Sturt Creek, and Gordon Downs, respectively. Three other homesteads once existed in the region—Wallamunga, 20 km west-northwest of Birrindudu homestead; Lewis Creek, on Lewis Creek at the northwest end of the Gardner Range*; and Black Hills, near Coomarie Spring, 32 km north of Tanami.

The main access route to The Granites-Tanami region is the unsealed road from Alice Springs to Halls Creek, which passes northwest, through The Granites, Rabbit Flat, and Tanami, to Billiluna homestead, and then north to Halls Creek, via Ruby Plains, in the Gordon Downs Sheet area. A formed track leaves this road southeast of The Granites, and runs west, past Mongrel Downs and Balgo homesteads, to Balgo Mission, and then north to rejoin the main road southeast of Billiluna. Other useful tracks lead from Balgo Mission north to Sturt Creek homestead, and from Tanami north-northeast to Hooker Creek, and there are tracks around the station homesteads. An old track shown on many maps as connecting Tanami and Gordon Downs homestead to the northwest has been disused for many years. The unsealed road and tracks are impassable after heavy rain, and at other times are unsuitable for other than four-wheel-drive vehicles.

* This is the correct spelling (Davidson, 1905). On some Western Australian maps it is incorrectly spelt Gardiner, an error perpetuated in the stratigraphic name Gardiner Sandstone.

Airstrips suitable for light aircraft are maintained at the station homesteads and at Rabbit Flat; Sturt Creek, Billiluna, Gordon Downs, Balgo Mission, and Hooker Creek, had scheduled air services in 1973. Unmaintained airstrips are located at Tanami and The Granites. Almost the whole area has unlimited helicopter landing sites.

The region has a warm dry monsoonal climate and is mostly semi-desert. Rainfall decreases from about 450 mm in the north to about 200 mm in the south, most being received during the summer months. However, the amount and distribution, both annually and seasonally, are very variable. These rainfall data and the following temperature data are extrapolated from those available for Halls Creek to the northwest and Giles to the southwest. Throughout the region, maximum daily temperatures over 38°C are general from October to March, and minimum daily temperatures of less than 10°C occur in June, July, and August, when frosts are common, especially in the south and east. The prevailing winds are easterly.

Most of the region lies in the Mueller botanical province (Beard & Webb, 1974). The vegetation is generally sparse, because of the arid climate and predominantly sandy soils, and consists mainly of spinifex grassland (steppe) with scattered low trees (mostly species of *Eucalyptus* and *Acacia*), shrubs, and herbaceous plants. In the north, where the average annual rainfall is over 380 mm, there are also areas of low savannah, in which the typical tree is snappy gum (*Eucalyptus brevifolia*), and extensive grass-covered clay plains, on which the main species is Mitchell grass (*Astrebla pectinata*) (Perry, 1970). Few trees are taller than 8 m, and relatively large trees are present only along creeks in the northern half of the region.

Topography

An immediate impression received on visiting The Granites-Tanami region is the overall flatness of the landscape, especially compared to that of the Kimberley region and the area around Alice Springs. Prominent hills appear to be lacking, and there are few readily identifiable landmarks. However, the impression is somewhat misleading as the region contains numerous hills and ridges (Fig. 4), although few of these are as high as 30 m. A striking feature of the hills and ridges, resulting from the overall flatness and the heat haze commonly present, is that at first sight they commonly seem much higher and farther away than they really are, and on approach they appear to decrease in height and become less pronounced.

The region ranges in height above sea level from about 300 m to about 650 m, and most lies between 350 and 450 m. Both the highest and lowest points are in the Billiluna Sheet area—respectively, Mount Brophy in the Gardner Range (Fig. 3) and the plain on the west side of the Elsey Hills. The maximum local relief is also in the Gardner Range, which in places is over 200 m high.

Parts of the region have previously been subdivided into various topographic, physiographic, and geomorphic units. Three units were recognised in the southern part of Gordon Downs Sheet area by Gemuts & Smith (1968)—the Canning Plain in the east, and the Halls Creek Ridges and Albert Edward Range in the west. All three continue southwards into Billiluna Sheet area. The Canning Plain is part of the Sturt Plateau (Traves, 1955; Paterson, 1970), which extends eastwards into Birrindudu and Tanami Sheet areas (Simpson, 1970;

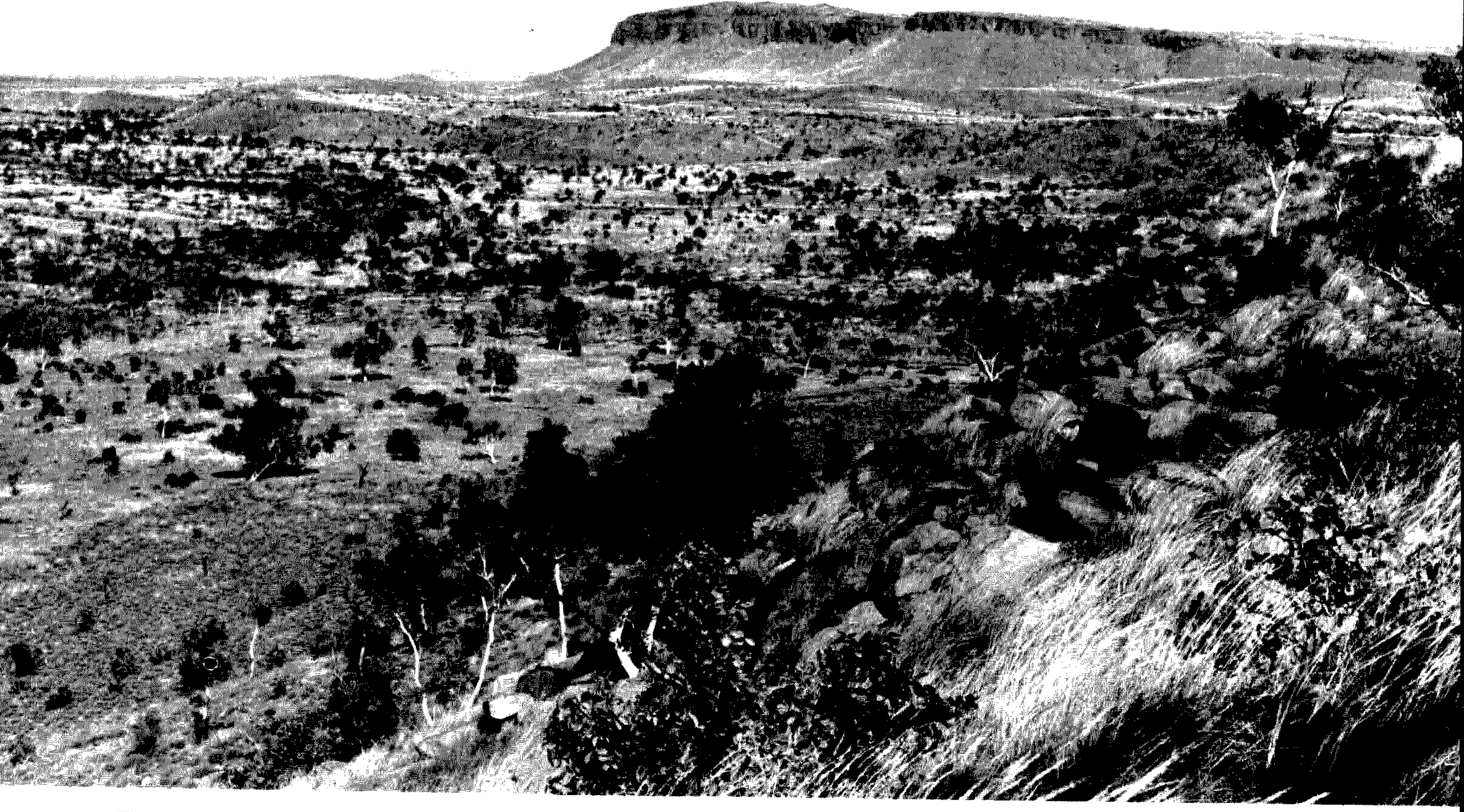

Fig. 3. Mount Brophy, the highest point in the Gardner Range and The Granites-Tanami region; from the east. (M2239)

Blake & others, 1975) and is not to be confused with a unit of the same name which covers most of the Canning Basin, including the western parts of the Billiluna, Lucas, and Stansmore Sheet areas (Veevers & Wells, 1961). Veevers & Wells described the eastern parts of the last three sheet areas as the Stansmore Highlands.

No attempt has been made to follow and extend any of the above units in this account. Instead, four general topographic units are distinguished—hills and ridges, undulating terrain with rocky outcrops, plains, and salt lakes (Fig. 4). Named features mentioned in this bulletin are shown in Figure 5.

Hills and ridges

The hills and ridges range in height from less than 30 m to over 200 m, and are formed mainly of resistant Precambrian sandstone. Strike ridges with narrow to broad and more or less flat tops predominate; they generally have steep sides, and are incised by narrow drainage channels, which pass into outwash fans before disappearing on the surrounding plain. The soil cover on the hills and ridges is patchy or non-existent, and runoff is very rapid. Some permanent or semi-permanent rockholes are present, mainly in the northern half of the region as, for instance, in the Gardner and Tanami Ranges, and there are permanent springs on the margins of some ranges: for example, the two Palm Springs of the Denison Range in the northwest, and Uritu Spring (Fig. 8) at the southern end of the Gardner Range. This topographic unit also includes cuestas, such as the Lewis Range (Fig. 9), a few flat-topped hills capped by Phanerozoic rocks, and, in the northwest, Wolf Creek Meteorite Crater.

Wolf Creek Meteorite Crater was discovered from the air in 1947 by F. Reeves (Reeves & Chalmers, 1949) and has since been described by Guppy & Matheson (1951), Casey & Wells (1964), and McCall (1973). It is about 850 m wide, and consists of an almost circular flat crater floor about 420 m in diameter, bounded by a steep wall, which rises 50 m above the floor and 30 m above the surrounding plain. The structure has been little eroded, and was probably formed less than 10 million years ago.

Undulating terrain with rocky outcrops

The rocky outcrops of this unit are generally less than 10 m high. They consist mainly of granite, commonly as spheroidal boulders and tors and cleaved metamorphic rocks, and are surrounded by gently undulating terrain on which a thin and locally impersistent cover of sand and residual gravel overlies weathered bedrock.

Plains

This is by far the most extensive unit, forming both large expanses and smaller areas between other units. The plains are flat to very gently undulating, and, except in some drainage depressions and on black soil plains in the north, are sand-covered. They contain innumerable longitudinal sand dunes (Fig. 10), mainly in the south and west (Fig. 6), low rises of laterite, and small isolated rock outcrops.

The dunes, which have been described by Veevers & Wells (1961), trend more or less east-west (Figs. 6 & 10), roughly parallel to the prevailing wind. They range in length from less than one to over 30 km, the longest being in the southwest, and in height from a few metres

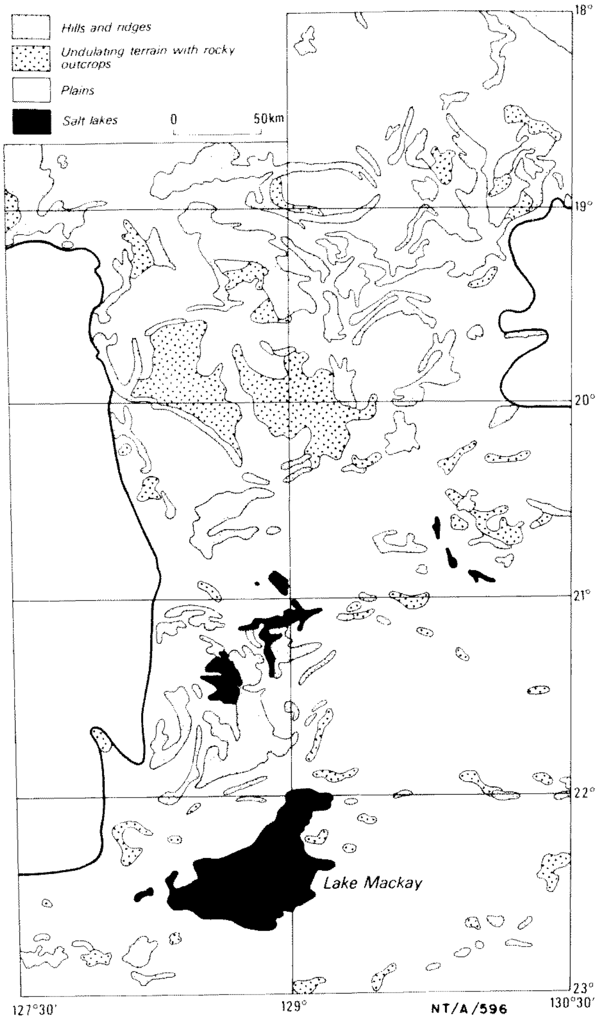

Fig. 4. Topographic units.

to over 30 m, although few are over 15 m high. The dunes are generally 0.3 to 3 km apart. Individual dunes vary considerably in complexity: some have simple unbranched forms; some have a few side branches which join westwards with the main dune, forming tuning-fork patterns with the prongs of the fork pointing east; other have highly complex braided patterns with many anastomosing branches. All the dunes appear stable now, and they support a sparse vegetation of spinifex, low trees, and shrubs; the largest trees in the dune areas are close to the dune crests, not on the flat areas between dunes. The dunes terminate abruptly against hills and ridges, but continue uninterrupted over many low laterite rises and rock outcrops.

The plains are drained by several broad depressions, but only in the north, where the rainfall is higher, do any of these have prominent drainage channels; mostly they are barely perceptible. Patches of chemically precipitated limestone (calcrete) and chalcedony form irregular surfaces in the depressions. These are commonly exposed by wind erosion so that they are several metres higher than the general level of the depression. Many depressions are crossed by dunes, and in such cases the interdune areas abound in small clay pans or salt pans, or both.

Low laterite rises (Fig. 12), generally less than 10 m high, are present within the plains throughout most of the region. On aerial photographs these rises can be readily identified, as they form sharply bounded, smooth-toned areas which are darker than the surrounding plains. The dark tone is due to fine ironstone gravel which covers the rises and shows through the sparse vegetation. The rises are commonly highly irregular in plan, and many have cumulous outlines. The tops are smooth and flat, and sides typically gently convex, although many are partly bounded by breakaways in which lateritic weathering profiles are exposed. The breakaways, some of which in the north are over 5 m high, are capped by pisolitic ironstone a metre or so thick. Shallow drainage gullies are developed on the gently sloping sides of the rises, which in most places have an abrupt change of slope at their base, but which locally merge into the surrounding plain. The rises appear to be erosional remnants of a lateritised surface, which probably extended over most of the region, and which may be correlated with the probably mid-Tertiary or older Tennant Creek Surface recognised by Hays (1967) to the east and northeast.

Salt lakes

The main salt lakes are Lakes Dennis, White, Wills, Hazlett, and Mackay, in the southern half of the region. The largest of these, Lake Mackay (Fig. 13), is about 360 m above sea level, and covers about 3500 km^2. The others are about 330 m above sea level. The floor of Lake Dennis is underlain at a depth of a few centimetres by Palaeozoic bedrock, and is firm enough for vehicles to drive on, but the other salt lakes are floored by unknown thicknesses of soft saline mud. The salt lakes are centres of inland drainage, and are covered by water after heavy rain. At most times, though, they are dry and wholly or partly covered by a thin white salt crust.

Drainage

The main surface streams (Fig. 7), all in the north, are Sturt Creek, which drains southwest into Gregory Salt Lake, and Hooker Creek, Winnecke Creek, and Wilson Creek, which drain eastwards before disappearing in the sand plains of the Wiso Basin region. These and smaller creeks in the north are ephemeral, but several have permanent or semi-permanent waterholes, the largest of which are along Sturt Creek. However, the largest permanent body of surface water is Nongra Lake, a centre of inland drainage in the extreme north; this lake is brackish, and fluctuates in area both annually and seasonally.

In the centre and south of the region there are few surface drainage channels away from the hills and ridges, and most of the drainage is subsurface. The only streams of any significance are Brookman Waters, which has some small permanent or semi-permanent waterholes, and Nicker Creek in Stansmore Sheet area; both drain northwards into Lake Hazlett.

Previous investigations

Recorded exploration and geological investigations are listed below—

1856 Gregory (1857) followed Sturt Creek downstream to Gregory Salt Lake, passing southwest across the northernmost part of the region.

1873 Warburton (1875) crossed the southern part of the region, travelling northeast to Lake White, and then turning west, eventually reaching the coast near Port Hedland.

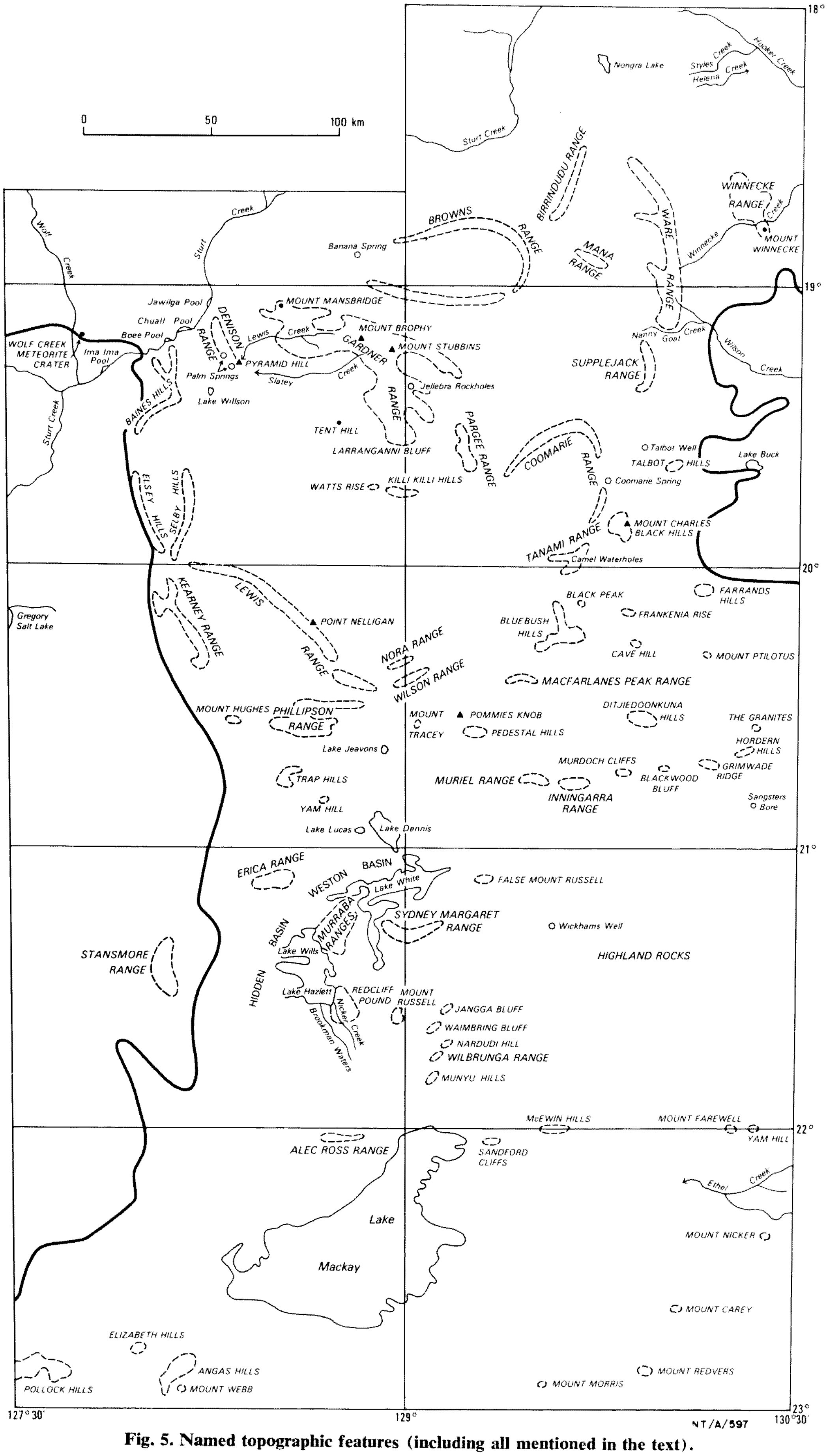

Fig. 5. Named topographic features (including all mentioned in the text).

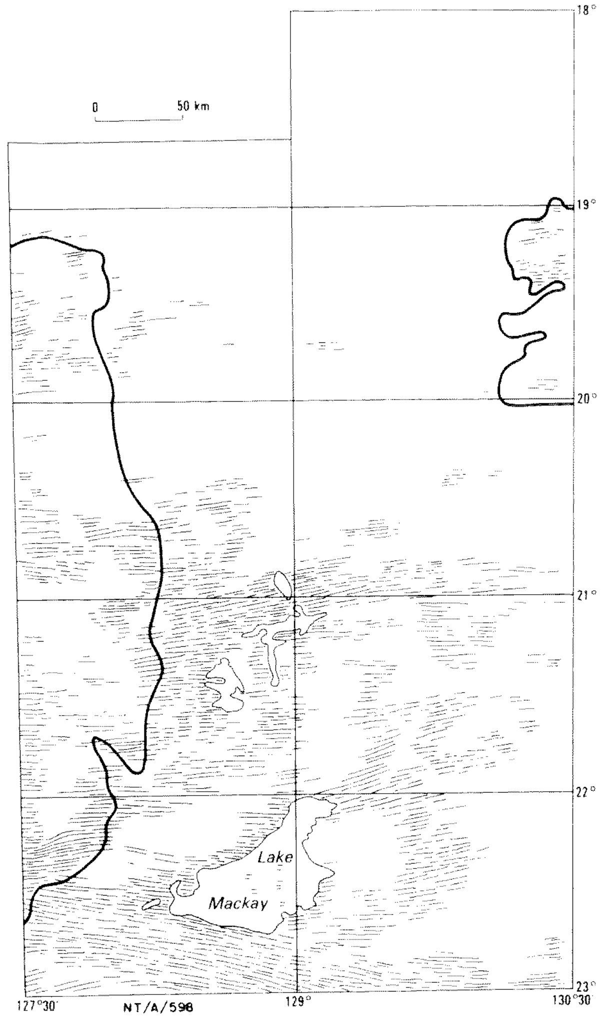

Fig. 6. Generalised distribution and trends of sand dunes.

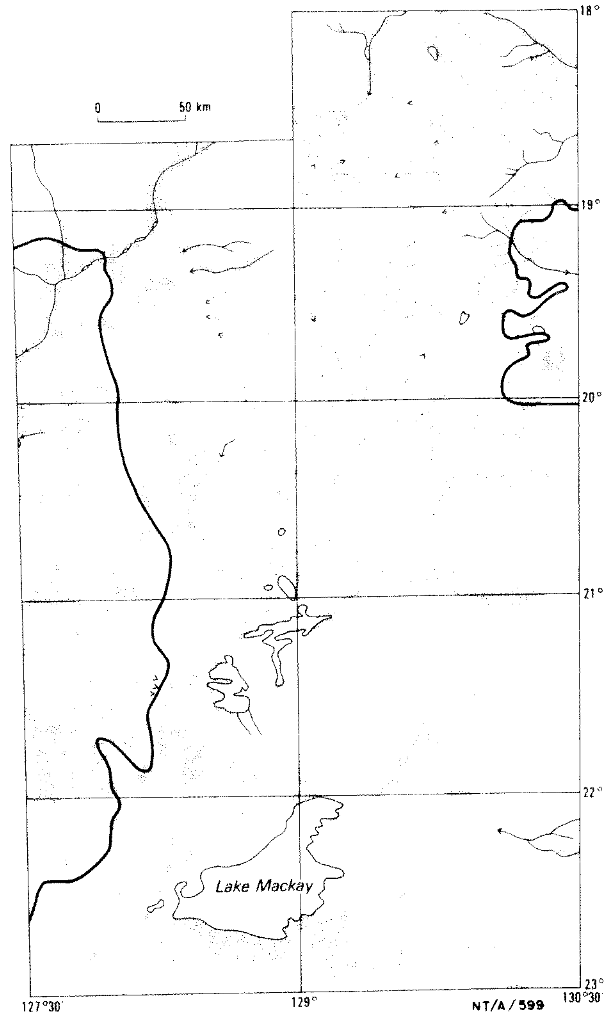

Fig. 7. Distribution and trends of drainage depressions.

1897 Carnegie (1898) passed southwards along the west side of the region on his way from Halls Creek to Coolgardie. He gave the name Erica Range to hills in the north of Stansmore Sheet area.

1900 A gold prospecting expedition led by Davidson (1905) entered the region from the east and travelled west as far as the Gardner and Lewis Ranges. The expedition discovered gold at Tanami and The Granites, and named several topographic features.

1909 Brown (1909) visited the gold mines at Tanami from Pine Creek, and made notes on the geology he observed along his route. The same year Talbot (1910) travelled southeast from Halls Creek to Tanami and back, and described the geology he saw. In particular he observed sandstone and conglomerate in the Gardner Range, metamorphic rocks cut by quartz reefs containing traces of gold near Larranganni Bluff, and granite at Tent Hill overlain by sandstone, which he considered to be younger than that of the Gardner Range.

1910 Gee (1911) visited the Tanami goldfield, and described the workings there. He also noted that prospecting was being carried out south of Tanami, the best results being 'obtained at Granite Hill' (The Granites).

1914 Jensen (1915) travelled from Pine Creek to Tanami, and described the geology in the vicinity of the gold workings and along his route between Hooker Creek and Tanami. He named the metamorphic rocks at Tanami the 'Tanami Metamorphic Series'.

1916 Weston led an expedition from Tanami south to Lake White (reported by Terry, 1934, 1937), and named the hills to the south the Sydney Margaret Range.

1925 Terry (1927) followed Sturt Creek downstream from north of Birrindudu southwest to Gregory Salt Lake.

1928 Terry (1930, 1931) led a prospecting expedition from Halls Creek to Tanami via the Gardner Range, and explored the country to the south and southeast as far as The Granites (then also known as Bugagee).

1930 Lake Mackay was discovered by the Mackay Aerial Survey Expedition (Mackay, 1934).

1932 Madigan (reported in Kleeman, 1934) investigated The Granites goldfield and collected specimens of the granite; he noted that the granite intrudes the gold bearing schistose rocks. Also in 1932, Terry (1937) reached the northeast shore of Lake Mackay from the east, and named several features in Highland Rocks and Lake Mackay Sheet areas.

1933 Terry (1934, 1937) returned on another expedition to the southern part of the region, exploring the northeast part of Webb and the eastern part of Stansmore Sheet areas before proceeding northeast to The Granites Sheet area. He gave names to several more features during the expedition.

1937–38 The Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) carried out geological investigations in the Tanami and The Granites goldfields. The results were reported by Hossfeld (1940a, 1940b) who later suggested an Early Proterozoic age for the low-grade metamorphic rocks at the two localities (Hossfeld, 1954).

1939 AGGSNA carried out a geophysical survey of The Granites goldfield, using potential-ratio and magnetic methods. The survey report, by Thyer, Rayner, & Nye, was not issued, but a summary of the results has been given by Daly (1962).

1938–48 Anglo Queensland Mining Pty Ltd, a subsidiary of Mount Isa Mines, examined The Granites goldfield, and put down 20 diamond-drill holes (Hall, 1953).

1947 Wolf Creek Meteorite Crater was discovered by Reeves (Reeves & Chalmers, 1949).

1949 and 1952 The CSIRO Division of Land Research, and the Bureau of Mineral Resources (BMR) carried out a regional survey of the Ord–Victoria region of Western Australia and the Northern Territory including Birrindudu and Gordon Downs Sheet areas. The geological results were reported by Traves (1955) and were later summarised by Traves & others (1970).

1955–56 BMR undertook a reconnaissance geological survey of the northeast part of the Canning Basin (Veevers & Wells, 1961; Casey & Wells, 1964). The area mapped included the part of The Granites-Tanami region covered by Billiluna, Lucas, and Stansmore Sheets, Explanatory Notes for which were compiled by Wells (1962a, b, c).

1959–62 Phillips, of Consolidated Zinc Pty Ltd, investigated parts of Tanami and The Granites Sheet areas (Phillips, 1959, 1961, 1962).

1960 Clark & Blockley, of New Consolidated Gold Fields (Australasia) Pty Ltd, discovered uranium mineralisation in the Killi Killi Hills (Clark & Blockley, 1960; Clark, 1961); details of the mineralisation are given in Prichard & others (1960). Crohn, BMR, investigated The Granites goldfield (Crohn, 1961).

1961 BMR carried out a low-level airborne radiometric survey of the Killi Killi Hills, part of the Gardner Range, and Tanami (Mulder, 1961).

1962 BMR carried out an airborne magnetic and radiometric survey of Tanami and The Granites Sheet areas (Spence, 1964; BMR, 1965a, 1965b).

1962 The results of gravity surveys carried out in the Canning Basin region between 1952 and 1960 were reported by Flavelle & Goodspeed (1962). The area covered includes Billiluna, Lucas, Stansmore, and parts of Gordon Downs and Webb Sheet areas.

1962–64 BMR and the Geological Survey of Western Australia (GSWA) jointly mapped the east Kimberley region (Dow & Gemuts, 1969), including Gordon Downs Sheet area (Gemuts & Smith, 1968).

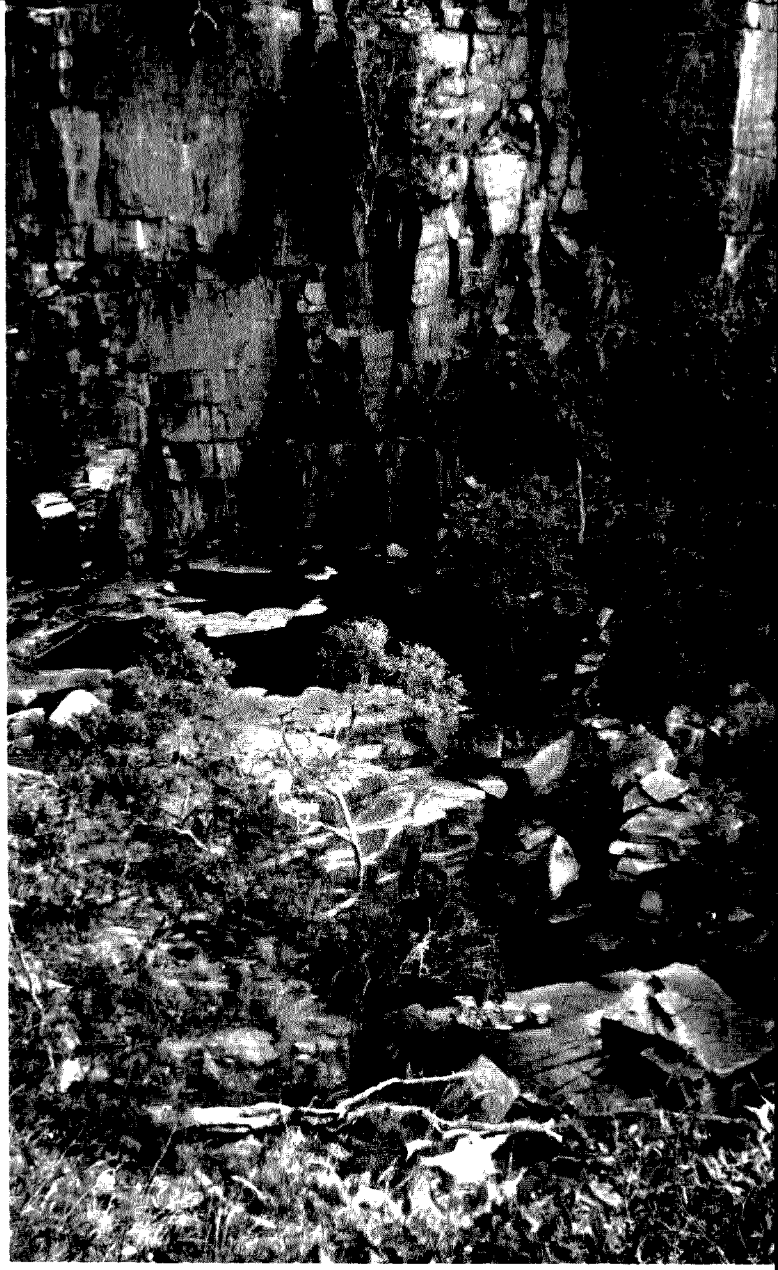

Fig. 8. Uritu Spring, at the foot of Larranganni Bluff, Gardner Range, on the Western Australia-Northern Territory border. (M1288/24)

1965 Dunn (BMR) paid a brief visit to the region, and outlined some of the geological features (Dunn, 1965). BMR surveyed the geology of the Wiso Basin at a broad reconnaissance level (Milligan & others, 1966). The survey included the easternmost parts of Birrindudu and Tanami Sheet areas. A gravity survey of Tanami Sheet area was carried out the same year.

1967 BMR carried out a reconnaissance gravity survey of Gordon Downs, Highland Rocks, and most of Birrindudu and The Granites Sheet areas. The report of this survey (Whitworth, 1970) also includes discussion of the gravity of adjacent sheet areas. An aeromagnetic survey was made of Birrindudu Sheet area (BMR, 1971).

1967–69 BMR geologists mapped the Victoria River region to the north (Sweet, 1977).

1968 Anaconda Australia Inc. carried out geological and geochemical investigations in the Black Hills area northeast of Tanami (Roberts, 1968).

Fig. 9. Cuestas of the eastern part of the Lewis Range; looking west, Lucas Sheet area. The scarp faces are up to 280 m high and are formed of Lewis Granite capped by Lewis Range Sandstone. (M2239/31)

1969 BMR geologists mapped Lake Mackay Sheet area (Nicholas, 1972), and visited the Alec Ross Range in the northeast of Webb Sheet area. Simpson photo-interpreted Birrindudu and Tanami Sheet areas (Simpson, 1971).

1970 Geopeko mapped parts of Tanami Sheet area (Twigg, 1970). At about the same time the company also carried out additional work both at Tanami and The Granites, including some diamond drilling, but the results of this work are not available.

Present investigations

The recent geological survey of The Granites-Tanami region commenced in 1971, when Blake, Hodgson, and Smith, all of BMR, mapped Birrindudu and Tanami Sheet areas (Blake & others, 1972, 1975). The following year a party consisting of Blake, Hodgson, and Muhling (GSWA) mapped The Granites and northernmost part of Highland Rocks Sheet areas, and the Precambrian parts of Billiluna, Lucas, and Stansmore Sheet areas (Blake & others, 1973). The remainder of Highland Rocks Sheet area and all but the northwest corner of Webb Sheet area were mapped in 1973 by Blake and Hodgson (Hodgson, 1974; Blake & Towner, 1974). The Canning Basin parts of Billiluna, Lucas, and Stansmore Sheet areas were mapped in 1972 by a joint BMR-GSWA party led by Yeates (Yeates & others, 1975). At the same time as the geological mapping, a program of shallow stratigraphic drilling was carried out by BMR drilling crews (Blake, 1974), mainly to determine the nature of the bedrock beneath the Cainozoic superficial sediments that cover most of the region, and an isotopic dating program was undertaken by Page (BMR) on some of the Precambrian rock units (Page & others, 1976). Explanatory Notes for the 1:250 000 Sheet areas have been published (Blake, 1975c, 1977; Blake & Yeates, 1977; Blake & others, 1977; Crowe & Muhling, 1977; Hodgson, 1975, 1976, 1977) and are listed in the Bibliography, as are other recent papers on the geology of the region (Blake, 1975a, 1978; Blake & Hodgson, 1975).

Several exploration companies investigated parts of the region during the survey period, including Esso Australia Ltd, who drilled several stratigraphic holes in Billiluna and Lucas Sheet areas (reported in Blake & others, 1973, and Blake, 1974), Trend Exploration, who carried out an airborne radiometric survey and some field work in the Mount Winnecke area between Tanami and Hooker Creek (Dunn, 1973), and CRA Exploration Pty Ltd, who made a reconnaissance airborne radiometric survey, followed by a ground survey, of the southeast corner of Tanami Sheet area (Klaric, 1972; Edwards, 1973).

Survey methods

Field work was planned from photogeological maps prepared by Simpson (1971, 1972) from the 1st edition geological maps of Billiluna, Lucas and Stansmore Sheet areas (Wells, 1962a, 1962b, 1962c), from 1:250 000 topographic maps, and from vertical aerial photographs. Observation sites were recorded on the aerial photographs, a list of which is given in Table 1: copies of these are available from the Division of

Fig. 10. Sand dunes, up to 30 m high, between Lakes Dennis and White; The Granites and Highland Rocks Sheet areas. (GA/8678)

National Mapping, Department of National Development, Canberra, as also are flight diagrams and 1:250 000 topographic maps. Traverses were undertaken using Land Rovers and helicopters—Land Rovers mainly in the north, and helicopters mainly in the south, where sand dunes, large salt lakes, and lack of tracks make this part of the region almost inaccessible for wheeled vehicles.

Mapping problems

The main problems encountered during the geological mapping arose from the region having been tectonically stable and subject to subaerial erosion and deposition throughout the Cainozoic and probably for most, if not all, of the Mesozoic and Palaeozoic. As a result the region has a subdued topography with few prominent landmarks, and is largely covered by Cainozoic superficial sediments. Outcrops of bedrock are commonly widely separated from one another (Fig. 11), and most rocks exposed are quartz-rich sandstones, which are difficult to tell apart. Other rocks cropping out are generally weathered, commonly to such a degree that they are difficult to identify either in the field or in the laboratory. In addition, there are few distinctive marker horizons among the Precambrian rock units, and abrupt changes in bedding orientation are common. Consequently, considerable difficulties were found in making correlations between many of the different outcrops, working out some of the structures, and collecting fresh rock samples for petrographic examination and analysis.

Acknowledgements

P. A. Smith, BMR, was a geologist in the 1971 field party.

We thank for their help during the field work: 'Tas' Armstrong, 'Doc' Ashworth, John Debenham, Jerry Fish, Don Hughes, Mick Legrand, Ron Parneman, Jim Pollard, Clive Richardson, Fred Stevenson, and Mark Vale; and Jayrow Helicopters personnel, Ron Newman, John Bitcon, and Tony Gadsden.

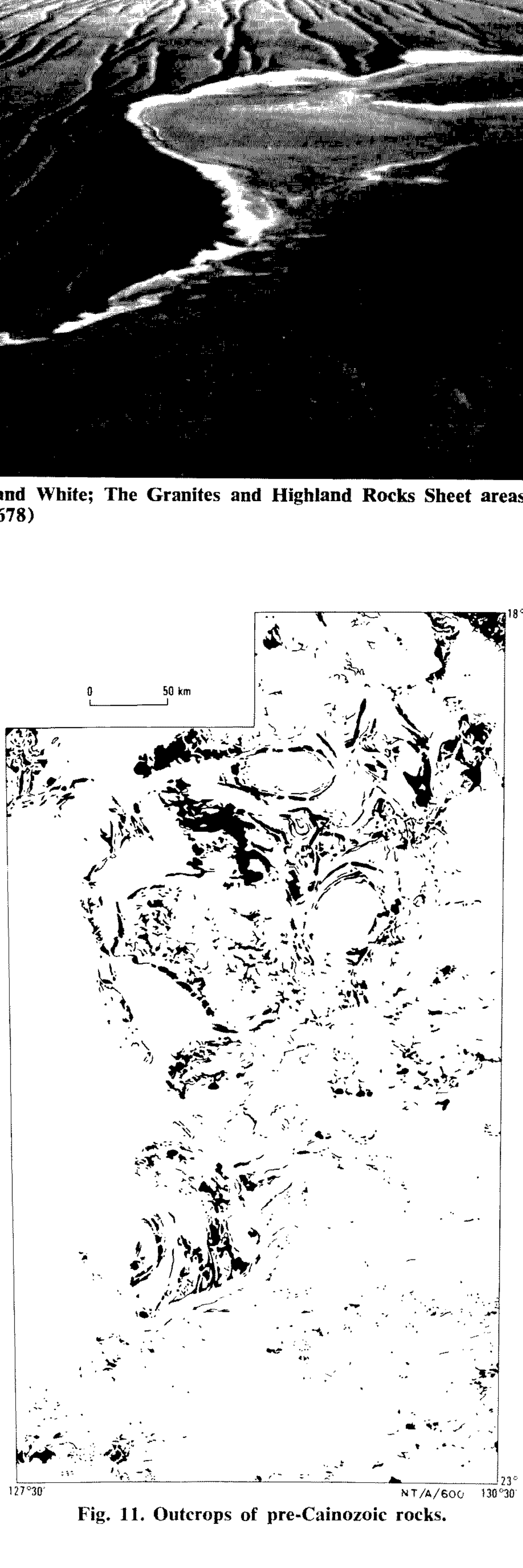

Fig. 11. Outcrops of pre-Cainozoic rocks.

Fig. 12. Sand plain with low laterite rises in the central part of Highland Rocks Sheet area. The laterite is developed on gneiss, schist, and granite of the Arunta Complex, and forms rises up to 10 m high. (GA/8671)

TABLE 1. AERIAL PHOTOGRAPHS OF THE GRANITES-TANAMI REGION

Western Australia			*Northern Territory*		
Name	*Nominal scale*	*Date*	*Name*	*Nominal scale*	*Date*
Gordon Downs	1:50 000	1948	Birrindudu	1:50 000	1948
Gordon Downs	1:80 000	1968	Birrindudu	1:80 000	1967
Billiluna	1:50 000		Tanami	1:50 000	1950
Billiluna	1:80 000	(1968 (run 1) (1971 (runs 2-8)	Tanami	1:80 000	(1967 (run 1) (1971 (runs 2-8)
Lucas	1:50 000	1950	The Granites	1:50 000	1950
Lucas	1:80 000	1971	The Granites	1:80 000	1971
Stansmore	1:50 000	1953	Highland Rocks	1:50 000	1950
Stansmore	1:80 000	1971	Highland Rocks	1:80 000	(1971 (run 1) (1972 (runs 2-8)
Webb	1:50 000	1953			
Webb	1:80 000	1972			

We also thank for their help and hospitality: Mr & Mrs Fred Colson of Mongrel Downs, Mr & Mrs Bruce Farrands of Rabbit Flat, Father Hevern and his colleagues of Balgo Mission, Mr & Mrs John Kersh of Balgo, Mr & Mrs Len Peterson of Sturt Creek, Mr & Mrs. Bob Savage of Supplejack Downs, and Mr & Mrs Les Verdon of Billiluna.

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Nomenclature

Precambrian subdivisions

The subdivision of the Precambrian used is that adopted by the Bureau of Mineral Resources: the Archaean is older than 2300 m.y., the Early Proterozoic ranges from 2300 m.y. to 1770 m.y., the Carpentarian from 1770 m.y. to 1400 m.y., and the Adelaidean from 1400 m.y. to 570 m.y.

Fig. 13. Lake Mackay. The lake surface is a white salt crust; the shore in the foreground and the small island in the centre are formed of aeolian and evaporitic sediments, which support a sparse vegetation of low grass and small herbaceous plants. (GA/8954)

The formal names of all rock units described have been approved by the Stratigraphic Nomenclature Committee of the Geological Society of Australia. Definitions of these units are given in the Appendix.

Sandstones

In this work the Precambrian sandstones are classified according to Pettijohn, Potter & Siever (1972) as follows: sandstone containing less than 15 percent matrix is termed *quartz arenite*, *sublithic arenite*, and *lithic arenite*, where over 95 percent, 75 to 95 percent, and less than 75 percent, respectively, of the detrital grains are quartz; sandstone having over 15 percent matrix is termed *greywacke;* if abundant volcanic rock fragments are present the sandstone is termed *tuffaceous*, and if it contains megascopic glauconite it is termed *glauconitic*. The arenites characteristically have a quartz overgrowth cement: that is, a cement of quartz in optical continuity with adjacent detrital quartz grains.

Phanerozoic sandstones are termed *quartzose* if at least 75 percent of the detrital grains are quartz; otherwise they are described as *lithic*. These sandstones commonly have over 15 percent matrix, and would be termed greywackes by Pettijohn and others (1972).

The so-called lithic grains in both the Precambrian and Phanerozoic sandstones commonly consist of white kaolinitic clay, which may be altered feldspar; hence many of the sandstones may have been feldspathic originally.

Bedding-thickness terms used are: less than 1 cm, *laminated;* 1-50 cm, *thin-bedded;* 50 cm-2 m, *medium-bedded;* over 2 m, *thick-bedded*.

Plutonic igneous rocks

The classification of Hatch, Wells & Wells (1961) is used for plutonic igneous rocks. Those having an average grain-size of less than 1 mm are described as *fine-grained;* those of 1-5 mm, *medium-grained;* those of 5 mm-3 cm, *coarse-grained;* and those of over 3 cm, *pegmatitic*.

Metamorphic rocks

Terms describing metamorphic facies are as defined by Turner & Verghoogen (1960). Phyllite is distinguished from shale and mudstone in having fine white mica developed along cleavage planes; schist is characterised by the development of coarser mica.

OUTLINE OF GEOLOGY

Tectonic units

The area described comprises parts of seven major Precambrian tectonic units (Fig. 1). These are The Granites-Tanami Block, Halls Creek Province and Arunta Block, which together form the basement, and four basins—Birrindudu, Amadeus, Ngalia, and an unnamed basin in the northwest—which contain Carpentarian and Adelaidean sedimentary rocks. Marked angular unconformities separate the basement rocks from the younger basin sediments.

The Granites-Tanami Block (Geological Society of Australia, 1971) is exposed in the centre and north of the area. It is made up of Early Proterozoic metasediments, metavolcanics, unmetamorphosed sedimentary and volcanic rocks, and Early Proterozoic and Carpentarian granites. The *Halls Creek Province* (Geological Society of Australia, 1971) is represented by metamorphics cropping out in the Halls Creek Mobile Zone in the northwest. In the south, Early Proterozoic metamorphics and Carpentarian sedimentary, volcanic, and granitic rocks form the *Arunta Block*. The boundaries between the three basement blocks are concealed. However, the Granites-Tanami Block is probably separated from the Halls Creek Province to the northwest by a concealed northeast-trending major fault, and it appears to merge southwards into the Arunta Block. The fault in the northwest is also taken as the boundary between the *Birrindudu Basin* and the *unnamed basin*, both of which contain unmetamorphosed Carpentarian and Adelaidean sedimentary rocks. The Adelaidean sediments of the Birrindudu Basin are correlated with sediments of the *Amadeus* and *Ngalia Basins* to the south. The four basins were probably interconnected at times during the Adelaidean.

The Precambrian rocks of the area are overlain in the northeast by Lower Cambrian basalt and in the centre and west by younger Palaeozoic sediments. The Palaeozoic rocks are generally flat-lying, and appear to be non-marine, occupying shallow erosional, rather than structural, basins. Palaeozoic marine sediments of the Wiso and Canning Basins overlie the Precambrian rocks to the east and west, respectively.

Stratigraphy and regional correlations

(Figs. 14, 15) (see also Blake, 1978)

The oldest rocks exposed in The Granites-Tanami Block are tightly folded low-grade metasediments and metavolcanics of the *Tanami Complex*. These are correlated with lithologically similar rocks of the *Halls Creek Group*, in the Halls Creek Province exposed in the northwest, and the *Arunta Complex*, exposed in the Arunta Block in the south and southeast. Other possible correlatives are the Inverway Metamorphics in the Victoria River region to the north, highly metamorphosed basement rocks of the Tennant Creek Block, the Murphy Metamorphics of the Murphy Tectonic Ridge, at the southeast end of the McArthur Basin, and the Pine Creek geosynclinal succession, northwest of the McArthur Basin. The metamorphism of the Halls Creek Group has been isotopically dated at 1961 ± 27 m.y. (Dow & Gemuts, 1969), indicating that this group and its correlatives are at least as old as Early Proterozoic, and could be Archaean. However, a recent reassessment of the available isotopic data shows that the probable maximum age for the Halls Creek Group is 2200 m.y. (Page, 1976); hence an Archaean age for these rocks is considered unlikely.

The Tanami Complex is overlain unconformably by three younger Early Proterozoic units, the *Mount Winnecke Formation, Supplejack Downs Sandstone,* and *Pargee Sandstone;* these three formations are not metamorphosed, are moderately to tightly folded, and are considered to be more or less equivalent in age. The Mount Winnecke Formation, unlike the other two units, includes acid lavas and pyroclastics as well as sedimentary rocks, and is intruded by a high-level granitic unit. This intrusive unit, the *Winnecke Granophyre,* is dated at 1802 ± 15 m.y., and is probably comagmatic with the acid lavas of the Mount Winnecke Formation, which are dated at 1808 ± 15 m.y. The Winnecke Granophyre also intrudes the Tanami Complex, as do other granitic rocks of The Granites-Tanami Block, including *The Granites Granite, Slatey Creek Granite,* and *Lewis Granite.*

The Mount Winnecke Formation and Winnecke Granophyre appear to be somewhat younger than the Whitewater Volcanics (about 1900 m.y.) and later granitic units, such as the Bow River Granite (about 1850 m.y.), of the Kimberley region, and are slightly older than the Cliffdale Volcanics and associated granite of the Murphy Tectonic Ridge; the Cliffdale Volcanics, dated at 1770 ± 20 m.y., define the base of the Carpentarian System (Dunn, Plumb, & Roberts, 1966). The Mount Winnecke Formation and its equivalents may be correlated with the Kimberley Basin succession of the Kimberley region, the Bunda Grit of the Victoria River region, and perhaps the Warramunga Group of the Tennant Creek Block. Granites similar in age to those of The Granites-Tanami Block crop out in the Arunta Block to the southeast, in the Tennant Creek Block, and on the Murphy Tectonic Ridge.

A major unconformity separates rocks of The Granites-Tanami Block from overlying mainly clastic sedimentary rocks deposited in the Birrindudu Basin. These younger rocks comprise the Carpentarian *Birrindudu Group,* the Adelaidean *Redcliff Pound Group,* and their probable correlatives in the northwest and southwest. The Birrindudu Group, dated at about 1560 m.y., is moderately to gently folded. It may correlate with the *Mount Parker Sandstone* and *Bungle Bungle Dolomite* of the unnamed basin in the northwest, which overlie the Halls Creek Group, and with the *Limbunya Group,* which overlies the Bunda Grit and Inverway Metamorphics in the Victoria River region. Part of the Tawallah and McArthur Groups of the McArthur Basin may also be stratigraphic correlatives of the Birrindudu Group.

Carpentarian rocks younger than the Birrindudu Group are exposed in the Arunta Block to the southwest of the Birrindudu Basin: these are the *Pollock Hills Formation,* which includes acid lava dated at 1510 ± 240 m.y., and the *Mount Webb Granite,* which intrudes this formation. The Mount Webb Granite, dated at 1518 ± 40 m.y., was probably comagmatic with the acid lava of the Pollock Hills Formation.

The Redcliff Pound Group overlies the Birrindudu Group unconformably, and is generally gently dipping. It is correlated with the *Heavitree Quartzite* and *Bitter Springs Formation* of the Amadeus Basin, which crop out in the southwest, and with the *Vaughan Springs Quartzite* of the Ngalia Basin, exposed in the southeast. The Redcliff Pound Group is therefore younger than

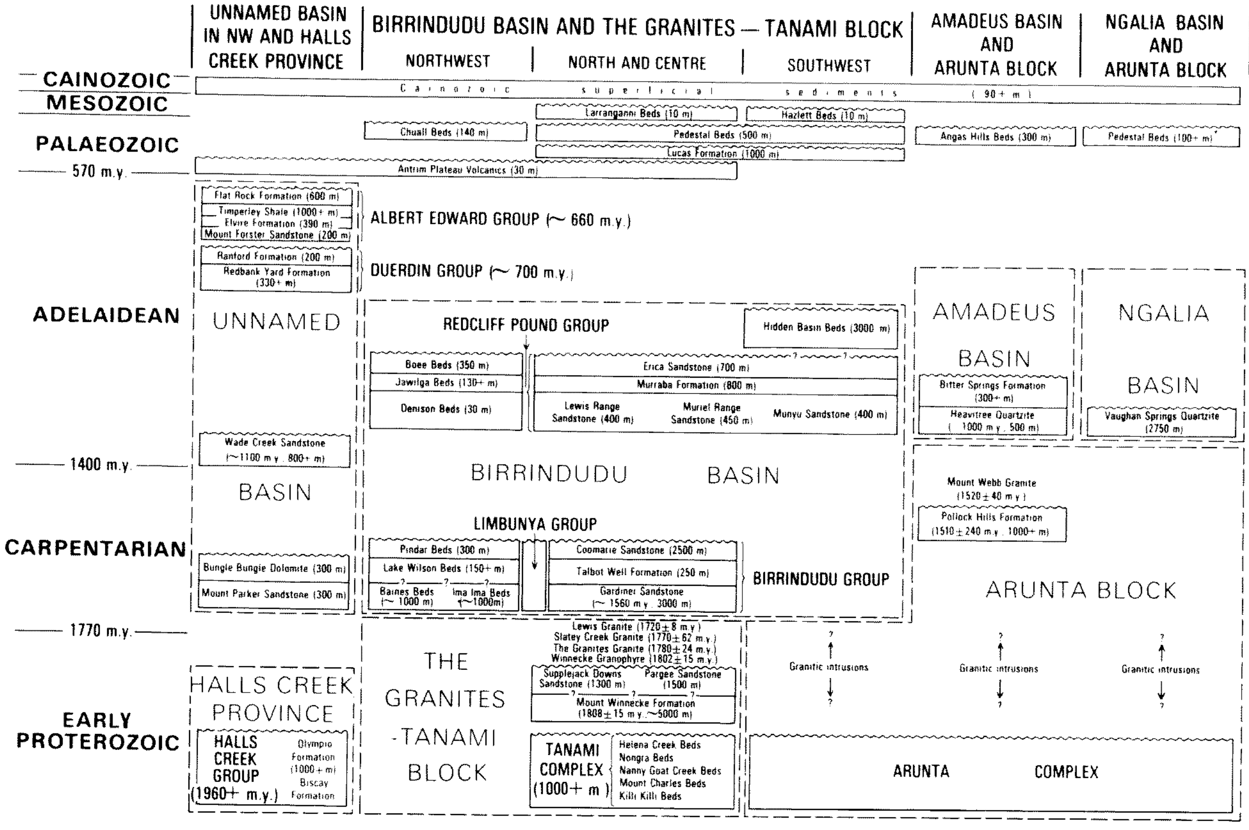
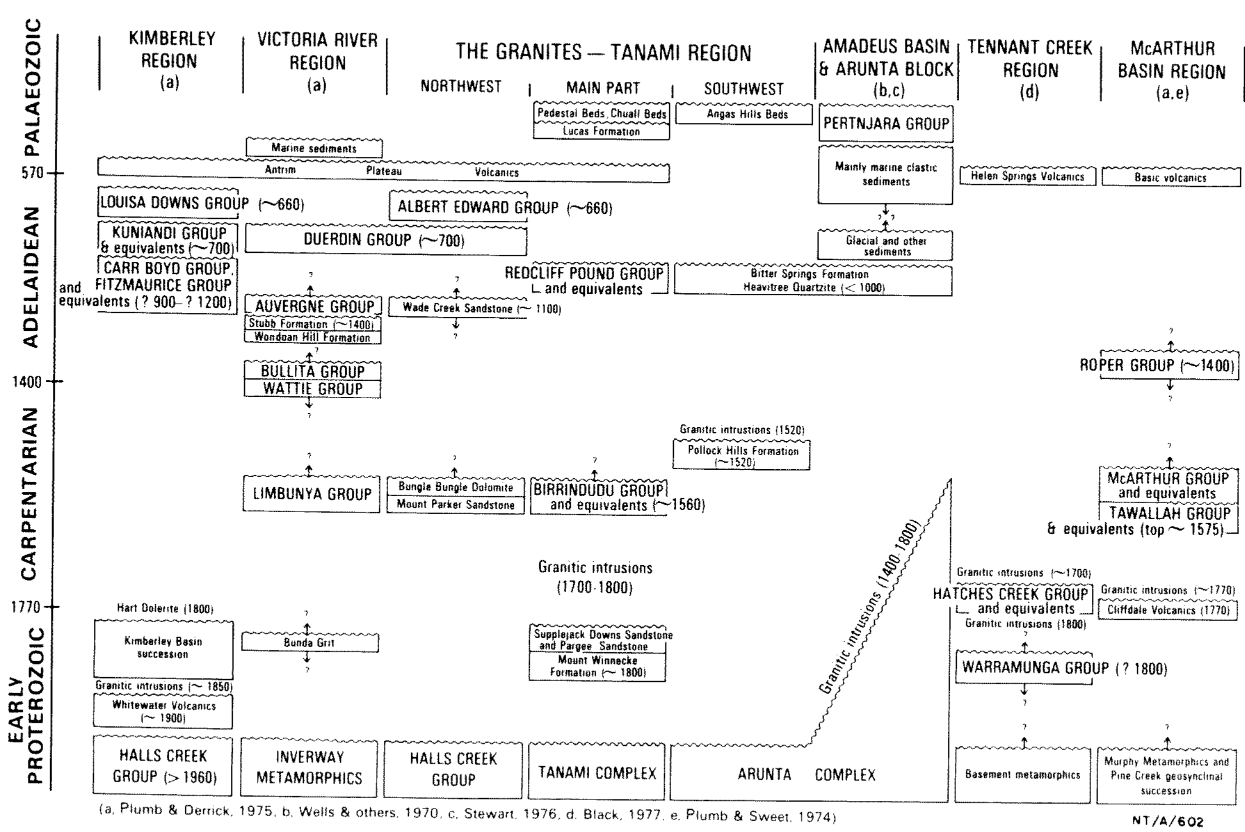


Fig. 14. Stratigraphic correlation chart for The Granites-Tanami region.



(a. Plumb & Derrick, 1975. b. Wells & others, 1970. c. Stewart, 1976. d. Black, 1977. e. Plumb & Sweet, 1974)

Fig. 15. Regional correlation chart—Precambrian and Palaeozoic (isotopic ages in millions of years).

1076 ± 50 m.y., the age of migmatite underlying Heavitree Quartzite to the east-southeast (Marjoribanks & Black, 1974) and was probably deposited less than 1000 m.y. ago. Other possible stratigraphic equivalents are the younger parts of the Carr Boyd and Fitzmaurice Groups on the northeast margin of the Kimberley region. No correlatives of the Redcliff Pound Group are known in the unnamed basin in the northwest, where the Bungle Bungle Dolomite is overlain unconformably by the *Wade Creek Sandstone*, dated at about 1100 m.y. The upper part of the Wade Creek Sandstone is correlated with the lower part of the Auvergne Group of the Victoria River Basin. Both these units are overlain by the *Duerdin Group*, which includes glacigene rocks, and is dated at about 700 m.y. Glacial rocks of probably similar age to the Duerdin Group are unconformable on Bitter Springs Formation and Vaughan Springs Quartzite outside The Granites-Tanami region. In the northwest, the Duerdin Group is separated by an unconformity from the overlying *Albert Edward Group*, dated at about 650 m.y., the youngest Proterozoic group of rocks exposed in the region.

The Phanerozoic rocks in The Granites-Tanami region are generally flat-lying and overlie the Precambrian rocks with marked angular unconformity. All are probably non-marine. The oldest exposed are basalt lavas and minor associated sediments of the *Antrim Plateau Volcanics*. These are probably Lower Cambrian —older than the earliest sediments preserved in the Wiso Basin to the east, which are later Cambrian, and in the Canning Basin to the west, which are Ordovician. The other Palaeozoic units exposed are mapped as the *Lucas Formation*, *Pedestal Beds*, *Angas Hills Beds*, and *Chuall Beds*; these may be similar in age to the Devonian and possibly Lower Carboniferous non-marine Pertnjara Group of the Amadeus Basin. There are also scattered outcrops of probably Mesozoic sediments, which include the *Hazlett Beds* and *Larranganni Beds*. In addition, superficial Cainozoic deposits cover most of the area.

Economic mineralisation

Little mineral exploration has taken place in the region, and the only known mineralisation of possible economic significance is gold and minor copper in the Tanami Complex, notably at Tanami and The Granites, and uranium and associated rare earths at the base of the Birrindudu Group in the Killi Killi Hills, south of the Gardner Range.

EARLY PROTEROZOIC TO CARPENTARIAN BASEMENT

THE GRANITES-TANAMI BLOCK

Except in the south, where it appears to grade into the Arunta Block, The Granites-Tanami Block forms the basement to the Birrindudu Basin. It comprises the Tanami Complex, which consists of Early Proterozoic metamorphics; younger Early Proterozoic unmetamorphosed Pargee Sandstone, Supplejack Downs Sandstone, and Mount Winnecke Formation, which postdate the Tanami Complex; and various intrusive granites, ranging in age from late Early Proterozoic to early Carpentarian. The distribution of rock units in The Granites-Tanami Block is shown in Figure 16.

TANAMI COMPLEX

The oldest rocks exposed in The Granites-Tanami Block are low-grade regionally metamorphosed rocks mapped as the Tanami Complex (defined by Blake & others, 1975). Outcrops of these rocks are widely scattered in the centre and north of the region. Those in Western Australia were previously mapped as Halls Creek Metamorphics (Casey & Wells, 1964) and undivided Halls Creek Group (Dow & Gemuts, 1969). The complex generally forms gently undulating terrain with rocky hills and ridges. Locally, it is capped by laterite, and the exposed rocks are invariably much weathered.

The Tanami Complex consists of metasediments and metavolcanics, which probably reach a thickness of several thousands of metres. Because of tight folding, probable complex faulting, and a lack of marker beds, no sequences have been established within it, although five separate units, based on different proportions of rock types present and on geographic separation, are recognised. These units, the Killi Killi, Mount Charles, Nanny Goat Creek, Nongra, and Helena Creek Beds, may be lateral equivalents. In addition, some outcrops are mapped as undivided Tanami Complex.

The rocks of the complex are generally steeply dipping, and commonly possess a cleavage or schistosity developed more or less parallel to the bedding and probably also to the axial planes of tight to isoclinal major folds. Some rocks show one or more fracture cleavages. The metamorphic grade is difficult to establish, because most metamorphic minerals other than quartz and white mica have been altered during weathering, and there is a general absence of green minerals, such as chlorite and actinolite. However, sedimentary and volcanic structures and textures are commonly preserved, and it is thought that most of the complex probably belongs to the low greenschist facies of regional metamorphism. Local higher-grade metamorphism, indicated, for instance, by the presence of fibrolite, a variety of sillimanite, can be related to nearness to granite intrusions. Such higher-grade metamorphism is most common in the south of The Granites-Tanami Block. The metamorphism is most apparent where the rocks are relatively fresh; at many exposures weathered rocks do not show obvious metamorphic effects. Throughout the complex cross-cutting quartz veins are common; most of these are white, but bluish-grey veins are present locally.

The Tanami Complex is of economic interest, as it is host for the known lode gold deposits in the region (mainly at Tanami and The Granites). It also contains traces of copper mineralisation and many gossans.

Stratigraphic relations and regional correlations indicate that the Tanami Complex is Lower Proterozoic. The complex is intruded by granites, isotopically dated as late Early Proterozoic and early Carpentarian, and is overlain unconformably by late Early Proterozoic, Carpentarian, and Adelaidean units. It is similar in lithology, deformation, and metamorphism to the Halls Creek Group of the Halls Creek Province, and is thought to be stratigraphically equivalent to this group. The Halls Creek Group is older than 1961 ± 27 m.y.,

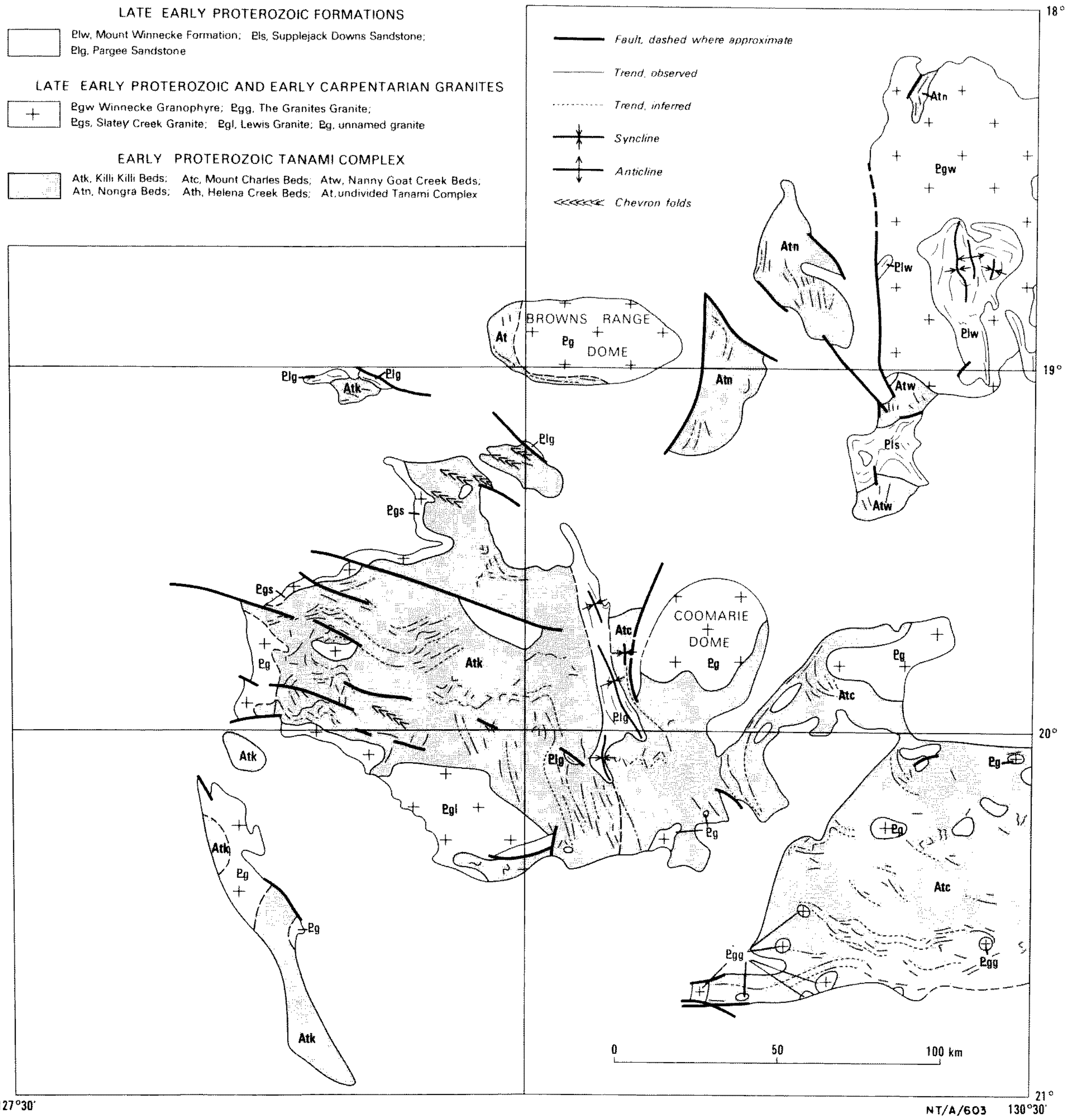


Fig. 16. Distribution of rock units in The Granites-Tanami Block (solid geology).

the age of the regional metamorphism (Dow & Gemuts, 1969; Bennett & others, 1975), but is probably younger than 2200 m.y. (Page, 1976); the Archaean age suggested by Dow & Gemuts (1969) and Gellatly (1971) is now considered unlikely. Rocks of the Tanami Complex are also correlated with metamorphic rocks of the Arunta Complex to the south.

Killi Killi Beds

The Killi Killi Beds, defined by Blake & others (1975), crop out in the west of The Granites-Tanami Block, and are best exposed in foothills flanking parts of the Gardner Range. They are named after the Killi Killi Hills, which straddle the Northern Territory-Western Australia border at 19°45'S. The maximum thickness of the unit is unknown, but a minimum thickness of several thousand metres is estimated from aerial photographs.

The reference area for the Killi Killi Beds is 5 km south of Mount Stubbins (at 19°13'30"S, 128°54'30"E) in the Gardner Range, in Billiluna Sheet area. Here, schistose greywacke, lithic arenite, siltstone and mudstone, the main rock types of the unit, are well displayed in steep hilly terrain. Other rock types present locally are quartzite, banded chert, basalt, dolerite, gabbro, and acid volcanics. Most rocks possess a foliation given by secondary mica generally lying parallel to bedding. An oblique fracture cleavage is also commonly developed, especially in greywacke and lithic arenite.

Lithology

The greywacke is mainly medium to fine-grained, but is locally coarse and gritty. It is grey to greenish grey where unweathered, and generally forms beds about 1 m thick, some of which are graded. It is composed of

Fig. 17. Steeply dipping and tightly folded Killi Killi Beds (foreground and middle distance) overlain unconformably by flat-lying Gardiner Sandstone (background); west side of the Gardner Range northeast of Tent Hill, Billiluna Sheet area. (GA/7996)

subangular clasts, mostly of quartz, but also of quartzite, schist, tourmaline, zircon and feldspar, set in a recrystallised fine matrix of quartz and sericite. With decreasing amount of matrix, the greywacke grades into lithic arenite, which is mostly coarser grained, contains rounder clasts, and commonly shows cross-bedding. Siltstone forms beds generally less than 1 m thick interbedded with greywacke; some is laminated and shows small-scale low-angle cross-bedding.

Banded red, cream, grey, and black chert is present in the east, close to outcrops of Mount Charles Beds. The chert consists of very fine quartz and minor sericite, magnetite, and hematite. Some contains sufficient hematite to be classified as banded iron formation.

Basic igneous rocks are exposed at a few places. One such exposure is near the eastern end of the Lewis Range, in Lucas Sheet area (at 20°24′00″S, 128°52′00″E), where basalt is associated with schistose to phyllitic greywacke, lithic arenite, and mudstone, and is veined by granite. The basalt here shows pillow-like structures, consisting of dark very fine-grained skins, about 1 cm thick, enclosing amygdaloidal interiors, and some shows scaly 'popcorn' weathering. Most of the known dolerite and gabbro exposures are in the south of Billiluna Sheet area, where field evidence suggests they may form sills. These rocks have dark brown to red weathered surfaces on which ophitic textures can commonly be recognised.

Acid volcanic rocks have been found in the Killi Killi Beds only in the northeast, where they are interbedded with greywacke. Non-porphyritic acid tuff crops out on the south side of the Pingidijarra Hills, between the Gardner and Pargee Ranges; acid porphyry is exposed at the same locality and also 8 km east of Mount Stubbins and 9 km north of the Jellebra Rockholes. The porphyry contains phenocrysts of quartz and altered feldspar and mica in a fine-grained recrystallised groundmass.

At some places much-weathered sedimentary rocks of the Killi Killi Beds have been replaced by iron oxide, and now consist of lateritic ironstone, forming false gossans. A typical example is a small conical hill east of the Nora Range, at 20°16′00″S, 129°08′00″E.

Prominent ridge-forming quartz veins, many kilometres long, which cross some outcrops of Killi Killi Beds, mainly in the south, are inferred to be along fault lines.

Depositional environment

The presence of greywacke showing graded bedding and interbedded siltstone showing small-scale cross-bedding indicates deposition by turbidity currents, probably in deep water. The beds of lithic arenite may have resulted from local reworking of the turbidites by traction currents. The clasts in the sediments suggest derivation from a mixed igneous and metamorphic terrain.

Stratigraphic relations

The Killi Killi Beds are intruded by the Slatey Creek Granite, Lewis Granite, and unnamed granitic rocks, and are unconformably overlain by the Lower Proterozoic Pargee Sandstone, the Carpentarian Birrindudu Group, and the Adelaidean Redcliff Pound Group. They are correlated with the Olympio Formation of the Halls Creek Group on the basis of similarity in lithology and deformation.

At granite contacts the Killi Killi Beds commonly form parts of lit-par-lit injection zones, in which conformable sheets of granite several metres thick are intercalated with sequences of greywacke, siltstone, and shale thermally metamorphosed to quartzitic and micaceous hornfels. One such lit-par-lit zone is well exposed 5 km northeast of Point Nelligan, on the north side of the Lewis Range. Unconformities between the Killi Killi Beds and younger Precambrian units are well exposed around the Gardner Range (Fig. 17), the Killi Killi Hills, the Lewis Range, and the Wilson Range.

Mount Charles Beds

In the southeast of The Granites-Tanami Block, south of latitude 19°14′S and east of longitude 129°17′E, the probable stratigraphic equivalents of the Killi Killi Beds are the Mount Charles Beds (Blake & others, 1975), the unit of the Tanami Complex that contains all the known gold lodes in the region. This unit is locally complexly folded, and minor contortions are common.

Lithology

The characteristic rock types of the Mount Charles Beds are thin-bedded to laminated chert, silicified siltstone, and phyllitic siltstone (Fig. 18); the chert ranges in colour from white to grey-green and black. Also present locally are interbedded phyllitic to schistose greywacke, siltstone, and shale; higher-grade schist; breccia-veined massive quartzite; thin-banded gossanous quartz-ironstone; jaspilite; altered basic volcanics; and acid porphyry.

The chert is commonly recrystallised to quartzite, some of which has a glassy appearance. The recrystallisation may be partly a regional metamorphic effect, but some can be attributed to thermal metamorphism associated with granite intrusions. The black chert consists of very fine magnetite and quartz, and may contain enough iron to be termed banded iron formation. Some of the chert may represent silicified carbonate, and some may be silicified clay, as, for instance, at Mount Charles and 13 km northeast of Rabbit Flat, where bands of kaolinite up to 8 cm thick grade into chert along strike.

Of the other rock types within the Mount Charles Beds, interbedded greywacke, siltstone, and shale are the most widespread, and are indistinguishable from similar rocks of the Killi Killi Beds. Micaceous and locally hematitic schist crops out mainly near granite exposures, as near The Granites goldfield and Muriel Range, where it accompanies recrystallised banded chert. Local thermal metamorphic effects in schist include the development of porphyroblasts of chiastolite (generally pseudomorphed by sericite or iron oxide), garnet (generally weathered to iron oxide), and tourmaline. Unaltered garnet has been found at depth in The Granites goldfield. Some of the schist near The Granites contains abundant microcline, and may be either metamorphosed arkose or granite, but most probably represents metamorphosed greywacke, siltstone and shale.

Gossanous ironstone is interbedded with banded chert and siltstone at several localities, and commonly forms ridges, the most prominent being in the Black Hills northeast of Tanami. At least some of the gossans are developed in black carbonaceous pyritic shale (Phillips, 1962). Jaspilite is also locally associated with banded chert.

Weathered and altered basic volcanics, with basaltic textures preserved, crop out in the abandoned gold mining area at Tanami. Basic volcanics metamorphosed to amphibolite are exposed at several localities elsewhere, and were intersected in several stratigraphic drill holes in the Tanami Sheet area (Blake, 1974). It is not known whether the basic bodies are extrusive or intrusive. Acid porphyry has been recorded at one locality only, 5 km north of the Macfarlanes Peak Range.

Magnetite appears to be a common accessory mineral in the Mount Charles Beds. This is indicated by the intense aeromagnetic anomaly patterns given by most outcrops of the unit (Spence, 1964; BMR, 1965a, 1965b).

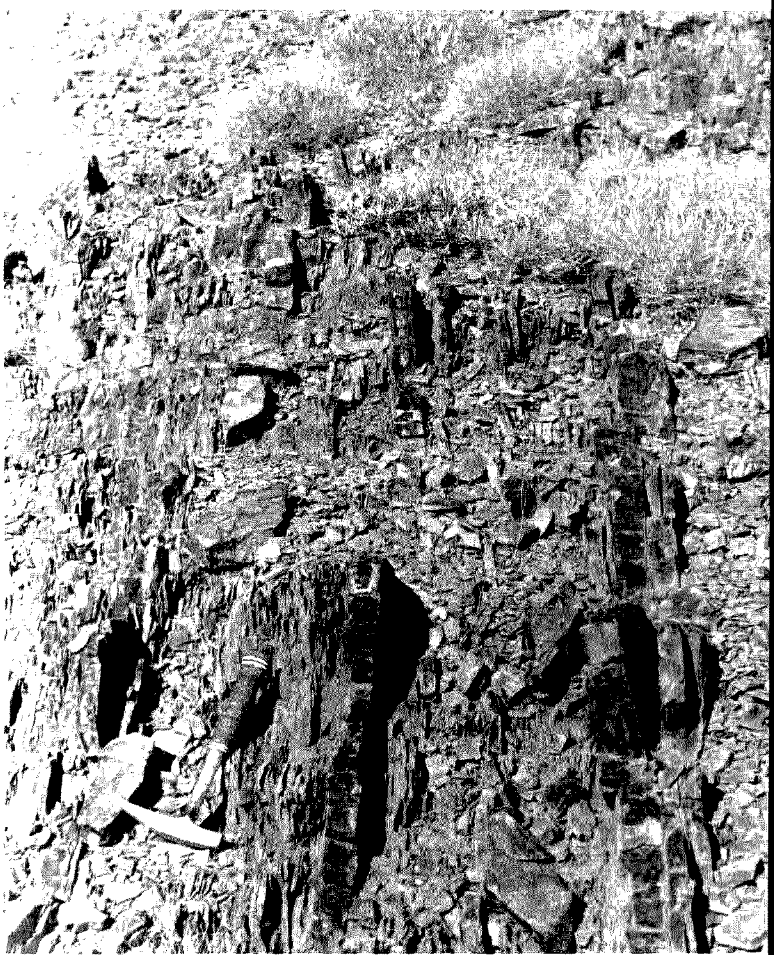


Fig. 18. Steeply dipping, thinly interbedded chert and siltstone of the Mount Charles Beds; near Mount Charles, in the Black Hills, Tanami Sheet area. (M1352/33)

Depositional environment

The Mount Charles Beds differ markedly from the Killi Killi Beds in having a much higher proportion of fine-grained sedimentary rocks, especially chert (mainly representing silicified carbonate clay, and banded iron formation). Such fine-grained rocks were deposited under stable conditions, probably in shallow water with little influx of terrigenous material. At times during deposition, restricted circulation led to the production of black carbonaceous pyritic shale. Local greywacke and interbedded siltstone indicate sporadic turbidity current deposition. The source rocks for the turbidites were probably the same as those for the turbidites of the Killi Killi Beds.

Stratigraphic relations

The Mount Charles Beds are intruded by The Granites Granite and unnamed granitic rocks, and are overlain unconformably by Lower Proterozoic rocks (the Pargee Sandstone and possibly the Mount Winnecke Formation), by the Carpentarian Birrindudu Group and Adelaidean Redcliff Pound Group, and by Palaeozoic units. They are correlated with other units of the Tanami Complex to the north, as well as with the Killi Killi Beds to the west, and also with metamorphic rocks of the Arunta Complex to the south.

Nanny Goat Creek Beds

The Nanny Goat Creek Beds (Blake & others, 1975) are confined to the northeast part of the Tanami Sheet area, north of latitude 19°40'S and east and south of the Ware Range. Unlike the other units of the Tanami Complex, they consist predominantly of volcanic rocks, especially in the north.

Lithology

The volcanics consist of ignimbritic acid porphyry, amygdaloidal non-porphyritic basaltic lava flows, patchily porphyritic basalt that may be intrusive, and tuff. In the acid porphyry the phenocrysts are generally less than 2 mm long; most are of altered feldspar, but subordinate phenocrysts of quartz and altered ferromagnesian minerals are also commonly present, as also are small altered xenoliths and fiamme. Tuff, which crops out mainly in the northeast, is recrystallized to a fine mosaic of white mica, quartz, iron oxide, and clay; its original clastic nature is indicated by detrital grains of tourmaline and rare pebbles. The recrystallisation is attributed to thermal metamorphism associated with the intrusion of the nearby Winnecke Granophyre. Bedding in the tuff is marked by close jointing, which is parallel to local thin lenses and interbeds of arenite. The basaltic rocks show well-preserved igneous textures, although the original minerals have been replaced by iron oxide and clay.

Subordinate sedimentary rocks include greywacke, lithic arenite, phyllitic to schistose shale and siltstone, and, in the south, minor banded chert similar to that characteristic of the Mount Charles Beds, the probable lateral equivalent of the Nanny Goat Creek Beds. Part of the Nanny Goat Creek Beds may have been deposited in shallow water, but at least part, including the ignimbritic acid porphyry, is probably terrestrial.

Stratigraphic relations

The unit is overlain unconformably by the Lower Proterozoic Supplejack Downs Sandstone and by the Gardiner Sandstone of the Carpentarian Birrindudu Group, and is probably intruded by the Lower Proterozoic Winnecke Granophyre. It appears to be generally less affected by regional metamorphism than are units of the Tanami Complex to the south, as original textures are little changed, except near the Winnecke Granophyre, and few schistose rocks are developed.

Nongra Beds

In the northeast of The Granites-Tanami Block, outcrops of the Tanami Complex west of the Ware Range and east and south of the Birrindudu Range have been mapped as Nongra Beds (Blake & others, 1975). These beds consist of interbedded phyllitic shale, siltstone, greywacke, and lithic arenite; banded chert; tuff; and acid porphyry. The tuff is micaceous and medium to fine-grained, and contains little or no quartz. The acid porphyry appears to be similar to that of the Nanny Goat Creek Beds. The Nongra Beds are overlain unconformably by the Birrindudu Group and the Antrim Plateau Volcanics. Most of their outcrops, especially those south of the Birrindudu Range, are capped by laterite.

Helena Creek Beds

The Helena Creek Beds (Blake & others, 1975) are the most northern representatives of the Tanami Complex in The Granites-Tanami Block. They crop out in a narrow belt northwest of the Winnecke Range, where they are intruded by Winnecke Granophyre and unconformably overlain by Antrim Plateau Volcanics. Lithic arenite, greywacke, and conglomerate, which contain clasts of quartz, chert, jasper, quartzite, phyllite, and acid volcanics are exposed in the north of the outcrop area, together with phyllitic mudstone. Thin-bedded to laminated grey tuff and acid porphyry are exposed in the southeast, and massive maroon tuff and quartzitic hornfels crop out in the southwest. The massive tuff in the southwest is a fine-grained, iron-stained aggregate of quartz, sericite, minor chlorite, and some tourmaline grains.

Undivided Tanami Complex

Rocks of the Tanami Complex which have not been assigned to any of the named units crop out in two areas in The Granites-Tanami Block. One of these is in the northwest, in the southwest of the Browns Range Dome. Here, schist, banded chert, schistose conglomerate, sublithic arenite, hornfels, and quartzite are overlain unconformably by Gardiner Sandstone. The other area is on the east side of The Granites-Tanami Block, east and southeast of the Farrands Hills, where sheared and brecciated quartzite, partly recrystallised sublithic arenite, and schistose greywacke, siltstone, mudstone, and amphibolite crop out. In both areas the Tanami Complex rocks are intruded by unnamed granite.

Metamorphism

Most rocks of the Tanami Complex belong to the greenschist facies of regional metamorphism, although locally, in the southeast of The Granites-Tanami Block, they may reach the almandine amphibolite facies. Contact metamorphism associated with post-tectonic granitic intrusions reaches hornblende hornfels facies. The grade of metamorphism in the northeast appears to be generally lower than that in the west and south.

Killi Killi Beds, Mount Charles Beds, and undivided Tanami Complex

Away from granitic intrusions the rocks of the Killi Killi Beds, Mount Charles Beds, and undivided Tanami Complex are commonly phyllitic, and some primary structures and textures are preserved. In greywacke, for example, much of the quartz is present as subangular sedimentary clasts, around some of which are wrapped sedimentary muscovite flakes and sericite; the matrix consists of fine-grained quartz, sericite, and muscovite. Metamorphic mineral assemblages recorded are quartz + biotite + muscovite, quartz + sericite, and quartz + biotite + sericite. The fine grainsize of the rocks and the presence of sericite indicate probable greenschist facies metamorphism.

In the metamorphic rocks close to granitic intrusions there is little or no preservation of original sedimentary and igneous textures, and porphyroblasts of andalusite, chiastolite, or garnet, generally altered, are common.

In the southeast there is evidence that some deformation took place during or after the emplacement of the granitic rocks; some porphyroblasts contain spiral trails of elongate quartz grains, forming 'snowball' textures, and in one example the main schistosity and sericite aggregates pseudomorphing porphyroblasts are kinked by a later cleavage. Mineral assemblages present in these contact metamorphosed rocks are muscovite + quartz, garnet + muscovite ± biotite + quartz, andalusite + muscovite + quartz, and quartz + magnetite + sericite. The presence of andalusite is indicative of low-pressure metamorphism (Miyashiro, 1973).

Near granitic intrusions in the central part of The Granites-Tanami Block the contact metamorphism postdates the development of any schistosity. This is evident from schist of the Killi Killi Beds near the Lewis Granite, for instance, which contains randomly oriented porphyroblastic muscovite flakes strongly oblique to the schistosity. Mineral assemblages recorded in contact-metamorphosed rocks in this part of the area are muscovite + quartz + tourmaline, andalusite + muscovite + quartz, biotite + muscovite + sillimanite (fibrolite) + alkali feldspar + plagioclase, quartz + tourmaline, hornblende + andesine + epidote, and actinolite + labradorite (An_{60}) + sphene. These assemblages indicate a range in facies from upper greenschist to hornblende hornfels. The highest grade, represented by the assemblage containing sillimanite, is present in Killi Killi Beds forming a lit-par-lit zone with Lewis Granite. The assemblage containing actinolite corresponds to the actinolite-calcic plagioclase zone between the greenschist and amphibolite facies of Miyashiro (1973).

Hornfelsic rather than schistose rocks are present locally. Sericitic alteration of andalusite, chiastolite, and sillimanite indicates that the contact metamorphism was followed by some retrograde metamorphism.

Nanny Goat Creek Beds, Nongra Beds, and Helena Creek Beds

Rocks of these units show low greenschist facies regional metamorphism and low-grade contact metamorphism. They are partly to completely recrystallised, but show some well-preserved primary sedimentary and igneous structures and textures. Schistosity is generally less well developed than in the south and west of The Granites-Tanami Block. Most rocks consist largely of sericite, quartz, and iron oxides (replacing mafic minerals). Tourmaline and, less commonly, chlorite are present in contact metamorphic rocks. The low grade of metamorphism is indicated by the fine grainsize of the sericite.

Structure

The scattered distribution of outcrops, general absence of marker horizons, and partial obliteration of small-scale structures and textures by weathering make the overall structure of the Tanami Complex difficult to determine without detailed mapping. The superimposition of Carpentarian and Adelaidean deformations, which affect the Birrindudu Basin succession, on Lower Proterozoic structures of the Tanami Complex adds to the difficulty.

The rocks of the complex are predominantly steeply dipping and generally have a cleavage or schistosity more or less parallel to bedding, indicating tight to isoclinal folding about steeply dipping axes.

Two main structural trends can be distinguished: a northerly trend, which prevails in the northeast, but is present in most other parts of The Granites-Tanami Block, and an east-southeasterly trend, which is largely confined to the west and south of the Block. The latter trend is similar to that predominating in the King Leopold Mobile Zone of the Kimberley region, along strike to the northwest.

Folding appears to be most complex in the west and south because of interaction between the two main trends. Here three main styles of folds can be distinguished: tight to isoclinal folds with limbs ranging in length from less than a metre to more than one kilometre, chevron folds with steeply dipping limbs generally about 1 km long, and large open folds which have limbs several kilometres long. The tight to isoclinal folds, which are generally the most obvious folds present, commonly trend east-southeast, and have an associated axial plane cleavage. The chevron folds, which also commonly trend east-southeast, are well exposed east and west of the Gardner Range in the northeast of the Billiluna Sheet area (Fig. 19), where they are associated with a cleavage formed by the crystallisation of muscovite during low-grade regional metamorphism. They are generally younger than the main cleavage and regional metamorphism, and are closely comparable in style and trend to some of the late folds in the King Leopold Mobile Zone (Gellatly and others, 1974). The schistosity is locally kinked, especially in southern outcrops of the Killi Killi Beds, by small-scale crenulations, which plunge northwest and southeast. The large open folds appear to be best developed in the south of Billiluna and southeast of The Granites Sheet area; many of these folds plunge north.

In the northeast of The Granites-Tanami Block the structural trends indicate that the Tanami Complex is probably tightly to isoclinally folded about northerly trending axes; no chevron folds or large open folds have been identified here.

The two main structural trends of the Tanami Complex existed before the emplacement of the granitic intrusions of The Granites-Tanami Block, but they appear to have had little influence on the shape of these intrusions. The granite of the Browns Range Dome, for instance, is probably elongated east-west, and the regional gravity anomalies (Fig. 49) indicate that the Coomarie Dome granite and the granite east of the Black Hills are probably elongated northeast. In some places the intrusions cut across regional trends and in others they appear to have distorted the earlier structures so that intrusive contacts are closely conformable with the trends of adjacent country rocks.

Beds of greywacke and arenite in the Tanami Complex commonly show a fracture cleavage which is younger than the regional cleavage or schistosity. Some of the fracture cleavage may have been formed during the development of the large north-plunging folds; some has east-southeast trends and may be related to late chevron folds; and some, especially in the south of

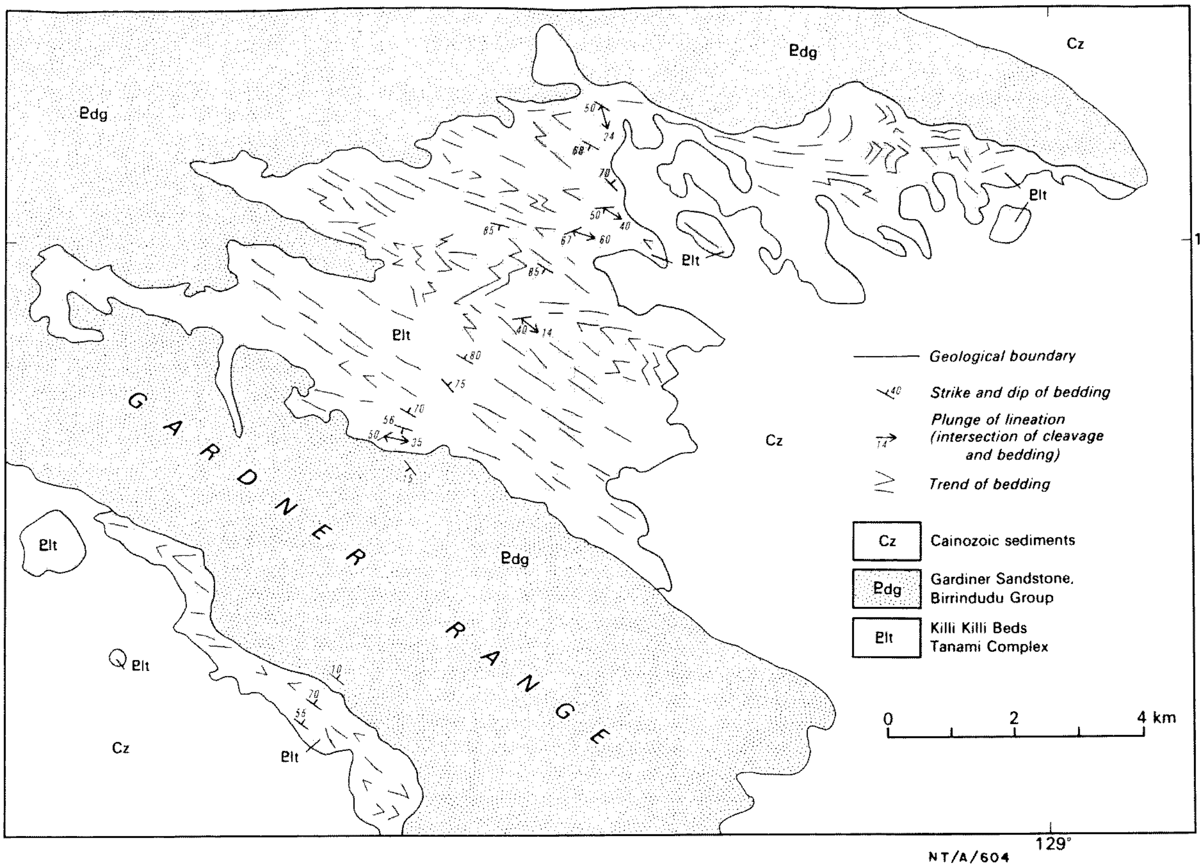


Fig. 19. Folds in the Killi Killi Beds, Tanami Complex, northeast part of Billiluna Sheet area.

Billiluna Sheet area, has a general easterly trend, which is parallel to nearby quartz veins and faults.

Several of the faults mapped displace rocks of the Tanami Complex. Most of these also affect Carpentarian and Adelaidean rocks of the Birrindudu Basin Succession, but they do not appear to displace Palaeozoic rocks; hence they are probably of late Adelaidean age. None of the faults mapped can be shown to have been active during the Early Proterozoic.

The overall east-southeasterly structural trends, and the rock types, fold styles, and regional metamorphism indicate that the western and southern parts of The Granites-Tanami Block may represent a southeasterly extension of the King Leopold Mobile Zone. The northerly structural trend within the Tanami Complex coincides with northerly trending gravity features in the north of The Granites-Tanami Block, and may reflect fundamental structures in older, deeply buried basement rocks.

Late Early Proterozoic Formations

The Granites-Tanami Block includes three formations which are younger than the Tanami Complex and older than the Birrindudu Group. These formations, the Mount Winnecke Formation, Supplejack Downs Sandstone, and Pargee Sandstone, are possibly lateral equivalents. The latter two formations are unconformable on the Tanami Complex, and are overlain unconformably by the Birrindudu Group, but are not seen in contact with granite and have not been isotopically dated. The first formation, on the other hand, is not seen in contact with either the Tanami Complex or Birrindudu Group, but is intruded by the Winnecke Granophyre and has been isotopically dated at about 1800 m.y.* All three formations are silicified and cut by quartz veins, but appear to have undergone little, if any, regional metamorphism. None is known to contain any mineralisation.

Mount Winnecke Formation

Unlike the other late Early Proterozoic formations, the Mount Winnecke Formation (Blake & others, 1975) includes acid volcanics as well as clastic sedimentary rocks. The main rock types present are sublithic arenite, acid lava, and tuffaceous sandstone and siltstone.

The formation crops out mainly in the Winnecke Creek-Winnecke Range area in the northeast of The Granites-Tanami Block, where it is intruded by Winnecke Granophyre and overlain unconformably by Cambrian rocks of the Wiso Basin succession. Sandstone mapped as possible Mount Winnecke Formation also crops out on the northeast side of the Ware Range, where it is faulted against Gardiner Sandstone, which probably overlies it unconformably. To the south, two small outcrops of acid porphyry have been mapped as Mount Winnecke Formation. One of these is 15 km east-northeast of Supplejack Downs homestead, where acid porphyry is overlain, possibly conformably, by Supplejack Downs Sandstone. The other outcrop is in the Black Hills, 17 km northeast of Tanami; there the acid porphyry is not seen in contact with adjacent rock units, but is inferred to overlie the Mount Charles Beds of the Tanami Complex, and to be overlain by Gardiner Sandstone.

* All Precambrian ages quoted are based on Rb-Sr geochronology using 1.39×10^{-11} yr as the decay constant of Rb^{87}.

In the main area of outcrop, the Mount Winnecke Formation has a maximum exposed thickness of about 4800 m, and has moderate to steep dips. Three broad major folds, with roughly vertical north-trending axes, have been identified there: a syncline in the west separated by an anticline from a basin in the east.

Isotopic data for the acid lavas of the Mount Winnecke Formation give a preferred age of 1808 ± 15 m.y. (Page & others, 1976)—late Early Proterozoic—indicating that the formation is probably younger than the Whitewater Volcanics of the Kimberley region (Page, 1976), as tentatively suggested previously by Blake & others (1975).

Lithology

Of the main rock types which make up the Mount Winnecke Formation, sublithic arenite is the most resistant to weathering and erosion, and forms strike ridges and plateaus up to 40 m high. Acid lava is the least resistant, and generally forms depressions. Tuffaceous sandstone and siltstone are intermediate in their resistance, and form ridges where they separate lavas, and depressions where they crop out between ridges of sublithic arenite. Laterite and silcrete are present on some ridges.

The sublithic arenite is generally medium to thick-bedded and medium to very coarse-grained, and it commonly shows cross-bedding. Unlike that of the Supplejack Downs Sandstone, sorting is mostly poor, and grit and pebble beds are common. Many of the lithic grains in the arenite are derived from acid volcanics.

The acid lava is generally much weathered and strongly iron-stained to deep maroon or purplish. Individual flows are dome-shaped and intercalated with clastic sedimentary rocks. Their interiors appear to be structureless, whereas their margins are scoriaceous, autobrecciated, and flow-banded. Phenocrysts of feldspar and quartz, and ferromagnesian and opaque minerals are present in most lavas, forming up to 20 percent of the rock. They are generally less than 1 cm across, and in most specimens examined those of feldspar and ferromagnesian minerals are completely pseudomorphed, mainly by clay and sericitic material. The quartz phenocrysts show resorption features. The groundmass of the lavas is recrystallised, and consists mainly of a mosaic of quartz or, in the least altered specimens, quartz and alkali feldspar; some original microlites are outlined by dust particles or opaque material. In most cases the groundmass was probably glass originally. Vesicles in scoriaceous lava are filled with quartz, celadonite, and, at one place, diaspore and pyrophyllite. The highly altered nature of the acid lavas may be largely due to hydrothermal propylitisation during and immediately after extrusion.

Five specimens of acid lava have been chemically analysed (Tables 2, 5). The analyses show that the lavas samples are rhyolitic, and very similar in composition. They contain 71.5 to 72 percent SiO_2, 31 to 34 percent normative quartz, 3 to 4 percent total iron as FeO, and have K_2O/Na_2O values from 2.0 to 2.5, and differentiation indices (D.I) (Thornton & Tuttle, 1960) of 85 to 89.

Unlike the sublithic arenite, the tuffaceous sandstone contains more than 15 percent acid volcanic clasts and more than 10 percent matrix. Also it is strongly ironstained. Some tuffaceous sandstone is medium to thick-bedded, and shows cross-bedding, but is more poorly sorted than the sublithic arenite. Some that is thinly interbedded with tuffaceous siltstone shows ripple marks.

The Mount Winnecke Formation also contains conglomerate, water-laid acid tuff, and rare agglomerate. Conglomerate, commonly containing abundant fragments of acid volcanics, is locally interbedded with tuffaceous sandstone and, less commonly, sublithic arenite. Thin-bedded to laminated, medium to very fine-grained tuff is closely associated with some lava flows. Medium-bedded lapilli tuff is exposed 6 km south-southwest of Mount Winnecke.

The intimate association of acid lava flows with water-laid sedimentary rocks, and the absence of subaerial pyroclastics, including ignimbritic deposits, indicate that the acid volcanicity may have been subaequeous (Blake & others, 1975).

Relations with the Winnecke Granophyre

The Mount Winnecke Formation is thermally metamorphosed where it is intruded by Winnecke Granophyre, but the metamorphic aureoles, which are locally characterised by abundant porphyroblastic tourmaline, are only a metre or so wide. The lack of much thermal metamorphism, and the textural types of intrusive rocks present—granophyre, acid porphyry, medium to fine-grained granite—indicate that the Winnecke Granophyre represents one or more high-level intrusions. From this field evidence, and from petrographic evidence, it was suggested that the Winnecke Granophyre and the acid lavas of the Mount Winnecke Formation were probably comagmatic (Blake & others, 1975). This suggestion is supported by the chemical similarity of the intrusive and extrusive rocks (Table 2), and by Rb-Sr geochronology (Page & others, 1976). The latter indicates that both the acid lavas of the Mount Winnecke Formation and the intrusive Winnecke Granophyre crystallised about 1800 m.y. ago.

Supplejack Downs Sandstone

A group of sandstone ridges, less than 30 m high, east of the Supplejack Range in the northeast of the Tanami Sheet area are mapped as Supplejack Downs Sandstone (Blake & others, 1975). This formation has been irregularly deformed into open and tight folds, mainly trending north, and has a maximum exposed thickness of about 1300 m. Most outcrops consist only of sublithic arenite and quartz arenite, but some shale and siltstone are exposed locally, and may underlie much of the sand-covered areas between outcrops.

The arenites are medium to thin-bedded and are commonly closely jointed and cross-bedded. They are medium-grained and well sorted, although some beds include layers of shale pellets and rare conglomeratic lenses. The sublithic arenite commonly contains appreciable amounts of acid volcanic material, as well as grains of chert, quartzite, phyllite, altered basalt, tourmaline, zircon, and iron oxide. It has up to 10 percent matrix, mainly sericite and kaolin, whereas the quartz arenite has little or no matrix.

The Supplejack Downs Sandstone overlies the Nanny Goat Creek Beds of the Tanami Complex unconformably, and acid porphyry mapped as Mount Winnecke Formation possibly conformably. The Antrim Plateau Volcanics and probably also the Gardiner Sandstone overlie it unconformably.

Fig. 20. The derelict gold mining settlement of The Granites, and the type area of The Granites Granite (exposures in the background). (M1402/34)

Pargee Sandstone

The Pargee Sandstone (Blake & others, 1975) crops out as strike ridges, mainly less than 30 m high, in the west and centre of The Granites-Tanami Block. The most extensive exposures are west and south of the Pargee Range, and it is in this area that the maximum thickness, about 1500 m, is exposed. The formation is mainly steeply dipping to overturned, and forms several tight major folds with steep axes. Most of the folds trend between northwest and north, except in the northwest of the Gardner Range, where trends are westerly.

The formation is made up of interbedded sublithic, lithic, and quartz arenite, conglomerate, and greywacke. The arenites are mainly poorly sorted and medium to coarse-grained. Individual beds are generally about 1 m thick. They commonly show cross-bedding, and some show ripple marks. Pebbly beds and conglomerate are present, mainly near the base of the formation. Most clasts are subangular, and pebbles in the arenite and conglomerate can be matched with rocks of the underlying Tanami Complex. No granite pebbles have been seen within the formation, but many of the sand-sized grains in the arenites and greywacke are probably derived from granite. The sediments are tentatively interpreted as shallow marine deposits.

The Pargee Sandstone is unconformable on the Killi Killi and Mount Charles Beds of the Tanami Complex, and is overlain unconformably by the Gardiner Sandstone of the Birrindudu Group and the Muriel Range Sandstone of the Redcliff Pound Group. The unconformity between the Pargee Sandstone and the Gardiner Sandstone is exposed at the northwest end of the Gardner Range and in the Pargee Range. The Muriel Range Sandstone is seen to overlap onto steeply dipping Pargee Sandstone in the Wilson Range.

GRANITES

Granitic intrusions of late Early Proterozoic and early Carpentarian age are an integral part of The Granites-Tanami Block. They occupy much more extensive areas than are apparent from the generally small and widely scattered outcrops shown on the 1:250 000 and 1:500 000 geological maps, as large areas of granite are concealed beneath Cainozoic superficial sediments (compare the 1:500 000 geological map with Fig. 16). Most outcrops consist of partly lateritised granite exposed in breakaways bounding low laterite-capped rises. Granite also crops out in scarps below cappings of younger Proterozoic sandstone, where it is generally bleached and friable, and as tors and isolated boulders of unweathered rock surrounded by superficial Quaternary sand (Fig. 20).

Granites intrude the Tanami Complex and Mount Winnecke Formation, and are overlain by basal formations of the Birrindudu and Redcliff Pound Groups. Isotopic age data indicate that the intrusions were emplaced between 1820 and 1700 m.y. ago (Page & others, 1976), and hence they straddle the Early Proterozoic-Carpentarian boundary. They postdate the regional metamorphism which affected the Tanami Complex, and are younger than the granites of the Kimberley region to the northwest; but they are older than the Mount Webb Granite of the Arunta Block to the south.

Some of the granite is foliated, and some shows flow alignment of phenocrysts. None appears to have any mineralisation associated with it.

Four granitic units within The Granites-Tanami Block have been formally named: Winnecke Granophyre, Lewis Granite, Slatey Creek Granite, and The Granites Granite.

Winnecke Granophyre

The most extensive outcrops of granitic rocks in The Granites-Tanami Block are in the northeast, where they are mapped as Winnecke Granophyre (Traves, 1955; Blake & others, 1975). Rock types present are granophyre, adamellite, and intrusive acid porphyry. In places these are cut by thin aplitic and andesitic veins or dykes.

At intrusive contacts the Winnecke Granophyre is bordered by a metamorphic aureole which is generally only a few metres wide. Country rocks within the aureole are weakly hornfelsed and locally greisenised or tourmalinised. Exposed contacts with the Mount Winnecke Formation range from flat-lying to steeply dipping.

The intrusive rock types, together with the distribution of their outcrops and the lack of much associated thermal metamorphism, indicates that the Winnecke Granophyre is a composite intrusion emplaced at a shallow depth in the Earth's crust. It is an epizonal pluton, according to the classification of Buddington (1959).

Petrography

Granophyre, the main rock type, is pale pink to grey, and is commonly porphyritic. It is made up essentially of quartz, alkali feldspar, plagioclase, and brown biotite, and is characterised by a micrographic groundmass of quartz and alkali feldspar. The adamellite is similar mineralogically, but is coarser and mainly non-porphyritic, and has a general granitic rather than micrographic texture; at a few localities it contains small dark xenoliths. Acid porphyry contains phenocrysts of plagioclase, alkali feldspar, and biotite and other ferromagnesian minerals in a fine to very fine-grained generally granitic groundmass.

Eight samples of Winnecke Granophyre have been chemically analysed (Tables 2, 5). These samples are generally similar in their major-element composition to the analysed lavas from the Mount Winnecke Formation, but show a wider range of composition. Compared with the lavas, they are generally richer in SiO_2, and depleted in total iron and TiO_2.

Stratigraphic relations and age

The Winnecke Granophyre intrudes the Helena Creek Beds and probably the Nanny Goat Creek Beds, both of the Tanami Complex. It also intrudes the Mount Winnecke Formation. It is overlain by Cambrian rocks—the Antrim Plateau Volcanics and sediments of the Wiso Basin succession—and probably by the Gardiner Sandstone of the Birrindudu Group, with which it has a faulted contact to the west, on the east side of the Ware Range. The intrusion has been isotopically dated by the Rb-Sr method at 1802 ± 15 m.y. (Page & others, 1976), and is considered to be comagmatic with the acid lavas of the Mount Winnecke Formation.

The Granites Granite

Scattered outcrops of granite between latitudes 20°14′ and 20°50′S in the centre and east of The Granites Sheet area and on the western margin of the Mount Solitaire Sheet area to the east are mapped as The Granites Granite (Hodgson, 1976). The unit is named after the abandoned gold mining settlement of The Granites, and its type area is 1 km south of The Granites, at latitude 20°34′30″S, longitude 129°21′10″E (Fig. 30). At most outcrops the granite is friable and much weathered, but fresh granite is exposed as tors and spheroidal boulders, such as at the type area, where it consists of grey, medium to fine-grained adamellite, which contains variable amounts of quartz and feldspar phenocrysts and dark fine-grained xenoliths. Unweathered granite, probably belonging to The Granites Granite, was intersected in shallow stratigraphic holes drilled northwest and northeast of Sangsters Bore in 1973 (Blake, 1974). The granite is locally foliated and sheared, and in places it has up to four times the background radioactivity. It has a broad metamorphic aureole, possibly several kilometres wide, and is probably a mesozonal intrusion rather than an epizonal intrusion like the Winnecke Granophyre.

Petrography

The Granites Granite consists of pink and grey, locally porphyritic, biotite adamellite and associated minor aplite and pegmatite. Cross-cutting quartz veins are common. Some of the adamellite contains poikilitic crystals of alkali feldspar over 1 cm across.

In samples examined in thin section, the quartz is generally strained and locally granulated. Plagioclase forms subhedral crystals, mainly of oligoclase, although in some specimens the crystals have cores of andesine. The crystals show weak normal zoning, and alteration, especially in the cores, to sericite, muscovite, epidote, clay minerals, and in a few cases calcite. Myrmekitic intergrowths with quartz are not uncommon. Alkali feldspar, which is microcline, is mainly anhedral, slightly perthitic, and unaltered. Biotite is brown or greenish-brown, and is partly altered to chlorite, epidote, and white mica. Accessory minerals commonly present include allanite, apatite, epidote, fluorite, muscovite, sphene, and opaque and metamict minerals.

Chemical and modal analyses of a specimen of biotite adamellite collected from The Granites by Madigan in 1932 have been given by Kleeman (1934). The chemical analysis and three new ones are presented in Table 3; trace-element analyses and element ratios are given in Table 5. The samples analysed are similar in chemical composition to those of the Winnecke Granophyre, except that they have generally lower K_2O/Na_2O values.

Stratigraphic relations and age

The Granites Granite has intruded and thermally metamorphosed the Mount Charles Beds at The Granites, where the intrusive relationship was reported first by Madigan (in Kleeman, 1934) and later by Hossfeld (1940a, 1940b), and also southwest of the Hordern Hills and in the Muriel Range-Inningarra Range area. The granite is overlain by Muriel Range Sandstone on the north side of Murdoch Cliffs. An age of 1780 ± 24 m.y. has been determined using the whole-rock Rb-Sr method, indicating that The Granites Granite was emplaced either late in the Early Proterozoic or early in the Carpentarian (Page & others, 1976).

Slatey Creek Granite

The Slatey Creek Granite (Blake & others, 1977) forms scattered outcrops southwest of the Gardner Range, in the east of Billiluna Sheet area. Most outcrops are to the south of Slatey Creek (19°19′S, 128°45′E), after which the granite is named. The most extensive exposures are of friable weathered granite in scarps capped by Lewis Range Sandstone north and west of Tent Hill, but fresh granite is exposed as isolated tors and boulders close to the scarps. The granite was previously included within the Lewis Granite of Casey & Wells (1964), but it is now mapped as a separate unit, as it crops out many kilometres away from the Lewis Granite of the Lewis Range.

The type area for the Slatey Creek Granite is a scarp face 60 m high, 16 km north-northwest of Tent Hill and 3 km south of Slatey Creek, at 19°22′S, 128°41′30″E. Here unweathered, medium-grained, mainly non-porphyritic, muscovite and biotite-muscovite adamellites are exposed, intruding Killi Killi Beds and overlain by about 30 m of Lewis Range Sandstone.

Petrography

Rock types cropping out are muscovite, biotite-muscovite, and biotite adamellite, and minor biotite granodiorite. Most of the adamellite is medium to fine-grained, although some contains tabular feldspar phenocrysts over 1 cm long. Veins of muscovite-quartz-feldspar pegmatite and aplite (muscovite and biotite-muscovite microadamellite) are common, and dark fine-grained xenoliths are present in places, as for example, in biotite adamellite and biotite granodiorite 45 km southwest of Tent Hill. Locally, the Slatey Creek Granite is either weakly foliated or sheared.

The adamellite and granodiorite consist essentially of quartz, which is commonly strained; sodic plagioclase, partly altered to white mica, clay minerals, and calcite; alkali feldspar, which is mainly microcline; and either muscovite or biotite, or both; the biotite commonly shows some alteration to chlorite and epidote. Accessory minerals present include allanite, apatite, fluorite, sphene, zircon, and opaque and metamict minerals.

Three samples have been chemically analysed (Tables 3, 5). Two are closely similar to those of the Winnecke Granophyre, except for having lower K_2O/Na_2O values. The remaining sample, from an aplite vein, is very low in Na_2O, and consequently has a very high K_2O/Na_2O value—much higher than that of any other analysed granite sample from The Granites-Tanami Block.

Stratigraphic relations and age

The Slatey Creek Granite intrudes the Killi Killi Beds of the Tanami Complex, in places forming lit-par-lit injection zones, as in the type area and 75 km east-southeast of Billiluna homestead, where adamellite containing tourmaline intrudes hornfelsed greywacke. It is overlain by Gardiner Sandstone in the north and by Lewis Range Sandstone along the scarps north and west of Tent Hill. The granite has been isotopically dated by the Rb-Sr method at 1770 ± 62 m.y. (Page & others, 1976), indicating emplacement either late in the Early Proterozoic or early in the Carpentarian.

Lewis Granite

Granite cropping out in Billiluna and Lucas Sheet areas was mapped as a single rock unit, the Lewis Granite, by Casey & Wells (1964; Wells, 1962a, 1962b). This name is now restricted to granite north and east of the Lewis Range in Lucas Sheet area, on the southwest side of The Granites-Tanami Block, as the granite here belongs to a single intrusion, or group of closely related intrusions, and is separated geographically and possibly also in time from other granites in the region.

Casey & Wells (1964) selected the Lewis Range as the type locality for the Lewis Granite. As this range covers an extensive area, a more precise type locality is nominated here: a hill about 40 m high, situated 1 km northwest of Point Nelligan (at 20°11′30″S, 128°38′00″E), where the main varieties of Lewis Granite are well exposed.

The Lewis Granite crops out in scarps up to 80 m high along the north and east sides of the Lewis Range, where it is overlain by Lewis Range Sandstone. Along the scarp the sandstone dips very gently south and west, and forms cappings up to 10 m thick on the granite (Fig. 9). In many places the granite is partly or completely obscured by fallen blocks of sandstone or banks of wind-blown sand. On the sides of the hill at the type locality, large slabs of sandstone, remnants of a boulder scree, rest on small pedestals of weathered granite. The granite immediately below the sandstone cappings is friable and kaolinised, but it becomes more coherent and less weathered several metres below the cappings, where it commonly forms convex surfaces many metres across.

Northeast of the Lewis Range the granite forms tors of rounded to angular blocks and boulders, low mounds with rubbly surfaces, and flat-topped hills capped by laterite. Most exposures are surrounded by gently sloping aprons of coarse granitic sand.

Northeast of Point Nelligan the granite is well exposed in a lit-par-lit injection zone. Sheets of granite alternate with layers of greywacke, mapped as Killi Killi Beds, that have been thermally metamorphosed to a micaceous hornfels. Individual sheets are up to 30 m thick, and dip 40° east.

Petrography

The Lewis Granite is mainly a pinkish to pale grey muscovite or muscovite-biotite adamellite. However, the most westerly outcrops consist of biotite adamellite and granodiorite, and some biotite adamellite is also present north of Point Nelligan. The adamellite is medium to coarse-grained, and commonly contains abundant phenocrysts of feldspar over 1 cm long. Close to the granite margins the phenocrysts show a well-defined flow alignment parallel to the contacts, but away from the margins the flow alignment is generally irregular and less well defined. In the granite immediately below the Lewis Range Sandstone capping the Lewis Range the flow alignment is consistently flat-lying, indicating that the tops of the granite exposures here are probably close to the original roof of the intrusion.

Cross-cutting sheets of pegmatite and aplite, generally less than 0.5 m thick, are common within the Lewis Granite, and quartz veins, fine-grained biotite-rich xenoliths, and slickensided surfaces are present locally. The pegmatites consist of quartz and pale pink feldspar crystals several centimetres across, and subordinate books of muscovite up to 5 cm across; coarse graphic intergrowths of quartz and alkali feldspar, and crystals of black tourmaline are common.

In some specimens of Lewis Granite the quartz is strained and partly granulated. Most of the plagioclase present is probably oligoclase, as it has refractive indices slightly less than those of quartz; it is weakly zoned, and forms phenocrysts and smaller subhedral crystals, which show alteration, especially in the cores, to sericite, muscovite, clay minerals, and in some cases epidote, calcite, and zeolites. The alkali feldspar is generally microcline, less commonly orthoclase; it forms both anhedral crystals and subhedral to euhedral, commonly poikilitic megacrysts; some crystals are turbid, owing to patchy alteration to clay. Muscovite appears quite fresh, but brown biotite commonly shows some alteration to chlorite and epidote. Apatite, fluorite, zircon, and metamict minerals are common accessories, and some specimens also contain tourmaline.

In their major-element composition, the four samples of Lewis Granite that have been chemically analysed (Table 3) are essentially identical to those of Slatey Creek and The Granites Granite. They differ from those of Winnecke Granophyre in being generally richer in Na_2O and poorer in K_2O, and hence have lower K_2O/Na_2O values—average 0.5, as against 1.0 for the Winnecke Granophyre.

Stratigraphic relations and age

The Lewis Granite intrudes the Killi Killi Beds, and is overlain by the Adelaidean Lewis Range Sandstone in the Lewis Range, and the Carpentarian Gardiner Sandstone on the north side of the Nora Range.

Samples of Lewis Granite have been dated, by the whole-rock Rb-Sr method, at 1720 ± 8 m.y., indicating that the granite was emplaced early in the Carpentarian (Page & others, 1976). The Lewis Granite is therefore significantly younger than the Winnecke Granophyre, and may also be younger than the Slatey Creek and The Granites Granites, the only other dated granites of The Granites-Tanami Block.

Unnamed granites

Unnamed granitic rocks crop out in each of the 1:250 000 Sheet areas covering The Granites-Tanami Block. They intrude the Tanami Complex, and are overlain by Carpentarian and younger units. Most, if not all, the unnamed granitic bodies are mesozonal intrusions.

Unnamed granitic rocks in Birrindudu and Tanami Sheet areas have been described by Blake & others (1975). Small outcrops of weathered, medium to coarse-grained and locally pegmatitic granite are present in the centre of the Browns Range Dome and east of the Black Hills, and granitic rocks underlie superficial Cainozoic sediments in both these areas and also in the Coomarie Dome. The granitic rocks intrude the Tanami Complex, and are overlain by Gardiner Sandstone.

In Billiluna Sheet area outcrops of unnamed granite are confined to a small area east of the Selby Hills and south of the Billiluna-Tanami road. These outcrops were previously mapped as Lewis Granite (Wells, 1962a; Casey & Wells, 1964), but as they may equally well be part of the Slatey Creek Granite or a separate granitic body, they are no longer assigned to a named unit. The unnamed granite here intrudes the Killi Killi Beds, and is overlain by the Lewis Range Sandstone.

In Lucas Sheet area unnamed granitic rocks, previously mapped as Lewis Granite (Wells, 1962b), crop out near Mount Hughes and on the west and possibly also the northeast sides of the Kearney Range. The main rock types exposed are porphyritic adamellite and quartz-feldspar-muscovite-tourmaline pegmatite. On the west side of the Kearney Range, on the eastern edge of the Phanerozoic Canning Basin, the granite shows a strong foliation, defined by biotite and quartz, that is parallel to north-northwest-trending joints and faults in overlying Lewis Range Sandstone to the east.

Unnamed granitic rocks crop out in the west and northeast of The Granites Sheet area. They are mainly medium to fine-grained and non-porphyritic, and are commonly foliated. Cross-cutting veins of pegmatite, aplite, and quartz, and dark fine-grained xenoliths are present locally. The granitic rocks intrude the Tanami Complex north and east of the Macfarlanes Peak Range, where they locally form lit-par-lit injection zones, and also east of the Farrands Hills. They are seen to be overlain by the Gardiner Sandstone in the Nora Range in the west and in the Farrands Hills in the northeast, and by the Pedestal Beds north of the Macfarlanes Peak Range.

HALLS CREEK PROVINCE

The Halls Creek Province (GSA, 1971) comprises the Halls Creek and King Leopold Mobile Zones on the east and southwest sides, respectively, of the Proterozoic Kimberley Basin. The Halls Creek Mobile Zone extends south into the northwest corner of the area described here, where it consists of rocks of the Halls Creek Group.

HALLS CREEK GROUP

Like the Tanami Complex, with which it is correlated, the Halls Creek Group (Dow & Gemuts, 1969) is made up of low-grade regionally metamorphosed rocks. Higher-grade metamorphic equivalents in the Halls Creek Mobile Zone are found in the Tickalara Metamorphics of the Lamboo Complex (Gemuts, 1971), to the north and west, which have been dated at 1961 ± 27 m.y. (Dow & Gemuts, 1969; Gellatly, 1971; Bennett & others, 1975). This is the age of the regional metamorphism, and provides a minimum age for the Halls Creek Group. Available isotopic data indicate a probable maximum age of 2200 m.y. for the group (Page, 1976) i.e., Early Proterozoic, although an Archaean age cannot be discounted.

Olympio Formation

The main unit of the Halls Creek Group exposed in the area is the Olympio Formation (Dow & Gemuts, 1969), which consists of interbedded schistose and phyllitic greywacke and siltstone, phyllite, minor quartzite, and local calcsilicate lenses; some beds show graded bedding. These rocks form gently undulating to low hilly terrain. At most exposures they are iron-stained. The formation has been regionally metamorphosed to lower greenschist facies, is probably tightly folded, and has a steep to vertical cleavage that is generally parallel to bedding. Cross-cutting quartz veins are common. The thickness of the formation is not known, but is probably in the order of several thousand metres.

The Olympio Formation is probably marine, and was described by Dow & Gemuts (1969, p. 15) as 'a monotonous turbidite sequence of great extent and uniformity which probably once covered the whole of the East Kimberley region'. It is overlain unconformably to the east by the Mount Parker Sandstone, which is probably Carpentarian, and is correlated with the lithologically similar Killi Killi Beds of the Tanami Complex.

Biscay Formation

The only other unit of the Halls Creek Group cropping out in the area is the Biscay Formation (Dow & Gemuts, 1969), in the extreme northwest, where it is overlain by the Olympio Formation. It consists of metamorphosed marine sedimentary rocks and basaltic volcanics.

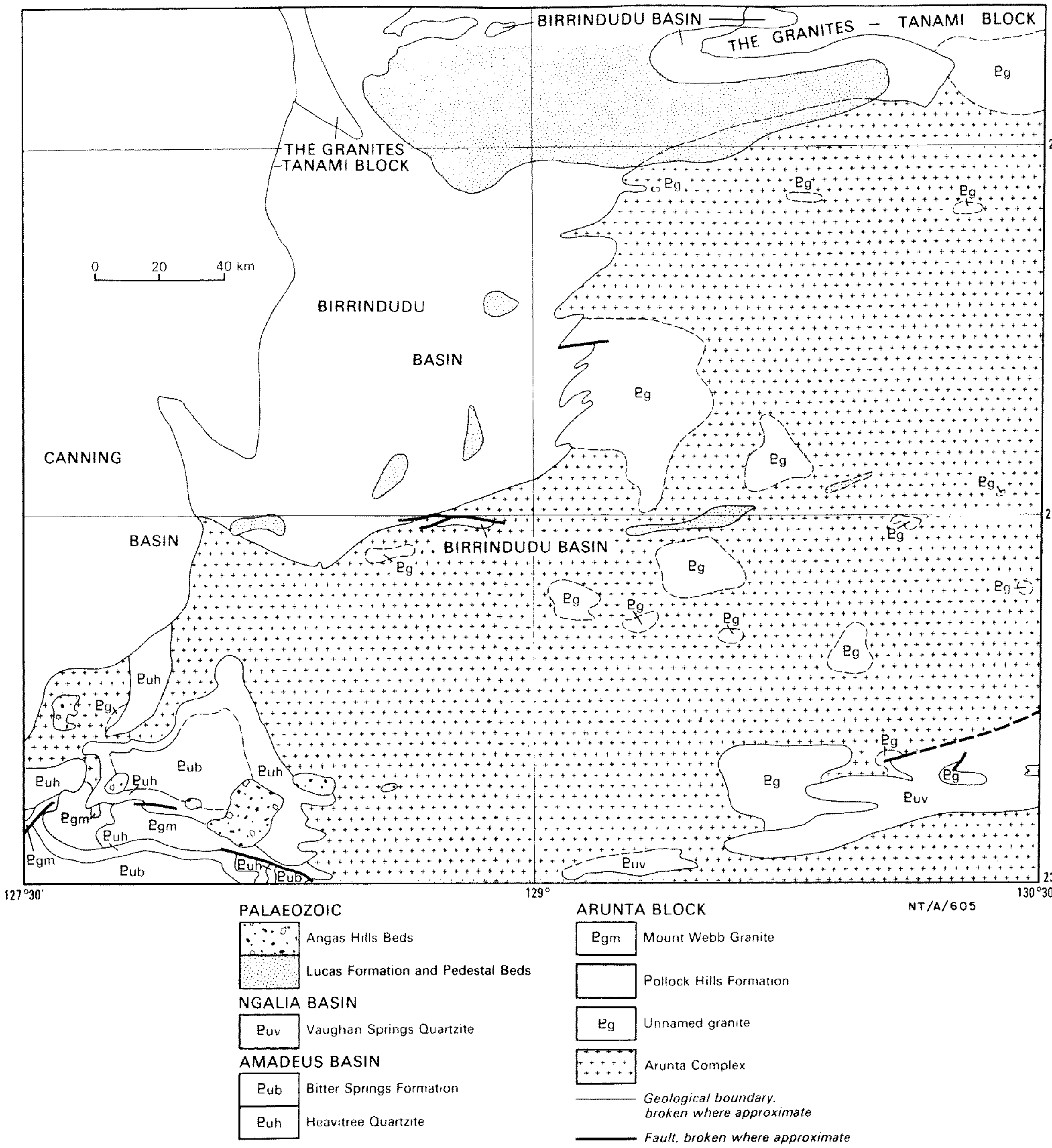


Fig. 21. Distribution of rock units in the Arunta Block, Amadeus Basin, and Ngalia Basin (solid geology).

ARUNTA BLOCK

The Arunta Block occupies most of the southern and southeastern parts of the area, and extends eastwards for at least a further 700 km, forming a large part of central Australia (GSA, 1971). Its contact with The Granites-Tanami Block to the north appears to be gradational, and the boundary between the two Blocks is an arbitrary one, taken for convenience, where the units of the blocks are concealed beneath Birrindudu Basin sediments and superficial Cainozoic deposits.

In The Granites-Tanami region the Arunta Block is represented by regionally metamorphosed rocks and granites assigned to the Arunta Complex; by the Pollock Hills Formation in the southwest, which consists of unmetamorphosed acid volcanics and associated sedimentary rocks; by the Mount Webb Granite; and by basic dykes (Fig. 21). No mineralisation has been recorded in this part of the Arunta Block. The metamorphic rocks of the Arunta Complex are correlated with those of the Tanami Complex, and hence are probably Early Proterozoic. The Mount Webb Granite and the acid volcanics of the Pollock Hills Formation are thought to be comagmatic, and have been dated at 1526 $\pm$ 25 m.y. (Page & others, 1976).

The Arunta Block is overlain by the Redcliff Pound Group of the Birrindudu Basin succession in the north and northwest, the Vaughan Springs Quartzite of the Ngalia Basin succession in the southeast, and Heavitree Quartzite of the Amadeus Basin succession in the southwest. The basal sediments of the Redcliff Pound Group and the Vaughan Springs Quartzite are thought to be stratigraphic equivalents of the Heavitree Quartzite, which is probably younger than 1000 m.y. (Wells, 1976).

Arunta Complex

Metamorphic rocks

Outcrops of metamorphic rocks in the Arunta Block form low ridges and gently undulating terrain, and are commonly capped by laterite. The main rock types exposed are quartzite, schist, and gneiss, both separately and interbedded with one another.

The quartzite commonly forms strike ridges, some nearly 20 m high, which trend mainly west-northwest, west, and west-southwest. It is generally thin-bedded and steeply dipping and ranges from fine-grained and cherty (closely resembling parts of the Mount Charles Beds of the Tanami Complex) to coarse-grained and glassy. Small-scale cross-bedding has been recorded at a few localities. The quartzite contains variable amounts of mica, and locally grades into schist. A cleavage is commonly developed parallel or subparallel to bedding. In places, as in the northeast, a strongly developed steeply-dipping lineation has led to the formation of mullions. Cross-cutting quartz and quartz-tourmaline veins are common, especially in the southwest. The quartzite is fine to coarse-grained and consists of strained quartz, minor muscovite and biotite, and accessory tourmaline, zircon, and opaque minerals. Most of the quartzite probably represents recrystallised and regionally metamorphosed quartz arenite and siltstone.

The schist is less resistant to erosion than the quartzite and is generally poorly exposed. In places, such as at Mount Farewell, it forms depressions between quartzite ridges. Most of the schist consists mainly of quartz and either muscovite or biotite or both, and probably represents metamorphosed greywacke-type sediments, but some, such as 20 km east of Mount Webb, is made up largely of green hornblende, chlorite, and epidote, and may be metamorphosed basic volcanics. Graphitic schist is exposed in the McEwin Hills, and schist spotted with iron oxide pseudomorphs, possibly after andalusite, crops out east of Mount Farewell.

Outcrops of gneiss appear to be confined to the Northern Territory part of the Arunta Block. The gneiss is almost invariably much weathered, and is difficult to distinguish from weathered foliated granite; however, compared with the granite, the gneiss is generally more quartzose and micaceous, and less feldspathic, and has a better developed foliation. The foliation is generally steeply dipping. Unweathered gneiss was found at only one place, in Highland Rocks Sheet area, in the vicinity of 21°22′S, 130°12′E, where it forms low mounds and spheroidal boulders. The gneiss here is fine to coarse-grained and consists of quartz, muscovite, biotite, sillimanite, and garnet or cordierite or both. Similar gneiss, though somewhat weathered, is exposed east of Mount Farewell. Tourmaline-bearing gneiss is present near some granite intrusions. In most of the weathered gneiss the only primary minerals preserved are quartz and some muscovite, the remainder being altered to clay and iron oxide. The nature of the rocks from which the gneiss has formed is not known.

The presence of muscovite, biotite, green hornblende, chlorite, and epidote indicates that most of the metamorphic rocks probably belong to the greenschist facies of regional metamorphism. Locally, some of the epidote, and also porphyroblasts of tourmaline, can be related to granite intrusions. Sillimanite, cordierite, and garnet-bearing gneisses indicate a higher grade of metamorphism, which may be due either to a nearness of large granite intrusions or to an overall southeastward increase in regional metamorphic grade.

Granitic rocks

Outcrops of unnamed granitic rocks have been mapped in each of the 1:250 000 Sheet areas which include part of the Arunta Block. Where exposed, these rocks are commonly much weathered, and most outcrops are capped by laterite. The granites are intrusive into the metamorphic rocks of the Arunta Complex, and are overlain by Adelaidean and younger sedimentary rocks.

In The Granites Sheet area, unnamed granitic rocks, including biotite adamellite, biotite granite, and greisen, crop out in the south-southeast, and were also intersected beneath Cainozoic superficial sediments in a stratigraphic drill hole (Blake, 1974). The rocks are foliated and mainly medium-grained.

In Stansmore Sheet area, 40 km south-southeast of Redcliff Pound, weathered granite, cut by veins of pegmatite, is overlain by about 2 m of flat-lying silicified sandstone that is probably Mesozoic. The granite is medium-grained, and consists of quartz, altered feldspar, white mica, and minor tourmaline. The only other granite occurrence known in the Sheet area is on the west side of the Murraba Ranges, where a pebble of granite was found enclosed in calcrete bordering a gully on the west side of the Murraba Ranges; there are no granite outcrops in the vicinity, and the derivation of the pebble is unknown.

Granite forms scattered rises (Fig. 12) and hills less than 6 m high in the Highland Rocks Sheet area, mainly in the southeast. Most outcrops are capped by laterite, and exposures are largely confined to breakaways. The exposed granite is generally lateritised and silicified, and as it commonly has a prominent steeply dipping foliation, it cannot everywhere be reliably distinguished from gneiss. It ranges from fine-grained to pegmatitic, and some is porphyritic. Unweathered granite has been found at three places: two of these are at small rockholes situated in depressions between sand dunes in the north (at 21°08′10″S, 129°48′30″E, and 21°11′00″S, 130°15′30″E), and the other is in the northeast (at 21°02′S, 139°28′E), where some spheroidal granite boulders are present. Biotite granite containing feldspar phenocrysts up to 10 cm long is exposed at the first rockhole, and at the second the exposure consists of equigranular, medium to fine-grained, muscovite-biotite adamellite. The spheroidal boulders in the northeast are of biotite granodiorite containing feldspar phenocrysts up to 3 cm across.

A metamorphic aureole is associated with granite in the southeast of Highland Rocks Sheet area, at Mount Farewell; hornfelsic quartzite within a few metres of the granite contact contains tourmaline porphyroblasts.

Widely scattered outcrops of much weathered granite, locally capped by laterite, are present in the northern part of Webb Sheet area. The exposed granite is generally richly micaceous and strongly foliated. In places it forms pegmatitic veins, which are commonly conformable with the schistosity of the surrounding metamorphic rocks. The pegmatites are locally associated with quartz-tourmaline veins.

In Lake Mackay Sheet area the main outcrops of granite are in the northwest and east. Some of the granite contains feldspar phenocrysts, and garnet is

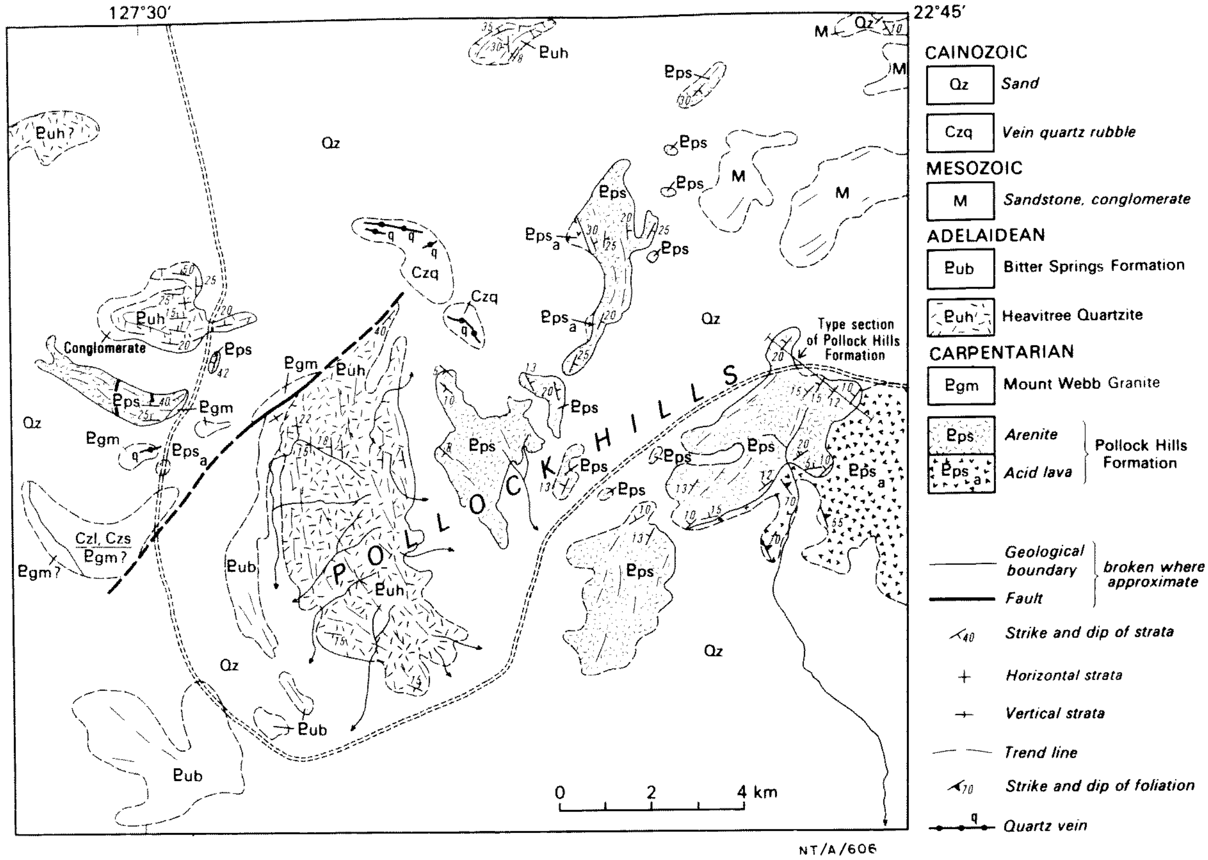


Fig. 22. Geological map of the Pollock Hills, Webb Sheet area.

present in the northwest. The granites are cut by veins of aplite, muscovite and tourmaline-bearing pegmatite, and massive quartz.

Stratigraphic relations and age

The metamorphic rocks of the Arunta Complex in The Granites-Tanami region are correlated with those of the Tanami Complex to the north, which are thought to be Early Proterozoic. They have been affected by two regional metamorphic events dated at 1719 ± 24 m.y. (Armstrong & Stewart, 1975) and about 1800 m.y. (Stewart, 1976), and have been intruded and thermally metamorphosed by granitic rocks of the complex and by the Mount Webb Granite (1526 ± 25 m.y., Page & others, 1976). They are overlain unconformably by the Carpentarian Pollock Hills Formation, the Adelaidean Redcliff Pound Group, and by Palaeozoic terrestrial sediments, and are overlapped to the west by Palaeozoic marine sediments of the Canning Basin succession.

Some of the granitic rocks of the Arunta Complex are probably late Early Proterozoic to early Carpentarian, like those of The Granites-Tanami Block, but others may be somewhat younger, perhaps similar in age to the mid-Carpentarian Mount Webb Granite.

Pollock Hills Formation

The Pollock Hills Formation (Blake, 1977) comprises volcanic and sedimentary rocks which form strike ridges, hills, cuestas, and undulating terrain in the southwest corner of Webb Sheet area and the southeast corner of the adjoining Wilson Sheet area. The formation is named after the Pollock Hills (22°50′S, 127°40′E), and the type section is across part of these, from 22°50′S, 127°40′E to 22°49′S, 127°38′E (Fig. 22). In the type section porphyritic acid lava of unknown thickness is overlain by 600 m of westerly dipping, interbedded, medium to thin-bedded, lithic arenite, sublithic arenite, and tuffaceous sandstone. The maximum thickness of the formation is uncertain, as the base is not exposed, but it is probably more than 1000 m, and may be over 1500 m.

Lithology

Rock types exposed are porphyritic acid lava in the lower part of the formation, and lithic arenite, sublithic arenite, tuffaceous sandstone, and minor tuffaceous siltstone, conglomerate, lapilli tuff, and agglomerate, in the upper part.

Acid lava crops out mainly on the east side of the Pollock Hills, but is also exposed in the northwest and west. Differences in phenocryst content within the lava indicate that more than one flow may be present, although no contacts between flows have been recognised. Flow tops, consisting of much-altered, yellowish to greenish or maroon, flow-banded and brecciated lava, are exposed in the lower parts of some scarps, where they are overlain either by arenite and tuffaceous sandstone, or, less commonly, by agglomerate and tuff. The highly altered lava, once glassy, but now felsitic, ranges in thickness from a few metres to over 10 m, and grades down into relatively unaltered massive lava, which is generally little weathered. The massive lava is hard and dense, and mainly dark grey to greyish maroon. It forms low tors and rocky undulating terrain, and commonly has a prominent, steeply dipping to ver-

Fig. 23. Mount Webb, from the south. Scarp-forming quartz arenite of the Heavitree Quartzite overlies foliated Mount Webb Granite which is largely concealed by scree; Webb Sheet area. (The only road in the Sheet area is in the foreground). (M2239/25)

tical foliation or close jointing that trends north to west-northwest.

Microscopic examination shows that the massive lava contains 10 to 20 percent phenocrysts, less than 5 mm long, of feldspar and subordinate quartz. Some altered ferromagnesian phenocrysts and microphenocrysts of opaque minerals and apatite are also present in most specimens. The groundmass is fine to very fine-grained, and ranges from felsitic to microgranitic or micrographic; it consists of quartz, turbid alkali feldspar, and opaque granules, commonly accompanied by some chlorite, greenish biotite, and amphibole. One specimen examined contains small xenolithic clots of quartz, biotite, and opaque minerals. Most feldspar phenocrysts are of weakly zoned sodic plagioclase, showing different degrees of alteration to clay, epidote, sericite, chlorite, and calcite. Some phenocrysts of alkali feldspar have also been distinguished. Quartz phenocrysts are of the β-quartz type; they are commonly partly resorbed, and show strained extinction. Ferromagnesian phenocrysts are pseudomorphed by aggregates of one or more of chlorite, iron oxide, greenish biotite, pale green amphibole or sphene.

Chemical analyses, CIPW norms, and differentiation indices of six acid lava samples are given in Table 4. The analyses indicate that the lava samples are dacitic (67-71 percent SiO_2). Five of the six samples (omitting the most altered sample, no. 120C) have K_2O/Na_2O values of 1.29-1.88, somewhat lower than those of analysed lavas from the Mount Winnecke Formation. They are also lower in silica (less than 71 percent), but richer in total iron (over 4 percent as FeO), and have generally lower differentiation indices (less than 86 percent).

The upper part of the Pollock Hills Formation, overlying the acid lava, consists mainly of lithic arenite, sublithic arenite, and tuffaceous sandstone. Clasts of acid lava are present in all three types of sandstone, and form more than half the clasts in the tuffaceous sandstone. The arenites and tuffaceous sandstone are mainly medium to thin-bedded and medium to coarse-grained; cross-bedding, lenses of coarse gritty arenite, and lenses of conglomerate made up of quartz pebbles and volcanic rock fragments are locally common; ripple marks are present in places. The lithic arenite and tuffaceous sandstone are iron-stained to deep maroon, and are not as well sorted as the sublithic arenite. They are also less resistant to erosion, as they are generally unsilicified and friable, and form depressions between ridges of sublithic arenite.

The arenites and tuffaceous sandstone contain clasts of quartz, quartzite, acid volcanics, feldspar, and small amounts of tourmaline, muscovite, and zircon. The volcanic clasts are generally subangular to angular, and some have shard-like forms. Clasts of sodic plagioclase and alkali feldspar make up to 10 percent of some samples. Between the clasts are various amounts of sericitic matrix, which is commonly iron-stained, and quartz-overgrown cement.

In places the arenites and tuffaceous sandstone rest directly on acid lava, as in the type section, but elsewhere, such as at the base of a scarp 2 km southwest of

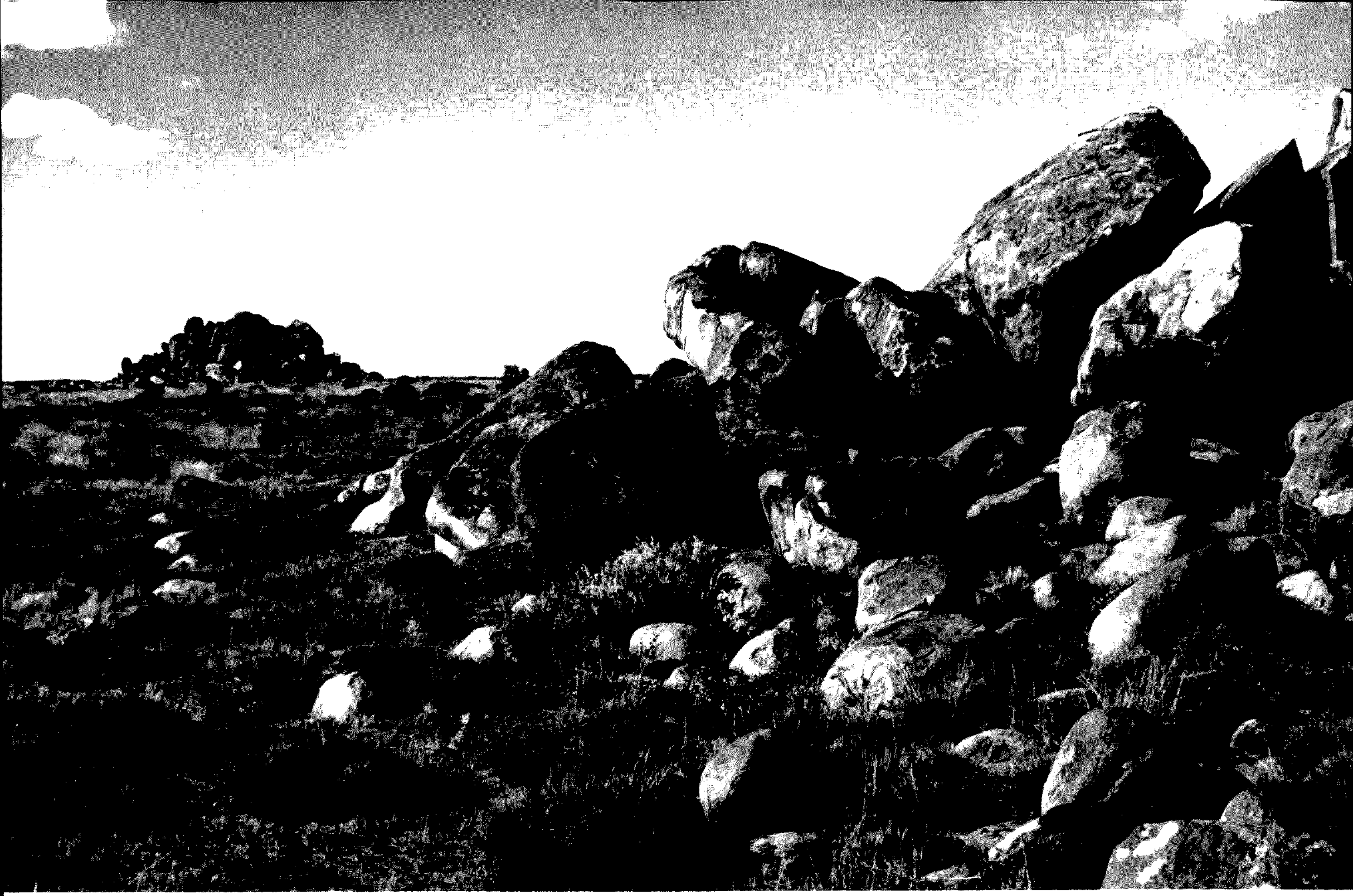


Fig. 24. Mount Webb Granite, 8 km east of the Pollock Hills, Webb Sheet area. (GA/8668)

the type section, they are separated from underlying lava by volcanic agglomerate, laminated tuffaceous siltstone, agglomeratic tuff, and lapilli tuff. The close association of water-laid sediments and volcanics indicates that at least part of the volcanism may have been subaqueous.

Stratigraphic relations and age

The Pollock Hills Formation is intruded by Mount Webb Granite and by at least one basic dyke, and is overlain unconformably by Heavitree Quartzite and Mesozoic rocks. It is inferred to overlie metamorphic rocks of the Arunta Complex.

Tuffaceous sandstone of the Pollock Hills Formation is intruded by Mount Webb Granite on the west side of the Pollock Hills, near the western edge of Webb Sheet area (Fig. 22). Here, dense mottled hornfelsed tuffaceous sandstone is exposed within 1 m of granite. An intrusive contact between acid lava and granite was observed north of the track, 7 km east of the Pollock Hills, where dense mottled hornfelsed lava lies next to unaltered granite. Three kilometres to the northwest similar horfelsed lava cut by granitic veins contains feldspar phenocrysts which have ragged outlines, attributed to partial melting. Thermal metamorphism of the Pollock Hills Formation appears to be restricted to slight recrystallisation and minor partial melting immediately next to intrusive contacts, indicating that the granite was probably a high-level, epizonal, intrusion.

An unconformable relation between the Pollock Hills Formation and Heavitree Quartzite is inferred in the western part of the Pollock Hills, where hilly outcrops of the two formations are separated by depressions covered by superficial sediments. Northeast of the Pollock Hills, gently dipping sublithic arenite mapped as Heavitree Quartzite overlies flow-banded and highly altered acid lava and weathered Mount Webb Granite.

Acid lava of the Pollock Hills Formation has been dated by the whole-rock Rb-Sr method at 1510 ± 240 m.y. (Page & others, 1976). The large uncertainty is due to the small range in Rb/Sr values in the specimens analysed. However, the Pollock Hills Formation is known to be intruded by the Mount Webb Granite, which has been dated at 1520 ± 40 m.y. (see below), and it is probable that the latter intrusion and the acid lavas were comagmatic, like the late Early Proterozoic acid lavas of the Mount Winnecke Formation and the intrusive Winnecke Granophyre, 350 km to the north-northeast. When the analysed lava samples are grouped with those of the Mount Webb Granite, a combined regression results, which indicates an age of 1526 ± 25 m.y. and an initial Sr^{87}/Sr^{86} of 0.7114 ± 0.004: this age is considered to be the best estimate for both the Pollock Hills Formation and Mount Webb Granite.

Mount Webb Granite

The Mount Webb Granite (Blake, 1977) crops out in the southwestern part of the Webb Sheet area, and is named after a prominent hill (at 22°56′30″S, 128°08′30″E), where it is exposed beneath a capping of Heavitree Quartzite (Figs. 23, 25). Between the Pollock Hills in the west and Angas Hills in the east, and near Mount Webb, unweathered Mount Webb Granite forms scattered groups of spherical boulders and tors up to 30 m high, surrounded by sand (Fig.

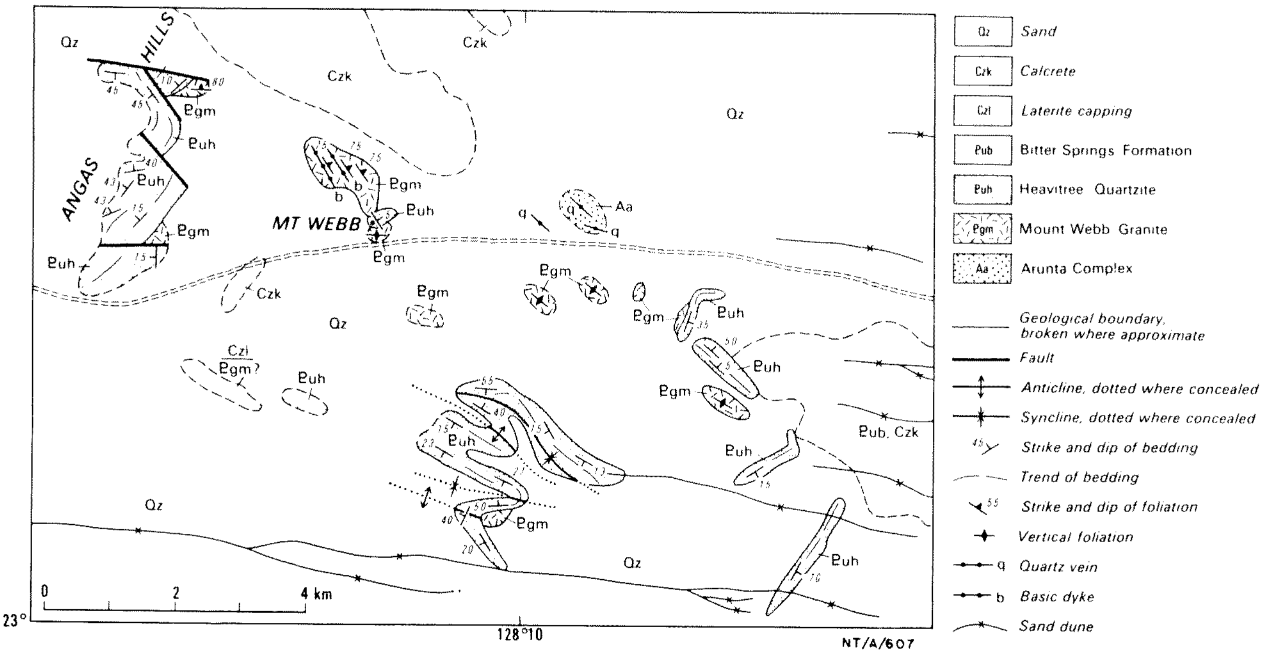


Fig. 25. Geological map of the Mount Webb area.

24). One of these outcrops, 32 km west-northwest of Mount Webb (at 22°50′00″S, 127°50′30″E), was selected as the type locality. On aerial photographs outcrops of unweathered granite are dark in tone, in marked contrast to surrounding pale-toned sand. Weathered granite is exposed in scarp slopes beneath Heavitree Quartzite, and also forms irregular rocky knolls up to 10 m high west of the Pollock Hills and near Mount Webb; it is very pale-toned on aerial photographs.

The Mount Webb Granite is mainly pinkish to greyish and medium to coarse-grained. It generally contains biotite, which in places is accompanied by hornblende. At most outcrops a moderately to steeply dipping foliation is present, trending west to north-northwest, and at some places, such as northwest of Mount Webb, the granite has a gneissic texture. The granite is cut by rare aplite veins less than 1 m wide, by quartz veins, and by later unfoliated basic dykes, all of which generally parallel the foliation.

Petrography

Most of the Mount Webb Granite is an even-grained adamellite, consisting essentially of quartz, about equal proportions of sodic plagioclase and alkali feldspar, and biotite. Hornblende and, less commonly, augite are present locally. Common accessory minerals in the adamellite are apatite, sphene, white mica, zircon, and metamict and opaque minerals; allanite and tourmaline are less common. Quartz shows strained extinction, and is commonly granulated, especially in gneissose adamellite. Sodic plagioclase (refractive indices less than those of quartz) shows weak zoning, and is partly altered to epidote, white mica, clay minerals, and chlorite. In contrast, alkali feldspar, most of which is slightly perthitic microcline, is generally unaltered. Biotite is mainly greenish-brown, and shows minor alteration to chlorite and epidote. Bluish-green, strongly pleochroic hornblende is commonly associated with biotite in adamellite east of 127°47′E. Augite granite, consisting essentially of quartz, albite, colourless augite, partly altered to pale green uralitic amphibole, and subordinate microcline, is present at a few places, mainly near Mount Webb.

Twelve kilometres east of the Pollock Hills, partly recrystallised granite is exposed alongside a cross-cutting basic dyke. Within 1 m of the chilled margin of the dyke, the granite is altered to quartz-feldspar 'porphyry' containing anhedral megacrysts of plagioclase, partly resorbed quartz and microcline, and chloritised biotite, set in a fine-grained partly granophyric groundmass; narrow zones of clay alteration have developed along cleavage planes in many of the microcline megacrysts, giving the crystals a striped appearance. Farther away from the dyke the granite has a normal even-grained medium to coarse granitic texture.

Chemical analyses (Tables 4 & 5) show that the Mount Webb Granite is generally similar in composition to the acid lava of the Pollock Hills Formation, and it is suggested that the intrusives and extrusives were comagmatic (Page & others, 1976). However, the analysed granite samples are richer in silica, and generally have higher differentiation indices. They also show a wider range of K_2O/Na_2O values, and are lower than the acid lava in iron, TiO_2, P_2O_5, and, except for sample 73490274A, in CaO.

Stratigraphic relations and age

The Mount Webb Granite intrudes the Arunta Complex and the Pollock Hills Formation, is cut by basic dykes, and is unconformably overlain by Heavitree Quartzite. Contacts with the Pollock Hills Formation are exposed 7 km east of the Pollock Hills, where hornfelsed acid lava is intruded by granite; 3 km to the northwest, where granitic veins cut acid lava; and west of the Pollock Hills, near the western edge of the Webb Sheet area, where granite has intruded and weakly metamorphosed overlying tuffaceous sandstone. The lack of much thermal metamorphism indicates that the

Mount Webb Granite was intruded into the Pollock Hills Formation at a high level.

Basic dykes cut the granite at outcrops between the Pollock Hills and Mount Webb, and are younger than the foliation of the adamellite. Heavitree Quartzite overlies weathered granite at several localities, including Mount Webb.

The Mount Webb Granite has been dated by the Rb-Sr method at 1520 ± 40 m.y. (Page & others, 1976), and hence is Carpentarian. It is probably comagmatic with the acid lavas of the Pollock Hills Formation, and not related to either of the two major metamorphic events that affected the Arunta Complex to the east at 1719 ± 24 m.y. (Armstrong & Stewart, 1975) and 1076 ± 50 m.y. (Marjoribanks & Black, 1974). These ages do not correlate with the 1526 ± 25 m.y. age obtained from a regression of both Mount Webb Granite and Pollock Hills Formation results, and thought to be the best estimate for both these units (Page & others, 1976).

The Mount Webb Granite is appreciably younger than the Winnecke Granophyre, Slatey Creek Granite, The Granites Granite, and Lewis Granite of The Granites-Tanami Block, and is also younger than the Gardiner Sandstone, the basal unit of the Birrindudu Group, in the Birrindudu Basin.

Basic dykes

Numerous basic dykes are present in the southeast of the Arunta Block, in Webb Sheet area. They intrude the Mount Webb Granite between Mount Webb and the Pollock Hills, and at least one intrudes acid lava of the Pollock Hills Formation. Most of the dykes are less than 10 m wide, but some are over 100 m. Outcrops commonly consist of spheroidal boulders which are smaller and darker than adjacent granite boulders. The dykes have north-northwesterly trends, although in detail they are commonly irregular and anastomosing. Prominent lineaments visible on aerial photographs between the Angas Hills and Pollock Hills probably indicate dykes concealed by superficial deposits.

The basic dykes are locally parallel to the foliation of the Mount Webb Granite, but are not themselves foliated, indicating that they were intruded after the granite was foliated. At one locality, near the track 11 km east of the Pollock Hills, a large basic dyke has caused recrystallisation of adjacent granite. The dykes are older than the Heavitree Quartzite, and are probably late Carpentarian.

The basic dykes have chilled fine-grained basaltic margins and doleritic to gabbroic centres. They are aphyric, and consist essentially of subhedral plagioclase laths (bytownite-labradorite showing normal zoning), ophitic pale brown augite, orthopyroxene that is pleochroic from pale pinkish to greenish-grey, equant olivine generally altered to serpentine, and opaque minerals. Most samples examined contain minor primary yellow-brown biotite, greenish-brown hornblende, and apatite, and secondary actinolite, calcite, chlorite, epidote, and sericite; some also contain small amounts of interstitial quartz and alkali feldspar.

CHEMISTRY OF THE BASEMENT GRANITIC ROCKS AND ASSOCIATED ACID VOLCANICS

Chemical analyses, CIPW norms, element ratios, and differentiation indices of granitic rocks and associated acid volcanics from The Granites-Tanami and Arunta Blocks are presented in Tables 2-5, and conventional variation diagrams are shown in Figures 26-29. The analysed samples are too few to establish any chemical trends within individual rock units. However, for the purposes of this account, all the units are regarded as belonging to the same petrographic province, in spite of their wide age range (Table 7), and the analysed samples are therefore treated as a single group.

In Figure 26, CaO, MgO, total Fe (as FeO), TiO_2, and Sr are shown to generally decrease, and K_2O, Rb, Rb/Sr, and, perhaps, U/Th to increase as the differentiation index increases. On the AFM diagram (Fig. 27) the samples plot close to the AF join, and may indicate an iron-enrichment trend. The CaO-Na_2O-K_2O diagram (Fig. 28) shows that most of the rocks are potassium-rich. The very high K_2O in two samples, and low K_2O in another sample, are attributed to local metasomatism or alteration.

On the Q-Ab-Or diagram (Fig. 29) most of the granitic rocks cluster around the granite 'minimum' for water vapour pressures of 4 Kb and Ab/An of 2.9. This is in agreement with field observations that the granitic bodies are high-level, epizonal intrusions.

The analysed samples show more chemical properties of the 'S-type' granites of Chappell & White (1974), thought by them to be derived from sedimentary material, than of their 'I-type' granites, thought to be derived from igneous material: mafic representatives appear to be absent, trends on variation diagrams are generally irregular and poorly defined, and many of the samples have more than one percent normative corundum and K_2O/Na_2O values greater than 1.0. Crustal contamination is indicated by the relatively high initial Sr^{87}/Sr^{86} values of the various units (Table 7).

TABLE 7. Rb-Sr ISOTOPIC AGES AND INITIAL $Sr^{87/86}$ VALUES OF GRANITIC AND ASSOCIATED VOLCANIC ROCK UNITS OF THE GRANITES-TANAMI AND ARUNTA BLOCKS

(from Page & others, 1976)

Rock unit	*Isotopic age*	*Initial Sr^{87}/Sr^{86}*
Mount Winnecke Formation	1808 ± 15 m.y.	0.7052 ± 0.0038
Winnecke Granophyre	1802 ± 15 m.y.	0.7074 ± 0.0036
The Granites Granite	1780 ± 24 m.y.	0.7066 ± 0.0019
Slatey Creek Granite	1770 ± 55 m.y.	0.709 ± 0.019
Lewis Granite	1720 ± 8 m.y.	0.7091 ± 0.0010
Pollock Hills Formation	1510 ± 240 m.y.	0.711 ± 0.013
Mount Webb Granite	1518 ± 40 m.y.	0.7146 ± 0.0099

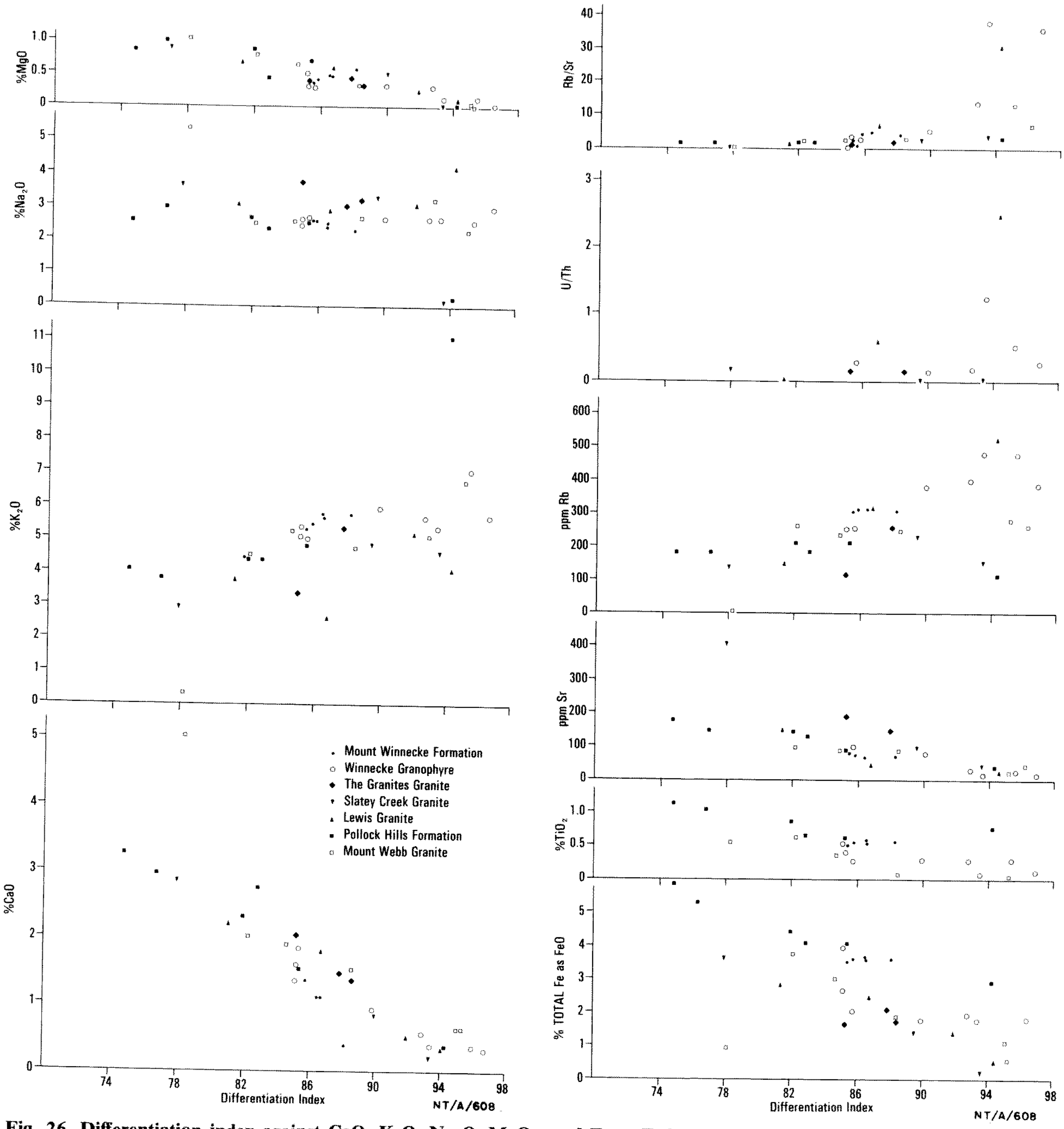


Fig. 26. Differentiation index against CaO, K_2O, Na_2O, MgO, total Fe as FeO, TiO_2, Sr, Rb, U/Th and Rb/Sr for granitic rocks and associated acid volcanics from The Granites-Tanami and Arunta Blocks.

TABLE 2. CHEMICAL ANALYSES, CIPW NORMS, AND DIFFERENTIATION INDICES (DI): MOUNT WINNECKE FORMATION AND WINNECKE GRANOPHYRE

(sample types and localities are given in Table 6)

	Acid lavas of the Mount Winnecke Formation					*Winnecke Granophyre*							
	7249–5029A	7249–5029C	7249–5029I	7249–5030	7249–5031	7149–0156	7249–5022B	7249–5023A	7249–5023D	7249–5025A	7249–5025B	7249–5026B	7249–5028
SiO_2	71.8	71.6	71.5	71.6	72.0	71.6	73.2	75.9	77.0	73.0	76.6	71.4	75.7
TiO_2	0.52	0.58	0.59	0.54	0.57	0.40	0.28	0.28	0.12	0.27	0.08	0.53	0.26
Al_2O_3	12.8	12.8	12.9	12.9	12.9	14.2	14.1	12.2	12.1	14.0	12.4	12.8	11.7
Fe_2O_3	0.75	0.65	0.75	0.55	0.50	0.70	0.35	0.75	1.00	0.30	0.60	1.10	0.35
FeO	2.85	3.05	2.95	3.10	3.15	2.05	1.70	1.30	0.35	1.55	1.25	2.95	1.50
MnO	0.06	0.06	0.07	0.07	0.14	0.07	0.03	0.03	0.01	0.04	0.05	0.09	0.05
MgO	0.38	0.44	0.49	0.47	0.59	0.53	0.31	0.31	0.04	0.32	0.13	0.32	0.14
CaO	1.56	1.33	1.09	1.09	0.39	1.38	1.85	0.58	0.33	0.96	0.39	1.58	0.38
Na_2O	2.55	2.55	2.40	2.50	2.30	2.45	2.65	2.70	3.00	2.65	2.65	2.65	2.50
K_2O	5.25	5.45	5.75	5.65	5.75	5.05	4.95	5.65	5.65	5.95	5.30	5.40	7.05
P_2O_5	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.06	0.16	0.13	0.11	0.09	0.03
H_2O+	0.68	0.79	0.88	0.63	0.96	0.75	0.22	0.23	0.16	0.24	0.19	0.48	0.18
H_2O-	0.32	0.37	0.28	0.39	0.36	0.43	0.26	0.28	0.36	0.30	0.39	0.38	0.38
CO_2	0.05	—	—	—	0.11								
Total	99.7	99.8	99.8	99.6	99.9	99.8	100.0	100.3	100.3	99.7	100.1	99.8	100.2
Total Fe as FeO	3.53	3.64	3.63	3.60	3.60	2.68	2.02	1.98	1.25	1.82	1.79	3.94	1.82
CIPW Norms													
Q	32.19	31.34	31.54	31.23	34.00	33.59	33.87	36.52	37.72	31.92	39.57	30.36	32.79
co	0.57	0.66	1.12	1.07	2.84	2.59	1.36	0.74	0.84	1.78	1.87	—	—
or	31.42	32.64	34.44	33.85	34.47	30.27	29.37	33.46	33.46	35.45	31.45	32.26	41.79
ab	21.85	21.85	20.58	21.44	19.74	21.02	22.51	22.89	25.43	22.60	22.51	22.66	21.00
an	6.53	5.69	4.49	4.49	0.26	5.95	8.30	2.49	0.59	3.95	1.22	7.17	—
ac	—	—	—	—	—	—	—	—	—	—	—	—	0.19
di-wo	—	—	—	—	—	—	—	—	—	—	—	0.07	0.71
di-en	—	—	—	—	—	—	—	—	—	—	—	0.01	0.11
di-fs	—	—	—	—	—	—	—	—	—	—	—	0.06	0.66
hy-en	0.96	1.11	1.24	1.19	1.49	—	0.78	0.77	0.10	0.80	0.33	0.79	0.24
hy-fs	3.92	4.27	4.01	4.54	4.76	—	2.44	1.36	—	2.25	1.77	3.78	1.53
mg	1.10	0.96	1.10	0.81	0.74	1.34	0.51	1.09	0.81	0.44	0.87	1.61	0.42
he	—	—	—	—	—	2.69	—	—	0.44	—	—	—	—
il	1.10	1.12	1.14	1.04	1.10	1.03	0.53	0.53	0.23	0.52	0.15	1.02	0.50
ap	0.36	0.36	0.36	0.36	0.36	0.77	0.33	0.14	0.38	0.31	0.26	0.22	0.07
ca	0.12	—	—	—	—	0.36	—	—	—	—	—	—	—
DI	85.46	85.84	86.56	86.52	88.21	85.27	85.76	92.87	96.61	89.96	93.53	85.28	95.59
$\frac{K_2O}{Na_2O}$	2.06	2.14	2.40	2.26	2.50	2.06	1.87	2.09	1.68	2.25	2.00	2.04	2.82

Chemical analyses by Australian Mineral Development Laboratories, Adelaide (Report AN 4780/73)

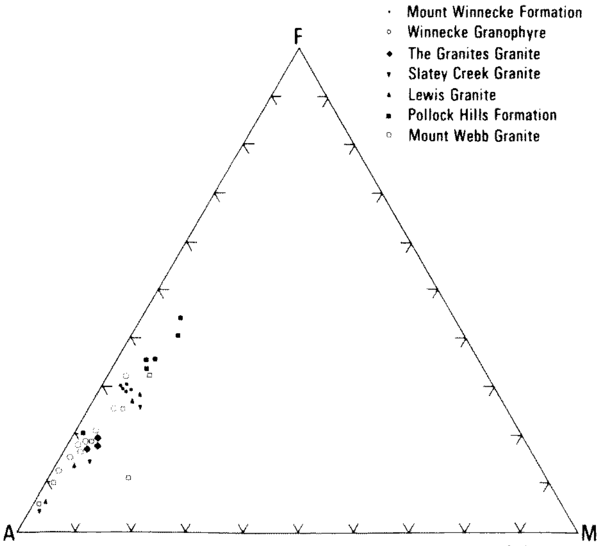


Fig. 27. AFM plot of granitic rocks and associated acid volcanics from The Granites-Tanami and Arunta Blocks.

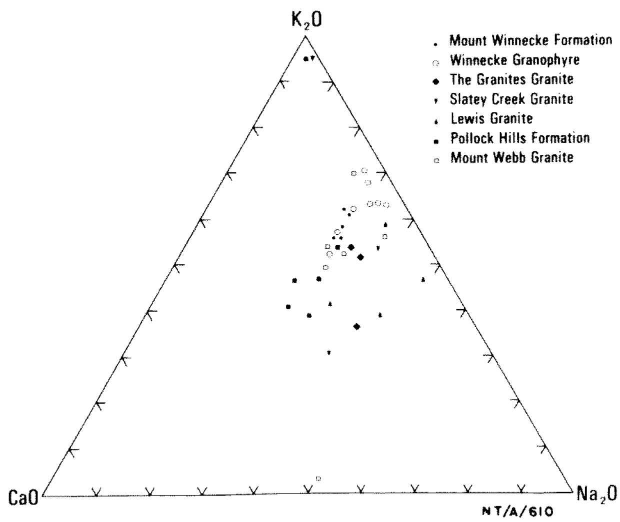


Fig. 28. CaO-Na_2O-K_2O plot of granitic rocks and associated acid volcanics from The Granites-Tanami and Arunta Blocks.

TABLE 3. CHEMICAL ANALYSES, CIPW NORMS, AND DIFFERENTIATION INDICES (DI): THE GRANITES GRANITE, SLATEY CREEK GRANITE, AND LEWIS GRANITE

(sample types and localities are given in Table 6)

	The Granites Granite				*Slatey Creek Granite*			*Lewis Granite*			
	7249–1492	7249–1495	7249–4150B	*	7249–0306	7249–1022	7249–5014B	7249–2071	7249–5001	7249–5005	7249–5007B
SiO_2	72.67	73.86	73.24	71.55	69.67	73.26	80.81	71.77	75.13	75.59	74.12
TiO_2	0.30	0.20	0.15	0.39	0.32	0.12	0.37	0.38	0.01	0.27	0.08
Al_2O_3	13.40	13.47	14.10	15.00	15.48	14.55	10.74	13.80	14.69	11.70	14.08
Fe_2O_3	0.48	0.28	0.30	0.56	0.63	0.16	0.01	0.35	0.15	0.61	0.23
FeO	1.66	1.52	1.37	2.13	2.08	1.32	0.20	2.47	0.42	1.91	1.14
MnO	0.05	0.06	0.03	0.04	0.05	0.04	0.00	0.03	0.03	0.04	0.06
MgO	0.46	0.33	0.41	0.14	0.90	0.54	0.07	0.70	0.11	0.61	0.29
CaO	1.49	1.38	2.03	2.18	2.89	0.85	0.02	2.24	0.37	1.08	0.52
Na_2O	3.05	3.20	3.71	3.92	3.70	3.31	0.17	3.04	4.14	2.92	3.07
K_2O	5.26	4.76	3.32	3.68	2.98	4.84	4.57	3.75	4.00	2.57	5.11
P_2O_5	0.02	0.01	0.00	0.19	0.03	0.05	0.00	0.06	0.12	0.08	0.14
H_2O+	0.52	0.31	0.46	0.43	0.35	0.78	2.36	0.58	0.60	0.97	0.69
H_2O-	0.02	0.01	0.04	0.05	0.03	0.00	0.24	0.02	0.02	0.03	0.03
Total	99.38	99.39	99.16	99.16	99.11	99.82	99.55	99.19	99.79	98.38	99.56
Total Fe as FeO	2.09	1.77	1.64		2.65	1.46	0.21	2.79	0.56	2.46	1.35
CIPW Norms											
Q	30.32	32.87	33.52		28.37	32.34	64.14	32.87	35.12	45.79	35.12
co	0.03	0.58	0.73		1.00	2.47	5.65	0.83	3.19	2.41	2.92
or	31.44	28.39	19.88		17.83	28.87	27.85	22.47	23.83	15.59	30.55
ab	26.10	27.32	31.80		31.70	28.27	1.48	26.08	35.31	25.36	26.27
an	7.34	6.84	10.20		14.23	3.93	0.10	10.87	1.06	4.96	1.69
di-wo	—	—	—		—	—	—	—	—	—	—
di-en	—	—	—		—	—	—	—	—	—	—
di-fs	—	—	—		—	—	—	—	—	—	—
hy-en	1.16	0.83	1.03		2.27	1.36	0.18	1.77	0.28	1.56	0.73
hy-fs	2.28	2.36	2.10		2.90	2.19	—	3.73	0.69	2.70	1.90
mt	0.70	0.41	0.44		0.93	0.23	—	0.51	0.22	0.91	0.34
he	—	—	—		—	—	0.01	—	—	—	—
il	0.58	0.38	0.29		0.62	0.23	0.44	0.73	0.02	0.53	0.15
ru	—	—	—		—	—	0.15	—	—	—	—
ap	0.05	0.02	—		0.07	0.12	—	0.14	0.29	0.19	0.34
DI	87.86	88.57	85.20		77.90	89.48	93.47	81.42	94.26	86.74	91.94

Chemical analyses by Australian Mineral Development Laboratories, Adelaide (Report AN 2008/75), except * — by Kleeman (1934), includes 0.04% ZrO, 0.06% S.

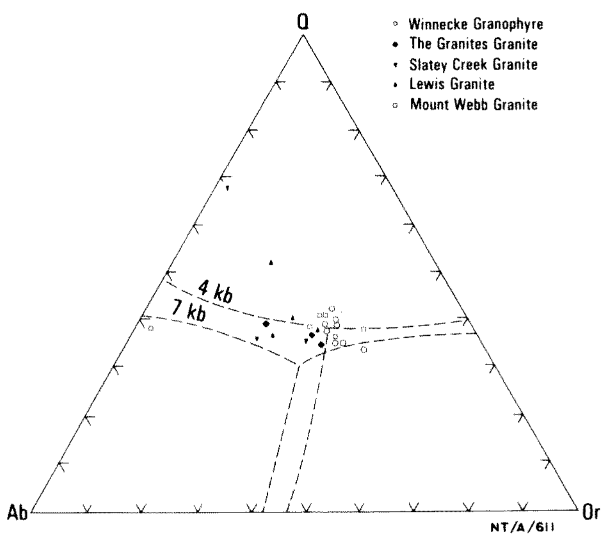


Fig. 29. Q-Ab-Or plot of granitic rocks from The Granites-Tanami and Arunta Blocks, showing cotectic lines for water vapour pressure in the system at 4 kb and 7 kb, with Ab/An = 2.9.

TABLE 4. CHEMICAL ANALYSES, CIPW NORMS, AND DIFFERENTIATION INDICES (DI): POLLOCK HILLS FORMATION, AND MOUNT WEBB GRANITE
(sample types and localities are given in Table 6)

	Pollock Hills Formation						*Mount Webb Granite*					
	7349–0088	7349–0097	7349–0098	7349–0103	7349–0120C	7349–0122	7349–0101	7349–0102A	7349–0102B	7349–0121	7349–0274A	7349–0276
SiO_2	70.2	69.6	70.7	67.1	69.6	68.7	71.4	76.4	71.4	74.7	72.5	76.5
TiO_2	0.60	0.70	0.65	1.11	0.78	1.02	0.34	0.03	0.60	0.07	0.55	0.01
Al_2O_3	13.0	13.1	12.4	13.7	13.2	13.3	13.5	12.5	13.1	13.0	13.7	12.9
Fe_2O_3	3.00	2.40	2.80	2.90	2.85	2.30	1.03	0.73	1.50	0.82	0.21	0.14
FeO	1.36	2.25	1.49	3.25	0.42	3.20	2.05	0.36	2.40	1.09	0.71	0.41
MnO	0.05	0.08	0.06	0.11	0.02	0.10	0.05	0.01	0.06	0.07	0.03	$<$0.01
MgO	0.71	0.74	0.47	0.75	0.11	1.00	0.64	0.03	0.79	0.32	1.03	0.01
CaO	1.58	2.30	2.75	3.25	0.35	2.95	1.90	0.65	2.00	1.52	5.00	0.66
Na_2O	2.55	2.65	2.35	2.50	0.24	2.95	2.65	3.30	2.55	2.75	5.40	2.25
K_2O	4.80	4.40	4.35	4.05	11.10	3.80	5.30	5.05	4.50	4.80	0.33	6.70
P_2O_5	0.15	0.18	0.16	0.26	0.26	0.22	0.09	0.01	0.13	0.05	0.12	0.02
H_2O+	0.84	0.73	0.78	0.47	0.24	0.17	0.25	0.22	0.60	0.48	0.09	0.27
H_2O-	0.28	0.21	0.18	0.21	0.50	0.21	0.23	0.20	0.20	0.18	0.29	0.21
CO_2	0.45	0.50	0.80	0.10	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.10
S	0.05	0.03	0.03	0.02	0.01	0.01	0.04	0.06	0.03	0.02	0.02	0.01
Total	99.6	99.8	99.9	99.8	99.7	99.9	99.6	99.6	99.9	99.9	100.0	100.2
Total Fe as FeO	4.06	4.41	4.01	5.86	2.99	5.27	2.98	1.02	3.75	1.83	0.90	0.54
CIPW Norms												
Q	34.76	33.05	36.82	29.38	25.96	29.18	30.52	36.94	33.67	36.56	30.55	36.51
co	2.17	1.40	1.08	0.15	0.90	—	0.52	0.57	0.84	0.76	—	1.03
or	28.81	26.29	25.97	24.15	66.26	22.54	31.60	30.10	26.83	28.58	1.96	34.70
ab	21.91	22.66	20.08	21.35	2.05	25.05	22.62	28.16	21.77	23.44	45.84	19.09
an	4.08	7.15	7.62	13.92	—	11.88	7.96	2.87	8.84	6.95	12.22	2.52
di-wo	—	—	—	—	—	0.44	—	—	—	—	3.22	—
di-en	—	—	—	—	—	0.22	—	—	—	—	2.57	—
di-fs	—	—	—	—	—	0.22	—	—	—	—	0.28	—
hy-en	1.80	1.85	1.18	1.88	0.28	2.28	1.61	0.08	1.99	0.80	—	0.02
hy-fs	—	1.15	—	1.96	—	2.27	2.47	0.03	2.31	1.35	—	0.62
mt	2.85	3.52	3.15	4.24	—	3.55	1.51	1.07	2.20	1.20	0.31	0.20
he	1.08	—	0.66	—	2.88	—	—	—	—	—	—	—
il	1.16	1.34	1.25	2.13	0.94	1.95	0.65	0.06	1.15	0.13	1.05	0.02
ru	—	—	—	—	0.29	—	—	—	—	—	—	—
ap	0.36	0.43	0.38	0.62	0.62	0.52	0.22	0.02	0.31	0.12	0.29	0.05
ca	1.04	1.15	1.84	0.23	0.11	0.11	0.34	0.11	0.11	0.11	0.11	0.23
DI	85.47	82.00	82.86	74.88	94.27	76.77	84.73	95.20	82.27	88.58	78.35	95.31

Chemical analyses by Australian Mineral Development Laboratories, Adelaide (Report AN 835/75).

TABLE 5. TRACE ELEMENTS (ppm), ELEMENT RATIOS, AND DIFFERENTIATION INDICES (DI) OF GRANITIC ROCKS AND ASSOCIATED ACID VOLCANICS OF THE GRANITES-TANAMI AND ARUNTA BLOCKS

Rock Unit	*BMR Sample No.*	*U*	*Th*	*Rb*	*Sr*	*U/Th*	*K/Rb*	*Rb/Sr*	*K_2O/Na_2O*	*DI*
Mount Winnecke Formation	72495029A	—	—	307	80	—	142	0.4	2.06	85.46
	72495029C	—	—	313	73	—	145	4.3	2.14	85.84
	72495029D	—	—	309	76	—	—	4.1	—	—
	72495029E	—	—	275	60	—	—	4.6	—	—
	72495029H	—	—	302	81	—	—	3.7	—	—
	72495029I	—	—	—	—	—	—	—	2.40	86.56
	72495029K	—	—	308	87	—	—	3.5	—	—
	72495030	—	—	310	66	—	151	4.7	2.26	86.52
	72495031	—	—	309	70	—	154	4.4	2.50	88.21
	72495033	—	—	38	18	—	—	2.1	—	—
	72495034	—	—	240	9	—	—	26.7	—	—

TABLE 5. *(continued)*

Rock Unit	*BMR Sample No.*	*U*	*Th*	*Rb*	*Sr*	*U/Th*	*K/Rb*	*Rb/Sr*	K_2O/Na_2O	*DI*
Winnecke Granophyre	71490156	—	—	252	97	—	166	2.6	2.06	85.27
	72495022B	5	19	257	99	0.26	160	2.6	1.87	85.76
	72495023A	8	38	400	29	0.21	117	13.8	2.09	92.87
	72495023C	—	—	434	13	—	—	33.4	—	—
	72495023D	11	40	390	11	0.28	120	35.4	1.68	96.61
	72495023F	—	—	441	18	—	—	24.5	—	—
	72495024B	—	—	391	24	—	—	16.3	—	—
	72495024C	—	—	348	71	—	—	49	—	—
	72495025A	8	26	387	77	0.31	128	5.0	2.25	89.96
	72495025B	39	31	483	12	1.26	91	39.0	2.00	93.53
	72495025D	—	—	365	41	—	—	8.9	—	—
	72495026B	9	41	—	—	0.22	—	—	2.04	85.28
	72495028	22	42	480	28	0.52	122	1.6	2.82	95.59
	72495035A	—	—	306	80	—	—	3.8	—	—
	72495035B	—	—	302	84	—	—	3.6	—	—
The Granites Granite	72491492	—	—	259	148	—	169	1.8	1.72	87.86
	72491493	—	—	255	138	—	—	1.8	—	—
	72491494	—	—	273	56	—	—	4.9	—	—
	72491495	11	31	—	—	0.35	—	—	1.49	88.57
	72491496	6	20	—	—	0.30	—	—	—	—
	72494150AA	14	13	167	41	1.08	—	4.1	—	—
	72494150A	3	26	141	150	0.12	—	0.9	—	—
	72494150B	5	16	116	188	0.31	238	0.6	0.89	85.20
	72494210	5	44	250	144	0.11	—	1.7	—	—
Slatey Creek Granite	72490306	3	16	136	405	0.19	182	0.3	0.81	77.90
	72491022	<2	16	227	95	<0.13	177	2.4	1.46	89.48
	72492024	<2	14	—	—	<0.14	—	—	—	—
	72495011A	—	—	249	15	—	—	16.6	—	—
	72495014B	5	23	156	43	0.22	243	3.6	26.88	93.47
Lewis Granite	72490003B	—	—	600	11	—	—	54.5	—	—
	72490003C	—	—	691	26	—	—	26.6	—	—
	72492071	3	39	148	148	0.08	210	1.0	1.23	81.42
	72492663	13	24	511	44	0.54	—	11.6	—	—
	72495001	10	4	520	17	2.50	64	31.2	0.97	94.26
	72495002	9	9	533	28	1.00	—	19.0	—	—
	72495003B	—	—	453	65	—	—	7.0	—	—
	72495003BB	—	—	706	26	—	—	27.2	—	—
	72495005	38	62	311	43	0.61	69	7.3	0.88	86.74
	72495006	16	47	—	—	0.34	—	—	—	—
	72495007B	27	25	—	—	1.08	—	—	1.66	91.94
Pollock Hills Formation	73490088	—	—	206	99	—	193	2.1	1.88	85.47
	73490097	—	—	208	136	—	175	1.5	1.66	82.00
	73490098	—	—	185	128	—	195	1.4	1.85	82.86
	73490099	—	—	122	116	—	—	1.1	—	—
	73490103	—	—	177	176	—	190	1.0	1.62	74.88
	73490115A	—	—	164	83	—	—	2.0	—	—
	73490120C	—	—	113	36	—	812	3.1	46.25	94.27
	73490122	—	—	179	141	—	176	1.3	1.29	76.77
Mount Webb Granite	73490101	—	—	239	98	—	184	2.4	2.00	84.73
	73490102A	—	—	280	21	—	150	13.3	1.53	95.20
	73490102B	—	—	260	95	—	144	2.7	1.76	82.27
	73490121	—	—	247	84	—	161	2.9	1.75	88.58
	73490274A	—	—	1	173	—	375	0.0	0.06	78.35
	73490276	—	—	260	36	—	214	7.2	2.98	95.31

U and Th determinations by XRF, by J. G. Pyke, BMR.
Rb and Sr determinations by isotope dilution, by R. W. Page, BMR.

TABLE 6. TYPES AND LOCALITIES OF CHEMICALLY ANALYSED ROCK SAMPLES FROM THE GRANITES-TANAMI AND ARUNTA BLOCKS

Rock unit	*BMR sample No.*	*Rock type*	*Locality* *Latitude* °	′	″	*Longitude* °	′	″
Mount Winnecke Formation	72495029A	Porphyritic acid lava						
	72495029C	Porphyritic acid lava						
	72495029D	Porphyritic acid lava						
	72495029E	Porphyritic acid lava	18	47	50	130	13	10
	72495029I	Porphyritic acid lava						
	72495029H	Porphyritic acid lava						
	72495029K	Porphyritic acid lava						
	72495030	Porphyritic acid lava	18	47	30	130	13	30
	72495031	Porphyritic acid lava	18	47	10	130	13	40
	72495033	Sparsely porphyritic acid lava	18	44	05	130	13	40
	72495034	Sparsely porphyritic acid lava	18	37	55	130	17	40
Winnecke Granophyre	71490156	Acid porphyry	18	48	20	130	24	20
	72495022B	Acid porphyry	19	02	18	130	10	12
	72495023A	Granophyre	18	54	30	130	08	30
	72495023C	Granophyre	18	54	30	130	08	30
	72495023D	Granophyre	18	54	30	130	08	30
	72495023F	Granophyre	18	54	30	130	08	30
	72495024B	Porphyritic granophyre	18	55	00	130	07	30
	72495024C	Porphyritic granophyre	18	55	00	130	07	30
	72495025A	Biotite adamellite	18	54	45	130	07	10
	72495025B	Aplite	18	54	45	130	07	10
	72495025D	Acid porphyry	18	54	45	130	07	10
	72495026B	Porphyritic granophyre	18	50	18	130	11	12
	72495028	Granophyre	18	47	40	130	12	30
	72495035A	Porphyritic granophyre	18	36	50	130	18	10
	72495035B	Porphyritic granophyre	18	36	50	130	18	10
The Granites Granite	72491492	Biotite adamellite	20	36	40	130	31	20
	72491493	Biotite adamellite	20	36	30	130	31	10
	72491494	Biotite adamellite	20	37	00	130	31	30
	72491495	Porphyritic biotite adamellite	20	34	30	130	21	00
	72491496	Biotite adamellite	20	34	30	130	21	00
	72494150AA	Aplite	20	43	50	130	14	30
	72494150A	Biotite adamellite	20	43	50	130	14	30
	72494150B	Biotite adamellite	20	43	50	130	14	30
	72494210	Biotite adamellite	20	35	45	130	30	10
Slatey Creek Granite	72490306	Biotite granodiorite	19	48	00	128	28	00
	72491022	Muscovite-biotite granodiorite	19	22	00	128	41	15
	72492024	Biotite adamellite	19	47	00	128	26	36
	72495011A	Muscovite adamellite	19	32	00	128	39	15
	72495014B	Aplite	19	24	20	128	41	30
Lewis Granite	72490003B	Muscovite-biotite adamellite	20	09	00	128	40	00
	72490003C	Aplite	20	09	00	128	40	00
	72492071	Porphyritic biotite adamellite	20	08	00	128	35	00
	72492663	Biotite-muscovite adamellite	20	07	40	128	38	00
	72495001	Muscovite microadamellite	20	12	40	128	40	35
	72495002	Microadamellite	20	12	40	128	40	35
	72495003B	Muscovite-biotite adamellite	20	12	40	128	40	35
	72495003BB	Aplite	20	12	40	128	40	35
	72495005	Muscovite-biotite adamellite, sparsely porphyritic	20	12	00	128	40	00
	72495006	Porphyritic muscovite-biotite adamellite	20	12	00	128	39	36
	72495007B	Porphyritic muscovite-biotite adamellite	20	10	42	128	39	06
Pollock Hills Formation	73490088	Porphyritic acid lava	22	51	25	127	38	10
	73490097	Porphyritic acid lava	22	51	00	127	38	50
	73490098	Porphyritic acid lava	22	51	40	127	39	00
	73490099	Porphyritic acid lava	22	52	00	127	40	20
	73490103	Porphyritic acid lava	22	51	20	127	43	30
	73490115A	Porphyritic acid lava	22	48	05	127	42	00
	73490120C	Porphyritic acid lava, highly altered	22	47	50	127	43	30
	73490122	Porphyritic acid lava	22	50	00	127	44	00
Mount Webb Granite	73490101	Foliated boitite adamellite	22	52	00	127	43	30
	73490102A	Aplite	22	52	00	127	43	50
	73490102B	Biotite adamellite	22	52	00	127	43	50
	73490121	Biotite adamellite	22	49	10	127	43	00
	73490274A	Foliated hornblende-augite-albite granite	22	50	30	127	53	25
	73490276	Aplite	22	50	00	127	50	35

CARPENTARIAN AND ADELAIDEAN COVER ROCKS

BIRRINDUDU BASIN

The sedimentary rocks of the Birrindudu Basin (Fig. 30) belong to two major sequences and their probable stratigraphic equivalents. The older major sequence, the Carpentarian Birrindudu Group, is overlain unconformably by the younger, the Adelaidean Redcliff Pound Group. Both groups consist predominantly of sandstone.

BIRRINDUDU GROUP

The Birrindudu Group (Blake & others, 1975) crops out extensively in the north of The Granites-Tanami region. It comprises three conformable formations, the Gardiner Sandstone at the base, the Talbot Well Formation, and the Coomarie Sandstone at the top, and reaches a maximum thickness of about 6000 m, east of the Gardner Range. The Group is probably mid-Carpentarian; seven samples of glauconite from near the top of the Gardiner Sandstone have been dated by the K-Ar and Rb-Sr methods (Page & others, 1976), and gives ages in the range 1400-1600 m.y. The preferred K-Ar age, 1560 ± 20 m.y., is consistent with the Rb-Sr age for four of the glauconite samples (1560 ± 180 m.y., initial Sr^{87}/Sr^{86} = 0.731 ± 0.016), and is considered the best estimate for the age of the Gardiner Sandstone and the Birrindudu Group as a whole.

The Birrindudu Group rests unconformably on the Tanami Complex, Pargee Sandstone, unnamed granites, and probably also on the Mount Winnecke Formation, Supplejack Downs Sandstone, and Winnecke Granophyre. It is overlain unconformably by the Cambrian Antrim Plateau Volcanics and Mesozoic sandstone, and by the Redcliff Pound Group. Probable stratigraphic equivalents of the Birrindudu Group are the Mount Parker Sandstone and Bungle Bungle Dolomite in the unnamed basin to the northwest, and the Limbunya Group, which may occupy a part of the Birrindudu Basin extending northwards into the Victoria River region (Plumb & Derrick, 1975; Sweet, 1977).

Glauconite in the Gardiner Sandstone, stromatolites in the Talbot Well Formation, and sedimentary structures indicate that the Birrindudu Group is probably marine and that much of it may have been deposited in shallow water.

Gardiner Sandstone

The Gardiner Sandstone was named the Gardiner Beds by Casey & Wells (1964), after the Gardner Range (so named by Davidson (1905) but incorrectly spelt 'Gardiner' on most Western Australian maps) in Tanami and Billiluna Sheet areas. It was redefined as a formation by Blake & others (1975). It is the oldest and most widespread formation of the Birrindudu Group, and forms most of the more prominent ridges and hills in the north of the area. The type section for the unit is at Larranganni Bluff at the southern end of the Gardner Range (Casey & Wells, 1964), and the maximum exposed thickness (about 3000 m) is in the Ware Range in the northeast of the area. About 2200 m of Gardiner Sandstone crops out in the Gardner Range northwest of Mount Stubbins.

The Gardiner Sandstone generally forms strike ridges where it is steeply dipping, plateaus bounded by scarps where it is flat or gently folded, and cuestas where it has a consistent gentle dip. On aerial photographs, bedding trends, joint patterns, and cross-cutting fault lines and quartz veins can be distinguished in most outcrops, and many fold structures can be delineated.

Lithology

Rock types exposed are sublithic arenite and subordinate quartz arenite, conglomerate, shale, siltstone, glauconitic sandstone, and at one locality, dolomitic sandstone. Although sandstone predominates in outcrops, stratigraphic drilling in Tanami Sheet area (Blake, 1974) indicated that it is mainly shale that underlies the superficial cover between outcrops; hence there may be nearly as much shale as sandstone in the formation.

The sublithic arenite and quartz arenite are mostly medium-grained, but range from coarse to fine. Locally they include shale pellets, scattered pebbles, and conglomerate lenses. They range in colour from white or grey to pink, maroon, and purple, according to the amount of iron-staining. Individual beds range in thickness from a few centimetres to a metre or more. Most are cross-bedded, and ripple marks are common in places. Mudcracks are present locally, as, for example, in the Killi Killi Hills. The arenites have a quartz-overgrowth cement and up to 10 percent sericitic matrix. The grains are subangular to rounded. Grains of little altered feldspar have been identified in only a few of the many arenite specimens examined microscopically, but grains of turbid quartz, which may be pseudomorphing feldspar, are common. Many of the lithic grains are derived from volcanic rocks. Heavy minerals present include tourmaline and zircon. Some of the sublithic arenite near the base of the formation is micaceous.

Conglomerate is common at or near the base of the Gardiner Sandstone; for example, on the east side of the Ware Range, on the south and west sides of the Gardner Range, and in the Pargee Range. At these places the conglomerate is up to 12 m thick and contains rounded to angular pebbles, cobbles, and boulders of various types, including vein quartz, greywacke, phyllite, quartzite, and rare basic volcanics, all of which were probably derived from the Tanami Complex. Locally it also contains boulders of conglomerate derived from the Pargee Sandstone. At the Killi Killi Hills, basal conglomerate contains appreciable amounts of uranium and rare-earth elements (this occurrence is described in the section on Economic Geology). Beds and lenses of conglomerate are also locally present higher in the formation; for instance, in the Farrands Hills, where a 10-m thick bed, 200 m above the base of the formation, forms a smoothly rounded strike ridge, and in the Mana and Supplejack Ranges. The conglomerates above the base of the formation are made up mainly of well-rounded pebbles and cobbles of quartz arenite, sublithic arenite and vein quartz.

Sequences of thinly interbedded shale, siltstone, and fine-grained sublithic arenite are best exposed in gullies developed on scarps and on the sides of ridges. At most places these sequences are near the base of the formation. Some are over 80 m thick. The shale is mainly banded or mottled maroon and greenish-grey, and some in the subsurface is gypsiferous.

Glauconitic sandstone is common at one or two stratigraphic levels in the top 500 m of the formation, where it forms useful marker beds. The glauconite occurs mainly as globular grains, and is present in both sublithic arenite and quartz arenite.

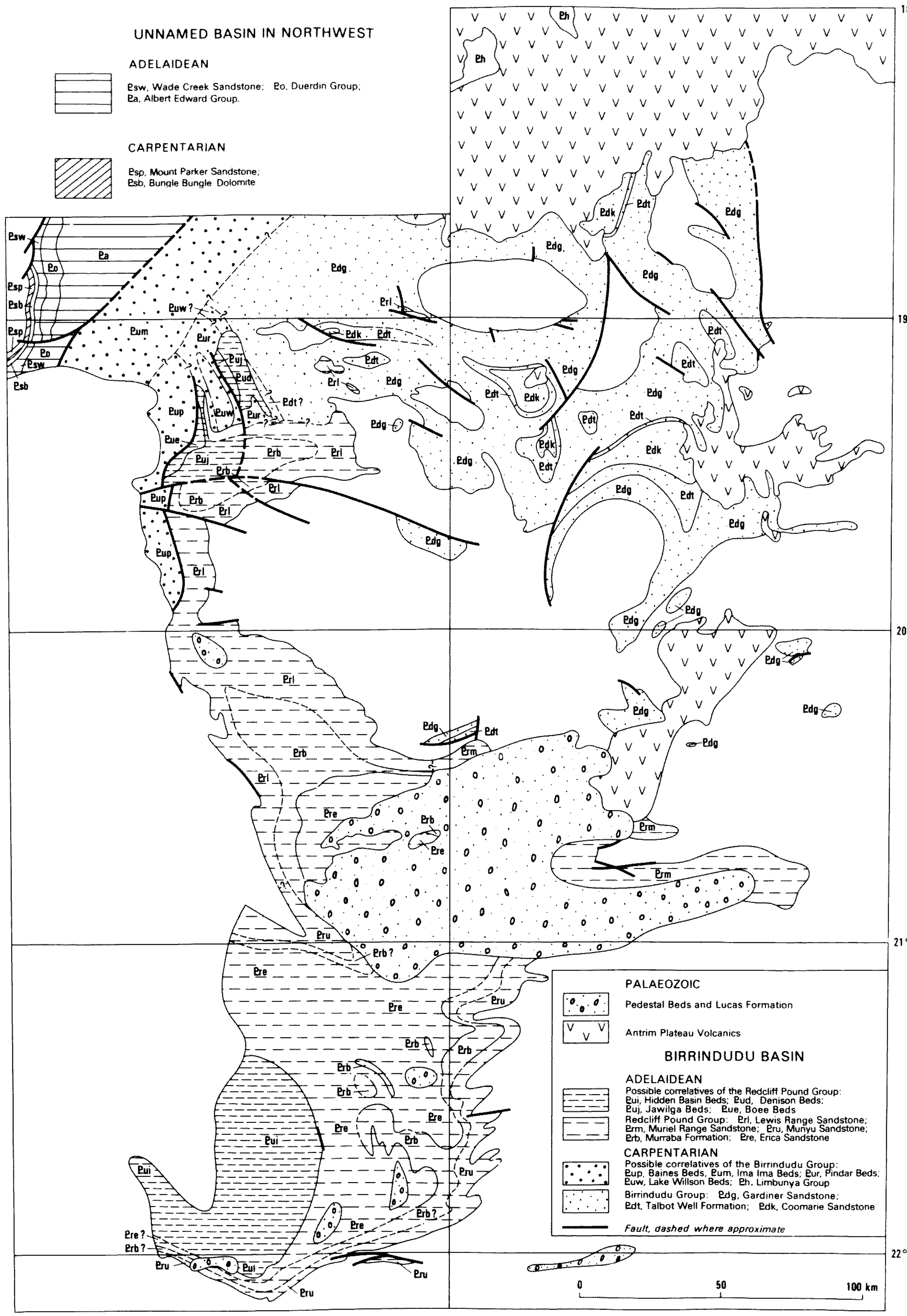


Fig. 30. Distribution of rock units in the Birrindudu Basin and unnamed basin in the northwest (solid geology).

Thin beds of dolomitic sandstone, interbedded with micaceous sublithic arenite and quartz arenite, crop out at the bottom of the scarp slope on the west side of Larranganni Bluff.

Representative sections

The type section at Larranganni Bluff is described by Casey & Wells (1964). At the base, a conglomerate 12 m thick is unconformable on metasediments of the Killi Killi Beds. The conglomerate is overlain by 36 m of laminated sandstone, some of which is micaceous. This is succeeded by 30 m of flaggy sandstone and minor interbedded micaceous shale; much of the flaggy sandstone is crowded with shale pellets. The section is completed by 18 m of cliff-forming, strongly-jointed, silicified, medium-grained sandstone, which contains some shale pellets, and shows cross-bedding and ripple marks.

A much thicker sequence (2200 m) is exposed in the Gardner Range northwest of Mount Stubbins:

Top	Talbot Well Formation: Chert.
40 m	Medium to coarse-grained quartz arenite and sublithic arenite, medium to thin-bedded; some laminated sublithic arenite and siltstone at top.
10 m	Medium-grained sublithic arenite containing glauconite.
1100 m	Mainly well-sorted, medium-grained quartz arenite showing low-angle cross-bedding and ripple marks, medium to thick-bedded except near top; some widely scattered well-rounded pebbles and cobbles and also conglomeratic bands and gritty layers.
30 m	Flaggy sublithic arenite.
20 m	Thinly interbedded micaceous siltstone, shale, and fine sublithic arenite.
800 m	Medium to coarse-grained and locally gritty sublithic arenite and quartz arenite showing cross-bedding; some bedding planes crowded with shale pellets; minor thinly-interbedded flaggy fine sublithic arenite and micaceous siltstone.
200 m	Cross-bedded medium to coarse-grained sublithic arenite; some pebbly and conglomeratic bands. Unconformable on metamorphics of the Killi Killi Beds.

The following sequence, about 1230 m thick, is exposed in the Farrands Hills in the southeast, where the top of the formation is concealed by sand.

Top	
250 m	Flaggy, medium-grained quartz arenite and sublithic arenite, medium to thin-bedded; ripple marks.
10 m	Medium to coarse-grained sublithic arenite containing glauconite.
150 m	Medium-grained sublithic arenite, medium to thin-bedded; low-angle cross-bedding; some bedding planes covered with shale pellets.
10 m	Medium-grained, thin-bedded to flaggy quartz arenite containing glauconite; some shale pellets.
500 m	Medium to coarse-grained quartz arenite and sublithic arenite, medium to thin-bedded, cross-bedded; some bedding planes covered with shale pellets; minor thin-bedded to laminated siltstone and fine sublithic arenite.
10 m	Pebble and cobble conglomerate.
200 m	Thinly-interbedded shale, siltstone, and fine-grained micaceous sublithic arenite.
100 m	Medium to coarse-grained quartz arenite and sublithic arenite, mainly thin-bedded; some ripple marks, low-angle cross-bedding; locally conglomeratic. Unconformable on unnamed granite and metamorphics of the Mount Charles Beds.

In the Nora Range, on the border between Western Australia and the Northern Territory, the Gardiner Sandstone is only about 500 m thick. Here the following sequence is exposed:

Top	Talbot Well Formation: stromatolitic chert.
70 m	Medium to coarse-grained quartz arenite and sublithic arenite, mainly thin-bedded.
10 m	Medium to thin-bedded sublithic arenite and quartz arenite containing variable amounts of glauconite.
400 m	Medium to coarse-grained sublithic arenite and quartz arenite; medium to thin-bedded; some ripple marks; some beds with shale pellets and some with pebbles; a few thin interbeds of laminated siltstone.
0–4 m	Conglomerate unconformably overlying Killi Killi Beds and granite.

Stratigraphic relations, age, and correlation

The Gardiner Sandstone is unconformable on the Killi Killi, Mount Charles, Nanny Goat Creek, and Nongra Beds of the Lower Proterozoic Tanami Complex, on Lower Proterozoic Pargee Sandstone, on Lower Proterozoic to Carpentarian unnamed granite, and probably also on the Lower Proterozoic Mount Winnecke Formation, Supplejack Downs Sandstone and Winnecke Granophyre. It is overlain conformably by the Talbot Well Formation, and unconformably, in the west of the Gardner Range, by the Adelaidean Lewis Range Sandstone.

Unconformable contacts with units of the Tanami Complex are exposed around the edges of the Gardner Range (Fig. 17), on the eastern sides of the Birrindudu and Ware Ranges, on the southwest side of the Browns Range Dome, in the Nora Range, and around the Bluebush and Farrands Hills. The unconformity with the Pargee Sandstone is visible on the south and west sides of the Pargee Range and in the northwest of the Gardner Range. Contacts with unnamed granite can be seen on the north sides of the Browns Range Dome and the Nora Range, and on the southeast side of the Farrands Hills.

As discussed above, the probable age of the Gardiner Sandstone, determined by the K-Ar and Rb-Sr methods on glauconite, is about 1560 m.y., or mid-Carpentarian. The formation may be correlated with the Mount Parker Sandstone of the unnamed basin northwest of the Birrindudu Basin; both formations are unconformable on basement metamorphic rocks, and both are overlain by a unit consisting largely of stromatolitic chert. The Gardiner Sandstone may also be correlated with the Limbunya Group of the Victoria River region (Sweet, 1977).

Talbot Well Formation

The Talbot Well Formation (Blake & others, 1975) crops out along the western edge of the Birrindudu Range, between the Supplejack, Coomarie and Gardner Ranges, in the west and northwest parts of the Gardner Range, and on the southern side of the Nora Range. Most outcrops are in structural basins, where the formation is generally gently dipping to flat-lying. It appears to be less resistant to erosion than the ridge-forming Gardiner Sandstone, and is exposed mainly as low mounds partly covered with chert rubble. It is locally capped by laterite and silcrete. The maximum thickness exposed is about 250 m, in the Gardner Range.

The characteristic rock type cropping out is chert, but the formation also includes sublithic arenite, quartz arenite, and laminated siltstone and shale, which are locally interlayered with chert, and cherty arenite and limestone. The chert is commonly stromatolitic, indicating that it is silicified limestone or dolomite, and is locally brecciated. The cherty arenite has a chert cement and contains spherical grains of quartz, which may be silicified ooliths. Limestone crops out in a small basin in the northwest of the Gardner Range, where it is stromatolitic, and was intersected in one of two stratigraphic holes that penetrated the formation between Coomarie Spring and Talbot Well (Blake, 1974; Blake & others, 1975). A sequence of sublithic arenite, shale, siltstone, mudstone and chert that appears to overlie the Gardiner Sandstone conformably southwest of the Ware Range is mapped as possible Talbot Well Formation.

The formation is seen to lie conformably on the Gardiner Sandstone at several places, including the Gardner and Supplejack Ranges, and, in the northwest of the Gardner Range, to be conformably overlain by the Coomarie Sandstone. It may correlate with the Bungle Bungle Dolomite which crops out in the unnamed basin to the northwest, and with part of the Limbunya Group of the Victoria River region. The Cambrian Antrim Plateau Volcanics overlie the formation west of the Supplejack Range and northeast of the Gardner Range.

Coomarie Sandstone

Outcrops of Coomarie Sandstone (Blake & others, 1975), the youngest unit of the Birrindudu Group, have been mapped north of the Coomarie Range, between the Pargee and Browns Ranges, in the northwest of the Gardner Range, and west of the Birrindudu Range. The formation is probably at least 2500 m thick. It is conformable on the Talbot Well Formation, and is overlain unconformably by the Antrim Plateau Volcanics.

Rock types exposed are sublithic arenite and minor quartz arenite, siltstone, and shale. The arenites are mainly medium-grained, and thin-bedded to flaggy, and show cross-bedding and ripple marks. Shale pellets are common in the sublithic arenite.

Possible Correlatives of the Birrindudu Group

West of the Gardner Range several Proterozoic units have been mapped whose interrelations are uncertain because of isolated outcrops, concealed contacts, and the probable presence of concealed major and minor faults. Some of these units—the Baines, Ima Ima, Lake Willson, and Pindar Beds—are possible stratigraphic equivalents of the Carpentarian Birrindudu Group, as also are rocks of the Limbunya Group to the northeast. The other units may correlate with the Adelaidean Redcliff Pound Group.

Limbunya Group

Rocks of the Limbunya Group crop out extensively in the Victoria River region to the north (Sweet & others, 1974; Sweet, 1977), and extend south as low strike ridges and undulating terrain into the northwest part of the Birrindudu Sheet area (Blake & others, 1975; Blake, 1976), where they are overlain unconformably by basalt of the Antrim Plateau Volcanics. Like the Birrindudu Group, the Limbunya Group is probably mainly shallow marine, and may have been deposited in a northerly extension of the Birrindudu Basin (Plumb & Derrick, 1975; Sweet, 1977).

The predominant rock types of the Limbunya Group in the area are silicified medium to fine-grained sublithic arenite and quartz arenite. They are cross-bedded, and locally show ripple marks. Strongly disturbed bedding, probably due to slumping, is apparent in places. Some beds contain shale pellets. Stromatolitic chert and chert-bearing conglomerate exposed in the general area of outcrop may be part of the Limbunya Group, as stromatolitic carbonates are important further north, but alternatively they may belong to the overlying Antrim Plateau Volcanics (Blake & others, 1975).

Baines Beds

The Baines Beds (Blake & others, 1977) are confined to the western half of the Billiluna Sheet area (Fig. 30), where they form the Baines Hills, after which they are named, and the Elsey Hills to the south. They were previously mapped as part of the Kearney Beds (Wells, 1962a; Casey & Wells, 1964). In the north the Baines Beds are folded into tight anticlines and synclines with subparallel northwest-trending axes. In the south dips are mainly very steep, and facings of beds can rarely be determined, because of shearing and close jointing associated with faulting and, presumably, tight folding; a cleavage is also locally developed, which further obscures any bedding structures present. The eastern side of the outcrop area is thought to be marked by a concealed major fault. The reference area is in the Baines Hills, between 19°22′12″S, 128°08′12″E and 19°22′40″S, 128°07′30″E, where a thickness of about 1000 m is exposed.

The Baines Beds consist mainly of maroon, grey and pink interbedded medium to fine-grained quartz arenite and sublithic arenite. These are thin to medium-bedded, and generally silicified. Cross-bedding, ripple-marks, and shale pellets are common. In the south, sequences of greywacke and lithic arenite up to 15 m thick are interbedded with the quartz arenite and sublithic arenite, and near the Billiluna-Tanami road the unit includes beds of pebbly to conglomeratic sublithic arenite. The latter beds contain rounded clasts up to 5 cm across of quartzite, chert, quartz, greywacke, and jasper, which are probably derived from the Tanami Complex or Halls Creek Group, and also some granite clasts. In the north, the youngest rocks exposed are laminated siltstone, which crops out 18 km southwest of Sturt Creek homestead, and thin-bedded kaolinitic and dolomitic mudstone, which crops out in the reference area; the mudstone overlies cross-bedded silicified quartz arenite and sublithic arenite containing scattered pebbles.

The unit is unconformably overlain to the west by Palaeozoic rocks of the Canning Basin, and is separated by inferred faults from Proterozoic rocks to the east. Near the southern end of the Elsey Hills it appears to be overlain unconformably by sandstone that may belong to the Lewis Range Sandstone. Contacts with other Proterozoic units are concealed.

The Baines Beds are more steeply dipping and tightly folded than is general for the Birrindudu Group, and they are locally cleaved. However, their lithology is similar to that of the Gardiner Sandstone, except that no glauconitic sandstone has been found. Also, as they include conglomerate containing granite fragments, they are thought to be Carpentarian rather than Lower Proterozoic. Hence, they are regarded as likely stratigraphic equivalents of the Gardiner Sandstone. If this is the case, the thin-bedded dolomitic mudstone at the top of the unit in the reference area may be equivalent to part of the Talbot Well Formation. Alternatively, the Baines Beds could be equivalent to the Lower Proterozoic Pargee Sandstone, as they are similar in lithology and structure.

Ima Ima Beds

The Ima Ima Beds (Blake & others, 1977) form a group of low strike ridges north of Carranya homestead in the northwest of Billiluna Sheet area and adjacent part of Gordon Downs Sheet area. The unit consists mainly of silicified sandstone, and is named after Ima Ima Pool (19°18′S, 127°53′E) on Sturt Creek. It was previously mapped as Kearney Beds (Wells, 1962a; Casey & Wells, 1964) and Gardiner Beds (Gemuts & Smith, 1968; Dow & Gemuts, 1969).

The unit dips gently to steeply, mainly to the southeast and east. Local shearing is indicated by brecciated zones, quartz-veining, and slickensided surfaces, and is probably related to faulting. The reference area is 10 km north-northeast of Wolf Creek Meteorite Crater, where sandstone about 450 m thick dips southeast. The thickest sequence exposed is about 1000 m, 3 km southwest of Redbank Yard. Whether or not the maximum thickness of the unit is much more than this is not known, as individual outcrops are separated from one another by sand plains, which may conceal faults, and neither the top nor bottom of the unit is exposed.

Rock types exposed are sublithic arenite and minor conglomerate, which are most common in the eastern outcrops, including the reference area, and quartz arenite, which predominates in the west. The sublithic arenite and quartz arenite are mainly medium to coarse-grained and medium to thin-bedded, and commonly have a sparse clayey matrix. Gritty lenses and bands are present in places, and most beds show cross-bedding. Scattered pebbles and bedding planes covered with shale pellets are common in the sublithic arenite. Beds and lenses of conglomerate, generally less than 1 m thick, contain pebbles up to 7 cm across of quartz, quartzite, chert, various types of sandstone, and shale.

At Wolf Creek Meteorite Crater the beds are generally unsilicified, in contrast to those at other outcrops. At the crater the dominant rock type is a slightly friable, medium to coarse-grained sublithic arenite, which has a sparse clayey matrix. Some beds show cross-bedding. Gritty lenses are present locally, and thin interbeds of flaggy micaceous sandstone are exposed on the north side of the crater.

The relations of the Ima Ima Beds to other pre-Tertiary units are unknown, as contacts are concealed beneath superficial sand. The outcrop area is inferred to be bounded to the northwest by a concealed fault which separates the unit from Precambrian rocks of the unnamed basin; elsewhere it is surrounded by sandy plains. The gentle to steep dips of the unit, and the presence of local shearing and quartz-veins, indicate that the Ima Ima Beds are Proterozoic, and they are tentatively correlated with the Birrindudu Group. Lithologically, the unit is unlike any of the Adelaidean formations in the unnamed basin. It is less tightly folded than the Lower Proterozoic formations of The Granites-Tanami Block, but is generally more deformed than the known Adelaidean rocks of the Birrindudu Basin.

Lake Willson Beds

The Lake Willson Beds (Blake & others, 1977), which are named after Lake Willson (19°23′S, 128°16′E), crop out in the core of an anticline west of the Denison Range in Billiluna Sheet area. Exposures consist mainly of flat-lying chert, which is commonly stromatolitic. Steep dips, probably related to faulting, occur locally, as for example 20 km south of Sturt Creek homestead, on the track to Balgo, where a sequence about 150 m thick of interbedded chert and cross-bedded medium to coarse-grained sublithic arenite dips northwest at 70°. This locality is chosen as the reference area. Cuttings from stratigraphic holes drilled by Esso Australia in 1972 (Blake, 1974) show that the unit includes shale and siltstone as well as chert and sublithic arenite. The northern outcrops of the unit are largely covered by laterite.

The Lake Willson Beds are tentatively correlated with the Talbot Well Formation of the Birrindudu Group, as both units contain stromatolitic chert; hence, they may overlie the Gardiner Sandstone or equivalent unit in the subsurface. Contacts with overlying units are not exposed, but the Lake Willson Beds are inferred to be overlain conformably by the Pindar Beds and unconformably by the ?Palaeozoic Chuall Beds.

Pindar Beds

The Pindar Beds (Blake & others, 1977) are exposed as low strike ridges and as rubble on sandy plains near Sturt Creek and the Denison Range, in Billiluna Sheet area. They are named after Pindar Yard (19°05′S, 128°15′E), beside Jawilga Pool on Sturt Creek. The beds dip steeply and locally are overturned. They consist of cross-bedded, medium to coarse-grained quartz arenite and sublithic arenite. At some localities bedding planes are crowded with shale pellets. The reference area is 2 km southwest of the northern Palm Springs in the Denison Range, where a thickness of about 300 m is exposed.

The Pindar Beds are tentatively correlated with the Coomarie Sandstone of the Birrindudu Group, and are inferred to be overlain unconformably by the Denison Beds, which are probably Adelaidean, and by the Chuall Beds.

Redcliff Pound Group

The Redcliff Pound Group (Blake & Yeates, 1977) is named after Redcliff Pound (21°35′S, 128°45′E) in the east of Stansmore Sheet area. It crops out in the northwest, centre, and southwest of The Granites-Tanami region and consists predominantly of sublithic arenite and quartz arenite. It comprises the Munyu, Muriel Range, and Lewis Range Sandstones, which are laterally equivalent basal formations unconformably overlying Carpentarian and older rocks, the Murraba

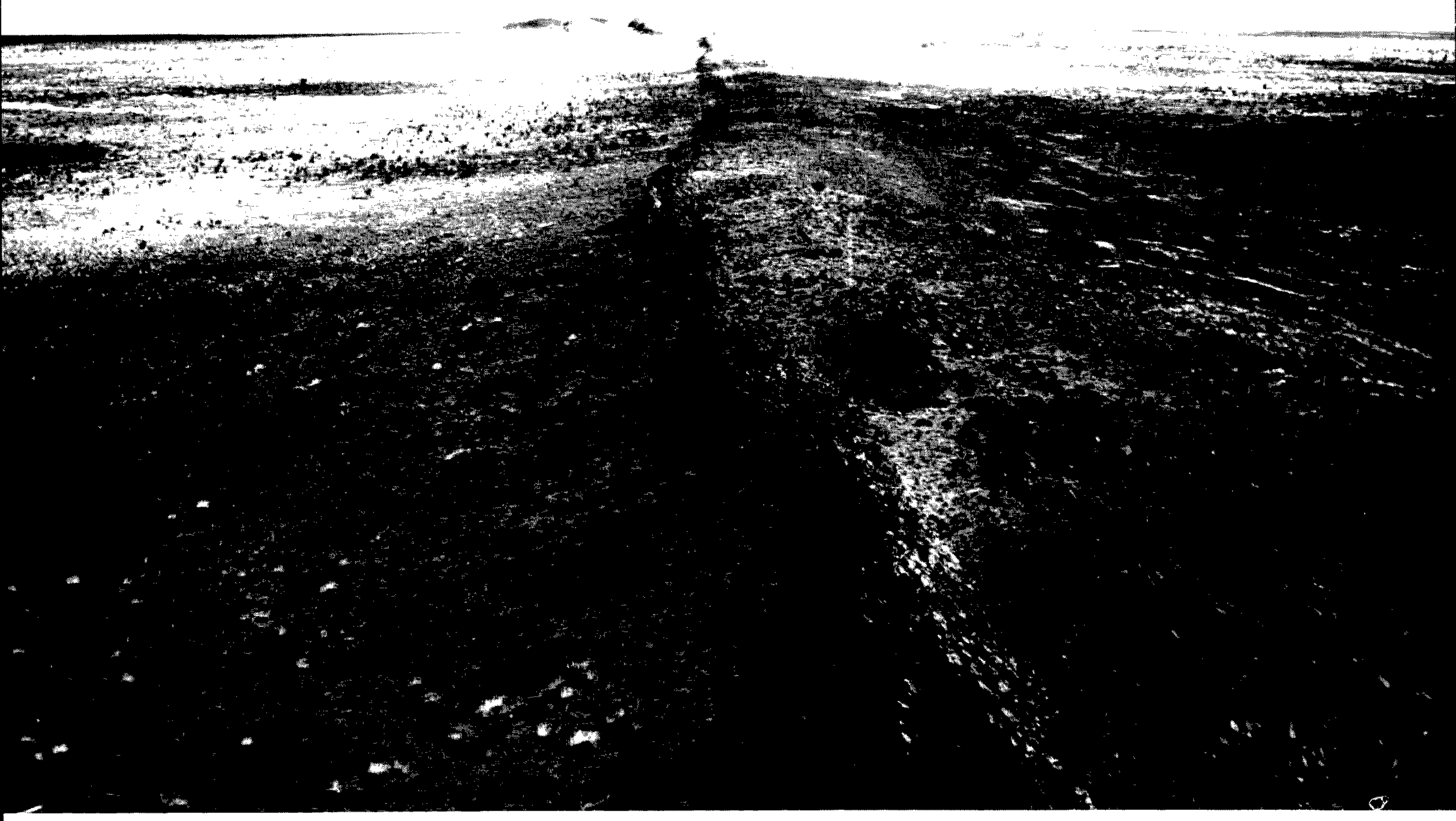


Fig. 31. View west along the Alec Ross Range, Webb Sheet Area. Steeply dipping Munyu Sandstone overlies rocks of the Arunta Complex, concealed by superficial deposits, to the south. The highest part of the range (on the skyline) rises about 40 m above the sand plain. (GA/8929)

Formation, which is conformable on the Munyu and Lewis Range Sandstones, and the Erica Sandstone, which conformably overlies the Murraba Formation. The distribution of the units is shown in Figure 30. The maximum thickness of the group exposed in any one area is about 1300 m, in the vicinity of Redcliff Pound, but here only the Murraba Formation and part of the Erica Sandstone are seen. The true thickness of the group is probably at least 2000 m and may be much greater, as an unknown amount is concealed beneath Cainozoic superficial sediments.

The local development of glauconite in the Erica Sandstone and carbonates in the Munyu Sandstone and Murraba Formation show that at least part of the group is probably marine, and most of the group may have been deposited in a shallow near-shore marine environment.

The Redcliff Pound Group has not been affected by either regional or thermal metamorphism, and is generally less silicified and less steeply dipping than rocks of the Birrindudu Group. However, it has been involved in tectonism, especially in the south, and is displaced along several faults, mainly in the north. Dips are mostly gentle, but range from flat-lying to vertical. No mineralisation has been found within the group.

In the southwest the Redcliff Pound Group is overlain by a sandstone unit, the Hidden Basin Beds. However, the relations of the group to this unit and the Proterozoic units of the Denison Range-Baines Hills-Elsey Hills area in the northwest are uncertain because contacts with them are concealed by sand.

The group is separated by major unconformities from the underlying Carpentarian Birrindudu Group and overlying Palaeozoic units, and is correlated with the Heavitree Quartzite and Bitter Springs Formation of the Amadeus Basin. The Heavitree Quartzite overlies migmatite which has been dated at 1076 ± 50 m.y. (Marjoribanks & Black, 1974), and is probably less than 1000 m.y. old (Wells, 1976), indicating that not only it, but also the Redcliff Pound Group, are late Adelaidean.

Munyu Sandstone

The Munyu Sandstone (Blake & Yeates, 1977), one of the basal units of the Redcliff Pound Group, is named after the Munyu Hills (21°47′S, 129°08′E), in the Highland Rocks Sheet area. It crops out in the south of the region: in the southeast of Stansmore Sheet area, where it was previously mapped as Gardiner Beds (Wells, 1962c), in the northeast of Webb Sheet area (Blake, 1977), and in the west of Highland Rocks Sheet area (Hodgson, 1977).

The formation forms a series of strike ridges up to 40 m high and trending east to north-northeast. Some of the ridges are bounded by scarp faces. The highest ridges are those of False Mount Russell and the western part of the Alec Ross Range (Fig. 31). At most outcrops the Munyu Sandstone dips 5° to 50° north to west-northwest. However, it dips south on the northern limb of a syncline at False Mount Russell, and is tightly folded in places, such as the Alec Ross Range (Fig. 32) and southwest of the Munyu Hills.

The type section is a strike ridge in the Stansmore Sheet area (at 21°55′00″S, 128°55′00″E), where the formation has its maximum exposed thickness, about 400 m, and dips 45° north. The formation here consists almost entirely of quartz arenite. A similar thickness is also exposed in the western part of the Alec Ross Range.

Lithology

The dominant rock type, silicified quartz arenite, is medium to thin-bedded and commonly shows low-angle cross-bedding, some of which is of festoon type. It is generally poorly sorted, medium to very coarse-grained, and commonly contains scattered pebbles and layers and lenses of grit and quartz-pebble conglomerate, especially near the base of the formation. Also present locally near the base of the formation are sublithic arenite beds rich in mica and feldspar grains. The quartz arenite contains some quartzite and chert clasts and small amounts of tourmaline, zircon, and muscovite. It has a quartz-overgrowth cement and generally some sericitic matrix.

Limestone lenses, a few metres thick, are interbedded with quartz arenite at one place in Stansmore Sheet area (at 21°59′30″S, 128°46′00″E), and limestone containing laminae of dark grey chert crops out in the west of the Alec Ross Range to the south (at 22°02′S, 128°42′E), where it is probably at or near the top of the Munyu Sandstone. Both the limestone and chert are crystalline and appear to be unfossiliferous, although local laminar banding indicates that they may be stromatolitic. Several specimens of limestone and chert have been examined for microfossils, but were barren (M. R. Walter, pers. comm. 1974), possibly because of post-depositional recrystallisation.

Some low partly sand-covered strike ridges north of the Erica Range in Stansmore and Lucas Sheet areas have been mapped as possible Munyu Sandstone (Blake & Yeates, 1977; Crowe & Muhling, 1977). They are formed of silicified, mainly medium-bedded, medium to fine-grained sublithic arenite and quartz arenite. Cross-bedding and layers of shale pellets are common, and some beds show ripple marks. The arenites form an east-plunging anticline, and appear to underlie Erica Sandstone, which crops out to the south and north.

Stratigraphic relations, age, and correlation

The Munyu Sandstone is unconformable on unnamed granite and regionally metamorphosed rocks of the Arunta Complex at False Mount Russell and on the south side of the Alec Ross Range. It is inferred to be overlain conformably by the Murraba Formation and

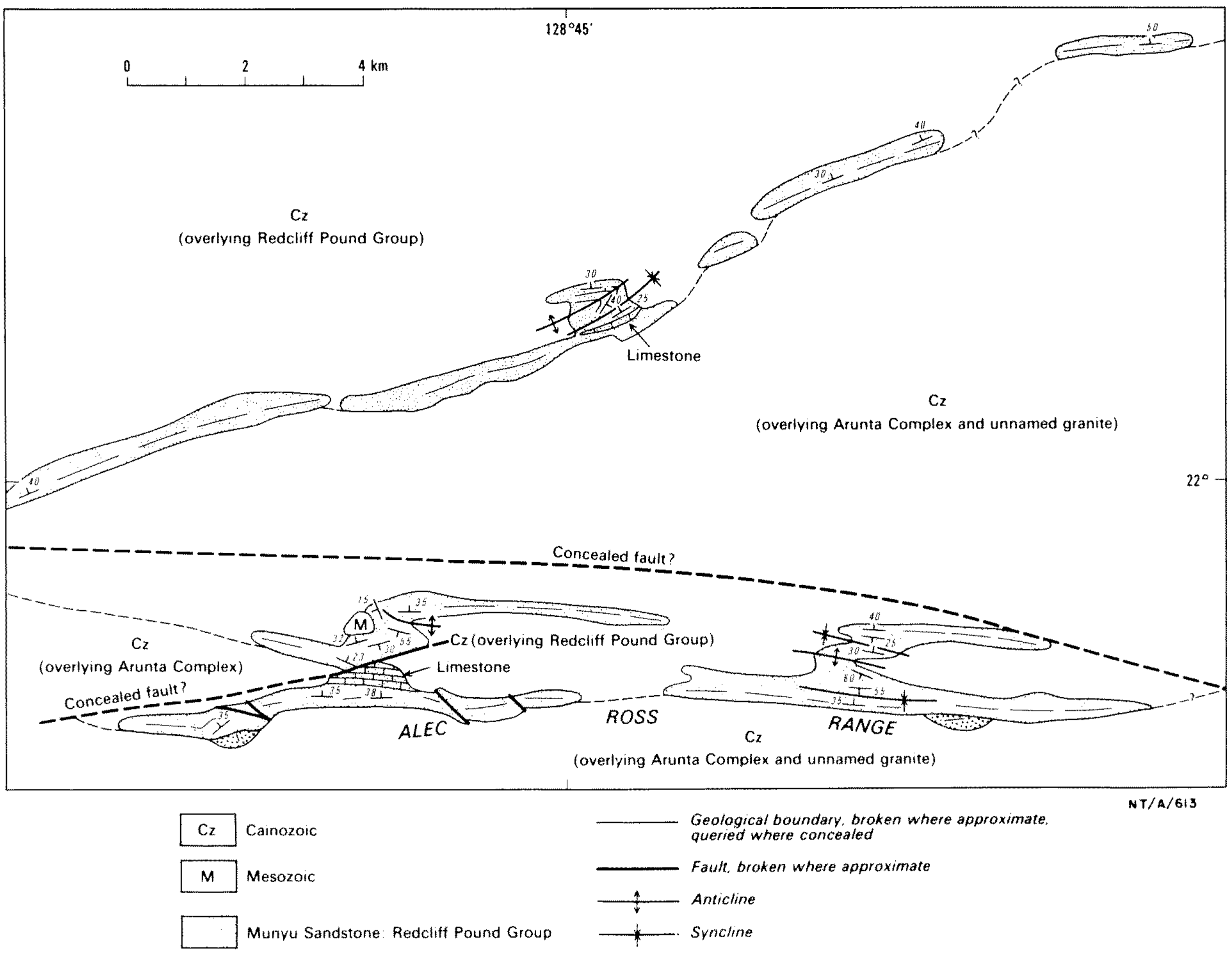


Fig. 32. Geological map of the Alec Ross Range area.

unconformably by the Palaeozoic Pedestal Beds; however, these relations cannot be verified as the contacts are concealed by sand.

The Munyu Sandstone is correlated with the Lewis Range and Muriel Range Sandstones, the basal formations of the Redcliff Pound Group to the north. It is considered to be stratigraphically equivalent to the nearby Vaughan Springs Quartzite of the Ngalia Basin to the southeast and the Heavitree Quartzite of the Amadeus Basin to the south. These three formations are similar lithologically, and they lie with a pronounced unconformity on rocks of the Arunta Block. The Heavitree Quartzite is younger than 1076 ± 50 m.y., the age of migmatite which underlies it to the east (Marjoribanks & Black, 1974), and is probably younger than 1000 m.y. (Wells, 1976). This conflicts with the 1280 m.y. age, determined on glauconite, for the Vaughan Springs Quartzite (Cooper & others, 1971); this older age could be explained if some or all of the glauconite analysed was detrital rather than authigenic.

Muriel Range Sandstone

The Muriel Range Sandstone (Hodgson, 1976) crops out in the southeast of The Granites-Tanami region, mainly in The Granites Sheet area; it is named after the Muriel Range (20°46′S, 129°30′E). The formation is mainly gently dipping, and forms cuestas up to 20 m high, but steep dips occur close to some faults, as, for instance, 8 km north of the Muriel Range, where the sandstone forms steep-sided strike ridges.

The type section is across the Inningarra Range, southwest of Mongrel Downs homestead. It extends south from where the Muriel Range Sandstone is faulted against the Mount Charles Beds (from 20°45′10″S, 129°38′45″E to 20°47′00″S, 129°54′30″E) and is where the maximum known thickness of the formation, about 450 m, is exposed.

Lithology

The formation consists predominantly of sublithic arenite and quartz arenite, but also includes minor siltstone, shale, arkose, conglomerate, and breccia. The sublithic arenite and quartz arenite are mainly pale pinkish to greyish and medium to fine-grained. They have a quartz-overgrowth cement and commonly some sericitic matrix.

In the lower part of the formation the arenites are characteristically thin to very thin-bedded. They are generally well sorted, although some beds contain coarse-grained and gritty lenses and some contain scattered pebbles. Ripple marks and low-angle cross-bedding are very common. In the Wilson Range, disturbed cross-bedding in the basal 2 m of the formation suggests slumping. Elsewhere bedding planes are generally well defined and commonly crowded with shale pellets. Many bedding surfaces show minor undulations.

In the upper part of the formation, exposed in the main scarps of the Muriel and Inningarra Ranges, at Murdoch Cliffs, and 7 km southwest of Blackwood Bluff, individual beds are generally thicker than in the lower part, averaging about 1 metre, and they appear to be better sorted; shale pellets and ripple marks are less common, and the bedding planes are less well defined.

Thinly-interbedded micaceous siltstone and maroon shale are present at several places, but are generally poorly exposed, as they commonly form depressions and flats between sandstone cuestas. Friable arkose about 10 m thick is exposed at Blackwood Bluff, underlying 3 m of thin-bedded sublithic arenite; it is medium to coarse-grained and consists of feldspar, mica and quartz clasts derived from nearby granite. Conglomerate beds less than 1 m thick are present locally at the base of the formation; they contain pebbles of rocks from the underlying Tanami Complex. Breccia up to 1 m thick is overlain by conglomerate at the base of the Muriel Range Sandstone in the Wilson Range.

In the type section, across the Inningarra Range, the beds dip gently south. Here, about 300 m of thin to very thin-bedded medium to coarse-grained arenite forms a series of low cuestaes in the north, mainly less than 3 m high, and is overlain to the south by about 150 m of medium-bedded medium to fine-grained arenite that forms stepped scarp faces each about 15 m high.

Stratigraphic relations and correlation

The Muriel Range Sandstone is seen to be unconformable on steeply dipping Killi Killi Beds of the Tanami Complex and Pargee Sandstone in the Wilson Range, and to overlie The Granites Granite at Murdoch Cliffs. Its unconformable contacts with the underlying Mount Charles Beds and The Granites Granite are obscured by a fault downthrown to the south on the north sides of the Muriel and Inningarra Ranges, and are concealed by superficial deposits in the Blackwood Bluff area. The Palaeozoic Lucas Formation and Pedestal Beds are inferred to overlie the Muriel Range Sandstone unconformably.

The Muriel Range Sandstone is correlated with the Munyu Sandstone to the south and with the Lewis Range Sandstone, which crops out along strike to the west. It is distinguished from the Munyu and Lewis Range Sandstones by being mainly thin to very thin-bedded and containing abundant shale pellets.

Lewis Range Sandstone

The Lewis Range Sandstone (Crowe & Muhling, 1977) most of which was previously mapped as parts of the Phillipson Beds and Kearney Beds (Wells, 1962a, 1962b; Casey & Wells, 1964), crops out in the northwest of the region, in Lucas and Billiluna Sheet areas. It caps the northwesterly-trending line of cuestas, up to 80 m high, that form the Lewis Range, after which the formation is named, and similar cuestas north to the western part of the Gardner Range where it forms flat-topped plateaus. The scarp faces of the cuestas consist of granite or, less commonly, metamorphic rocks, overlain by up to 10 m of sandstone (Fig. 9), which in places, such as west of Tent Hill, forms two or three benches. The Lewis Range Sandstone also forms the strike ridges of the Kearney Range and other ridges near Mount Hughes, southwest of the Lewis Range.

Most of the Lewis Range Sandstone dips at less than 5°, and is well jointed; close vertical jointing on scarp edges is a characteristic feature visible on aerial photographs. Steep dips have been recorded only in the Kearney Range and near faults at the northwest end of the Lewis Range; at these localities the sandstone is sheared, silicified, and cut by quartz veins.

The maximum exposed thickness of the formation is about 1000 m, in the northern part of the Kearney Range. The greatest thickness exposed along the Lewis Range is about 400 m, in the southeast. The type section is the steep side of a cuesta 1.5 km southwest of Point Nelligan, in the Lewis Range (at 20°13′00″S,

Fig. 33. Medium-bedded quartz arenite of the Lewis Range Sandstone, showing low-angle cross-bedding; eastern part of the Lewis Range, Lucas Sheet area. (M1356/32)

128°38′00″). Here a sandstone sequence about 20 m thick is exposed, overlying Lewis Granite.

Lithology

The Lewis Range Sandstone consists of well-sorted, medium to fine-grained quartz arenite, subordinate poorly-sorted sublithic arenite, quartz arenite, and conglomerate, and rare siltstone. The formation is generally friable, but is locally silicified, as in the Kearney Range.

The well-sorted quartz arenite is either white or iron-stained to shades of brown or maroon. It has a clayey matrix, and is medium to thin-bedded. Low-angle cross-bedding (Fig. 33) is very common, and high-angle planar cross-bedding is present locally. Ripple marks are widespread. Bedding planes with shale pellets occur in places, but are not a common feature. Near the base of the formation the quartz arenite is less well sorted and is interbedded with sublithic arenite; both arenites here contain some angular grit-sized grains and pebbles, which in places are concentrated in thin layers and lenses.

A basal conglomerate is commonly present where the formation overlies granite and metamorphic rocks. It is up to 3 m thick and is locally interbedded with cross-bedded layers and lenses up to 20 cm thick of micaceous sublithic arenite, quartz arenite, and siltstone. The conglomerate consists of subangular to rounded pebbles and cobbles in a poorly sorted sandy matrix. The pebbles and cobbles are mainly of quartz, although pebbles of quartz-tourmaline aggregates, chert, jasper, greywacke, muscovite schist, granite, and other rock types are present locally; they commonly have a coating of white clay.

In the type section, the basal 3 m of the formation, which overlies friable weathered Lewis Granite, consists of poorly sorted, fine to coarse-grained arenite and thin lenses of sublithic arenite and conglomerate. Above this is 17 m of mainly well-sorted, medium-bedded, medium-grained quartz arenite, the top of which has a nodular to pitted weathered surface.

A sequence mapped as possible Lewis Range Sandstone on the southwest side of the Browns Range Dome is about 60 m thick. The lower part consists of poorly sorted conglomerate with lenses of coarse to fine-grained sublithic arenite, and the upper part is made up of coarse-grained sublithic arenite containing conglomerate layers and lenses up to 2 m thick. Some large-scale cross-bedding is apparent in places. The conglomerate contains angular to rounded clasts, some over 30 cm across, of quartz, quartzite, chert, various types of sandstone, and kaolinite (which may represent altered tuff) enclosed in a poorly sorted sandy matrix. Most of the clasts are probably derived from the Birrindudu Group. The sequence is faulted against Gardiner Sandstone to the south and west, but its concealed northeastern contact with the Gardiner Sandstone may be an unconformity. This sequence was previously mapped as part of the Gardiner Beds (Wells, 1962a; Gemuts & Smith, 1968).

Stratigraphic relations and correlation

The Lewis Range Sandstone is unconformable on the Killi Killi Beds of the Tanami Complex, the Slatey Creek Granite, Lewis Granite, and unnamed granites, the Gardiner Sandstone, and possibly the Baines Beds. Its contact with the overlying Murraba Formation is concealed but inferred to be conformable. Contacts with granite and the Killi Killi Beds are exposed along the scarps of the cuestas extending from the Lewis Range to the Gardner Range (Figs. 9, 33), in the Kearney Range, near Mount Hughes, and at Mount Mansbridge. In the western part of the Gardner Range, flat-lying Lewis Range Sandstone is seen to be unconformable on Gardiner Sandstone. Steeply dipping sandstone, possibly belonging to the Lewis Range Sandstone, appears to be unconformable on Baines Beds near the southern end of the Elsey Hills (at 19°54′30″S, 128°03′00″E).

The Lewis Range Sandstone is correlated with the Muriel Range and Munyu Sandstones, the other basal formations of the Redcliff Pound Group. Unlike the Muriel Range Sandstone, it consists mainly of medium-bedded quartz arenite and has relatively few bedding planes covered with shale pellets. Compared with the Munyu Sandstone, it is generally finer grained and better sorted. The Lewis Range Sandstone may also be correlated with the lithologically similar Denison Beds, which crop out in the Denison Range west of the Gardner Range.

Murraba Formation

The Murraba Formation (Blake & Yeates, 1977) is named after the Murraba Ranges in the northeast of Stansmore Sheet area (21°15′S, 128°45′E). It crops out in the east of Lucas and Stansmore Sheet areas and the west of Highland Rocks Sheet area, and is inferred to be present beneath superficial sediments in Webb and Billiluna Sheet areas. The formation is generally less resistant to erosion than the other formations of the Redcliff Pound Group, and outcrops consist mainly of subdued strike ridges (Fig. 34) and low cuestas. It forms both open and tight folds, although dips are mainly gentle.

The maximum thickness exposed is about 800 m, at Redcliff Pound. However the formation is much thinner locally—for instance, on the north side of the Phillipson Range the apparent thickness is only about 20 m. In the type section, on the east side of Redcliff Pound at 21°36′30″S, 128°46′30″E), about 350 m is exposed, dipping west at about 25°.

Lithology

The Murraba Formation consists of interbedded chert-granule conglomerate, sublithic arenite, quartz arenite, siltstone, shale, mudstone, pebble conglomerate, and dolomite. The beds are mainly thin to laminated.

Conglomerate, the characteristic rock type at most outcrops, is made up of rounded to subangular granules and less commonly pebbles, predominantly of chert, set in a matrix of medium-grained sublithic to quartz arenite, which has a quartz-overgrowth cement. In places, the conglomerate shows cross-bedding.

The sublithic arenite and quartz arenite are mainly medium to fine-grained, but locally include coarse-grained and gritty bands. They are commonly silicified. Some beds are micaceous and some contain scattered granules of quartz and chert. Low-angle cross-bedding, ripple marks, and pellet-covered bedding planes are very common. Mudcracks were seen at a few localities. The sublithic arenite has a sparse to abundant kaolinitic matrix, and is commonly friable. Friable siltstone and shale are interbedded with sublithic arenite in some outcrops. Shaly mudstone and thin dolomite interbeds were intersected in stratigraphic drill holes in Lucas Sheet area between the Lewis and Kearney Ranges, where the formation underlies unconsolidated Cainozoic sediments (Blake, 1974). Pinkish to purple laminated dolomite was recorded by Casey & Wells (1964) near Brookman Waters and on the east side of Redcliff Pound, and banded grey dolomite underlies sublithic arenite at the base of an east-facing scarp 8 km east of Redcliff Pound.

The type section, on the east side of Redcliff Pound, consists of 160 m of flaggy, thin-bedded to laminated, fine-grained sublithic arenite at the base, succeeded by about 110 m of thin-bedded, medium to fine-grained sublithic arenite with shale pellets, 10 m of medium-bedded quartz arenite, and 70 m of interbedded chert-granule conglomerate and ripple-marked, thin-bedded to laminated sublithic arenite. The sequence is overlain conformably to the west by mainly medium-bedded sublithic arenite of the Erica Sandstone.

Shale, calcareous sandstone, chert, and conglomerate referred to the Murraba Formation were intersected in stratigraphic hole Esso Billiluna 8, underlying Cainozoic sediments between the Elsey and Selby Hills in the south of Billiluna Sheet area (Blake, 1974).

Stratigraphic relations and correlation

The Murraba Formation is inferred to be conformable on the Lewis Range Sandstone in the northwest and the Munyu Sandstone in the south, and to be overlain unconformably by Palaeozoic and Mesozoic sedimentary rocks. Its contacts with these units are concealed by superficial sediments. Conformable contacts with the overlying Erica Sandstone, taken at the top of the highest bed of chert-granule conglomerate, are exposed on the north and west sides of the Phillipson Range, on the south side of Lake Jeavons, in the Murraba Ranges (Fig. 34), and in the Redcliff Pound area. The formation is overlain by Mesozoic Hazlett Beds in the Redcliff Pound area.

The Jawilga Beds, which crop out west of the Gardner Range in Billiluna Sheet area, are probable correlatives of the Murraba Formation.

Erica Sandstone

The Erica Sandstone (Crowe & Muhling, 1977) crops out extensively in the south and centre of the Birrindudu Basin: in the southeast of Lucas, east of Stansmore, and west of Highland Rocks Sheet areas. It also forms the southern part of the Elsey Hills in Billiluna Sheet area, and is inferred to be present beneath superficial sediments in the north of Webb Sheet area. The formation is named after the Erica Range (21°05′S, 129°30′E), and was previously mapped partly as Phillipson Beds and partly as Gardiner Beds (Wells, 1962b, 1962c; Casey & Wells, 1964). It is exposed as cuestas (Fig. 35), plateaus, strike ridges, and hills up to 60 m high; outcrops are separated by sand plains containing dunes, salt lakes and salt pans.

The type section is across the main cuesta of the Erica Range, from 21°05′50″S, 128°30′00″E, to 21°07′00″S, 128°29′00″E, where a sequence about 400 m thick dips 5° to 10° southwest. The maximum known thickness of the formation, about 700 m, is southeast of Redcliff Pound.

The Erica Sandstone has been affected by mainly broad folding, and is generally gently dipping (Fig. 35). However, tight folds with steep dips occur locally, as for instance on the west side of Redcliff Pound and in the southwest of the Murraba Ranges (Fig. 34).

Lithology

The predominant rock type is a well-sorted, medium to fine-grained, friable, sublithic arenite that has up to 10 percent clay matrix as well as a quartz-overgrowth

Fig. 34. Part of the Murraba Ranges and the salt-covered Lake Wills; from the southeast, Stansmore Steet area. The highest part of the ranges, to the left, is formed of steeply dipping Erica Sandstone. The more subdued strike ridges to the right are formed of relatively resistant beds within the Murraba Formation. (M1404/25)

cement. It is mainly medium-bedded and either white or iron-stained to purple or reddish-brown. Cross-bedding is very common, and generally low-angle: most sets are less than 1 m thick, but larger sets are present locally, as for example, in the western part of the Erica Range. Ripple marks and bedding planes covered with shale pellets are common, and scattered shale clasts, very coarse quartz grains, and well-rounded pebbles of quartz and chert are present in places, mainly in the lower part of the formation.

Other rock types present are medium-grained quartz arenite, containing little or no matrix, which is most common near the top of the formation; thin-bedded to laminated shale, siltstone, and fine-grained micaceous arenite, mainly near the base of the formation; rare beds of gritty to pebbly arenite; and glauconitic sandstone, which is exposed near the base of the formation 25 km northwest of Lake Jeavons in Lucas Sheet area and east of Lake Wills in Stansmore Sheet area.

Surface silicification is widespread and patches of silcrete are common. Laterite cappings are developed locally on unsilicified clayey sandstone. Close jointing, breccia zones, and slickensided surfaces are associated with local faulting, as, for example, on the south side of the Erica Range.

In the type section of the formation, in the Erica Range, about 400 m of medium to fine-grained, cross-bedded, sublithic arenite is exposed. At this locality Casey & Wells (1964) mapped a possible boundary between two units: the Gardiner and Phillipson Beds. The sandstones on either side of the boundary have different airphoto patterns, but are similar lithologically, show similar amounts of silicification, and are conformable. The only difference noted in the field was that the upper sandstone, unlike the lower, generally splits smoothly along bedding planes.

A representative section, about 200 m thick, has been measured in the northwest of the Phillipson Range, from 20°32′30″S, 129°30′30″E to 20°35′45″S, 129°35′00″E. The lower 100 m, conformably overlying chert-granule conglomerate of the Murraba Formation, consists of medium-grained sublithic arenite, some of which contains widely-scattered pebbles, and, near the base, some thin shale interbeds. The upper part is described by Casey & Wells (1964) as consisting, from the base upwards, of about 15 m of sandstone, 6 m of interbedded shale and sandstone, 15 m of flaggy to laminated medium-grained sandstone, and over 60 m of cross-bedded and ripple-marked medium-grained sandstone; the sandstone in this part, like that below, is sublithic arenite.

Stratigraphic relations and correlation

The Erica Sandstone, the youngest unit of the Redcliff Pound Group, conformably overlies the Murraba Formation, the boundary between the two units being taken as the top of the highest bed of chert-granule conglomerate. Its contacts with overlying units are concealed by Cainozoic sediments. However, near the Phillipson Range the Erica Sandstone is presumably overlain unconformably by the Palaeozoic Lucas Formation and unnamed Mesozoic sandstone, and to the south it

Fig. 35. Cuestas of Erica Sandstone in a broad gently northward-plunging syncline in the Murraba Ranges; from the south, Stansmore Sheet area. (M1404/19)

is inferred to be overlain, possibly conformably, by the Hidden Basin Beds and unconformably by the Palaeozoic Pedestal Beds and Mesozoic Hazlett Beds. At the southern end of the Elsey Hills, in Billiluna Sheet area, the Erica Sandstone is separated from the Lewis Range Sandstone to the east by the concealed Murraba Formation, and from the Baines Beds to the northwest by a postulated major fault.

The Boee Beds, which crop out on the east side of the Baines Hills in the northwest of the Birrindudu Basin, are probably a stratigraphic equivalent of the Erica Sandstone.

Possible Correlatives of the Redcliff Pound Group

Hidden Basin Beds

The Hidden Basin Beds (Blake & Yeates, 1977) crop out in the southwest of the Birrindudu Basin, in Stansmore and Webb Sheet areas. The unit is named after the broad depression containing Lake Wills and Lake Hazlett. In Stansmore Sheet area it was previously mapped as part of the Gardiner Beds (Wells, 1962c, Casey & Wells, 1964). The unit forms parallel strike ridges, developed on resistant quartz arenite and sublithic arenite, which are separated by sand plains, presumed to be developed on less resistant rocks.

The Hidden Basin Beds have been folded into broad and tight folds and have been faulted. Near faults they are closely jointed, brecciated, and veined by quartz.

The maximum known thickness of the unit, measured on aerial photographs, is about 3000 m, but the true thickness may be more than this, as much of the unit is concealed beneath superficial Cainozoic sediments. Over 2000 m is exposed in the reference area, 23 km southwest of Lake Hazlett (at 21°40′E, 128°25′E).

Lithology

The main rock types seen are quartz arenite and sublithic arenite. However, some thin-bedded to laminated shale, siltstone, and fine-grained sublithic arenite are exposed in a few creeks, as, for example, in the reference area, and similar beds may be present beneath the sandy plains between the sandstone ridges.

The arenites are white to pale grey, where they are not iron-stained, and are mainly well-sorted and medium to fine-grained. They commonly have a sparse white clayey matrix as well as a quartz-overgrowth cement. Low-angle cross-bedding is very common, and some ripple marks have been seen. The quartz arenite is medium to very thin-bedded, and commonly has a glassy appearance. In places it contains scattered quartz pebbles. The sublithic arenite is mainly medium-bedded, but is locally very thin-bedded to laminated, as in the centre of the structural basin 35 km west of the Alec Ross Range. Some sublithic arenite is micaceous and some has bedding planes crowded with shale pellets, especially near the base of the unit.

In the reference area, a sequence over 2000 m thick dips steeply west. About 1800 m of medium-bedded, medium to fine-grained quartz arenite and sublithic arenite dips west and forms a prominent strike ridge. A lower strike ridge, formed of medium-bedded glassy quartz arenite about 150 m thick, is present to the west. This ridge is separated from the higher ridge by a narrow plain developed on about 280 m of thin-bedded to laminated shale, siltstone, and fine-grained sublithic arenite.

Stratigraphic relations and age

The Hidden Basin Beds are faulted against the Erica Sandstone 10 km south-southwest of Lake Hazlett. Elsewhere contacts with Proterozoic units are concealed by superficial deposits. However, the regional structure indicates that the Hidden Basin Beds overlie the Erica Sandstone. The contact between those two units is possibly conformable and gradational; much of the sublithic arenite of the Hidden Basin Beds is similar to that of the Erica Sandstone, and the upper part of the latter unit locally includes glassy quartz arenite similar to that of the Hidden Basin Beds. The Hidden Basin Beds may therefore be a younger unit of the Redcliff Pound Group. They were folded at the same time as the Redcliff Pound Group, and are considered to be late Adelaidean.

In the southwest of Stansmore Sheet area, folded sandstone mapped as possible Hidden Basin Beds is overlapped by the Lightjack Formation, a Permian unit of the Canning Basin succession. In the south the Hidden Basin Beds are overlain unconformably by flat-lying Palaeozoic Pedestal Beds.

Denison Beds

Outcrops of the Denison Beds (Blake & others, 1977) are confined to the Denison Range, after which they are named, in the northwest of the Birrindudu Basin, in Billiluna Sheet area. The unit consists predominantly of quartz arenite.

The reference area is the southeast part of the Denison Range, south of Pyramid Hill, where the unit has been folded into a gentle syncline, and about 30 m is exposed. Here the basal 10 m consists of thick-bedded quartz arenite, which shows contorted bedding laminations, probably due to slumping. This is overlain by pale pinkish, medium to thin-bedded quartz arenite, about 15 m thick, which is mainly medium-grained; cross-bedding and ripple marks are common (Fig. 36), and one bed near the top shows convolute lamination. The top 5 metres consists of thin-bedded sublithic arenite containing abundant shale pellets. At the base of Pyramid Hill and at other places along the west side of the Denison Range the basal quartz arenite is underlain by siltstone and fine shaly sandstone, mainly concealed by scree, which may be part of the Pindar Beds.

The Denison Beds appear to be unconformable on the underlying Pindar Beds. The contact is not exposed, but an angular discordance is apparent on the west side of the reference area. The Denison Beds are inferred to be overlain conformably by the Jawilga Beds. They probably correlate with the lithologically similar Lewis Range Sandstone, and are considered to be Adelaidean.

Jawilga Beds

The Jawilga Beds (Blake & others, 1977), which are named after a pool on Sturt Creek, crop out on both sides of the major anticline between the Baines Hills and the Denison Range, in Billiluna Sheet area. On the west side of the anticline they form a low narrow strike ridge separated from the Baines Beds by a postulated major fault, and consist of conglomerate containing well-rounded chert clasts up to 3 cm across. On the east side of the anticline, the outcrops consist mainly of creamy-grey to pale maroon, medium to fine-grained sublithic arenite and thin-bedded chert granule conglomerate, similar to that characteristic of the Murraba Formation; the sublithic arenite is medium to thin-bedded and shows cross-bedding and ripple marks. The eastern outcrops are confined to a narrow fault-bounded band, where the Jawilga Beds are about 130 m thick. The reference area for the unit is the part of this band that lies 8 km west-northwest of Pyramid Hill.

The Jawilga Beds are inferred to be conformable on the Denison Beds and to be overlain conformably by the Boee Beds. They probably correlate with the Adelaidean Murraba Formation.

Fig. 36. Asymmetrical ripple marks in sandstone of the Denison Beds; 8 km east-northeast of Pyramid Hill, Billiluna Sheet area. (GA/7955)

Boee Beds

The Boee Beds (Blake & others, 1977) named after a pool on Sturt Creek, crop out as narrow strike ridges east of the Baines Hills, between 19°23' and 19°30'S, in Billiluna Sheet area. In the northeast of their outcrop area they form a small structural basin 3 km across; further south they dip northwest at about 12°. The reference area is the southwest of the outcrop area, where the maximum known thickness, about 350 m, is present.

The main rock type exposed is sublithic arenite similar to that of the Erica Sandstone. It is brown, maroon, or cream, medium to fine-grained, and medium to thin-bedded. Some beds show low-angle cross-bedding and some have layers with shale pellets. Beds of conglomerate and conglomeratic arenite containing boulders of quartzite are present in the reference area.

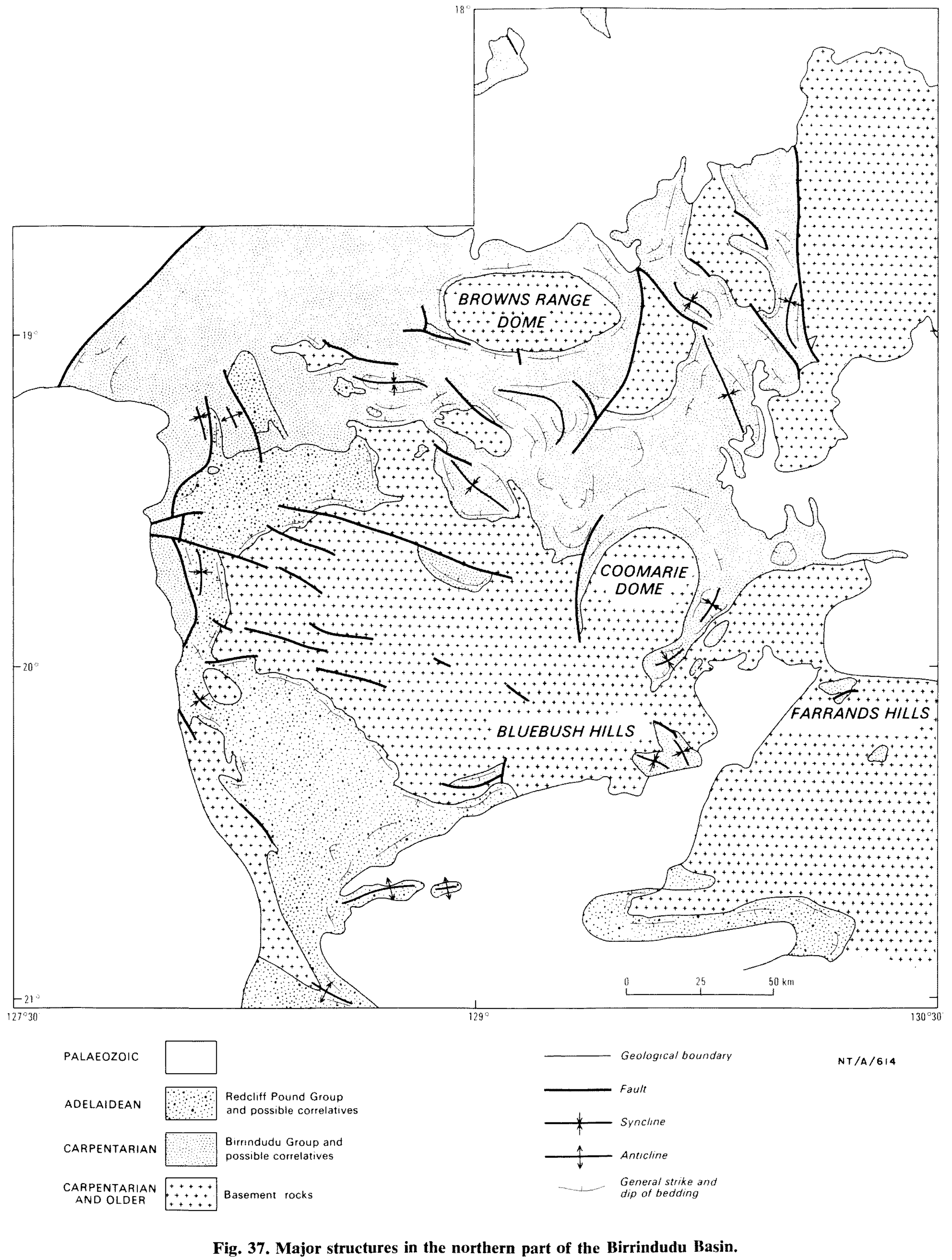


Fig. 37. Major structures in the northern part of the Birrindudu Basin.

where they are separated from underlying sublithic arenite, 120 m thick, by a zone of no exposure a few hundred metres wide.

Contacts between the Boee Beds and other Proterozoic units are not exposed. However, the Boee Beds are inferred to overlie the Jawilga Beds conformably. They may be equivalent to the Erica Sandstone, and are probably Adelaidean.

STRUCTURE

Major structures affecting the rocks of the Birrindudu Basin are shown in Figures 37 and 42.

Folding

The Carpentarian rocks of the Birrindudu Basin have mainly gentle to moderate dips (10° to 40°). Steeply dipping to vertical beds are generally found only near faults, and flat-lying sediments are mostly confined to the south and northwest parts of the Gardner Range and the southeast of Gordon Downs Sheet area. The trends of folds range from north-south to east-west.

Three major anticlinal structures affect the Birrindudu Group. These are the Browns Range Dome (Fig. 38), the Coomarie Dome (Fig. 39), and a large anticline in the northeast, between the Birrindudu, Mana, and Ware Ranges; all these have cores of basement rocks. Between these major structures and also east and southeast of the Coomarie Dome, the rocks of the Birrindudu Group have been deformed into a complex of irregular folds, small domes, and basins, which are well displayed on the Tanami 1:250 000 geological map. Small remnants of Birrindudu Group rocks forming the Bluebush Hills and Farrands Hills areas (Figs. 40, 41), have also been irregularly folded. The fold patterns, which have been further complicated by faulting, indicate that the Birrindudu Group has been affected by at least two intersecting sets of folds.

In the northwest of the Birrindudu Basin the most intensely folded rocks are those of the Baines Beds. These are tightly folded in the north, and are possibly isoclinally folded in the south, where a cleavage is locally developed. Other units of probable Carpentarian age in this part of the basin dip less steeply, and appear to form broad folds. The Limbunya Group in the north has been folded about northwest-trending axes.

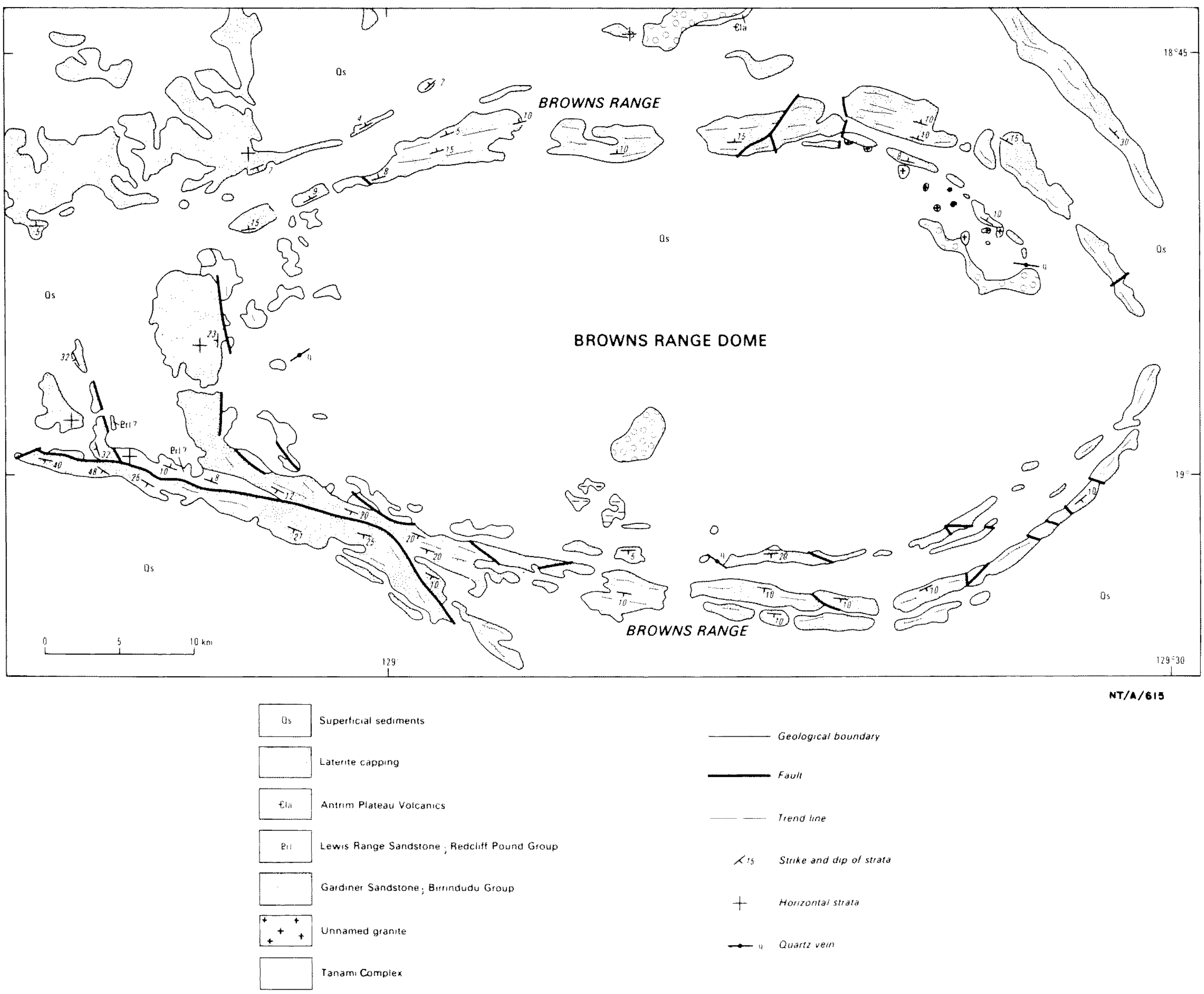


Fig. 38. Geological map of the Browns Range Dome, Birrindudu, Tanami, Gordon Downs, and Billiluna Sheet areas.

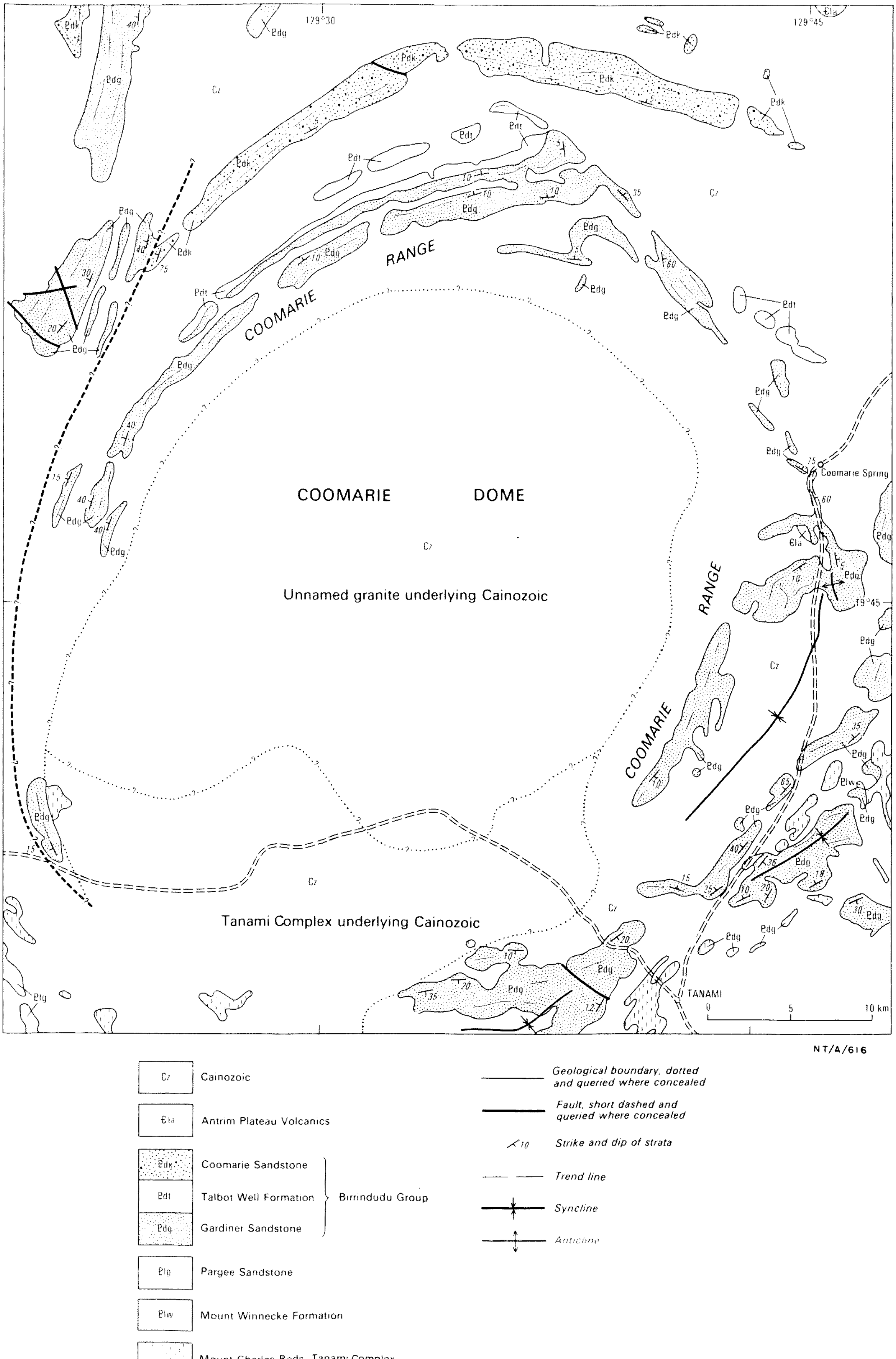


Fig. 39. Geological map of the Coomarie Dome, Tanami Sheet area.

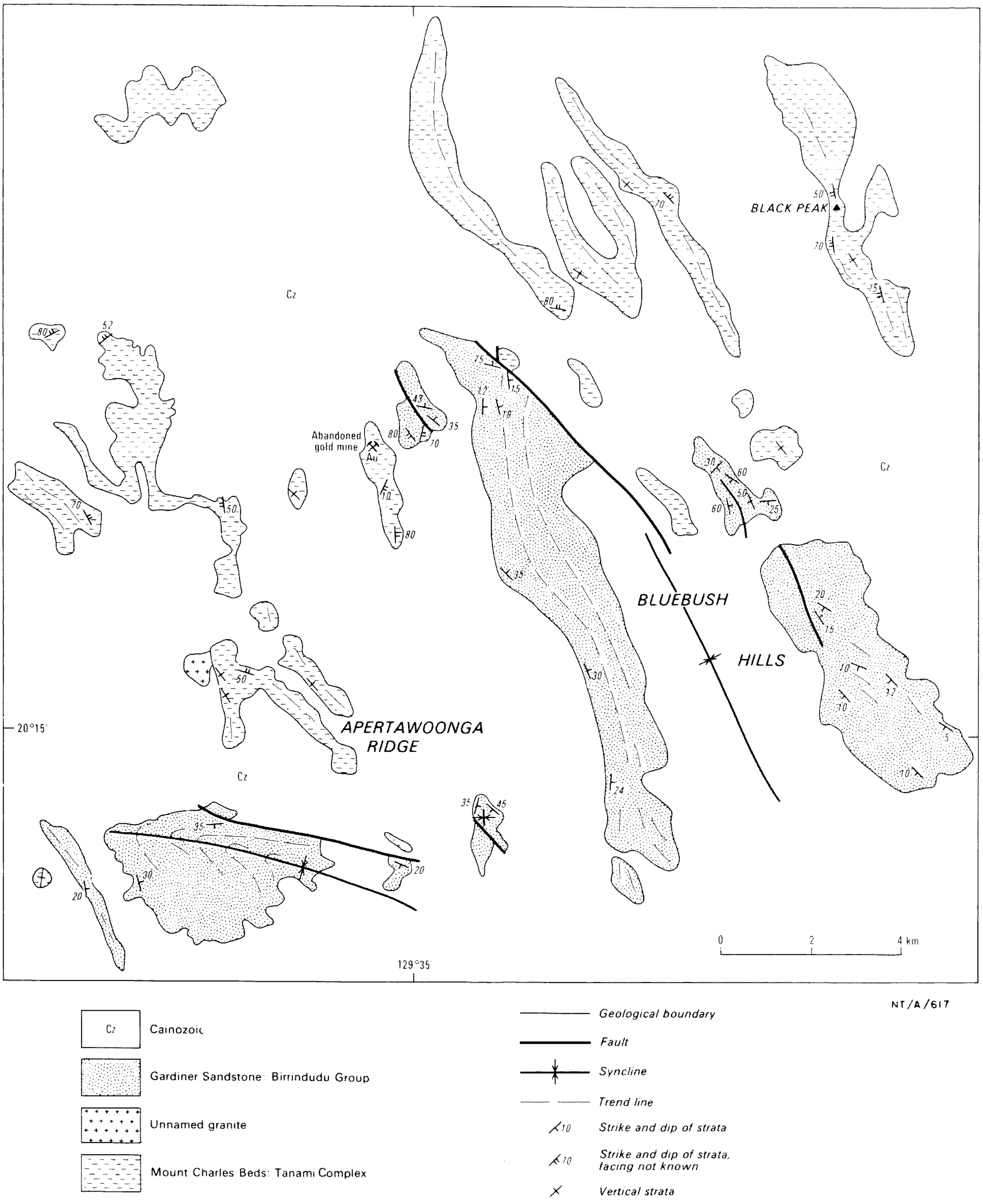


Fig. 40. Geological map of the Bluebush Hills, The Granites Sheet area.

The Adelaidean rocks are generally less steeply dipping than the Carpentarian rocks, especially in the north and centre of the basin, and they form more or less symmetrical folds with gently curved rather than sinuous axes. Dips of less than 5° predominate in the extensive outcrops of Lewis Range Sandstone in the northwest, and this unit is flat-lying where it unconformably overlies gently dipping Gardiner Sandstone in the Gardner Range. This angular unconformity indicates that some deformation of the Carpentarian rocks took place before the deposition of the Redcliff Pound Group. Steep to vertical dips are present locally, mainly next to faults.

Folding of Adelaidean rocks is best displayed in the southwest (Fig. 42), especially in the Redcliff Pound area (Fig. 43). Most fold axes in this part of the basin are gently curved, from northeast in the south, to northwest and west-northwest in the north. Folds plunge consistently northwards in the south, but are variable further north. The gently curved folds affect the Mur-

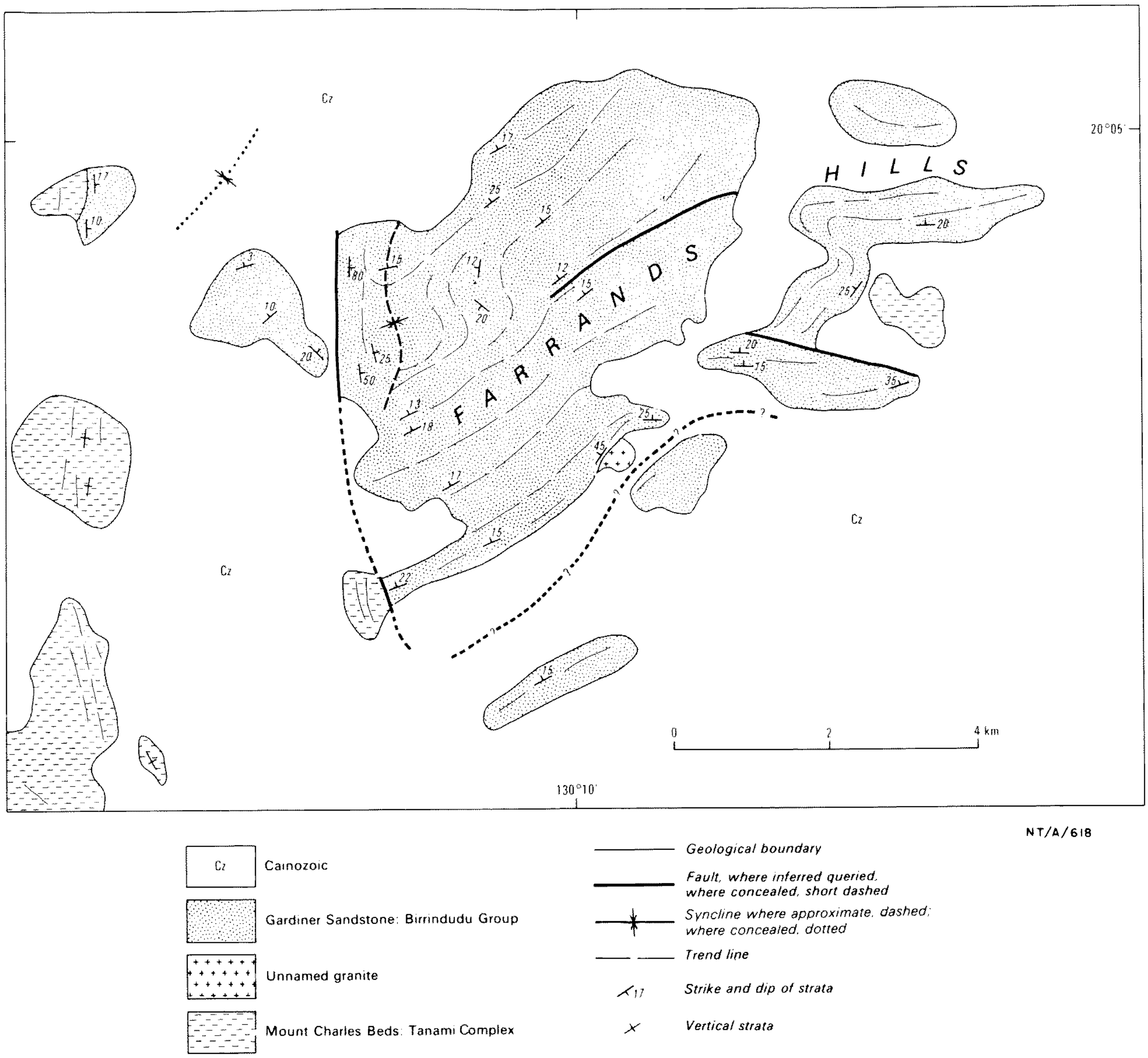


Fig. 41. Irregular folding in the Farrands Hills, The Granites Sheet area.

raba Formation and Erica Sandstone of the Redcliff Pound Group and also the overlying Hidden Basin Beds, but do not appear to extend down into the underlying Munyu Sandstone at the base of the Redcliff Pound Group to the south and east. The Munyu Sandstone here forms a series of strike ridges, mainly trending northeast, which are separated from outcrops of overlying Adelaidean sediments by sand-covered areas, presumed to be underlain largely by Murraba Formation. As the Murraba Formation consists of thinly interbedded sedimentary rocks, including some carbonates, it probably acted as a relatively incompetent layer during folding, and may have given rise to a décollement similar to that in the Bitter Springs Formation (Wells & others, 1970), its probable correlative in the Amadeus Basin to the south. The strike ridges of Munyu Sandstone to the east, in Highland Rocks Sheet area, are inferred to be parts of the limbs of a series of large anticlines and synclines; in most cases only the northwesterly-dipping limbs of these folds are exposed. Locally, the Munyu Sandstone shows small tight folds, as in the Alec Ross Range area, where the folding is also complicated by several faults (Fig. 32).

In the northwest of the Birrindudu Basin, in the Denison Range, probable correlatives of the Redcliff Pound Group are gently folded about south-southeast-trending axes, forming elongate basins. To the southwest of the Denison Range they are exposed as steeply dipping beds on the western limb of a broad anticline bounded to the west by a postulated major fault.

Faulting

Most of the major faults mapped in the Birrindudu Basin do not appear to have been affected by any folding, and they probably postdate the folding of the Adelaidean rocks. Many of the smaller faults though, were probably active during either this or earlier folding. Only two major faults, on the east and south sides of the Nora Range, in the centre of the basin, can be shown to be older than the Redcliff Pound Group; these displace the Gardiner Sandstone and Tanami Complex, but not gently dipping rocks of the Redcliff Pound Group, exposed nearby.

The positions of most of the larger faults cannot be accurately located, as their traces are concealed by

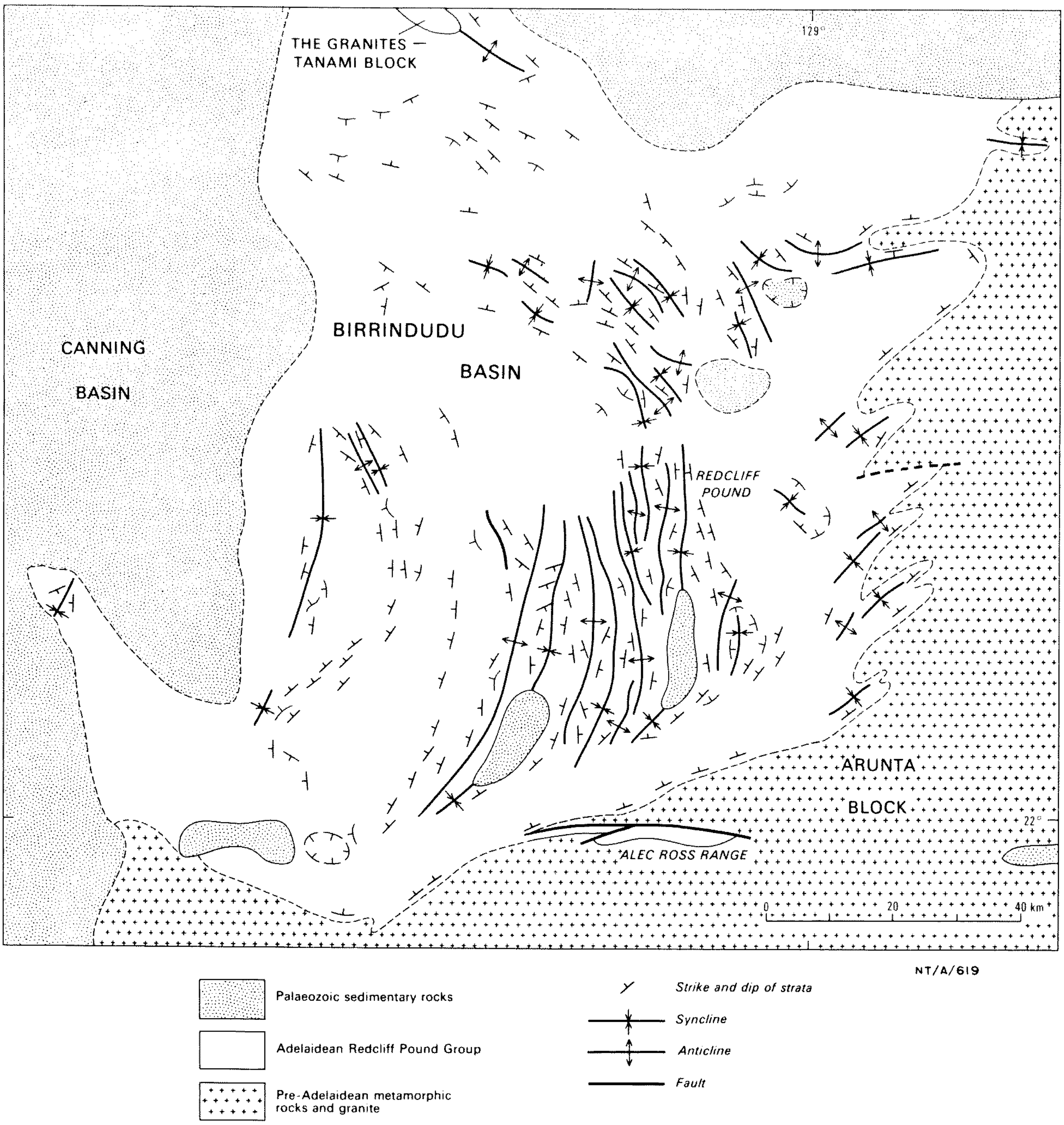


Fig. 42. Structural sketch map of the southwestern part of the Birrindudu Basin (Cainozoic and Mesozoic omitted).

Cainozoic sediments. However, some fault traces are probably represented in the northwest, between the Gardner and Lewis Ranges, by prominent quartz ridges trending east to east-southeast across The Granites-Tanami Block; these ridges are in line with gaps and horizontal displacements in cuestas of Lewis Range Sandstone to the west.

Major faults, involving displacements of probably several hundreds of metres are shown in Figures 37 and 42.

UNNAMED BASIN IN THE NORTHWEST

Northwest of the Birrindudu Basin, in Billiluna and Gordon Downs Sheet areas, Carpentarian and Adelaidean sedimentary units of the east Kimberley succession occupy the southern part of what in this report is termed an unnamed basin (Fig. 30). Of the units mapped in this basin, all but one, the Redbank Yard Formation (Blake and others, 1977), are defined by Dow & Gemuts (1969). Except for the Wade Creek Sandstone, individual formations are not shown separately on the 1:500 000 map. The basin is separated from the Kimberley Basin to the northwest by the basement Halls Creek Province, and from the Birrindudu Basin to the southeast by a postulated northeast-trending major fault, which separates Adelaidean rocks to the northwest from the probably Carpentarian Ima Ima Beds to the southeast (Fig. 30). Correlations between successions on either side of this fault are tentative, as they are based only on broad similarities in lithology and stratigraphic relations.

Plumb & Derrick (1975) and Sweet (1977) regard the Carpentarian units in the unnamed basin as part of the Birrindudu Basin succession; however, the available

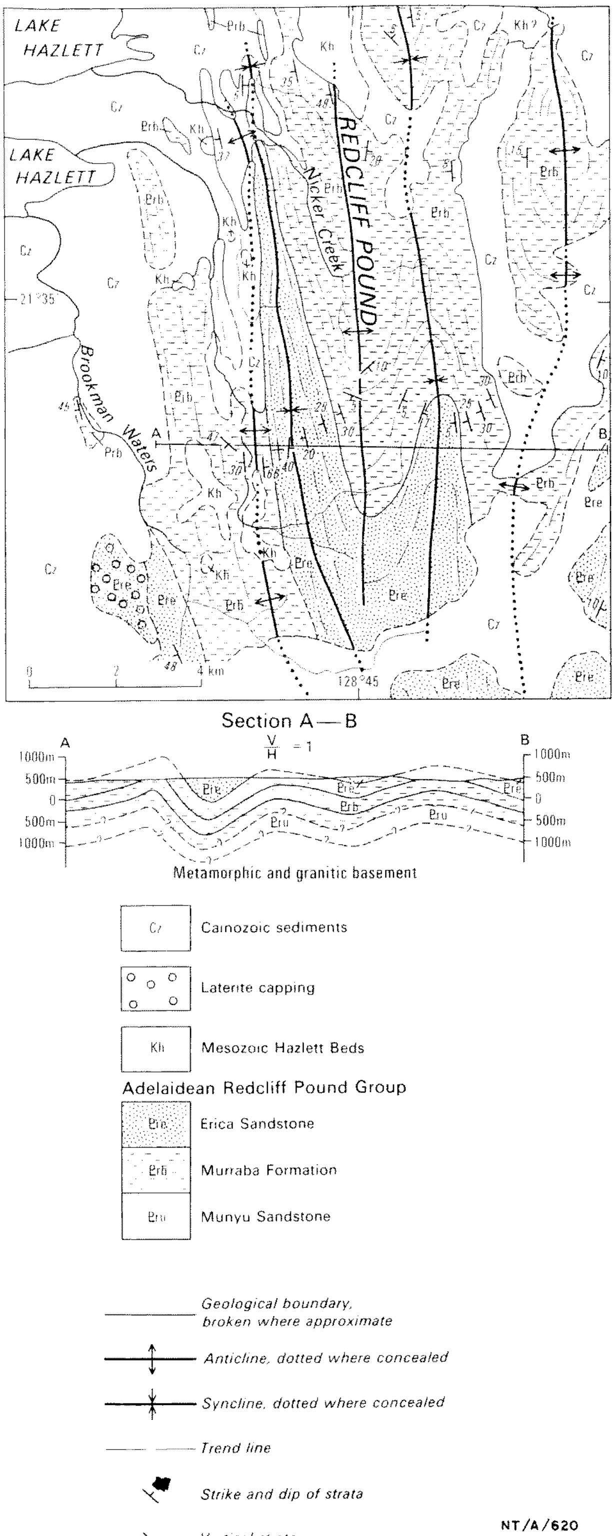


Fig. 43. Geological map of Redcliff Pound, Stansmore Sheet area.

evidence is insufficient to confirm this. They also state that the oldest Adelaidean unit present, the Wade Creek Sandstone, is part of the Victoria River Basin succession, and they regard only the younger Adelaidean units as belonging to an unnamed basin. Because of the doubt concerning the Carpentarian units, and the small area they and the Adelaidean units occupy in The Granites-Tanami region, the units are described together here as belonging to an unnamed basin. At times during its history this basin would have been connected with the Victoria River Basin to the northeast and probably also with the Birrindudu and Kimberley Basins.

The sedimentary rocks filling the unnamed basin have not been regionally metamorphosed, although they were irregularly folded and faulted late in the Adelaidean. No part of the basin in the area is known to contain any mineralisation.

Carpentarian Succession

Mount Parker Sandstone

The Mount Parker Sandstone, the oldest and most westerly unit in the unnamed basin, crops out as discontinuous strike ridges. It is about 300 m thick and has a general east to southeast dip of 30°-40°. The main rock type exposed is well-sorted, medium-grained quartz arenite, which is accompanied in the lower part of the formation by medium to coarse-grained sublithic arenite and minor pebbly arenite, conglomerate, and local siltstone. Individual beds are generally less than 1 m thick, and commonly show low-angle cross-bedding. Some bedding planes are crowded with shale pellets. Near faults the formation is brecciated and cut by quartz veins.

The Mount Parker Sandstone is unconformable on the Halls Creek Group and is conformably overlain by Bungle Bungle Dolomite. It can probably be correlated with the Gardiner Sandstone of the Carpentarian Birrindudu Group. This correlation is based on the relations of the two formations to underlying metamorphic rocks and overlying silicified carbonate rocks, as well as on broad lithologic similarities.

Bungle Bungle Dolomite

The Bungle Bungle Dolomite crops out as low mounds in Billiluna Sheet area, where it appears to be about 300 m thick. Rock types present are banded chert, brecciated chert, silicified oolite, bouldery cherty ironstone containing possible stromatolitic structures, minor lithic arenite, and, in the north, micaceous greywacke, siltstone, and shale. Microfossils have been found in silicified stromatolitic dolomite within the unit north of the area (Diver, 1974). The Bungle Bungle Dolomite is probably Carpentarian and stratigraphically equivalent to the lithologically similar Talbot Well Formation of the Birrindudu Group.

Adelaidean Succession

Wade Creek Sandstone

Sandstone forming the prominent range of hills to the east of the strike ridge of Mount Parker Sandstone is mapped as Wade Creek Sandstone. In the southwest of Gordon Downs Sheet area this sandstone was previously mapped as Mount Parker Sandstone (Gemuts & Smith, 1968), but it is now known, from field evidence in Billiluna Sheet area, to overlie rather than underlie the Bungle Bungle Dolomite. The formation has a regional dip to the east and is probably at least 800 m thick. It consists mainly of pale grey, medium-bedded, well-sorted, medium-grained sublithic arenite. Minor bands of siltstone are also present, and some lenses and beds of coarse arenite crop out near the base of the formation.

The contacts in the area between the Wade Creek Sandstone and both the underlying Bungle Bungle

Dolomite and overlying rocks of the Duerdin Group are concealed by superficial deposits, but to the north the sandstone rests unconformably on Bungle Bungle Dolomite and grades upwards into the Helicopter Siltstone, which is unconformably overlain by the Duerdin Group (Dow & Gemuts, 1969). Also to the north it includes a thick shale lens, the Mount John Shale Member, which has been dated at 1128 ± 110 m.y. (Dow & Gemuts, 1969), indicating that the formation is Adelaidean. It is correlated by Sweet (1977) with the Adelaidean Jasper Gorge Sandstone of the Auvergne Group in the Victoria River region, and appears to be appreciably older than the Redcliff Pound Group of the Birrindudu Basin.

Duerdin Group

The Duerdin Group crops out in the northwest of the area and more extensively to the north, in the Kimberley and Victoria River regions, where it includes some glacial rocks. The group lies unconformably on the Wade Creek Sandstone and is overlain unconformably by the Albert Edward Group (Gemuts & Smith, 1968). It has been dated isotopically at about 700 m.y. (Plumb & Derrick, 1975). Two constituent formations, the Redbank Yard Formation and the Ranford Formation, crop out in the south of the unnamed basin.

Redbank Yard Formation

The Redbank Yard Formation forms a group of isolated strike ridges east and south of the Wade Creek Sandstone in the northwest of Billiluna Sheet area. It is named after a yard on Wolf Creek (at 19°04'00"S, 127°47'00"E). The formation forms east-plunging open folds in the north, and tighter folds with east-trending axes in the south. The maximum known thickness, 330 m, is exposed in the type section, which is 16 km west-southwest of Redbank Yard.

The formation consists of conglomerate, medium-bedded sublithic arenite, and minor dolomite. The conglomerate is a poorly sorted deposit, containing well-rounded to angular fragments, many over 10 cm across, mainly of quartz, various types of sandstone, and chert. It forms thick beds and also thin bands and lenses, and is interbedded with medium to coarse-grained sublithic arenite, which is commonly pebbly. Conglomerate predominates in the southern outcrops, but sublithic arenite is the main rock type exposed in the north. A lens of grey dolomite about 1 m thick is present in sublithic arenite 14 km west-northwest of Redbank Yard.

In the type section a sequence about 330 m thick dips south at 20°. It consists of 200 m of thick to medium-bedded polymictic conglomerate containing thin lenses of sandstone, overlain by 130 m of medium to very coarse-grained sublithic arenite.

The Redbank Yard Formation overlies Wade Creek Sandstone to the west and is overlain by Ranford Formation to the east, but its contacts with these formations are concealed. It is considered to be a lateral equivalent of the Moonlight Valley Tillite, which occupies a similar stratigraphic position in the north of Gordon Downs Sheet area, and the conglomerate within it may be an outwash deposit derived from glacial moraines. The Redbank Yard Formation is therefore regarded as part of the Duerdin Group. As such, it is inferred to lie unconformably on the Wade Creek Sandstone (or the Helicopter Siltstone, if this is present beneath the Cainozoic cover) to the west, and to be overlain conformably by the Ranford Formation.

Ranford Formation

The Ranford Formation is exposed west of the Billiluna-Halls Creek road, in low strike ridges and along the lower parts of west-facing scarps capped by Mount Forster Sandstone. Rock types cropping out are thin-bedded to laminated micaceous siltstone and shale; flaggy, well-sorted, fine-grained sublithic arenite; and dolomitic sandstone. The maximum thickness exposed in Billiluna Sheet area is about 10 m, and that in Gordon Downs Sheet area, about 200 m (Gemuts & Smith, 1968). The Ranford Formation is overlain unconformably by the Mount Forster Sandstone (Gemuts & Smith, 1968).

Albert Edward Group

The Albert Edward Group extends south into the area from more extensive outcrops along the Albert Edward Range to the north. It comprises a conformable sequence of probably shallow marine sediments. Isotopic dating on shale from one of the constituent formations indicates an age for the group of 650 m.y. (Plumb & Derrick, 1975).

The basal formation of the group is the *Mount Forster Sandstone*. This unit is made up of quartz arenite, sublithic arenite and minor conglomerate, and forms prominent strike ridges and cuestas. In Billiluna Sheet area, where the formation is about 200 m thick, the lowest 15 m exposed consists of variably iron-stained, poorly sorted, and partly conglomeratic sublithic arenite. The remainder of the formation here comprises interbedded quartz arenite and pale grey, partly pebbly sublithic arenite. The arenites are commonly cross-bedded, and many beds show ripple marks.

The Mount Forster Sandstone is overlain conformably by the *Elvire Formation*. This unit is about 390 m thick on the northern edge of Billiluna Sheet area, where the following sequence is exposed:

Top	Conformably overlain by Timperley Shale
30 m	Thin-bedded, ripple-marked, medium-grained lithic arenite
150 m	Poorly exposed, thinly interbedded siltstone and shale; white medium-grained quartz arenite, 3 m thick, containing shale pellets, near the top
30 m	Ripple-marked, medium to fine-grained lithic arenite
150 m	Thinly interbedded micaceous siltstone, shale and fine-grained lithic arenite
30 m	Very thin-bedded, ripple-marked, fine-grained lithic arenite
Base	Conformable on Mount Forster Sandstone.

Here the *Boonall Dolomite*, which conformably overlies the Elvire Formation further north, is absent. The overlying *Timperley Shale* exposed at this locality is at least 100 m thick and consists of maroon micaceous shale and siltstone with minor thin interbeds of lithic arenite. In the Albert Edward Range, to the north, the Timperley Shale, which is probably over 1000 m thick (Dow & Gemuts, 1969), is overlain conformably by the *Nyuless Sandstone*. Rocks of the youngest unit of the Albert Edward Group, the *Flat Rock Formation*, have been tentatively identified on either side of the eastern branch of Wolf Creek, on the northern edge of Billiluna Sheet area (Blake & others, 1977), where about 600 m is exposed. The sequence here consists of poorly sorted and partly pebbly sublithic arenite, thinly interbedded mauve micaceous siltstone and shale, thin-bedded to laminated siltstone, and ripple-marked fine-grained sublithic arenite. To the east it is capped by laterite, and it is separated from outcrops of Timperley Shale to the west by Cainozoic superficial sediments.

STRUCTURE

The unnamed basin is inferred to be bounded on the southeast by a concealed northeast-trending major fault, separating it from the Birrindudu Basin. Its western edge is partly bounded in the north by the Halls Creek Fault. The eastern part of the basin is concealed by Cainozoic sediments and, in the north, Cambrian Antrim Plateau Volcanics.

The oldest units in the Basin, the Mount Parker Sandstone, Bungle Bungle Dolomite, and Wade Creek Sandstone, dip generally east, away from the basement metamorphics of the Halls Creek Group. West of Beaudesert Bore these units form a series of small folds plunging east (the 'concertina' folds of Gemuts & Smith, 1968). To the east the Adelaidean rocks of the Duerdin and Albert Edward Groups have been deformed into irregular folds and displaced along several small faults. Bedding dips of less than 40° predominate within the unnamed basin except near faults, where beds locally have steep to vertical dips.

AMADEUS BASIN

Adelaidean sedimentary rocks of the Amadeus Basin succession (Wells & others, 1970) crop out in the southwest, in Webb Sheet area. Units represented are the Heavitree Quartzite, which is the oldest formation in the north of the basin, and the conformably overlying Bitter Springs Formation (Fig. 21). Both these units can be correlated with the basal units of the Redcliff Pound Group in the Birrindudu Basin to the north. The Amadeus Basin was probably connected to the Birrindudu Basin, and also to the Ngalia Basin, during late Adelaidean times, but is now separated from them by parts of the basement Arunta Block. No mineralisation is known within the part of the Amadeus Basin in the area.

Heavitree Quartzite

The Heavitree Quartzite was named and defined by Joklik (1955), Heavitree Gap at Alice Springs being the type locality (Wells & others, 1970; Clarke, 1975, 1976). The formation extends northwest from the Dover Hills in Macdonald Sheet area (Wells & others, 1964, 1970) into Webb Sheet area, where the main outcrops are in the vicinity of Mount Webb (Fig. 25) and in the Pollock Hills (Fig. 22). Mount Webb, which rises almost 100 m above the surrounding plain (Fig. 23), is a mesa of foliated Mount Webb Granite capped by about 20 m of Heavitree Quartzite which dips gently east. In the Pollock Hills, where 500 m is exposed, the maximum in Webb Sheet area, the formation forms a series of cuestas, the highest of which is about 50 m. Elsewhere it crops out as isolated cuestas and strike ridges.

The Heavitree Quartzite consists of quartz arenite, sublithic arenite, and subordinate siltstone and greywacke. These rocks are mostly white to pale pink or maroon. Individual beds are generally thin to very thin, especially in the upper part of the formation, where a platy parting is commonly developed, and most show low-angle cross-bedding. The arenites are mainly medium to coarse-grained, although thin lenses and laminae of grit and conglomerate, formed largely of angular to subangular clasts of quartz, are present locally, generally near the base of the formation. Micaceous sublithic arenite and greywacke are commonly present immediately overlying weathered granite, as for example on Mount Webb. Conglomerate, containing pebbles and cobbles of vein quartz, quartzite, chert, quartz arenite, greywacke, and mudstone, is interbedded with medium to thick beds of pebbly arenite at basal exposures of the formation west of the Pollock Hills. Surface silicification is common, and most of the arenites have a siliceous cement. Beds that are friable form depressions between ridges of silicified arenite.

At most outcrops the Heavitree Quartzite has gentle to moderate dips, except where it has been affected by irregular folding and associated faulting. At such localities it dips steeply, and is brecciated, sheared, and cut by veins of quartz and chalcedony.

Wells & others (1970, p. 21) consider that '. . . The widespread distribution of the . . . Heavitree Quartzite suggests deposition in a shallow-marine epicontinental sea under relatively stable conditions', and they suggest that the coarse basal beds may indicate a littoral environment. Clarke (1975) has since suggested that some parts of the formation are fluvial. However, most if not all the Heavitree Quartzite in Webb Sheet area is probably shallow-marine.

Stratigraphic relations, age, and correlation

The Heavitree Quartzite is unconformable on the Arunta Complex, Pollock Hills Formation, and Mount Webb Granite of the Arunta Block, and is overlain conformably by Bitter Springs Formation. The Palaeozoic Angas Hills Beds and probably also Mesozoic sediments overlie it unconformably. Contacts with the Arunta Complex are exposed in low scarps east of Mount Webb. Those with the Pollock Hills Formation are concealed in the Pollock Hills by superficial deposits, but are exposed a few kilometres to the northeast and east, where the Heavitree Quartzite overlies the flow-banded and highly altered top of an acid lava flow belonging to the Pollock Hills Formation and also Mount Webb Granite. Other contacts with the Mount Webb Granite are exposed on and near Mount Webb, although here they are mainly concealed by sandstone scree, and at a small outcrop 27 km north-northeast of the Pollock Hills.

A conformable contact with the overlying Bitter Springs Formation is exposed on the west side of the Pollock Hills, where the boundary between the formations is taken to be the base of the lowest carbonate bed in a sequence consisting mainly of thin to very thin-bedded quartz arenite.

The Heavitree Quartzite is known to be younger than 1076 ± 50 m.y., the age of a migmatisation event affecting underlying rocks of the Arunta Complex to the east-southeast (Marjoribanks & Black, 1974), and is probably younger than 1000 m.y. (Wells, 1976). It is correlated with the Munyu Sandstone of the Redcliff Pound Group in the Birrindudu Basin to the north, and also with the Vaughan Springs Quartzite of the Ngalia Basin (Wells & others, 1972), although glauconite from the latter formation has been dated at about 1300 m.y. (Cooper & others, 1971).

Bitter Springs Formation

The Bitter Springs Formation (Ranford & others, 1966) extends northwest from Macdonald Sheet area into the south of Webb Sheet area, where it crops out as low mounds and, on the west side of the Pollock

Hills, as low hogback ridges; at the latter locality it is at least 300 m thick. Unlike the Heavitree Quartzite, the Bitter Springs Formation is generally steeply dipping, and in one outcrop area, southeast of the Pollock Hills, it may be isoclinally folded. Such folding could be attributed to it acting as an incompetent layer which deformed plastically during tectonism.

The main rock types exposed are pale greyish, finely crystalline limestone and dolomite, which contain thin lenses and laminae of dark grey chert. Also present near the base of the formation in the Pollock Hills is some thin-bedded quartz arenite. No indications of evaporitic minerals, known to be present in the formation further east in the Amadeus Basin (Wells & others, 1970) have been found. The limestone and dolomite are mainly thin-bedded, and locally show undulating to contorted laminations, which may be stromatolitic. They commonly have some calcrete developed on them. The carbonates and the associated chert are recrystallised and samples examined microscopically do not contain any preserved microfossils (M. R. Walter, BMR, personal communication, 1974).

Wells & others (1970) consider that the formation was probably deposited in a relatively stable shallow marine environment.

Stratigraphic relations, age, and correlation

The Bitter Springs Formation conformably overlies the Heavitree Quartzite on the west side of the Pollock Hills. Elsewhere its contacts with pre-Cainozoic units are concealed by superficial deposits. The formation is correlated with the upper part of the Munyu Sandstone to the north, which includes similar carbonate beds with chert lenses and laminae.

Stratigraphic and palaeontological evidence indicates that the Bitter Springs Formation is probably older than 740 m.y. and younger than 1000 m.y. (Walter, 1972; Walter & Priess, 1972).

STRUCTURE

The rocks of the Amadeus Basin exposed in the region have been affected by folding and faulting. The Heavitree Quartzite mainly dips gently, except near Mount Webb, where it has been folded into several tight elbow-like structures (Fig. 25). It forms more open folds in the Pollock Hills area to the west. The overlying Bitter Springs Formation, which is structurally incompetent, has steep to vertical dips southeast of the Pollock Hills; here it appears to be several kilometres thick, probably because of isoclinal folding, repetition by strike faulting, or plastic deformation.

Two major faults displace the basin rocks. One in the west, trending northeast, has brought both the Heavitree Quartzite and Bitter Springs Formation alongside Mount Webb Granite to the northeast. The other is inferred to trend east-southeast to the north of Mount Webb (Fig. 25).

NGALIA BASIN

Sedimentary rocks of the Ngalia Basin, an asymmetric structural depression within the Arunta Block, crop out as cuestas, mesas, and low rises in the south of Lake Mackay Sheet area (Nicholas, 1971; Wells & others 1972) (Fig. 21). The northern part of the basin here is inferred to be bounded in the east by the largely concealed Waite Creek Fault. The sedimentary rocks belong to the Adelaidean *Vaughan Springs Quartzite*, the basal formation of the Ngalia Basin succession (Nicholas, 1971; Wells & others, 1972).

The Vaughan Springs Quartzite lies with a major unconformity on metamorphic rocks and granite of the basement Arunta Block. It consists predominantly of cross-bedded and ripple-marked, generally silicified, quartz arenite, and reaches a maximum known thickness in the area of 2750 m in an east-plunging syncline 5 km southeast of Mount Carey. A thin basal pebble conglomerate is present locally, and a sequence of shale, siltstone, and thin interbeds of glauconitic sandstone, the *Treuer Member*, crops out 40 km east and 5 km southeast of Mount Carey; at the latter locality the Treuer Member is about 1825 m thick. The formation is folded about axes that have mainly east to east-northeast trends, more or less parallel to the axis of the Ngalia Basin, and it has gentle to moderate dips, except near faults. It is not metamorphosed and does not appear to be mineralised.

Glauconite from the Vaughan Springs Quartzite has been dated at 1280 m.y. (Cooper & others, 1971). However, the formation appears to be stratigraphically equivalent to both the Heavitree Quartzite of the Amadeus Basin, and the Munyu Sandstone of the Birrindudu Basin, and hence is younger than 1070 ± 50 m.y. (Marjoribanks & Black, 1974) and probably younger than 1000 m.y. (Wells, 1976).

PHANEROZOIC COVER

PALAEOZOIC

Scattered outcrops of Palaeozoic rocks are present in many parts of the area. These rocks, which are all probably non-marine, are mainly gently dipping to flat-lying, and appear to occupy relatively shallow erosional basins. Local steep dips can be related to faulting. The oldest Palaeozoic rocks are those of the Antrim Plateau Volcanics, which are probably Early Cambrian. The other Palaeozoic units are the Lucas Formation and the Pedestal, Angas Hills, and Chuall Beds: these are considered to be younger than the Antrim Plateau Volcanics, and may be Devonian. Mainly marine Palaeozoic sedimentary rocks of the Canning Basin and Wiso Basin sequences crop out to the west and east.

Antrim Plateau Volcanics

Tholeiitic basalt lavas and subordinate intercalated chert and sandstone of the Antrim Plateau Volcanics (Traves, 1955; Bultitude, 1976) extend from the Victoria River region (Sweet & others, 1974; Sweet, 1977) south to the vicinity of Mongrel Downs in The Granites Sheet area. The formation covers much of the north of Birrindudu Sheet area and continues south as a discontinuous tongue generally less than 30 km wide. Small isolated outcrops are also present in the northwest of Tanami Sheet area and the northeast of The Granites Sheet area.

No mineralisation is known to be associated with the Antrim Plateau Volcanics in The Granites-Tanami region, but in the Victoria River region to the north, minor copper mineralisation has been found in the basalt at several localities, and barite has been obtained from cross-cutting veins within the formation (Sweet & others, 1974).

The formation is probably over 30 m thick in the northeast and also near Mongrel Downs and at Frankenia Rise, west of Rabbit Flat. It has a maximum recorded thickness of 1500 m in the Kimberley region, west of Halls Creek (Roberts & others, 1972; Bultitude, 1976).

The lavas mainly form broad low rises capped by pisolitic laterite; many rises are partly bounded by breakaways in which weathered basalt is exposed. The lavas also form mesas and buttes and undulating terrain, mainly northeast of Hooker Creek, and they underlie extensive plains covered by clay in the northwest, and a similar but smaller plain 20 km west of Mongrel Downs in the south. The mesas and buttes in the northeast generally have benched sides, each bench representing a separate lava flow. On aerial photographs the laterite cappings show up as dark tones; where they are not present, the basalt has a pale tone.

Most of the basalt exposed is lateritised, commonly to depths of 8 m or more. The weathered basalt is generally various shades of purple and brown, and, locally, is strongly bleached. However, except in the uppermost 2 m or so of the weathering profile, the original basaltic texture is often partly preserved, even though the original constituents have been replaced. Most of the basalt is non-porphyritic, but dark grey fresh basalt containing plagioclase phenocrysts is well exposed west of Mongrel Downs. Amygdaloidal and vesicular varieties, containing colourless quartz, celadonite, and clay minerals, are common, and some near Supplejack Downs homestead contain smoky quartz, amethyst, and pseudomorphs of quartz and goethite after zeolites.

Most of the basalt was laid down as subaerial lava flows (Bultitude, 1976). However, pillow-like structures have been seen in basalt south of the Browns Range Dome and also at the northern end of the Ware Range, possibly indicating local extrusion into water. No associated intrusions or eruptive sites have been found in the area.

Chert and sandstone are intercalated with basalt lavas at Frankenia Rise in The Granites Sheet area, and at several localities to the north (Blake & others, 1975). The chert is commonly stromatolitic. Two main types of sandstone are exposed; one is thin-bedded to laminated and is probably tuffaceous, and the other, present locally at the base of the formation in Tanami Sheet area, is a very poorly sorted lithic arenite or greywacke. The chert and both types of sandstone were probably deposited in shallow water.

The basalt lava flows and associated sediments appear to be flat-lying, and they are presumed to occupy depressions in the former land surface. They are unconformable on the Tanami Complex, Winnecke Granophyre, Birrindudu Group, and Limbunya Group, and are overlain by the younger Palaeozoic Pedestal Beds and the probably Mesozoic Larranganni Beds. The contact with the Pedestal Beds was intersected in a stratigraphic hole (BMR The Granites 26) 18 km west of Mongrel Downs homestead; that with the Larranganni Beds is well exposed east of the Supplejack Range (Blake & others, 1975).

Outside The Granites-Tanami region the Antrim Plateau Volcanics are unconformable on late Adelaidean rocks and overlain by early Middle Cambrian sediments; they are probably of Early Cambrian age (Bultitude, 1976).

Lucas Formation

The Lucas Formation, previously known as the Lucas Beds (Casey & Wells, 1964), is named after Lake Lucas (20°56'S, 128°50'E). It consists predominantly of sandstone, siltstone, and mudstone, and crops out in the central part of the area, mainly in Lucas and The Granites Sheet areas, where it is mainly either flat-lying or gently dipping.

Over most of its outcrop area the Lucas Formation is covered by Cainozoic laterite, calcrete, aeolian sand, or alluvium, and good exposures are restricted to low breakaways bordering laterite rises, and low cliffs present locally around ephemeral lakes. The formation is well exposed in cliffs up to 15 m high along the east side of Lake Dennis. One of these cliffs, at 20°53'30"S, 28°56'00"E in Lucas Sheet area, is selected as the type section. Casey & Wells (1964) chose the bed of Lake Dennis ('the northern arm of Lake White') as the 'nominate' exposure, but here, even though bedding trends, joints, and small faults are clearly visible from the air, no rocks of the Lucas Formation are exposed, as they are covered by a thin layer of salt and alluvium.

The Lucas Formation was intersected in stratigraphic holes drilled in The Granites and Lucas Sheet areas (Blake, 1974). Several metres of unweathered core from these holes have been examined for fossils, but no identifiable forms were found.

On aerial photographs, bedding trends of the Lucas Formation, and cross-cutting joints and faults, are visible in many areas largely covered by calcrete, and also where interbedded sandstone and mudstone are overlain by alluvium, as in Lake Dennis and Lake Lucas in Lucas Sheet area, and in smaller 'lakes' in The Granites Sheet area.

A maximum thickness of 1000 m has been calculated for the Lucas Formation in the Lake Lucas-Lake Dennis area. This estimate is based on the assumption that the beds here have an average dip of 2-3°, are not repeated by folding or faulting, and do not overlap or grade laterally into one another to the east.

Lithology

The Lucas Formation consists of friable calcareous and non-calcareous sandstone, siltstone, and mudstone, and minor limestone and dolomite.

The calcareous sandstone is purplish to grey, mostly medium to fine-grained, and contains a high proportion of lithic fragments. It has a calcite cement, and some beds show lustre mottling of fontainebleau type, owing to the sand grains being embedded in a coarsely crystalline mosaic of calcite. Exposures are commonly criss-crossed by joints and cracks filled with calcrete. The non-calcareous sandstone ranges in composition from lithic to sublithic arenite. It is greyish or brownish to maroon, mainly medium to coarse-grained, and locally silicified. Both types of sandstone are medium to thin-bedded and commonly micaceous. Cross-bedding and mudstone pellets are common, and some beds show ripple marks. The sandstones are interbedded with banded grey to greenish-grey and maroon siltstone and mudstone, which are locally micaceous and calcareous. The siltstone and mudstone form thin to laminated beds, which show cross-bedding and ripple marks. They are friable, and commonly crumble to form debris slopes below cappings of the more resistant sandstone.

Fig. 44. The floor of Lake Dennis, consisting of flat depressions with thin white salt crusts separated by sparsely vegetated low rises; Lucas Sheet area. (GA/7994)

Thin beds of limestone, a pale pinkish calcilutite, were seen at a few places. Pink sandy dolomite was recorded northeast of Yam Hill in Lucas Sheet area by Casey & Wells (1964), who also noted a line of barite pebbles, probably representing a lens or bed in the Lucas Formation, on the east side of Lake Dennis.

At the type section, a cliff on the east side of Lake Dennis, the following sequence is exposed, dipping about 2° east.

Top of cliff	
2.5 m	calcrete
3.0 m	mudstone
2.0 m	sandstone
2.0 m	mudstone
0.3 m	sandstone
2.0 m	mudstone
1.5 m	sandstone
1.0 m	mudstone
Lake floor	

The mudstone in this sequence is calcareous and contains some thin sandstone laminae. The sandstone is also calcareous and shows lustre mottling; it is medium-grained, cross-bedded, and ripple-marked, and contains mudstone pellets.

At another cliff exposure, 10 km west of the type section, 3 m of calcrete caps 1 m of maroon calcareous mudstone overlying 0.5 m of pale pinkish to maroon calcilutite, below which is 2 m of brownish cross-bedded medium-grained calcareous sandstone containing pellets and laminae of mudstone.

The alternating bands visible on the floor of Lake Dennis (Fig. 44) consist of unvegetated flat depressions covered with a thin salt crust (white bands) separated by slightly hummocky, sparsely vegetated rises less than 1 m high (dark bands). Auger drilling in the northern part of Lake Dennis showed that the depressions are developed on mudstone and the rises on sandstone, in both cases overlain by about 30 cm of saline mud.

Pommies Knob, a prominent hill about 5 m high, in The Granites Sheet area, is formed of flat-lying Lucas Formation, which here consists of thinly interbedded lithic sandstone and maroon and grey banded mudstone. The sandstone is coarse and fine-grained, non-calcareous, and contains abundant mudstone pellets.

Grey micaceous and mainly non-calcareous fine-grained sandstone, siltstone, and shale were intersected in the stratigraphic holes that penetrated the formation in The Granites and Lucas Sheet areas (Blake, 1974).

The absence of marine fossils, together with the rock types and sedimentary structures present, indicate that the Lucas Formation is probably lacustrine.

Stratigraphic relations, age, and correlation

The Lucas Formation is inferred to be unconformable on the Redcliff Pound Group, and is seen to be overlain by sandstone of the Pedestal Beds both at Yam Hill in Lucas Sheet area and Mount Tracey in The Granites Sheet area. Its upper contact is probably a low-angle unconformity, as the Pedestal Beds appear to overlap westwards onto increasingly older beds of the Lucas Formation.

At Yam Hill, 2 m of thin-bedded, greyish calcareous sandstone of the Lucas Formation is overlain by about 10 m of pale yellowish to white clayey quartzose sandstone belonging to the Pedestal Beds. Both sandstones are flat-lying. At Mount Tracey the exposed Lucas Formation is about 35 m thick, and consists of 30 m of greenish-grey, thin-bedded, fine-grained sandstone and some thinly interbedded mudstone, overlain by 5 m of pale grey to maroon micaceous mudstone and siltstone. The formation here is capped by 3 m of quartzose sandstone belonging to the Pedestal Beds.

The Lucas Formation is probably Palaeozoic, but direct evidence for this is lacking. Outcrop samples and drill-core specimens have failed to yield any fossils other than a possible unidentifiable spore and some minute spheres of uncertain affinities (P. J. Jones, BMR, personal communication, 1974). However, these possible fossils do indicate that the formation is probably Palaeozoic or younger. Supporting evidence for a Phanerozoic age is that the sandstone and mudstone of the Lucas Formation are much softer and more friable than otherwise similar Proterozoic rocks in the area.

The Lucas Formation may be stratigraphically equivalent to one or more of the Palaeozoic formations of the Canning Basin, from which it is separated by a structural high formed by the Adelaidean Redcliff Pound Group. A correlation with the Permian Noonkanbah Formation of the Canning Basin was suggested by Casey & Wells (1964), on the grounds of similarities in lithology, photo-pattern, and structural expression. However, the Lucas Formation, unlike the Noonkanbah Formation, is considered to be lacustrine rather than marine. Hence, similarities in lithology and photopattern may be fortuitous. A more likely correlation is with the continental Pertnjara Group of the Amadeus Basin (Wells & others, 1970), which is Devonian (Playford & others, 1976). The basal unit of this group, the Parke Siltstone, is lacustrine and similar in lithology to the Lucas Formation.

Pedestal Beds

The Pedestal Beds (Hodgson, 1976) consist predominantly of clayey quartzose sandstone, and, like the Lucas Formation, they are mainly flat-lying. They form

Fig. 45. Cross-bedding in sandstone of the Pedestal Beds; in the Pedestal Hills, The Granites Sheet area. (M1402/26)

cuestas, mesas, hillocks, hummocky terrain, and rocky pinnacles, less than 10 m high. Outcrops are widely scattered in the centre and south of the area: in Lucas and Stanmore Sheet areas, where they were previously mapped as unnamed Permian and Palaeozoic sediments respectively (Wells, 1962b, 1962c; Casey & Wells, 1964), in Lake Mackay Sheet area, where they were mapped as undifferentiated Adelaidean (Nicholas, 1972) and in The Granites, Highland Rocks, and Webb Sheet areas. The most prominent topographic features formed by the unit are the Pedestal Hills (20°35′S, 129°17′E), after which the beds are named, Mount Tracey, and Macfarlanes Peak Range, all in The Granites Sheet area; Yam Hill in Lucas Sheet area; and McEwin Hills in Highland Rocks and Lake MacKay Sheet areas. The unit is locally capped by laterite and silcrete, and surface silicification is common. The reference area is in Macfarlanes Peak Range, at 20°22′10″S, 129°29′00″E, in The Granites Sheet area, where a thickness of 20 m is exposed.

Steep dips have been recorded at three places in the southeast: at Sandford Cliffs and the McEwin Hills, where the beds have been folded into locally tight east-trending synclines, and further north, east of Lake Dennis, alongside an east-trending fault. This last place is where the maximum known thickness of the Pedestal Beds, about 500 m, is exposed.

Lithology

Rock types cropping out are sandstone and minor conglomerate, shale, and siltstone. The sandstone is quartzose, mostly medium to fine-grained, and has a generally abundant clayey matrix. It is friable where not silicified, and white or pale grey where not iron-stained. Coarse-grained and micaceous varieties are present locally, and some of the sandstone contains scattered well-rounded pebbles up to 5 cm across. The micaceous sandstone is highly friable, and has a well-developed flaggy to almost shaly parting. Individual sandstone beds range from thick to thin, but are generally about 1 m thick. In places bedding planes are poorly defined. Most beds show low-angle cross-bedding (Fig. 45), and ripple marks and bedding planes covered with shale pellets are common.

Conglomerate is interbedded with sandstone and minor shale in the southernmost part of The Granites Sheet area and in the adjoining Highland Rocks Sheet area, north of False Mount Russell. It contains well-rounded pebbles and cobbles of Proterozoic sublithic arenite, quartz arenite, quartzite, milky vein quartz, and banded chert, enclosed in a sparse clayey sandstone matrix. Coarser polymictic conglomerate, about 4 m thick, is exposed in an outcrop of Pedestal Beds in the north of Webb Sheet area, at 22°02′30″S, 128°15′50″E, where it overlies thin-bedded fine micaceous sandstone and is overlain by cross-bedded pebbly quartzose sandstone. This conglomerate contains angular to rounded fragments, some over 1 m across, of Proterozoic sandstone, chert, schist, and granite in an abundant matrix of clayey quartzose sandstone. It is generally unbedded and unsorted, although some thin lenses of cross-bedded sandstone are present. The conglomerate is interpreted as a mudflow deposit.

In the reference area, in the Macfarlanes Peak, Range, about 20 m of Pedestal Beds dips gently south. The basal 5 m consists of ripple-marked medium-grained clayey quartzose sandstone with micaceous partings. This is overlain by about 5 m of flaggy sand-

Fig. 46. The Elizabeth Hills, in Webb Sheet area, formed of sandstone of the Angas Hills Beds. (GA/8931)

stone and minor thin beds of maroon siltstone, which is overlain by 10 m of thick-bedded sandstone showing large-scale cross-bedding.

Up to 10 m of flat-lying sandstone is exposed in the Pedestal Hills. The sandstone here is medium-grained, mainly medium-bedded and sparsely micaceous. Cross-bedding is well developed (Fig. 45), and some bedding surfaces show moulds of clay pellets.

The Pedestal Beds were possibly deposited on broad alluvial fans, as has been suggested for similar sediments in the Pertnjara Group of the Amadeus Basin (Wells & others, 1970; Jones, 1975). They are unfossiliferous.

Stratigraphic relations, age, and correlation

Contacts between the Pedestal Beds and underlying units are generally concealed by superficial deposits. However, the Pedestal Beds are seen to be unconformable on the Mount Charles Beds and unnamed granite in the Macfarlanes Peak Range area, and to overlie the Lucas Formation on Yam Hill and Mount Tracey. West of Mongrel Downs they overlie basalt of the Antrim Plateau Volcanics (contact intersected in BMR stratigraphic hole The Granites 26). They are inferred to be unconformable on the Redcliff Pound Group and, in the southwest, on Hidden Basin Beds.

Between Yam Hill and the Pedestal Hills the Pedestal Beds appear to overlie different stratigraphic levels within the Lucas Formation; hence the contact between these two units is inferred to be a low-angle unconformity.

An unconformable relation between the Pedestal Beds and underlying rocks of the Redcliff Pound Group is inferred in the southeast of Stansmore Sheet area. Here the Redcliff Pound Group forms a series of anticlines and synclines, and sandstone of the Pedestal Beds crops out in the centres of two of the synclines.

The Pedestal Beds are Phanerozoic, as they overlie the Lower Cambrian Antrim Plateau Volcanics, and they are probably pre-Tertiary, as they have been affected by Tertiary lateritisation, and their distribution is not related to the Cainozoic drainage system. Lithologically, they are similar to the Devonian Knobby Sandstone of the northeast Canning Basin and the Pertnjara Group of the Amadeus Basin, both of which are non-marine, and they are generally more compact and indurated than the Hazlett and Larranganni Beds, which are probably Mesozoic. The Pedestal Beds are therefore considered to be probably Palaeozoic and possibly equivalent stratigraphically to the Pertnjara Group.

Angas Hills Beds

The Angas Hills Beds (Blake, 1977) crop out in the south of Webb Sheet area, where they form the Angas Hills (22°50'S, 128°10'E) after which they are named, the Elizabeth Hills, and other low hills (Fig. 46). Outcrops consist of cuestas and mesas, some nearly 40 m high, and craggy to smoothly rounded knolls and ridges. They generally show up as smooth dark tones on aerial photographs. The beds have a maximum exposed thickness of about 300 m, on the west side of the Angas Hills, where they dip 15° to 20° southeast. Elsewhere they are mainly gently dipping to flat-lying. The reference section is a cliff face 36 m high, at 22°52'00"S, 128°12'30"E, on the east side of the Angas Hills.

Lithology

The Angas Hills Beds comprise interbedded conglomerate and sandstone (Fig. 47), and minor mudstone. The conglomerate typically forms smoothly rounded ridges. It is medium to thick-bedded, and commonly contains thin sandstone lenses. In it, pebbles, cobbles, and in some places boulders are enclosed in an abundant matrix of poorly sorted clayey sandstone. The clasts, which are mainly well rounded, weather out readily from the matrix, and many exposures consist of pebble-strewn surfaces. Most of the pebbles are of quartzite, chert, quartz arenite, and sublithic arenite; but pebbles of gneiss and vein quartz are present at some places. All the pebbles are probably derived from Proterozoic rocks cropping out locally.

In contrast to the conglomerate, the sandstone commonly forms craggy exposures. It ranges in composition from quartzose to lithic, and generally has an abundant clay matrix, which is often iron-stained. Most of the sandstone is medium-grained and medium to thin-bedded. Micaceous flaggy partings, scattered pebbles, bedding planes covered with pellets, and ripple marks are present locally. The sandstone is generally friable, but many exposed surfaces are silicified, and some have silcrete cappings.

At the reference section, a cliff face on the east side of the Angas Hills, 12 km northeast of Mount Webb, the basal 12 m exposed consists of coarse pebble conglomerate with some thin lenses and layers of clayey sandstone. The conglomerate is overlain by 24 m of cross-bedded sandstone, some of which is pebbly, and which has some thin beds of maroon mudstone in the middle. The beds here dip 10° west. Westwards the conglomerate passes laterally into mainly sandstone.

Fig. 47. Cross-bedded pebbly sandstone overlying conglomerate; Angas Hills Beds, Angas Hills, Webb Sheet area. (GA/8956)

The Angas Hills Beds are unfossiliferous and are considered to be fluvial sediments, like their probable stratigraphic equivalents to the north, the Pedestal Beds.

Stratigraphic relations, age, and correlation

The Angas Hills Beds unconformably overlie metamorphic rocks of the Arunta Complex north of the Pollock Hills and Heavitree Quartzite east of the Angas Hills, and they are inferred to also overlie the Bitter Springs Formation. Because of striking similarities in lithology, degree of induration, and structure, they are correlated with the Pedestal Beds. Hence the Angas Hills Beds are probably Palaeozoic and may be stratigraphically equivalent to the Pertnjara Group of the Amadeus Basin.

Chuall Beds

The Chuall Beds (Blake & others, 1977) crop out southeast of Sturt Creek homestead in Billiluna Sheet area. The reference area is 4 km southeast of the homestead. The beds, named after nearby Chuall Pool in Sturt Creek, form low hills and cuestas up to 8 m high, and consist of flat-lying to gently dipping friable sandstone. The maximum thickness exposed is about 140 m in the reference area. The sandstone is quartzose to lithic and fine to medium-grained, although pellet-rich and gritty bands are common. Some beds show low-angle cross-bedding.

The Chuall Beds are not seen in contact with other pre-Cainozoic units. However, they are inferred to be unconformable on the nearby Proterozoic Lake Willson Beds and Pindar Beds, which are more steeply dipping. Their lithology and friable nature resembles that of the Pedestal Beds to the south, and they are thought to be probably Palaeozoic.

Canning Basin

In the west, the Precambrian rocks of The Granites-Tanami region are overlapped by Palaeozoic rocks of the Canning Basin, mapped by joint BMR-GSWA field parties in 1972 and 1973, and described by Yeates & others (1975). This mapping was more detailed than that carried out by BMR previously (Veevers & Wells, 1961; Casey & Wells, 1964). As in The Granites-Tanami region, scattered outcrops of indurated rock are separated by broad expanses of Cainozoic superficial sediments, mainly sand. The most extensive exposures of relatively fresh bedrock are along the Stansmore Range.

The oldest unit of the Canning Basin sequence exposed is the Ordovician *Carranya Beds*. This unit consists of fossiliferous marine sandstone and conglomerate, and crops out in Billiluna Sheet area. The conglomerate contains pebbles and boulders of various types of Precambrian rocks, including quartzite, phyllite, greywacke, and vein quartz. On the west side of the Elsey Hills the Carranya Beds overlap onto the Proterozoic Baines Beds, and north of Billiluna homestead they are inferred to lie unconformably on the Proterozoic Ima Ima Beds, Duerdin Group, and possibly the Albert Edward Group. The Carranya Beds are thought to be overlain unconformably by the Upper Devonian *Knobby Sandstone*, a fluvial unit which crops out in Billiluna and the north of Lucas Sheet areas.

The Knobby Sandstone contains plant and fish fossils, and consists of cross-bedded, medium to coarse-grained quartzose sandstone and minor amounts of conglomerate and siltstone. It rests unconformably on the Baines Beds in Billiluna Sheet area and on Proterozoic granite and rocks of the Redcliff Pound Group in Lucas Sheet area. Both the Carranya Beds and Knobby

Sandstone have gentle to moderate dips, unlike the younger formations of the Canning Basin sequence, which are generally flat-lying.

The Knobby Sandstone is overlain unconformably by a sequence of essentially conformable Permian units. From bottom to top of the sequence, these units are the *Grant Formation*, which consists mainly of fluvial sandstone and may be partly Upper Carboniferous; the largely fluvial *Poole Sandstone*; the marine *Noonkanbah Formation*, which consists mostly of fossiliferous siltstone and shale; the marine *Lightjack Formation*, which consists of fossiliferous siltstone, sandstone, and shale, and the fluvial *Condren Sandstone*, both of which are part of the *Liveringa Group*; and the *Godfrey Beds*, which comprise shallow marine sandstone, siltstone and conglomerate. Of these units only the Lightjack Formation appears to overlap onto the Precambrian rocks of The Granites-Tanami region. To the west the Permian units are succeeded by Triassic formations.

Wiso Basin

Flat-lying sedimentary rocks of probable Cambrian age belonging to the Wiso Basin succession overlap onto Precambrian rocks of The Granites-Tanami region in the east, north of The Granites, where they form low hills and rises commonly capped by laterite and partly bounded by breakaways. Rock types represented are lithic and quartzose sandstone, mudstone, micaceous siltstone and shale, chert, limestone, and dolomite. The siltstone and shale are thinly interbedded. The chert is generally thin-banded, and may be silicified calcareous mudstone or siltstone. Limestone crops out near Lake Buck, northeast of Tanami, where it is locally capped by Tertiary calcrete, from which it cannot always be distinguished. Dolomite was intersected in two stratigraphic holes drilled east of the Black Hills in 1971 (Blake, 1974; Blake & others, 1975).

The Wiso Basin rocks are unfossiliferous in this area. They are thought likely to correlate with Middle Cambrian rocks mapped in the adjoining Tanami East and Winnecke Creek 1:250 000 Sheet areas (Huleatt, 1977a, 1977b).

MESOZOIC

Hazlett Beds

The Hazlett Beds (Veevers & Wells, 1961) crop out in the southwest of The Granites-Tanami region, in Stansmore Sheet area. They consist of fine to medium-grained quartzose sandstone, siltstone, and soft white claystone, and are probably fluvial. These rocks are mainly medium-bedded. They generally form cappings up to 10 m thick on mesas and plateaus. However, between Redcliff Pound and Brookman Waters, they also form steep-sided hillocks up to 10 m high composed of massive, partly silicified, white quartzose sandstone, which has pitted, weathered surfaces.

The Hazlett Beds are flat-lying, and are unconformable on steeply dipping rocks of the Redcliff Pound Group. They appear to be less indurated than the Pedestal Beds, and are regarded as probably Mesozoic. Samples thought to contain radiolaria tentatively identified as cf. *Cenosphaera* by I. Crespin (in Veevers & Wells, 1961) have been re-examined and appear to be unfossiliferous (J. D. Gorter and D. J. Belford, personal communication, 1974), hence the previously suggested Cretaceous age for the unit is in doubt.

Larranganni Beds

Small scattered outcrops of Larranganni Beds (Blake & others, 1975) have been mapped in the northern and central parts of the region, in Tanami, Billiluna, and The Granites Sheet areas, where they consist of flat-lying sandstone and minor siltstone and conglomerate. The unit forms low mesas, some of which have cappings of silcrete or laterite. The Larranganni Beds are up to about 10 m thick, and are made up mainly of quartzose sandstone, although conglomerate and thin-bedded siltstone are present at a few places.

The quartzose sandstone (quartz arenite and sublithic arenite to quartz greywacke) is generally poorly sorted, locally conglomeratic, and either porous or cemented by opaline silica. Where it is silicified it closely resembles silcrete. It is mainly medium-bedded and commonly has pitted weathered surfaces. Some sandstone beds show ripple marks, and both the sandstone and conglomerate locally show low-angle or high-angle cross-bedding. Bedding planes are locally poorly defined. The conglomerate contains rounded to subangular pebbles, cobbles, and in some cases boulders. These consist of locally derived Precambrian rocks and, at an outcrop 7 km east-northeast of Supplejack Downs homestead, basalt from the Antrim Plateau Volcanics and a pale green porphyritic acid volcanic rock of unknown derivation.

The Larranganni Beds are considered to be continental, mainly fluvial sediments. They are unfossiliferous, and their suggested Mesozoic age is inferred from the following indirect evidence: they are flat-lying and overlie the Tanami Complex, Gardiner Sandstone, granite, and Antrim Plateau Volcanics; they are generally less indurated than lithologically similar Palaeozoic units in the region; they crop out as low mesas, some of which are capped by Tertiary laterite; and their distribution is not related to the present drainage system. The Larranganni Beds may be stratigraphically equivalent to the Hazlett Beds.

Unnamed Mesozoic Beds

Several small outcrops mapped as probable Mesozoic are present in the southeast, in Highland Rocks Sheet area, and in the west and southwest, in Lucas, Stansmore and Webb Sheet areas. They consist mainly of flat-lying, cross-bedded, quartzose sandstone, which forms low mounds, tor-like features up to 5 m high, and low rises partly capped by laterite and silcrete. Like that of the Hazlett Beds and Larranganni Beds, the sandstone is porous, commonly has pitted weathered surfaces, and is unfossiliferous. Most of the sandstone is pale yellowish or brownish, medium-bedded, and medium to fine-grained, and has over 10 percent opaline matrix. Bedding planes are commonly poorly defined. Grit and pebble bands and lenses, and thin interbeds of soft bleached siltstone and claystone are present locally. The pebbles are well rounded, and consist mainly of various types of sandstone, although pebbles of chert, phyllite, granite, and volcanic rocks have also been noted.

The unnamed Mesozoic beds are interpreted as fluvial sediments. They are less indurated than the Palaeozoic rocks in the area, and are tentatively correlated with the Hazlett Beds and Larranganni Beds.

CAINOZOIC

Over most of the region the pre-Tertiary rocks are covered by Cainozoic superficial deposits, ranging in thickness from over 90 m to less than 5 m. In many places this cover consists mainly or entirely of Quaternary sediments, especially aeolian sand and alluvial sand, silt, and clay, but elsewhere Tertiary laterite, calcrete, or alluvium predominate.

Where the cover is very thin, the trends of bedding, joints, and faults in the underlying bedrock are commonly visible from the air: for instance, bedding trends show through sand and vein-quartz rubble near many outcrops of steeply dipping metamorphic rocks, and bedding ,joints, and minor faults in the Lucas Formation show through alluvium and evaporites in Lake Dennis and through calcrete and aeolian sand nearby.

The Cainozoic cover is thickest along drainage depressions (Fig. 7), marked by areas of calcrete, alluvium, and evaporites. Stratigraphic drilling in such depressions has shown that unconsolidated sediments inferred to be Cainozoic are over 90 m thick between the Kearney and Lewis Ranges and between Rabbit Flat and Mongrel Downs, and over 50 m thick in a depression southeast of the Baines Hills (Blake, 1974).

Laterite

Laterite cappings, the ferruginous upper part of lateritic weathering profiles, are widespread, mainly on flat to gently undulating low rises (Fig. 12), some of which are only a metre or so higher than adjacent plains. Most of the rises have gently sloping sides in which shallow gullies have been incised, although many are partly bounded by breakaways.

The cappings are present on rocks ranging from Early Proterozoic to Mesozoic, and are best developed on basalt of the Antrim Plateau Volcanics, regionally metamorphosed rocks of the Tanami Complex and Arunta Complex, granite, and sedimentary rocks of the Lucas Formation. Complete lateritic weathering profiles are commonly present on such rocks, consisting of an upper pisolitic or massive iron-rich layer generally 1-2 m thick, which is the capping as mapped, a central mottled zone, and a lower pallid zone. Some of these weathering profiles are over 20 m thick, especially where they are developed on basalt. The capping upper layer has a smooth dark tone on aerial photographs, and consists mainly of limonite and either goethite or hematite or both. It is commonly cemented to a pisolitic ironstone on the edges of the lateritic rises. The central and lower zones show a wide range in thickness, and locally appear to be absent. The nature of the bedrock is not apparent from the laterite capping, but is commonly recognisable in the underlying zones.

The laterite cappings are remnants of a very extensive flat to gently undulating former land surface, much of which has been removed by erosion. The amount of erosion that has taken place indicates that the laterite is Tertiary rather than Quaternary, and the surface on which it is developed is probably part of the early or mid-Tertiary Tennant Creek erosion surface of Hays (1967).

In addition to that forming cappings on rises, pisolitic laterite is also present locally along some creeks, resting on Quaternary alluvium. Such laterite is an alluvial or colluvial deposit derived from nearby cappings.

Calcrete

Calcrete (Goudie, 1972) forms low rises and mounds in broad depressions that mark past and present drainage lines. In the east the rises are up to 5 m higher than adjacent Quaternary deposits, and they form rough rocky terrain studded with sink holes. To the south and west they decrease in relative relief, eventually merging with aeolian and alluvial sediments. However, in the far southwest, west of Mount Webb, there are calcrete rises up to 10 m high: these are incised by steep-sided drainage channels around their margins. Most calcrete overlies unconsolidated rocks, but some is developed on calcareous rocks of the Bitter Springs Formation, Wiso Basin succession, and Lucas Formation, and also locally on basalt, dolerite, granite, and metamorphic rocks, and along faults and other lineaments. Calcrete overlying Lucas Formation is well exposed on the tops of cliffs up to 15 m high on the east side of Lake Dennis, where it is 2 to 3 m thick. In many places the calcrete is overlain by Quaternary sand dunes, and at one locality, on a low rise southeast of Lake Jeavons, north of Lake Dennis, it is overlain by pisolitic laterite. Some calcrete has a thin and impersistent covering of grey soil.

The calcrete is a white to pale grey inorganic limestone commonly containing scattered sand grains, rock fragments, and nodular lumps of chalcedony. It is generally hard and cellular, although some is soft and powdery, as for example on the margins of Lakes Mackay, Hazlett, and Wills. Its maximum known thickness in the area is 18 m, intersected in a stratigraphic hole (BMR The Granites 24) 2 km south of Mongrel Downs homestead (Blake, 1974).

The calcrete appears to be a chemical deposit formed by evaporation of groundwater in depressions. As the calcrete now generally forms low rises, a considerable amount of erosion must have taken place since its formation, probably more than can be accounted for during the Quaternary. Hence most of the calcrete is probably Tertiary. However, some low-lying and locally powdery calcrete associated with salt lakes and salt pans in the southwest could be Quaternary, and some may be forming at the present time.

Tertiary alluvium

Stratigraphic drilling has shown that calcrete and aeolian sand along drainage depressions in The Granites, Lucas, and Billiluna Sheet areas overlie unconsolidated alluvial sediments (Blake, 1974). These sediments, which in places are over 50 m thick, are considered to be Tertiary. They consist predominantly of clay, some of which is either calcareous or gypsiferous or both, but also include thin chert laminae and minor sand. Several samples of clay and chert from drill holes have been examined for microfossils, but have failed to yield any organic remains (P. J. Jones, BMR, personal communication, 1974). The sediments are probably partly fluvial and partly lacustrine. Similar sediments of Tertiary age are probably present in other parts of the region.

Silcrete

Patches of silcrete, generally less than 3 m thick, are common in many parts of the region, but most are too small to be shown on 1:250 000-scale maps, and none are shown on the 1:500 000-scale maps. The silcrete is a white, buff, or pale grey rock, containing unsorted, angular, mainly sand-sized clasts of quartz sediments in small clay pans, evaporitic halite and gypsum in small salt pans, and aeolian dune sand.

The *lacustrine sediments* occupy the various salt lakes, salt pans, and claypans, and consist predominantly of silt, clay, and the evaporite minerals halite and gypsum. When not covered by water, the salt lakes and salt pans have a thin white surface crust, generally less than 1 cm thick, formed almost entirely of gypsum and halite. One sample of crust collected from Lake Wills in 1972 was found to contain some glauberite ($Na_2Ca(SO_4)_2$) (XRD determination by G. W. R. Barnes, BMR). The crust overlies saline mud, which is generally waterlogged at a depth of less than 1 m. Chemical analyses of some of the saline sediments in Lake Mackay have been given by Terry (1934, 1937) and Nicholas (1969): they indicate that the saline sediments contain less than 0.6 percent magnesium and potassium, and that no bicarbonates, nitrates, or borates are present. The lacustrine sediments are generally less than 1 m thick in Lake Dennis and similar 'lakes' in which the trends of underlying bedrock show through the superficial sediments, but are undoubtedly much thicker in the large salt lakes to the south.

GEOPHYSICAL INVESTIGATIONS

GRAVITY

Bouguer anomalies and gravity features of the area are shown in Figure 49. Parts of the following nine regional gravity features are present (after Whitworth, 1970, and Fraser, Darby, & Vale, 1977). The *Springvale Regional Gravity Ridge* in the northwest has Bouguer anomaly values ranging from −30 to +65 mGal. This feature trends north-northeast and is correlated with the Lamboo Complex of the Halls Creek Province (Gemuts, 1971). Local peaks within the gravity ridge may be due to basic intrusions.

The *Ord Regional Gravity Depression* to the southeast has Bouguer anomaly values in the range −20 to −60 mGal and mainly moderate gravity gradients. The magnitude of the depression indicates that about 3000 m of Proterozoic sediments may be present here.

The *Buchanan Regional Gravity Platform* in the northeast has an average Bouguer anomaly of about −20 mGal, and is characterised by small gravity gradients. It corresponds with an area having a thin and patchy cover of Proterozoic sedimentary rocks over metamorphic and granitic basement. Local gravity features may be due to density variations within the basement.

The *Tanami Regional Gravity Complex* consists of a series of local gravity features with Bouguer anomalies ranging from +10 to −40 within distances of a few kilometres. It reflects density contrasts in The Granites-Tanami Block. Some of the relative lows can be correlated at least partly with granite, and some of the relative highs can be attributed to metamorphosed basic rocks.

The *Pedestal Regional Gravity Low* to the south has Bouguer gravity values generally less than −40 mGal. The low values in the east are probably due partly to relatively thick Palaeozoic and Proterozoic sediments and partly to low density basement rocks, such as granite. In the west, the low values may be due to a thicker than normal accumulation of Palaeozoic sedimentary rocks, belonging to the Canning Basin succession, in a local basement depression.

The *Angas Regional Gravity High* in the southwest truncates westerly trending gravity features to the east, and has an amplitude of about 50 mGal. It may be caused by relatively dense basement rocks.

The *Willowra Regional Gravity Ridge*, which trends east-northeast across the northern part of the Arunta Block, has Bouguer anomaly values in the range −40 to +5 mGal. The relatively high values may be due partly to a regional crustal upwarp and partly to dense metamorphic and igneous rocks within the upper crustal layer.

The *Yuendumu Regional Gravity Low* to the south more or less coincides with the Ngalia Basin, but the low Bouguer anomaly values, ranging from −30 to −100 mGal, are probably due to low density basement rocks or crustal thickening or both.

The *Papunya Regional Gravity Ridge* has a maximum amplitude of over 150 mGal. A small part of this feature is present along the southern edge of the area. It is correlated with metamorphic rocks in the south of the Arunta Block, and may be due either to dense basement rocks or to a major crustal upwarp.

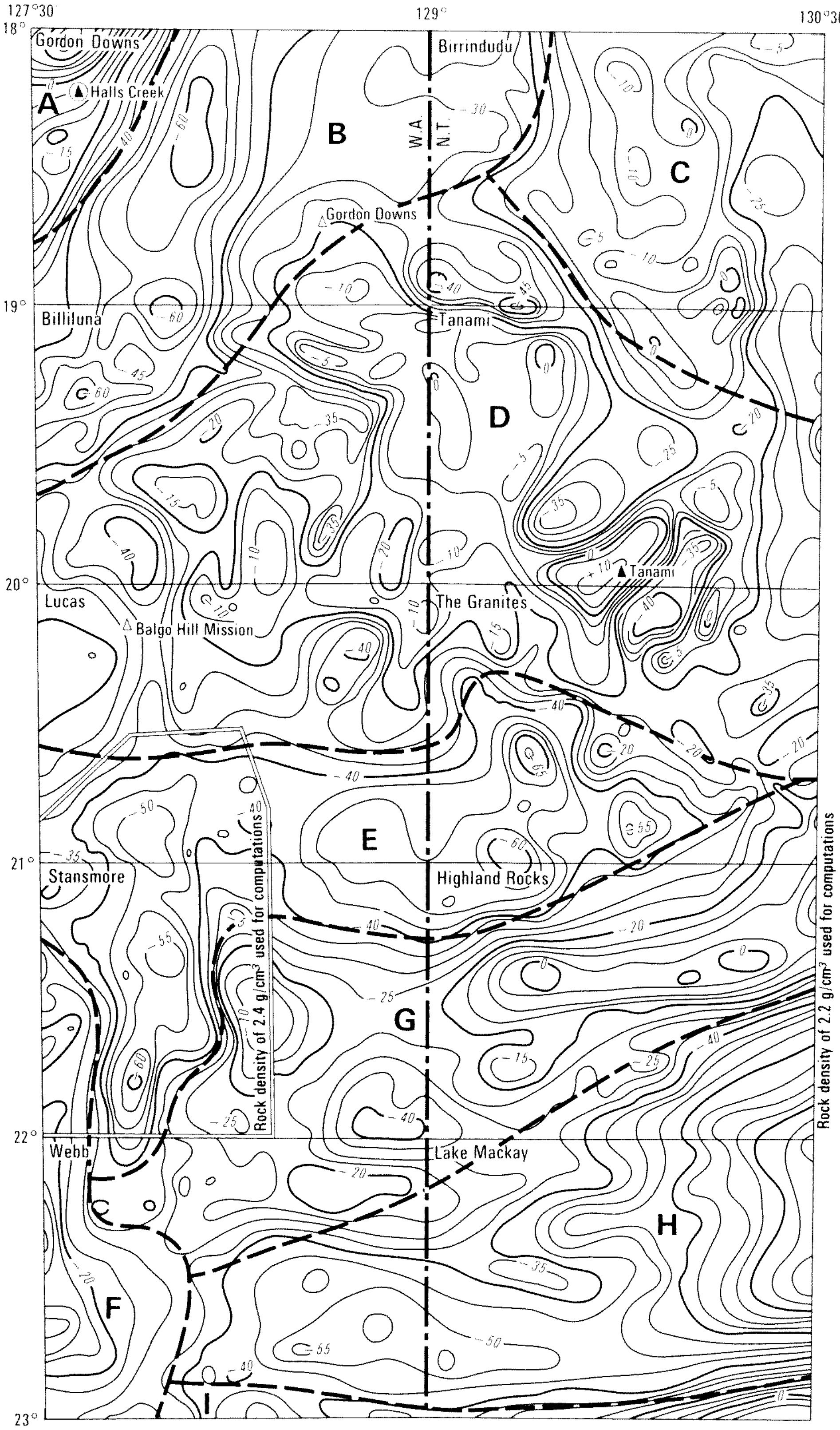
AEROMAGNETIC SURVEYS

Aeromagnetic data are available for the three northern sheet areas in the Northern Territory: Tanami and The Granites Sheet areas (Fig. 50) which were surveyed in 1962 (Spence, 1964; BMR, 1965a, 1965b), and Birrindudu Sheet area (Fig. 51), surveyed in 1967 (BMR, 1971). Several magnetically anomalous zones are present, but the data have not yet been fully analysed.

Most outcrops of metamorphic rocks and areas underlain at shallow depth by such rocks show complex patterns of short wavelength intense magnetic anomalies, with sources interpreted at depths of less than 300 m. Less-disturbed magnetic data with broad anomalies characterise areas of granite, acid volcanics, and Proterozoic and Palaeozoic sedimentary rocks, and are also present in some areas where thick superficial sediments are inferred to overlie metamorphics. The sources of some of these broad anomalies are estimated to be deeper than 1000 m. The Cambrian Antrim Plateau Volcanics, consisting mainly of basalt lavas, are generally thin (probably less than 100 m), and have a characteristic magnetic response, comprising short-wavelength anomalies with low amplitudes (up to about 100 nt) and very variable trends. Several prominent linear magnetic features are present, some of which coincide with postulated faults; however, the most prominent of these, a feature east of the Ware Range, in Birrindudu Sheet area, trends north across an area of Winnecke Granophyre in which no faulting is apparent.

AIRBORNE RADIOMETRIC SURVEYS

Airborne radiometric surveys over parts of The Granites-Tanami region were made in 1960, 1962, and 1972. The survey in 1960 covered the Killi Killi Hills, the south and southwest parts of the Gardner Range, and an area around Tanami, in Billiluna and Tanami Sheet areas (Mulder, 1961). The 1962 survey was



GRAVITY FEATURES:

A — Springvale Regional Gravity Ridge
B — Ord Regional Gravity Depression
C — Buchanan Regional Gravity Platform
D — Tanami Regional Gravity Complex
E — Pedestal Regional Gravity Low
F — Angas Regional Gravity High
G — Willowra Regional Gravity Ridge
H — Yuendumu Regional Gravity Low
I — Papunya Regional Gravity Ridge

NT/A/621

Fig. 49. Bouguer anomalies and gravity features of The Granites-Tanami region.

Fig. 48. Vein-quartz rubble developed on quartz-veined metamorphic rocks of the Killi Killi Beds, Tanami Complex; near the Lewis Range (left background), Lucas Sheet area. (M1356/35)

and, less commonly, chert in a very fine-grained to amorphous siliceous matrix, which commonly makes up 50 percent or more of the rock. Silcrete is best developed on rocks relatively rich in silica, especially quartz-rich sandstone. Exposures commonly consist of rounded surfaces strewn with pebbles, cobbles, and boulders. Columnar structures occur locally (cf. Senior & Senior, 1972). In places silcrete is closely associated with laterite, as for instance on Mesozoic sandstone on the west side of the Phillipson Range and on shale of the Gardiner Sandstone southeast of Coomarie Spring (Blake & others, 1975). Silcrete does not appear to be forming on the surface at the present time, and it may be as old as Tertiary.

Vein-quartz rubble

Metamorphic rocks of the Tanami Complex and the Arunta Complex, and, less commonly, granite are overlain by a thin veneer of vein-quartz rubble (Fig. 48). This rubble is not distinguished from bedrock on the accompanying 1:500 000-scale map, but is shown as a separate unit on the 1:250 000-scale maps. It commonly shows fold patterns, readily visible on aerial photographs, which reflect structures in the underlying rocks. Quartz veins locally project a few centimetres through the rubble, but exposures or even loose fragments of the host bedrock are rare. The rubble is a residual product resulting from prolonged weathering of quartz-veined bedrock.

Quaternary sediments

On the accompanying 1:500 000-geological map the superficial Quaternary deposits are grouped into four broad units, consisting mainly, but not exclusively, of aeolian, residual, fluvial, and lacustrine sediments.

Aeolian sediments, the most widespread unit, are made up mainly of the aeolian sand that forms the extensive sand plains in the region. These plains are generally higher than adjacent Quaternary units. They include the dune-fields, which are crossed by east-trending longitudinal (seif) dunes (Fig. 10). The dunes are mainly 5 to 15 m high, but in places reach 30 m. They are stationary and support a sparse vegetation, although their crests are locally bare. Their wide range in length, density, and complexity has been described by Veevers & Wells (1961) and is shown on the 1:250 000-geological maps. The unit also includes accumulations of halite and gypsum crystals banked up with aeolian sand by easterly winds in and around Lake Mackay, minor gravel and sand on gentle piedmont slopes flanking hills and ridges, and, in the southeast, patches of red soil, consisting of silt and clay derived from laterite.

The *residual sediments* comprise the heavy grey clay developed on basalt of the Antrim Plateau Volcanics mainly in the north, but also west of Mongrel Downs homestead in The Granites Sheet area. The clay cracks widely and deeply when it dries out after the wet season, and is probably several metres thick (up to 6 m has been penetrated in water bores in the northwest of Birrindudu Sheet area). It gives rise to grass-covered plains, some of which are locally strewn with small basalt fragments.

The *fluvial sediments*, mainly sand, silt, and clay, are present along the floodplains of major drainage channels and in broad, barely perceptible, drainage depressions; in the latter they are mixed with wind-blown sand and silt. This unit also includes some lacustrine

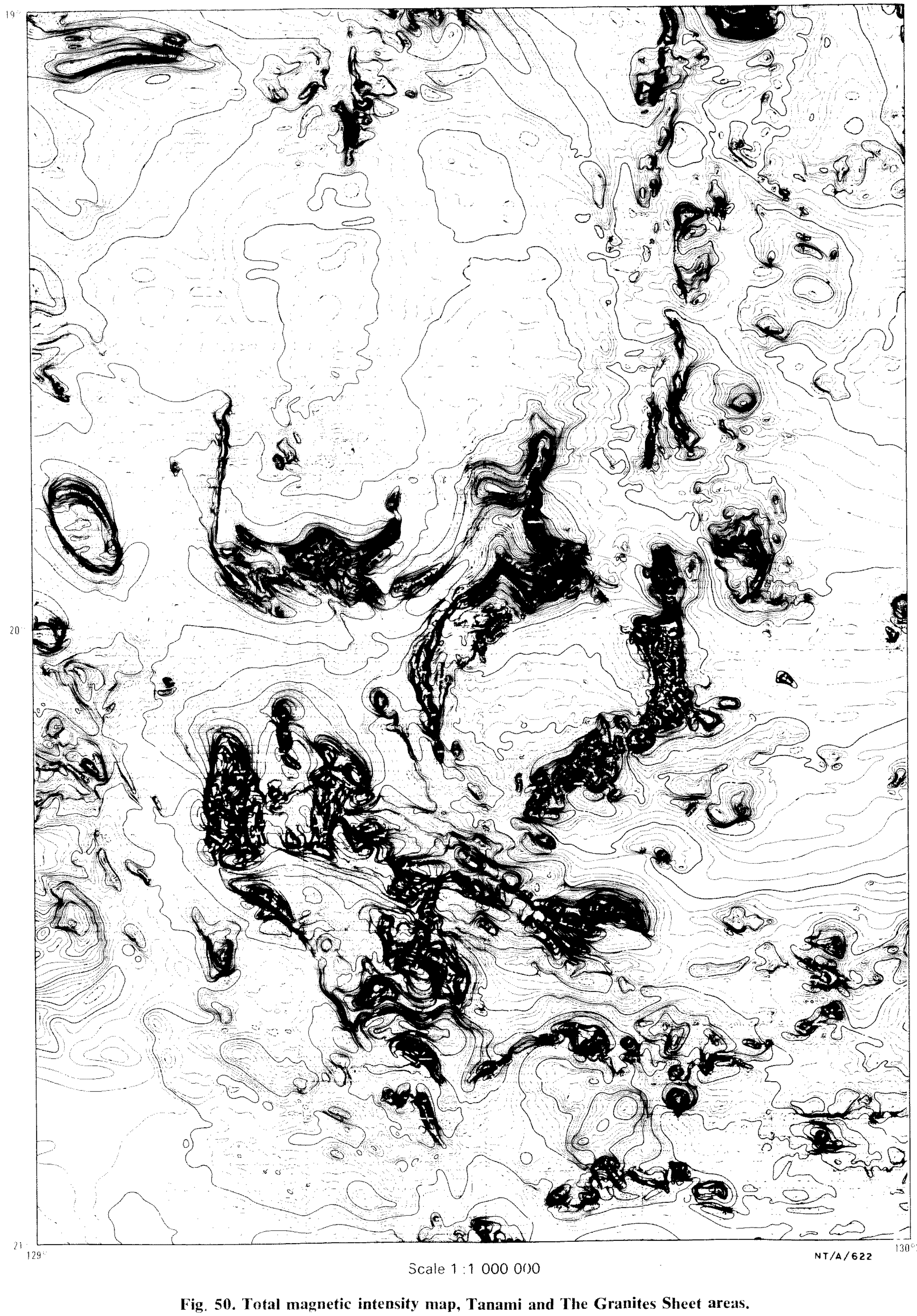
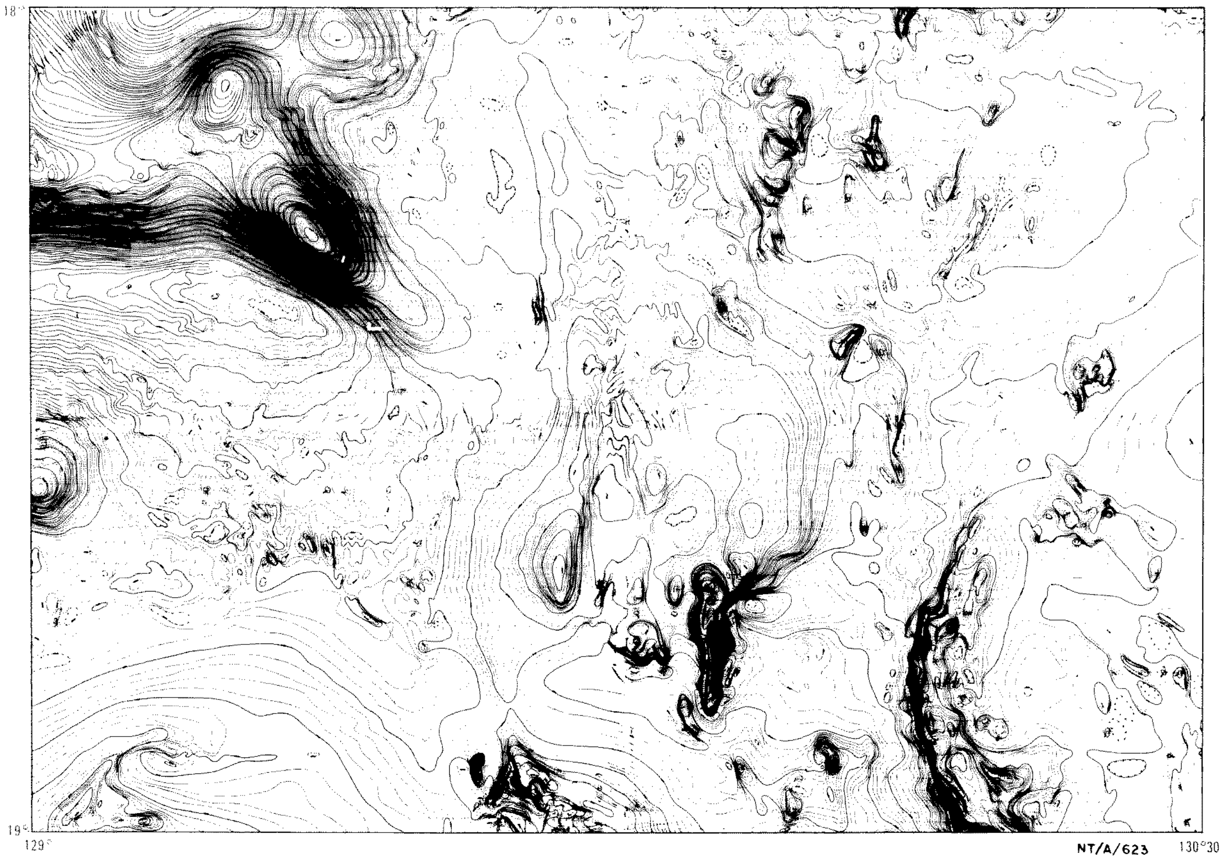


Fig. 50. Total magnetic intensity map, Tanami and The Granites Sheet areas.



Scale 1 :1 000 000

Fig. 51. Total magnetic intensity map, Birrindudu Sheet area.

combined with an airborne magnetic survey, and covered Tanami and The Granites Sheet areas (Spence, 1964; BMR, 1965a, 1965b). The 1972 survey covered the northeast part of Tanami and southeast part of Birrindudu Sheet areas (Dunn, 1973). The surveys showed that radioactivity is generally low and fairly uniform. Most anomalies detected were attributed to laterite, although the last survey also found higher than normal radioactivity in granite, acid volcanics, claypan sediments, and Cambrian basalt.

SUMMARY OF GEOLOGICAL HISTORY

Early Proterozoic

pre-2000 m.y. *Sedimentation*. The oldest rocks exposed in the region belong to the *Tanami Complex* and the stratigraphically equivalent *Halls Creek Group* in the northwest and *Arunta Complex* in the south and southeast. Most of these rocks were originally sediments, many of which appear to have been laid down by turbidity currents, and hence were probably deposited in a marine environment. They are probably between 2000 and 2200 m.y. old.

Volcanism. Basic and acid volcanics are locally intercalated with the sediments of the Tanami Complex. Some basic volcanics show pillow-like structures and may represent subaqueous extrusives, and others may be high-level minor intrusions. The acid volcanics include ignimbritic deposits as well as water-laid tuffs, suggesting that at least some of the volcanic activity was subaerial.

about 1960 m.y. *Tectonism*. After their deposition and subsequent burial, the Tanami Complex, Halls Creek Group, and Arunta Complex were tightly to isoclinally folded and affected by regional metamorphism of mainly low grade, during which an axial-plane cleavage was developed. This *earliest* major phase of tectonic activity recognised in the area took place about 1960 m.y. ago (the age of the regional metamorphism of the Halls Creek Group).

Denudation. Uplift associated with the 1960 m.y. tectonic event was accompanied and followed by subaerial erosion.

about 1800 m.y. *Sedimentation*. Clastic sediments were deposited unconformably on older metamorphics, probably in a shallow marine environment. Remnants of these sediments are represented by the *Pargee Sandstone*, *Supplejack Downs Sandstone* and *Mount Winnecke Formation* in the northern half of the region.

Igneous activity. Acid lavas, dated at 1808 ± 15 m.y., and associated tuffs are intercalated with the clastic sediments of the Mount Winnecke Formation in the northeast. Although tuffaceous rocks are abundant, no ignimbritic deposits are present, and the volcanism is thought to have taken place under water. Shortly after the acid volcanism, the Mount Winnecke Formation was intruded by the high-level *Winnecke Granophyre*, dated at 1802 ± 15 m.y., which is thought to be comagmatic with the acid volcanics. Little thermal metamorphism accompanied this intrusion.

EARLY PROTEROZOIC TO CARPENTARIAN

1800 m.y. to about 1700 m.y. *Tectonism and plutonism.* At about the same time as the emplacement of the Winnecke Granophyre, or shortly after (possibly contemporaneously with either the 1800 or 1700 m.y. regional metamorphism episodes recorded in the Arunta Block), the *second* major phase of tectonic activity took place. During this event the late Early Proterozoic formations were moderately to tightly folded, and the older metamorphics presumably refolded, about mainly north-trending axes. *The Granites Granite,* dated at 1780 ± 24 m.y., the *Slatey Creek Granite*, dated at 1770 ± 62 m.y., the *Lewis Granite,* dated at 1720 ± 8 m.y., and probably most of the unnamed granite bodies in the region were emplaced either at the same time as or a little later than the tectonism. Some of these granites, like the Winnecke Granophyre, may have had comagmatic volcanic equivalents, but if so, these have since been removed by erosion.

Denudation. Following uplift resulting from the tectonism, the area was subjected to subaerial erosion, and by about 1600 m.y. ago large areas of metamorphic rocks and granite were exposed.

CARPENTARIAN

about 1600 m.y. *Sedimentation.* The oldest sediments preserved in the Birrindudu Basin—at least in the northern part—were deposited at this time, on a highly irregular erosion surface marking a major unconformity. These sediments make up the *Birrindudu Group* and its probable equivalents in the far north (the *Limbunya Group*) and the northwest (the *Baines, Ima Ima, Lake Willson,* and *Pindar Beds*). Sedimentation also commenced in the unnamed basin to the northwest with the deposition of the *Mount Parker Sandstone* and *Bungle Bungle Dolomite*. Most of these Carpentarian sediments are probably marine; this is indicated by the presence of glauconitic sandstone, isotopically dated at 1560 ± 20 m.y., in the *Gardiner Formation,* the basal unit of the Birrindudu Group, and by the occurrence of stromatolitic rocks in the succeeding *Talbot Well Formation* and also in the Limbunya Group and Bungle Bungle Dolomite.

about 1525 m.y. *Sedimentation and igneous activity.* There is no record of sedimentation during this period in the Birrindudu Basin. However, clastic sediments were deposited, probably in shallow seas, near the western margin of the Arunta Block in the southwest, where they and associated acid lava make up the *Pollock Hills Formation.* This formation is intruded by the *Mount Webb Granite,* which is thought to be comagmatic with the acid lava. The lava and the granite are dated together at 1526 ± 25 m.y.

Tectonism. The *third* major phase of tectonism recognised in the area took place after the deposition of the Birrindudu Group, probably towards the end of the Carpentarian, perhaps at about the same time as the acid igneous activity in the Arunta Block in the southwest. During this phase large masses of mainly granitic basement in the north of the region were uplifted to form broad domes, such as the Browns Range and Coomarie Domes. Between these domes the Carpentarian sedimentary cover rocks were irregularly and, in places, tightly folded. No folding of this age has been recognised in the south of the Birrindudu Basin, where Carpentarian sediments are absent. The gentle folding that took place between the deposition of Carpentarian and Adelaidean sediments in the southwest of the region and in the unnamed basin in the northwest may have taken place at this time.

Denudation. Subaerial erosion followed the tectonic activity. Much of the Carpentarian cover was removed, and pre-Carpentarian sedimentary, igneous, and metamorphic rocks were exposed.

ADELAIDEAN

about 1200 m.y. *Sedimentation and denudation.* The only recorded sedimentation in this period is that of the probably marine *Wade Creek Sandstone* in the unnamed basin in the northwest. Shale in this formation north of the area has been dated at 1128 ± 110 m.y. (Dow & Gemuts, 1968, Bennett & others, 1975).

1000 m.y. to about 600 m.y. *Sedimentation.* Adelaidean sediments, represented by the Redcliff Pound Group in the west and south, and its probable correlatives in the northwest (*Denison, Jawilga,* and *Boee Beds*) and southwest (*Hidden Basin Beds*) were deposited in the Birrindudu Basin, mainly in a shallow marine environment, less than 1000 m.y. ago. The laterally equivalent basal formations of the Redcliff Pound Group (*Lewis Range, Muriel Range* and *Munyu Sandstone*), which may be partly fluvial, were deposited at the same time as the mainly shallow marine *Vaughan Springs Quartzite* in the Ngalia Basin and *Heavitree Quartzite* and *Bitter Springs Formation* in the Amadeus Basin. No sediments of similar age appear to have been deposited in the unnamed basin in the northwest, where the early Adelaidean *Wade Creek Sandstone* is overlain by the late Adelaidean *Duerdin Group*, which includes some glacial deposits and is dated at about 700 m.y., and the overlying *Albert Edward Group*, which was laid down about 650 m.y. ago; most of these younger Adelaidean sediments are also probably shallow marine.

Tectonism. The *fourth* major phase of tectonic activity took place after the deposition of the Adelaidean sediments and before the Early Cambrian, perhaps about 600 m.y. ago, at the time of the Petermann Ranges Orogeny. During this phase, folding affected Adelaidean rocks in all the sedimentary basins, faults mapped in the region were probably active, and the region was uplifted to form part of a mountainous land mass.

Denudation. Subaerial erosion accompanied and followed the tectonism.

PALAEOZOIC TO PRESENT

from about 570 m.y.

Volcanism. Outpourings of flood basalts belonging to the *Antrim Plateau Volcanics* took place in the Early Cambrian. Most, if not all, the basalt flows are subaerial, and they filled broad depressions on an old land surface. Associated water-laid sediments and stromatolitic chert beds indicate local fluvial, lacustrine, and possibly shallow marine deposition.

Sedimentation. In the Middle Cambrian, after the Antrim Plateau Volcanics had been laid down, marine sedimentation took place to the east, in the Wiso Basin. To the west, in the Canning Basin, marine sedimentation apparently did not begin until the Ordovician. In the area between these two basins, no marine sediments younger than the Antrim Plateau Volcanics are known. The *Lucas Formation* and the *Pedestal, Angas Hills,* and *Chuall Beds* are considered to be fluvial and lacustrine sediments deposited in intracontinental basins during the Devonian. The *Larranganni Beds, Hazlett Beds,* and unnamed sediments are erosional remnants of similar continental sediments of probable Mesozoic age. The youngest sediments present are the widespread superficial Cainozoic aeolian, alluvial, lacustrine, evaporitic, and residual deposits.

Tectonism. Most of the region has been tectonically stable since the end of the Proterozoic. However, the Palaeozoic Pedestal Beds were locally tightly folded, mainly near faults, during a *fifth and final* major phase of tectonic activity, the effects of which appear to be restricted to the southeast. This phase was probably part of the Alice Springs Orogeny, which took place during late Devonian or early Carboniferous time.

Denudation. The present subdued topography of widespread sand plains, barely perceptible drainage depressions, and scattered low residual hills and ridges, together with the deep weathering profiles on all but the most quartz-rich rocks, has resulted from prolonged subaerial weathering and erosion of an area that has been tectonically stable since the Palaeozoic and probably part of a land mass throughout most of the Phanerozoic.

ECONOMIC GEOLOGY

Any mineral resources in The Granites-Tanami region remain largely unknown, as little exploration has taken place. There appear to be three main reasons for this: firstly, the isolation of the area, which means high transport and development costs—hence any mineral deposits discovered need to be large and relatively rich if they are to be economically viable; secondly, the widespread cover of superficial sediments concealing the bedrock, which makes mineral prospecting difficult and expensive; thirdly, the lack of any known major mineral deposit either within the area or in adjacent areas lessens the incentive for mineral exploration. However, the area is not unprospective for minerals, as gold, copper, uranium, and rare earths have been found, although only the gold has been worked. Also, gossans are common locally in the Tanami Complex, and some of the oldest rocks exposed closely resemble the extensively mineralised rocks of the Tennant Creek area to the east, on the east side of the Wiso Basin.

GOLD

Gold was discovered in The Granites-Tanami region in 1900 by Davidson (1905), and was mined intermittently between 1904 and 1961. Total production is

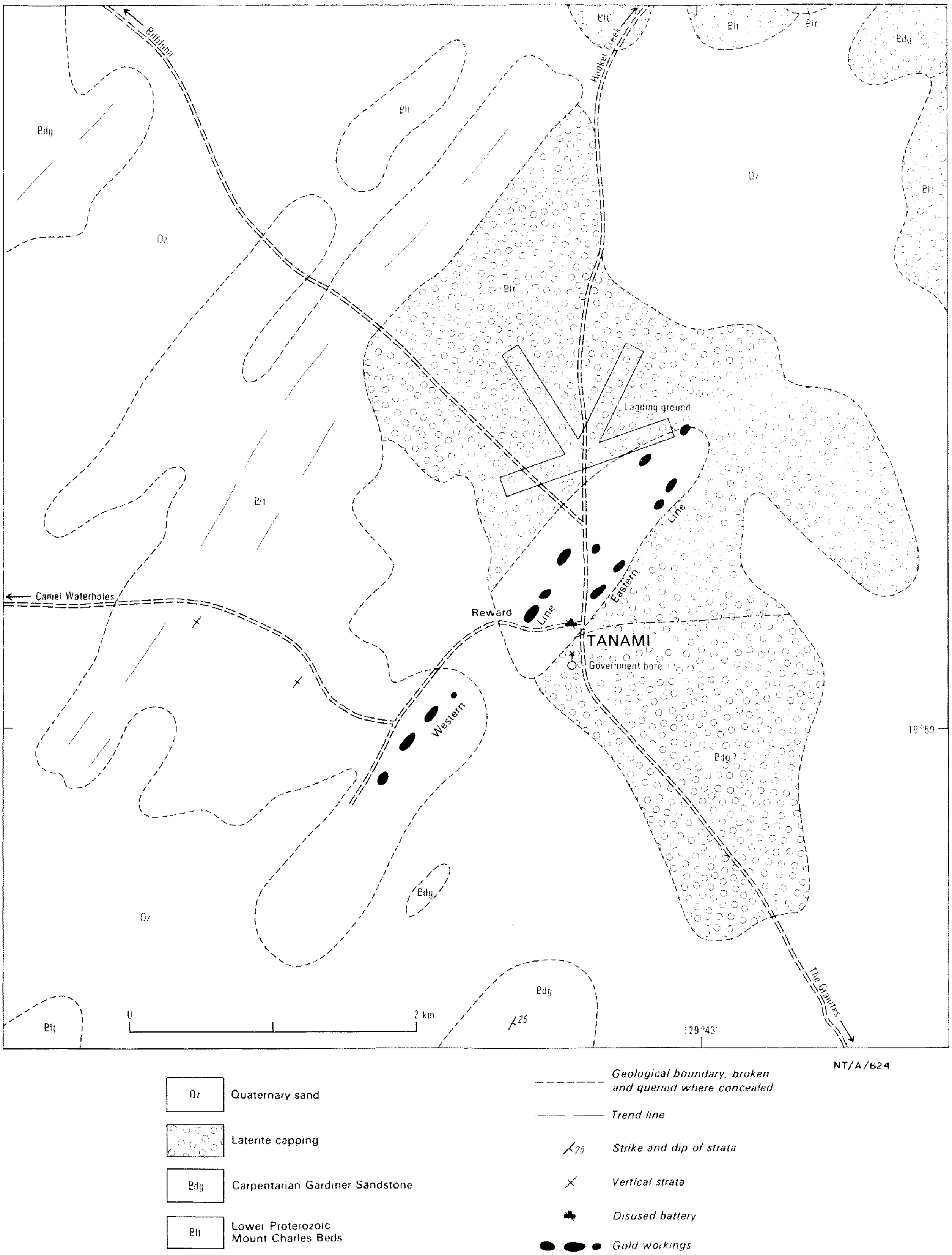


Fig. 52. Tanami goldfield.

uncertain, but may be about 540 kg. The main goldfields were at Tanami and The Granites, but gold has also been obtained from just west of the Bluebush Hills, in the Ditjiedoonkuna Hills, and near Cave Hill, all in The Granites Sheet area. All the gold has come from the Mount Charles Beds of the Tanami Complex. Gold was also recorded by Davidson (1905) in metamorphic rocks of the Killi Killi Beds near Larranganni Bluff, and small amounts have been found in the Mount Charles Beds in the Black Hills (Hossfeld, 1904b).

Tanami goldfield
(Fig. 52)

The following account is based largely on a report by Hossfeld (1904b).

Gold was first obtained at Tanami in 1904, and the first claim—the Reward—was registered in 1909. Relative boom years followed, and in 1910 and 1911 up to 200 men were living near Tanami. During this period many shafts were sunk, mostly of shallow depth, but very few appear to have given the miners any significant return for their labours. The richest part of the field was covered by the Reward claim. In 1925 this claim was acquired by the Tanami Gold Mining Company, NL, who arranged for a battery and treatment plant to be sent from Perth to Tanami. The plant was erected and working in 1927, after being transported from Perth to Derby by ship and from Derby to Tanami by truck and donkey team. Because of water shortages, the battery had to close down the following year, and the company ceased its mining operations. However, a battery was working again at Tanami in 1937 and 1938. The goldfield was surveyed and sampled in 1938 by the Aerial Geological and Geophysical Survey of Northern Australia, whose published report (Hossfeld, 1940b) is the most comprehensive available. Any work done in the goldfield since 1938 has not been reported. The goldfield is now abandoned, and the mine shafts are inaccessible. The amount of gold produced is not known although a total production of about 70 kg was suggested by H. A. Ellis (reported in Hossfeld, 1940b).

The host rocks for the gold mineralisation are thinly interbedded siltstone and shale, which are partly silicified to chert, minor greywacke, and intercalated basalt; it is not known whether the basalt, which is present at most, if not all, the mines, is extrusive or intrusive. The rocks are tightly folded, trend generally north-northeast, and have been affected by low-grade regional metamorphism. They form low rounded strike ridges and undulating terrain, and are partly capped by laterite. Exposures are much weathered and iron-stained. To the west, northeast, and southeast the Mount Charles Beds are overlain unconformably by mainly gently dipping sublithic arenite, quartz arenite, and minor conglomerate of the Gardiner Sandstone, the basal formation of the Carpentarian Birrindudu Group.

The reef gold was worked over an area of about 4 km long and up to about 1 km wide. It was found in two main fracture zones, termed the Western and Eastern lines by Hossfeld (1940b), the Western line being the more productive. The two zones trend northeast, and are about 450 m apart. Most of the gold obtained came from small lenticular quartz bodies in fissures. These were enriched where the fissures cut a favourable rock type referred to by early workers as 'felsite' (possibly silicified fine-grained sedimentary rocks or altered basalt). Workings consisted of shafts, small open cuts, stopes (Fig. 53), and trenches. Most shafts were less than 15 m deep, but one, the Water Shaft on the Reward Claim, was sunk to a depth of at least 56 m. The lodes appear to have had an average width of about 1 m, and when sampled in 1937, after most of the payable ore had been removed (Hossfeld, 1940b), gave average assays of about 7 g per tonne. Some gold is also present in quartz-jasper-hematite reefs parallel to and west of the Western line of lodes.

Quantities of eluvial gold were obtained when the field was first worked, and also in the 1930s, when coarse gold was recovered from the dry blowing of laterite in the northeast part of the field.

Fig. 53. Open stope at the Reward claim, Tanami goldfield, 1971. (GA/5756)

The Granites goldfield
(Fig. 54)

Gold was found close to granite outcrops at The Granites in 1900 (Davidson, 1905), shortly after the initial discovery at Tanami, and by 1910 small quantities of alluvial and lode gold had been obtained (Gee, 1911). The goldfield appears to have been abandoned shortly afterwards, and remained so until 1925, when gold-mining leases were applied for. It was abandoned again two years later. However, in 1932 a small area of rich alluvial gold was found (Hossfeld, 1940b), which resulted in a 'rush' to the area. However, because of the small amounts of gold that were recovered, an acute water shortage, and transport difficulties (although the track from Alice Springs to Tanami via The Granites had been constructed in 1929), the boom was short-lived. Nevertheless, gold mining continued on a small scale up to 1961, by which time about 470 kg of gold had been produced, over half of this amount being recovered during the period 1945-1951 (Crohn, 1961). Since 1961 the goldfield has once again been deserted (Fig. 20).

The Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) mapped the geology of the area during 1937-8 (Hossfeld, 1940a, 1940b), and carried out a geophysical survey in 1939 (Daly, 1962). Between 1938 and 1948 Anglo Queensland Mining Pty Ltd, a subsidiary of Mount Isa Mines, examined the goldfield, and put down twenty diamond drill holes (Hall, 1953), twelve of which intersected possible ore-grade material. Part of the goldfield was examined in 1960 by Crohn (1961), and an aeromagnetic survey of the area was carried out by the Bureau of Mineral Resources in 1962 (Spence, 1964).

The goldfield is a gently undulating sand-covered plain with low hills and ridges, most of which are less than 15 m high. Rocks exposed are schist and thin-banded chert and quartzite of the Mount Charles Beds, which contain the known gold lodes, and The Granites Granite, which intrudes the Mount Charles Beds. Some of the schist is garnetiferous and some contains chiastolite porphyroblasts, which are generally pseudomorphed. Most of the metamorphic rocks are strongly weathered and iron-stained. The weathered zone persists to depths of about 36 m (Hall, 1953), and in it some beds are selectively replaced by iron oxide to form ironstone. The main granite outcrops are in the south.

The Mount Charles Beds form a broken line of low ridges. General bedding trends are roughly parallel to the ridges, but in detail the beds show irregular tight to isoclinal minor folding. In the mineralised area the Mount Charles Beds appear to form an asymmetrical

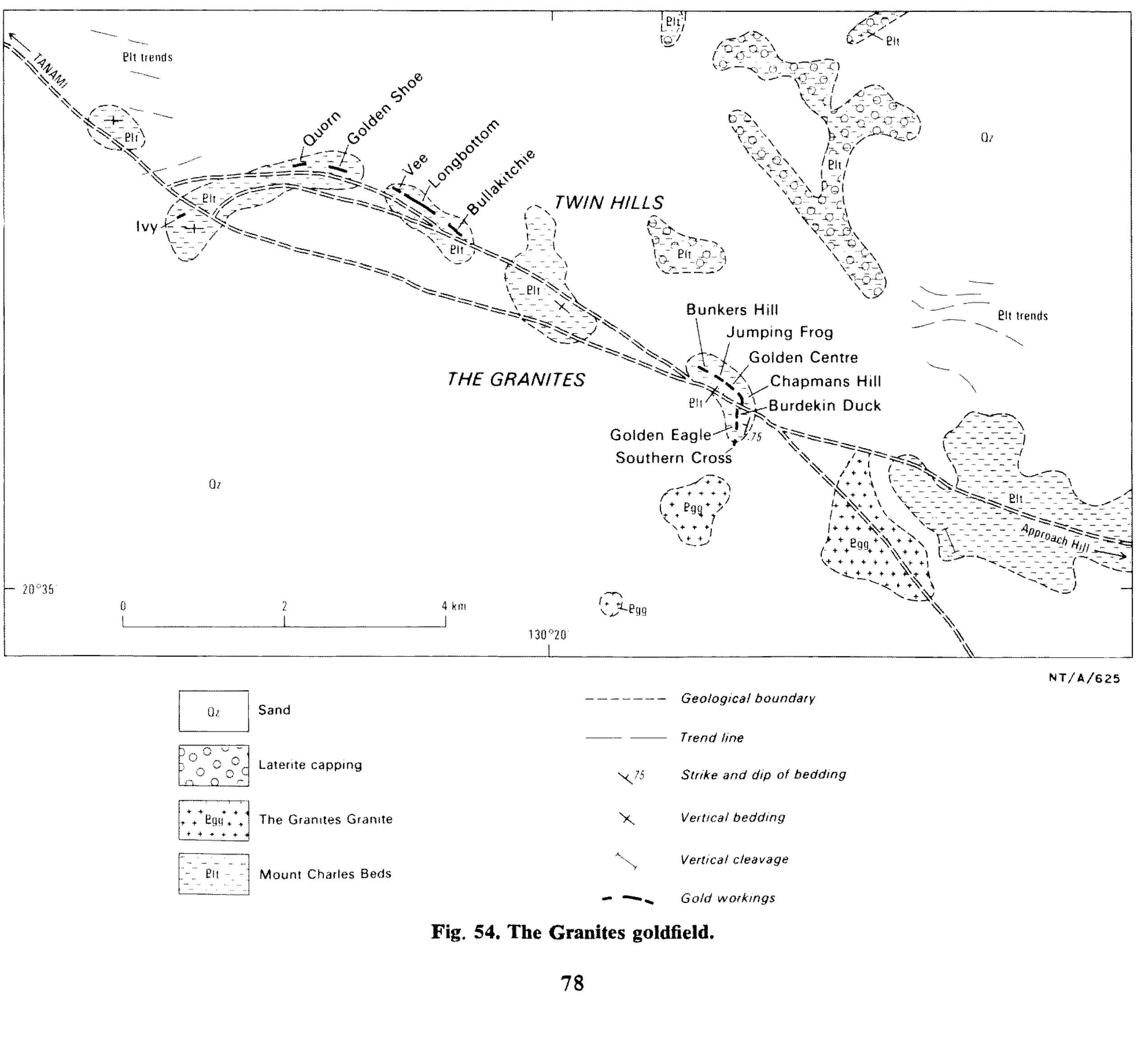


Fig. 54. The Granites goldfield.

anticline, trending northwest to west-northwest. The axial plane of this fold generally dips steeply southwest, and the lodes are on the partly overturned northeast limb (Hall, 1953). In the southeast, the structure is more complex than originally suggested by Hossfeld (1940b), who postulated a major syncline plunging east. No signs of such a structure were found by Crohn (1961). The relations of the minor folds to the major structure are not known.

Two main types of lodes were worked for gold. These were short narrow quartz veinlets carrying about 150 g gold per tonne, but which did not appear to persist at depth, and wider zones of quartz and calcite veinlets, carrying up to 17 g gold per tonne and proved by drilling to extend to depths of at least 120 m (Hall, 1953). Both types of lodes dipped steeply and were generally concordant or nearly so with the bedding of the host rocks; they appear to have been restricted to the same general stratigraphic level. The gold was present in the quartz veinlets and also in the adjacent country rock; the highest values were apparently found associated with iron-stained quartz (Crohn, 1961). As described by Hall (1953), the gold occurred free, commonly in coarse particles, and it averaged 900 fine; sulphides, mainly pyrite, but also minor arsenopyrite (and pyrrhotite, Crohn, 1961), made up less than 4 percent of the ore; iron carbonates formed bands in the host rock below the zone of oxidation. The gold mineralisation may be related to the nearby granite, as suggested by Hossfeld, although the granite itself does not appear to be mineralised, or it may have been associated with the pre-granite regional metamorphism.

Mine workings

Three main groups of mine workings are present in the goldfield (Crohn, 1961): the Bunkers Hill-Chapmans Hill workings, in the southeast; the Golden Shoe-Bullakitchie workings, 4 km to the west-northwest, which were the most productive; and the Ivy workings, 2 km west-southwest of the Golden Shoe (Fig. 54). They have an irregular distribution, reflecting the patchy nature of the gold mineralisation. The three groups were surveyed in 1938 (Hossfeld, 1940b), and the first two were surveyed again in 1960 (Crohn, 1961). Assays on samples collected from the workings have been reported by Hossfeld (1940b) and Hall (1953). No reliable production figures are available for either individual workings or groups of workings.

At the Bunkers Hill - Chapmans Hill workings the lodes consisted mainly of small but rich narrow quartz veinlets. Most were vertical and roughly parallel to the general strike of the country rocks. Assays of samples collected in 1938 range up to 54 g gold per tonne (Hossfeld, 1940b). At Bunkers Hill in the north, shafts and small open cuts followed small lodes; in addition, an adit was driven 35 m into the side of the hill, intersecting non-payable lode containing 2 g gold per tonne over a width of 15 m (Hall, 1953). At the Jumping Frog, the workings consist of pits and costeans. At the Golden Centre, the main producer between 1940 and 1960, shafts and open stopes were sunk to depths of about 10 m. At Chapmans Hill there are shallow shafts and open cuts. At the Burdekin Duck, the main producer of the group before 1940, some of the shafts and stopes were over 25 m deep, whereas at the Golden Eagle and Southern Cross most workings were less than 10 m deep. Alluvial gold was obtained southwest of the lodes, mainly downslope from the Burdekin Duck.

In the Golden Shoe-Bullakitchie area, the most productive in the goldfield, the workings are along a single main mineralised zone, in places over 20 m wide, which can be traced for nearly 2 km. This zone swings from west-northwest in the east to west-southwest in the west, and dips 70° to 90° north, conformably with the general bedding of the country rocks. Within the zone there are several shafts over 30 m deep and about 200 m of drives within 30 m of the surface; there has also been some stoping. Assays on samples collected in 1938 from the workings—the Bullakitchie, Longbottom, Vee, Golden Shoe, and Quorn—ranged from 0 to 185 g gold per tonne (Hossfeld, 1940b). Between 1941 and 1948 twenty diamond-drill holes with an aggregate length of about 2300 m were put down by Anglo Queensland Mining Pty Ltd on the north side of the workings (Hall, 1953; Crohn, 1961). They were inclined to the south, and reached vertical depths of 55 m to 120 m. Ore was intersected in twelve of the holes, and assays ranged up to 54 g gold per tonne. The results indicated the presence of 250 000 tonnes of ore containing 11.5 g per tonne within 120 m of the surface; the downward limit was not established. The unaltered rocks intersected in the drill holes were described as quartz schist, mica schist, garnetiferous schist, minor pegmatite, and some vein quartz; the lode material appears to consist mainly of quartz and calcite veinlets and disseminated sulphides, mainly pyrite, pyrrhotite, and arsenopyrite, in sheared and altered schist (Crohn, 1961).

The Ivy workings in the west consist of a shaft and costeans, which may be on the same lode as that at the Golden Shoe. Production was negligible. Several diamond-drill holes are said to have been put down in this area between 1961 and 1971 by Geopeko Ltd, but no reports of such drilling have been released.

Geophysical investigations

A report on the AGGSNA geophysical survey of The Granites goldfield in 1939 was prepared by Thyer, Rayner, & Nye, but was not published. However, a summary of the results was issued as a BMR Record (Daly, 1962). Four methods were tested and two were used: a potential-ratio survey, which indicated some anomalies possibly related to the zone of quartz veinlets from which most of the gold was obtained; and a magnetic survey, which found several strong anomalies, indicating a strongly magnetic bed closely associated with the known mineralisation. The nature of the magnetic beds is unknown, as samples of exposed rocks, except ironstone rubble, were found to be generally non-magnetic. It was recommended that the magnetic anomalies be tested by drilling, and that some of the potential-ratio anomalies be tested by trenching.

An airborne magnetic and radiometric survey was carried out over the goldfield in 1962 (Spence, 1964). Several magnetic anomalies were delineated: one recorded at about 700 gammas being estimated to have its source about 150 m below the surface. Radioactivity values were found to be low and fairly uniform, and no significant anomalies were located in the mineralised area.

Other gold mining localities

In 1904, about the same time as the first gold was being obtained at Tanami, Gee (1911) reported that gold was also being mined 28 km to the south-southwest. At this locality, 20°11′45″S, 129°34′30″E, just west of the Bluebush Hills (Fig. 40), the gold occurs with hematite in quartz veinlets cutting southerly dipping cleaved greywacke, lithic arenite, and phyllitic shale of the Mount Charles Beds. The workings consist of three shafts, which were probably about 15 m deep, and several shallow trenches.

Gee (1911) also reported that fine gold had been obtained from quartz reefs 40 km south-southeast of Tanami, in the Smoke Hills (Cave Hill area) southwest of Rabbit Flat. The precise position of these reefs is not known.

A third locality mentioned by Gee, and also by Hossfeld (1940b) and Phillips (1961), is near Dead Bullock Soak in the Ditjiedookuna Hills, 43 km west of The Granites, at 20°31′25″S, 129°55′30″E. Hossfeld stated that in 1938 the workings there consisted only of a few shallow trial holes. Phillips reported that quartz veins carrying 12 to 15 g gold per tonne cut thinly interbedded shale, chert, and quartzite.

Uranium and Rare Earths

In 1960, two uranium prospects were discovered by Clark & Blockley (1960) in the Killi Killi Hills area, south of the Gardner Range. Both prospects also contain appreciable amounts of rare-earth elements. No other uranium prospects are known in the region, although radioactivity anomalies have been found both on the ground and from the air at several places. Some granite exposures, for instance, when tested on the ground, show up to four times background values. Most anomalies found from the air can be attributed to laterite, and only a very weak anomaly was found over the main Killi Killi Hills prospect during an airborne radiometric survey (Mulder, 1961). In the Winnecke Range area in the northeast, higher than normal radioactivity was found in the following rock types (Dunn, 1973): granite and acid volcanics, owing to K, Th, and U; laterite, mainly owing to Th; claypan sediments, possibly owing to K; and Cambrian basalt. Some anomalies have also been reported, but not confirmed, from calcrete.

Killi Killi Hills prospects
(Fig. 55)

The Killi Killi Hills uranium prospects have been described in unpublished reports by Clark & Blockley (1960), Prichard & others (1960), and Blake & others (1973). The prospects are Killi Killi No. 1, situated on the north side of the Killi Killi Hills, just in Western Australia, and Killi Killi No. 2, which is 11 km to the west-northwest, on the southwest side of Watts Rise. At both prospects, anomalous radioactivity of four to more than eight times the background is confined to the basal 6 m of the Carpentarian Gardiner Sandstone. This formation dips gently north and northeast, and lies unconformably on steeply dipping, slightly schistose greywacke and siltstone of the Killi Killi Beds. The unconformity is well exposed at Killi Killi No. 1, but is concealed at Killi Killi No. 2. The basal beds of the Gardiner Sandstone at the prospects consist of medium-bedded, coarse-grained, and locally pebbly sublithic arenite, conglomerate, and minor thin-bedded micaceous siltstone and fine-grained sublithic arenite. The conglomerate and pebbly arenite contain rounded clasts, mainly of vein quartz, lithic arenite, greywacke, siltstone, shale, chert, and quartzite, all of which are probably derived from the underlying Killi Killi Beds.

At Killi Killi No. 1 the anomalous radioactivity persists for about 1350 m along strike. Specimens selected in 1960 for maximum radioactivity assayed 0.18 and 0.23 weight percent U_3O_8 (Prichard & others, 1960). In the east the basal conglomerate beds of the Gardiner Sandstone are repeated less than 200 m to the south of the prospect by a fault, but the southern outcrop does not show any anomalous radioactivity. At Killi Killi No. 2 the anomaly extends for about 30 m along strike. Specimens collected here in 1960 from sites giving values of four times the background radioactivity assayed 0.01 percent U_3O_8 (Prichard & others, 1960). Midway between the two prospects conglomerate and sandstone exposures less than 0.5 m high give readings of up to six times background values.

Specimens of conglomerate collected in 1960 and 1972 from both prospects have been examined microscopically. They consist of rounded pebbles in a coarse-grained matrix made up mainly of quartz grains. The matrix has a quartz-overgrowth cement enclosing patchy concentrations of uranium-bearing xenotime, which is responsible for the radioactivity, and a mineral that is probably a variety of florencite. The latter mineral forms anhedral to, more commonly, euhedral pseudo-cubic (rhombohedral) crystals up to 0.2 mm across, most of which have centres darkened by specks that are probably iron oxide. The crystals occur in aggregates, which generally also include abundant smaller granules of xenotime. Although mainly confined to the matrix of the conglomerate, both xenotime and florencite are also present in some of the constituent sandstone pebbles. In addition, strings of small xenotime granules are present along bedding planes in some shale pebbles, and Dallwitz & Roberts (in Prichard & others, 1960) recorded a vein of florencite cutting across part of a siltstone clast. These different modes of occurrence and the euhedral shapes of the florencite crystals indicate that both the xenotime and florencite are probably epigenetic rather than syngenetic. Possibly, the two minerals were introduced when the fault exposed south of Killi Killi No. 1 was active.

The mineral thought to be florencite gives an X-ray diffraction pattern that closely resembles that of florencite (G. H. Berryman, BMR, personal communication, 1973). It has refractive indices of 1.660-1.670 (Dallwitz, in Prichard & others, 1960), which are a little lower than those reported for florencite by Winchell (1951), but silghtly higher than those of Sr-rich florencite from Russia (Somina & Bulakh, 1966).

Both the xenotime and florencite from the Killi Killi Hills prospects have been analysed semiquantitatively by D. J. Ellis (BMR Laboratory Report 1975/58 in Weekes, 1976), using an electron microprobe. The minerals were found to be difficult to analyse by this method, partly because of their small grain-size and pronounced compositional zoning, and partly because the high operating voltages (20 KV) necessary for the detection of the rare-earth elements resulted in volatilisation of any water present. The analyses are shown in Table 8. All rare earth elements were searched for in both minerals, the detection limit being 0.01 weight percent.

The low totals can be attributed to inaccurate P_2O_5 values, the presence of uranium (not analysed for) in the xenotime, the possible presence of other elements not searched for, such as Sr (although Sr did not show up on cursory peak scans) and S (some sulphate was detected by A. D. Haldane in the aqueous extract from

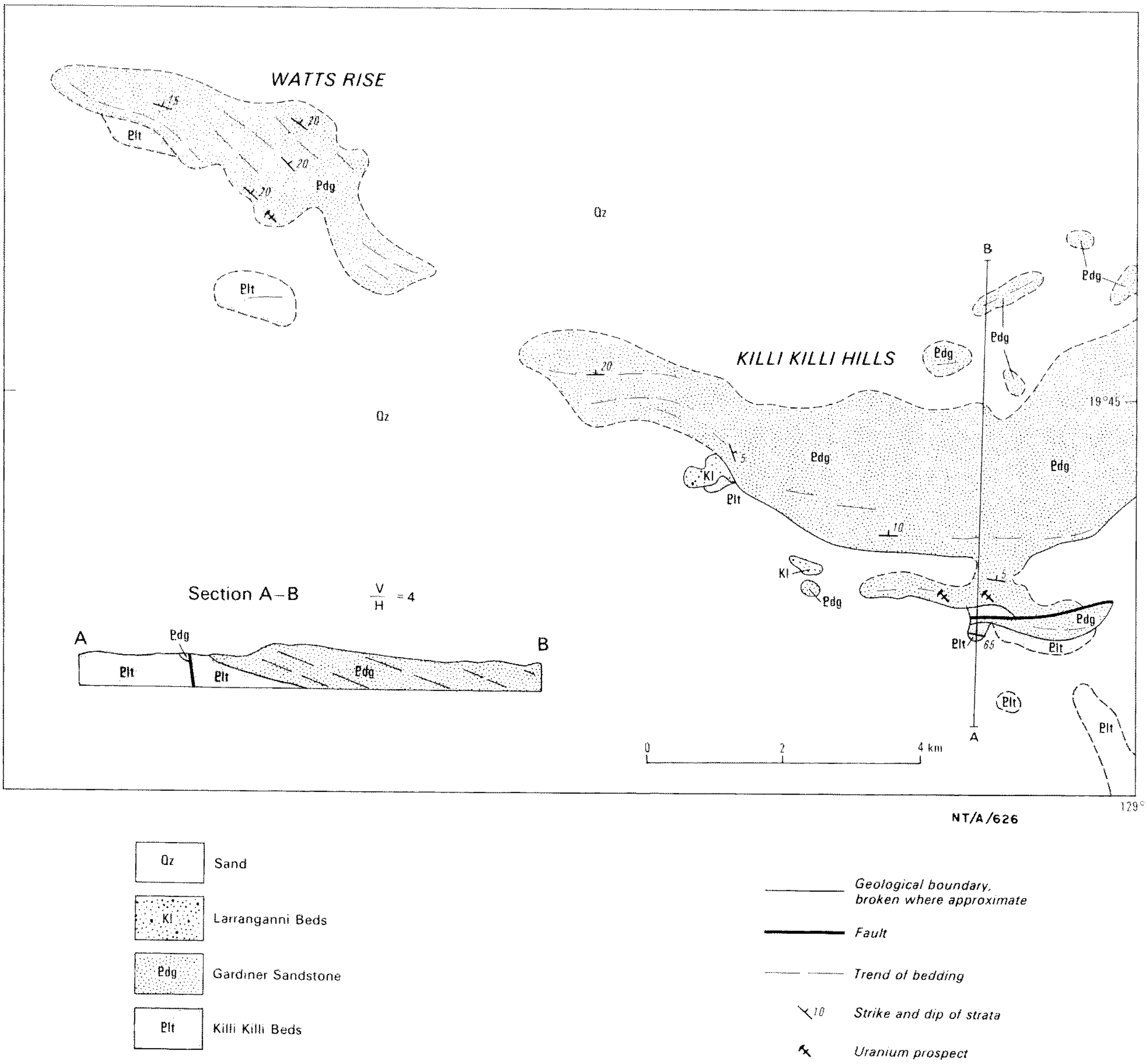


Fig. 55. Geological map of the Killi Killi Hills, Billiluna Sheet area.

TABLE 8. ELECTRON MICROPROBE SEMIQUANTITATIVE ANALYSES OF XENOTIME AND ?FLORENCITE FROM THE KILLI KILLI HILLS

	Xenotime YPO_4		*?Florencite* $CeAl_3(PO_4)_2(OH)_6$				
	1	*2*	*1*	*2*	*3*	*4*	*5*
Al_2O_3	n.d.	n.d.	33.87	35.54	44.85	42.12	48.24
P_2O_5	20.72	16.51	33.91	31.72	25.75	24.68	12.6
CaO	—	—	4.19	4.87	3.24	4.21	3.98
Y_2O_3	48.04	48.52	n.d.	n.d.	n.d.	n.d.	n.d.
La_2O_3	n.d.	n.d.	1.92	0.77	0.41	1.21	1.58
Ce_2O_3	n.d.	n.d.	5.94	2.67	1.34	3.95	4.84
Gd_2O_3	0.29	0.41	0.49	0.27	0.15	0.37	0.39
EuO	0.09	0.09	n.d.	n.d.	n.d.	n.d.	n.d.
Nd_2O_3	0.05	0.09	5.63	2.57	0.05	0.30	3.23
Sm_2O_3	0.13	0.20	0.48	0.34	0.07	0.43	0.34
Pr_2O_3	n.d.	n.d.	1.07	0.36	0.00	0.74	0.70
Yb_2O_3	0.19	0.12	n.d.	n.d.	n.d.	n.d.	n.d.
Dy_2O_3	0.43	0.53	n.d.	n.d.	n.d.	n.d.	n.d.
Er_2O_3	0.26	0.26	n.d.	n.d.	n.d.	n.d.	n.d.
Total	70.20	66.73	87.50	79.08	75.86	78.01	75.90

n.d. = none detected

a sodium carbonate fusion—Prichard & others, 1960) and volatilisation of water in the ?florencite (florencite containing 11.11 weight percent H_2O has been reported from Russia by Somina & Bulakh, 1966).

Copper

Thin smears on rock of the secondary minerals malachite and azurite have been recorded from the south side of the Browns Range Dome (Davidson, 1905; Phillips, 1959), in the Black Hills (Phillips, 1959; Roberts, 1968), on the north side of the Muriel Range, and in the Grimwade Ridge area southwest of The Granites, all in the Tanami Complex. At the last two localities the copper minerals occur in amphibolite close to intrusive veins of granite. Traces of chalcopyrite are present in phyllite beneath gossan in the Black Hills (see below). Small amounts of copper are known to be present locally in the Antrim Plateau Volcanics to the north (Bultitude, 1976), but none has been recorded in this unit in The Granites-Tanami region.

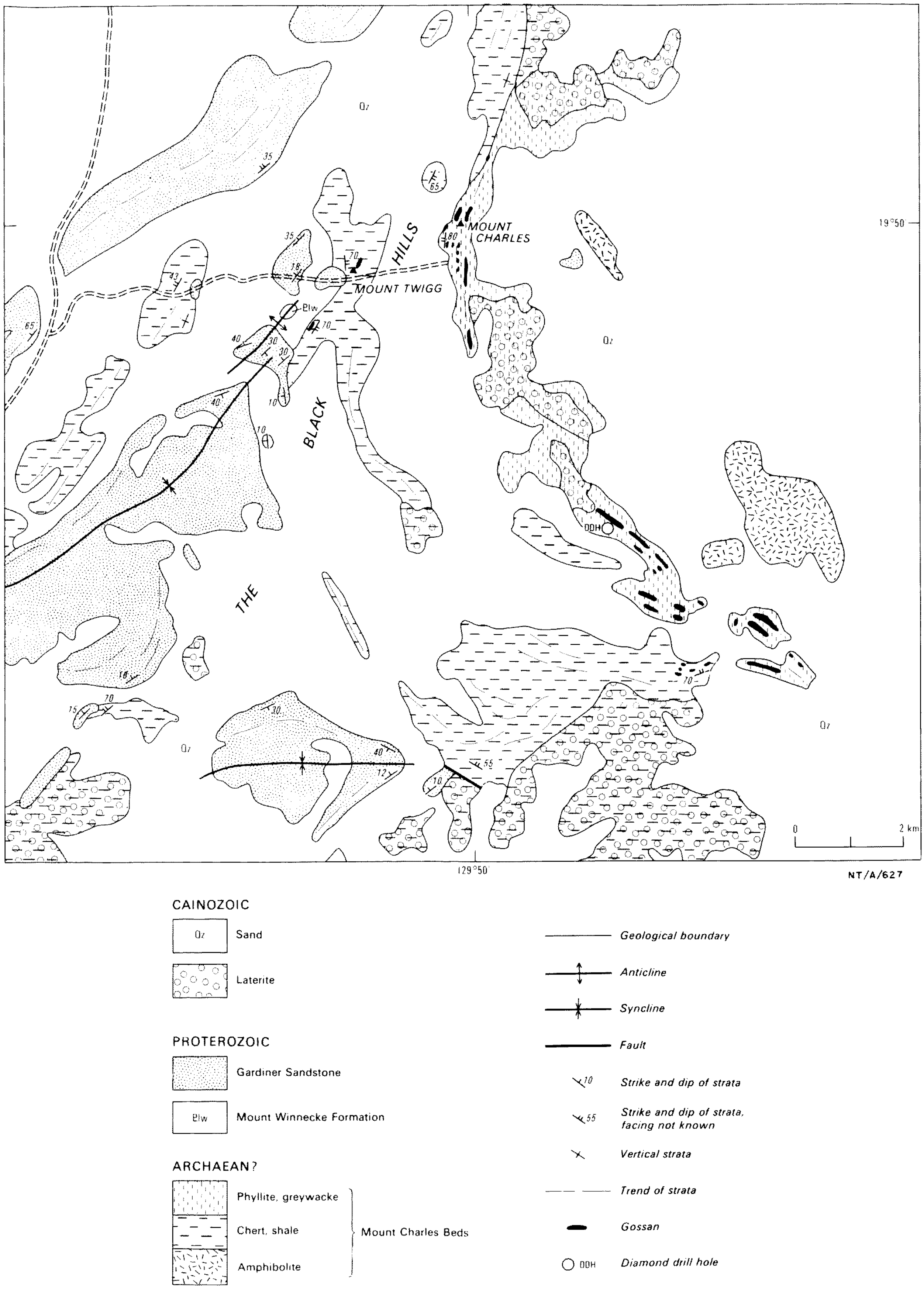


Fig. 56. Geological map of the Black Hills, Tanami Sheet area.

Gossans

Gossans are common locally, capping rocks belonging to the Tanami Complex. They are generally more resistant to erosion than the surrounding rocks, and form prominent strike ridges, such as those of the Black Hills, and cone-shaped pinnacles such as Black Peak, 20 km south-southwest of Tanami. At least forty-three gossan bodies are present in the Black Hills (Phillips, 1962), where they cap Mount Charles Beds (Fig. 56). All the gossans are strongly leached, and now consist almost entirely of iron oxides, quartz, and kaolinite. Except for rare copper smears in the Black Hills, they do not contain visible base metals or gold.

The gossans are generally a metre or more wide and are made up of numerous thin bands, commonly less than 10 cm thick. The bands are conformable with the bedding of adjacent rocks, and are probably developed in thin-bedded rocks containing pyrite and other sulphide minerals. They are cellular, but no identifiable boxworks other than those of pyrite have been recognised.

At the Black Hills, a diamond-drill hole put down in 1962 by Enterprise Exploration Pty Ltd (Phillips, 1962) showed that gossan was developed on black carbonaceous and pyritic shale. This hole, the only one to date to test a gossan, was drilled at an angle of 30° for 324.2 m. It passed through the black shale between 131 and 201 m, and continued through talcose phyllite, minor greenstone, and thin carbonate bands. The talcose phyllite, which is represented at the surface by hematitic shale, contains minor pyrite and traces of chalcopyrite. Oxidation was found to persist to depths of 100 m to 110 m. Phillips (1962) reported that gossan samples contain traces of copper, gold (also recorded by Hossfeld, 1940b), zinc, and silver. Work on the Black Hills gossans, carried out in 1968 by Anaconda Australia Inc., was reported by Roberts (1968): chip samples of gossans and soil samples were analysed for copper, lead, zinc, and nickel; values found were generally low, except for one 3-m interval, which contained 8000 ppm lead. A magnetic anomaly to the northeast of the gossans was found to be due to magnetite-bearing chlorite-sericite schist (Roberts, 1968).

Non-metallic Deposits

Evaporite minerals

When dry, the salt lakes and salt pans have thin surface crusts, generally only a few millimetres thick, formed predominantly of gypsum and halite. Both these minerals are also present in underlying waterlogged mud. Stratigraphic drilling carried out between 1971 and 1973 (Blake, 1974) showed that gypsum is also present in Tertiary clay filling the broad drainage depression between the Lewis and Kearney Ranges, and as joint fillings in the Gardiner Sandstone on the north side of the Coomarie Dome. No occurrences of any potash evaporite minerals are known.

Barite

Casey and Wells (1964) recorded a line of barite pebbles on the floor of Lake Dennis. This is the only known occurrence of barite in the region.

Limestone

Large deposits of limestone are available in the Bitter Springs Formation and Munyu Sandstone exposed in the southwest and in the Talbot Well Formation cropping out at the northwest end of the Gardner Range. The extensive outcrops of calcrete in the region offer a further source of lime.

Semi-precious stones

Smoky quartz and amethyst occupy geodes within basalt of the Antrim Plateau Volcanics overlying Gardiner Sandstone 9 km north-northwest of Supplejack Downs homestead.

Water

There is generally little surface water in the region because of the low and erratic rainfall, high evaporation rate, and resulting semi-desert climate. In the north, permanent and semi-permanent supplies are restricted to Nongra Lake, which is brackish; large pools along Sturt Creek; small water holes along some of the other larger creeks; small rock holes in the sandstone hills and ridges, such as the Camel Waterholes in the Tanami Range and Jellebra Rockholes in the east of the Gardner Range; and springs, such as Banana Springs southeast of Gordon Downs homestead, the two Palm Springs in the Denison Range, and Coomarie Spring north-northeast of Tanami. In the south there is probably no permanent surface water, although pools in Brookman Waters on the west side of Redcliff Pound, and a few very widely scattered small rock holes and soaks, such as Wickhams Well (Fig. 57), may contain water throughout most years. The many clay pans, salt pans, and salt lakes are usually dry, except after periods of heavy rain.

Numerous water bores have been sunk in the north of the area, but there are none south of latitude 21°S. The best supplies of water suitable for human consumption and stock have been obtained mainly at shallow depth from calcrete in the central part of the area, and from basalt of the Antrim Plateau Volcanics in the north. Salty water is obtained from bores tapping the Lucas Formation and from some of those tapping Precambrian rocks. Potable water supplied by the bores at Tanami and The Granites probably comes from the Gardiner Sandstone and The Granites Granite, respectively. The Government bore at Tanami, the deepest in the area, reached water at 40 m, but was continued to a depth of over 100 m.

Fig. 57. Wickhams Well, a soak surrounded by lateritised granite and Arunta Complex rocks, Highland Rocks Sheet area. (M2239/30)

REFERENCES CITED AND BIBLIOGRAPHY OF GEOLOGY

ARMSTRONG, R. L., & STEWART, A. J., 1975—Rubidium-strontium dates and extraneous argon in the Arltunga Nappe Complex, Northern Territory. *Journal of the Geological Society of Australia*, 22, 103-15.

BEARD, J. S., & WEBB, M. J., 1974—Vegetation surveys of Western Australia: Sheet 2, Great Sandy Desert. 1:1 000 000 vegetation series map and explanatory notes. *University of Western Australia Press, Nedlands.*

BENNETT, R., PAGE, R. W., & BLADON, G. M., 1975—Catalogue of isotopic age determinations on Australian rocks, 1966-70. *Bureau of Mineral Resources, Australia, Report* 162.

BLACK, L. P., 1977—A Rb-Sr geochronological study in the Proterozoic Tennant Creek Block, central Australia. *BMR Journal of Australian Geology & Geophysics*, 2, 111-122.

BLAKE, D. H., 1974—Shallow stratigraphic drilling in The Granites-Tanami region, Northern Territory and Western Australia, 1971-73. *Bureau of Mineral Resources, Australia, Record* 1974/104 (unpublished).

BLAKE, D. H., 1975a—The Proterozoic of The Granites-Tanami, central Australia, and regional correlations. *The Geological Society of Australia Incorporated, Abstracts of First Australian Geological Convention—Proterozoic Geology—Adelaide, 1975*, 96.

BLAKE, D. H., 1975b—The Granites-Tanami project. *In* Geological Branch, Summary of Activities 1974. *Bureau of Mineral Resources, Australia, Report* 189, 58-60.

BLAKE, D. H., 1975c—Birrindudu, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-11.

BLAKE, D. H., 1977—Webb, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-10.

BLAKE, D. H., 1978—The Proterozoic and Palaeozoic rocks of The Granites-Tanami region, Western Australia and Northern Territory, and interregional correlations. *BMR Journal of Australian Geology & Geophysics*, 3, 35-42.

BLAKE, D. H., & HODGSON, I. M., 1976—The Precambrian Granites-Tanami Block and Birrindudu Basin—geology and mineralisation. *In* KNIGHT, C. L. (editor), ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA: VOLUME 1—METALS. *Australasian Institute of Mining and Metallurgy, Monograph* 5, 417-20.

BLAKE, D. H., & TOWNER, R. R., 1974—Geology of the Webb 1:250 000 Sheet area, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1974/53 (unpublished).

BLAKE, D. H., & YEATES, A. N., 1977—Stansmore, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-6.

BLAKE, D. H., HODGSON, I. M., & SMITH, P. A., 1972—Geology of the Birrindudu and Tanami 1:250 000 Sheet areas, Northern Territory. Report on the 1971 field season. *Bureau of Mineral Resources, Australia, Record* 1972/92 (unpublished).

BLAKE, D. H., HODGSON, I. M., & MUHLING, P. C., 1973—Geology of The Granites and Precambrian parts of Billiluna, Lucas and Stansmore 1:250 000 Sheet areas, Northern Territory and Western Australia. *Bureau of Mineral Resources, Australia, Record* 1973/171 (unpublished).

BLAKE, D. H., HODGSON, I. M., & SMITH, P. A., 1975—Geology of the Birrindudu and Tanami 1:250 000 Sheet areas, Northern Territory. *Bureau of Mineral Resources, Australia, Report* 174.

BLAKE, D. H., PASSMORE, V. L., & MUHLING, P. C., 1977—Billiluna, Western Australia—1:250 000 Geological Series. 2nd edition. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-14.

BMR, 1965a—Tanami—Total magnetic intensity and radioactivity map, 1:126 720, 4 sheets. *Bureau of Mineral Resources, Australia*, E52/B1—5 to 8.

BMR, 1965b—The Granites—Total magnetic intensity and radioactivity map, 1:126 720, 4 sheets. *Bureau of Mineral Resources, Australia*, F52/B1—5 to 8.

BMR, 1971—Birrindudu—Total magnetic intensity map, 1:126 720, *Bureau of Mineral Resources, Australia*, E52/B1-27-1 to 4.

BROWN, H. Y. L., 1909—Report on the Tanami gold country. *South Australia Parliamentary Paper* 105.

BUDDINGTON, A. F., 1959—Granite emplacement with special reference to North America. *Geological Society of America Bulletin*, 70, 671-747.

BULTITUDE, R. J., 1976—Flood basalts of probable early Cambrian age in northern Australia. *In* JOHNSON, R. W. (editor), VOLCANISM IN AUSTRALASIA. *Elsevier, Amsterdam*, 1-20.

CARNEGIE, D. W., 1898—SPINIFEX AND SAND. *Pearson, London.*

CASEY, J. N., & WELLS, A. T., 1964—The Geology of the north-east Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Report* 49.

CHAPPELL, B. W., & WHITE, A. J. R., 1974—Two contrasting granite types. *Pacific Geology*, 8, 173-4.

CLARK, A. B., 1961—Report on 1961 Surveys. Authority to Prospect No. 847 Northern Territory. *New Consolidated Gold Fields (Australasia) Pty Ltd* (unpublished).

CLARK, A. B., & BLOCKLEY, J. C., 1960—A report on a geological reconnaissance. Authority to Prospect 769, Northern Territory. *New Consolidated Gold Fields (Australasia) Pty Ltd* (unpublished).

CLARKE, D., 1975—Heavitree Quartzite stratigraphy and structure near Alice Springs, N.T. *The Geological Society of Australia Incorporated, Abstracts of First Australian Geological Convention—Proterozoic Geology—Adelaide, 1975*, 73.

CLARKE, D., 1976—Heavitree Quartzite. *In* WELLS, A. T., Geology of the late Proterozoic-Palaeozoic Amadeus Basin. *25th International Geological Congress Excursion Guide* 48A, 26-28.

COOPER, J. A., WELLS, A. T., & NICHOLAS, T., 1971—Dating of glauconite from the Ngalia Basin, Northern Territory, Australia. *Journal of the Geological Society of Australia*, 18, 97-106.

CROHN, P., 1961—Visit to Granites goldfield, October, 1960. *Bureau of Mineral Resources Australia, Record* 1961/157 (unpublished).

CROWE, R. W. A., & MUHLING, P. C., 1977—Lucas, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-2.

DALY, J., 1962—Granites geophysical survey, NT 1939. *Bureau of Mineral Resources, Australia, Record*, 1962/154 (unpublished).

DAVIDSON, A. A., 1905—Journal of explorations in central Australia by the Central Australian Exploration Syndicate Ltd. *South Australia Parliamentary Paper* 27.

DIVER, W. L., 1974—Precambrian microfossils of Carpentarian age from Bungle Bungle Dolomite of Western Australia. *Nature*, 247, 361-3.

DOW, D. B., & GEMUTS, I., 1969—Geology of the Kimberley region, Western Australia: the east Kimberley. *Bureau of Mineral Resources, Australia, Bulletin* 106.

DUNN, P. R., 1965—Notes on a field trip to the Northern Territory, 1965. *Bureau of Mineral Resources, Australia, Record* 1965/246 (unpublished).

DUNN, P. R., 1973—Mount Winnecke project annual report 1972-73 (E.L.'s 568-572). *Trend Exploration* (unpublished).

DUNN, P. R., PLUMB, K. A., & ROBERTS, H. G., 1966—A proposal for time-stratigraphic subdivision of the Australian Precambrian. *Journal of the Geological Society of Australia,* 13, 593-608.

EDWARDS, R. G., 1973—Final report E.L. 450—Tanami. *Conzinc Riotinto Australia Exploration Pty Ltd Report* N.T. 171 (unpublished).

FLAVELLE, A. J., & GOODSPEED, M. J., 1962—Fitzroy and Canning Basins, reconnaissance gravity surveys, Western Australia, 1952-60. *Bureau of Mineral Resources, Australia, Record* 1962/105 (unpublished).

FRASER, A. R., DARBY, F., & VALE, K. R., 1977—A qualitative analysis of the results of the reconnaissance gravity survey of Australia. *Bureau of Mineral Resources, Australia, Report* 198; *BMR Microform* MF15.

GEE, L. C. E., 1911—General report on Tanami goldfield and district (northwestern central Australia). *South Australia Parliamentary Paper* 31.

GELLATLY, D. C., 1971—Possible Archaean rocks of the Kimberley region, Western Australia. *Geological Society of Australia Special Publication* 3, 93-101.

GELLATLY, D. C., SOFOULIS, J., DERRICK, G. M., & MORGAN, C. M., 1974—The older Precambrian geology of the Lennard River 1:250 000 Sheet area, Western Australia. *Bureau of Mineral Resources, Australia, Report* 153.

GEMUTS, I., 1971—Metamorphic and igneous rocks of the Lamboo Complex, east Kimberley region, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 107.

GEMUTS, I., & SMITH, J. W., 1968—Gordon Downs, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-10.

GEOLOGICAL SOCIETY OF AUSTRALIA, 1971—Tectonic map of Australia and New Guinea 1:5 000 000. *Geological Society of Australia, Sydney.*

GREGORY, A. C., 1857—Papers relating to an expedition recently undertaken for the purpose of exploring the northern portion of Australia. *British Parliamentary Paper, London.*

GOUDIE, A., 1972—On the definition of calcrete deposits. *Zeitschrift für Geomorphologie N.F.* 16, 464-8.

GUPPY, D. J., & MATHESON, R. S., 1950—Wolf Creek Meteorite Crater, Western Australia. *Journal of Geology,* 58, 30.

HALL, G., 1953—The Granites goldfield. *In* EDWARDS, A. B. (editor), GEOLOGY OF AUSTRALIAN ORE DEPOSITS. *5th Empire Mining and Metallurgical Congress Publications,* 1, 317-21.

HATCH, F. G., WELLS, A. K., & WELLS, M. K., 1961—PETROLOGY OF THE IGNEOUS ROCKS. 12th edition. *Murby, London.*

HAYS, J., 1967—Land surfaces and laterites in the north of the Northern Territory. *In* JENNINGS, J. N., & MABBUTT, J. A. (editors), LANDFORM STUDIES FROM AUSTRALIA AND NEW GUINEA. *Australian National University Press, Canberra,* 182-210.

HODGSON, I. M., 1974—Geology of the Highland Rocks 1:250 000 Sheet area, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1974/120 (unpublished).

HODGSON, I. M., 1975—Tanami, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-15.

HODGSON, I. M., 1976—The Granites, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-3.

HODGSON, I. M., 1977—Highland Rocks, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-7.

HOSSFELD, P. S., 1940a—Preliminary report on The Granites goldfield, Central Australia. *Aerial Geological and Geophysical Survey of Northern Australia, Northern Territory Report* 30.

HOSSFELD, P. S., 1940b—The gold deposits of the Granites-Tanami district, Central Australia. *Aerial Geological and Geophysical Survey of Northern Australia, Northern Territory Report* 43.

HOSSFELD, P. S., 1954—Stratigraphy and structure of the Northern Territory of Australia. *Transactions of the Royal Society of South Australia,* 77, 103-61.

HULEATT, M. B., 1978a—Winnecke Creek, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-12.

HULEATT, M. B., 1978b—Tanami East, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/52-16.

JENSEN, H. I., 1915—Report on the country between Pine Creek and Tanami. *Bulletin of the Northern Territory* 14.

JOKLIK, G. F., 1955—The geology and mica-fields of the Harts Range, central Australia. *Bureau of Mineral Resources, Australia, Bulletin* 26.

JONES, B. G., 1975—Devonian conglomerate deposition, Amadeus Basin, central Australia. *The Geological Society of Australia Incorporated, Abstracts of First Australian Geological Convention—Proterozoic Geology—Adelaide, 1975,* 71.

KLARIC, R., 1972—Reconnaissance airborne radiometric survey, The Granites/Tanami area, N.T. and W.A. *Conzinc Riotinto Australia Exploration Pty Ltd Report* NT 103 (unpublished).

KLEEMAN, A. W., 1934—An adamellite from "The Granites", Northern Territory. *Transactions of the Royal Society of South Australia,* 58, 234-6.

MCCALL, G. J. H., 1973—METEORITES AND THEIR ORIGINS. *David & Charles. Newton Abbot.*

MACKAY, D. F., 1934—The Mackay aerial survey expedition to central Australia. *Geographical Journal,* 84, 511-4.

MARJORIBANKS, R. W., & BLACK, L. P., 1974—Geology and geochronology of the Arunta Complex, north of Ormiston Gorge, central Australia. *Journal of the Geological Society of Australia,* 21, 291-9.

MAWSON, D., & MADIGAN, C. T., 1930—Pre-Ordovician rocks of the MacDonnell Ranges (central Australia). *Quarterly Journal of the Geological Society,* 86, 415-29.

MENDUM, J. R., & TONKIN, P. C., in prep.—Geology of the Tennant Creek 1:250 000 Sheet area, Northern Territory. *Bureau of Mineral Resources, Australia, Record* (unpublished).

MILLIGAN, E. N., SMITH, K. G., NICHOLS, R. A. H., & DOUTCH, H. F., 1966—Geology of the Wiso Basin, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1966/47 (unpublished).

MIYASHIRO, A., 1973—METAMORPHISM AND METAMORPHIC BELTS. *Allen & Unwin, London.*

MULDER, J. M., 1961—Gardiner Range, Killi Killi, and Tanami airborne radiometric survey, N.T. and W.A. 1961. *Bureau of Mineral Resources, Australia, Record* 1961/152 (unpublished).

NICHOLAS, T., 1969—The geology of the Lake Mackay Sheet area, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1969/89 (unpublished).

NICHOLAS, T., 1972—Lake Mackay, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/52-11.

PAGE, R. W., 1976—Reinterpretation of isotopic ages from the Halls Creek Mobile Zone, northwestern Australia. *BMR Journal of Australian Geology & Geophysics,* 1, 79-81.

PAGE, R. W., BLAKE, D. H., & MAHON, M .W., 1976—Geochronology and related aspects of acid volcanics, associated granites, and other Proterozoic rocks in The Granites-Tanami region, northwestern Australia. *BMR Journal of Australian Geology & Geophysics,* 1, 1-13.

PATERSON, S. J., 1970—Geomorphology of the Ord-Victoria area. *CSIRO Land Research Series* 28, 83-91.

PERRY, R. A., 1970—Vegetation of the Ord-Victoria area. *CSIRO Land Research Series* 28, 104-19.

PETTIJOHN, F. J., POTTER, P. E., & SIEVER, R., 1972—SAND AND SANDSTONE. *Springer-Verlag, Berlin.*

PHILLIPS, K. M., 1959—Geological reconnaissance, Tanami-Granites district, September-October 1959; and aerial reconnaissance, Tanami Desert, December 1959. *Consolidated Zinc Pty Ltd Report,* N.T. 103 (unpublished).

PHILLIPS, K. M., 1961—Tanami/The Granites, N.T. Geological maps and 1":4000' and 1":400' plans. *Consolidated Zinc Pty Ltd* (unpublished).

PHILLIPS, K. M., 1962—Tanami, Northern Territory. Report of activities on Authority to Prospect No. 845 from March 1961 to March 1962; and an assessment of the status of this project. *Consolidated Zinc Pty Ltd Report,* N.T. 171 (unpublished).

PLAYFORD, G., JONES, B. G., & KEMP, E. M., 1976—Palynological evidence for the age of the synorogenic Brewer Conglomerate, Amadeus Basin, central Australia. *Alcheringa,* 1, 235-43.

PLUMB, K. A., & DERRICK, G. M., 1975—Proterozoic geology of the Kimberley to Mount Isa region. *In* KNIGHT, C. L. (editor), ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA: VOLUME 1—METALS, *Australasian Institute of Mining and Metallurgy, Monograph* 5, 217-252.

PLUMB, K. A., & SWEET, I. P., 1974—Regional significance of recent correlations across the Murphy Tectonic Ridge, Westmoreland area. *Proceedings of the Australasian Institute of Mining and Metallurgy, North-west Queensland Branch, regional meeting, August, 1974.*

PRICHARD, C. E., DALLWITZ, W. B., & ROBERTS, W. M. B., 1960—The Killi Killi uranium prospects, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1960/140 (unpublished).

RANFORD, L. C., COOK, P. J., & WELLS, A. T., 1966—Geology of the central part of the Amadeus Basin, Northern Territory. *Bureau of Mineral Resources, Australia, Report* 86.

REEVES, F., & CHALMERS, R. O., 1949—The Wolf Creek meteorite crater. *Australian Journal of Science,* 11(5), 154-6.

ROBERTS, H. G., 1968—Final report Prospecting Authority 1945, Tanami district, Northern Territory. *Anaconda Australia Inc. Report* E52/15/1(2) (unpublished).

ROBERTS, H. G., GEMUTS, I., & HALLIGAN, R., 1972—Adelaidean and Cambrian stratigraphy of the Mount Ramsay 1:250 000 Sheet area, Kimberley region, Western Australia. *Bureau of Mineral Resources, Australia, Report* 150.

SENIOR, B. R., & SENIOR, D. A., 1972—Silcrete in south-west Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 125, 25-31.

SIMPSON, C. J., 1971—Report of photo-interpretation of the Birrindudu and Tanami 1:250 000 scale Sheets—Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1971/62 (unpublished).

SIMPSON, C. J., 1972—The Granites-part of Highland Rocks 1:250 000 photogeological sketch map, SF/52-3, 7. *Bureau of Mineral Resources, Australia* (unpublished).

SOMINA, M. Y., & BULAKH, A. G., 1966—[Florencite from the carbonatites of Eastern Sayan and the chemical constitution of the crandallite group] in Russian. *Zapiski Vsesoiuznogo Mineralogicheskogo Obshchestva,* 95, 537-550. Also Mineralogical Abstracts, 18, 204 (1967).

SPENCE, A. G., 1964—Tanami/The Granites airborne magnetic and radiometric survey, Northern Territory, 1962. *Bureau of Mineral Resources, Australia, Record* 1964/102 (unpublished).

STEWART, A. J., 1976—The Arunta Block. *25th International Geological Congress Excursion Guide* 47C, 1-6.

SWEET, I. P., 1977—Precambrian geology of the Victoria River region, Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 168.

SWEET, I. P., MENDUM, J. R., BULTITUDE, R. J., & MORGAN, C. M., 1974—The geology of the southern Victoria River region, Northern Territory. *Bureau of Mineral Resources, Australia, Report* 167.

TALBOT, H. W. B., 1910—Geological observations in the country between Wiluna, Halls Creek, and Tanami. *Geological Survey of Western Australia, Bulletin* 39.

TERRY, M., 1927—THROUGH A LAND OF PROMISE. *Jenkins, London.*

TERRY, M., 1930—A journey through the north-west of Central Australia in 1928. *Geographical Journal* 75, 218-24.

TERRY, M., 1931—HIDDEN WEALTH AND HIDING PEOPLE. *Putnam, London.*

TERRY, M., 1934—Explorations near the border of Western Australia. *Geographical Journal,* 84, 498-510.

TERRY, M., 1937—SAND AND SUN. *Michael Joseph, London.*

THORNTON, C. P., & TUTTLE, O. F., 1960—Chemistry of igneous rocks. I. Differentiation index. *American Journal of Science,* 258, 664-84.

TRAVES, D. M., 1955—The geology of the Ord-Victoria region, northern Australia. *Bureau of Mineral Resources, Australia, Bulletin* 27.

TRAVES, D. M., DUNN, P. R., & JONES, P. J., 1970—Outline of the geology of the Ord-Victoria area. *CSIRO Land Research Series* 28, 75-82.

TURNER, F. J., & VERHOOGEN, J., 1960—IGNEOUS AND METAMORPHIC PETROLOGY. 2nd edition. *McGraw-Hill, New York.*

TWIGG, A. R., 1970—Final reports on A.P. 2356, 2557, 2558, 2559. *Geopeko Ltd* (unpublished).

VEEVERS, J. J., & WELLS, A. T., 1961—The geology of the Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 60.

WALTER, M. R., 1972—Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian. *Palaeontological Association, London, Special Paper* 11.

WALTER, M. R., & PREISS, W. V., 1972—Distribution of stromatolites in the Precambrian and Cambrian of Australia. *Proceedings of the 24th International Geological Congress, Section 1, Precambrian Geology,* 85-93.

WARBURTON, P. E., 1875—Diary of Colonel Warburton's exploring expedition to Western Australia in 1872-3. *South Australia Parliamentary Paper* 28.

WEEKES, J. C. W., 1976—Miscellaneous chemical, petrographic and mineragraphic investigations carried out in the geological laboratory, January-December, 1975. *Bureau of Mineral Resources, Australia, Record* 1976/55 (unpublished).

WELLS, A. T., 1962a—Billiluna, W.A. 4-Mile Geological Series, Sheet E/52-14. *Bureau of Mineral Resources, Australia, Explanatory Notes* 24.

WELLS, A. T., 1962b—Lucas, W.A. 4-Mile Geological Series, Sheet F/52-2. *Bureau of Mineral Resources, Australia, Explanatory Notes* 25.

WELLS, A. T., 1962c—Stansmore, W.A. 4-Mile Geological Series, Sheet F/52-6. *Bureau of Mineral Resources, Australia, Explanatory Notes* 27.

WELLS, A. T., 1976—Geology of the late Proterozoic-Palaeozoic Amadeus Basin. *25th International Geological Congress Excursion Guide* 48A.

WELLS, A. T., FORMAN, D. J., & RANFORD, L. C., 1964—Geological reconnaissance of the Rawlinson and McDonald 1:250 000 Sheet areas, Western Australia. *Bureau of Mineral Resources, Australia, Report* 65.

WELLS, A. T., FORMAN, D. J., RANFORD, L. C., & COOK, P. J., 1970—Geology of the Amadeus Basin, central Australia. *Bureau of Mineral Resources, Australia, Bulletin* 100.

WELLS, A. T., MOSS, F. J., & SABITAY, A., 1972—The Ngalia Basin, Northern Territory—recent geological and geophysical information upgrades petroleum prospects. *APEA Journal* 12, 144-51.

WHITWORTH, R. I., 1970—Reconnaissance gravity survey of parts of Northern Territory and Western Australia 1967. *Bureau of Mineral Resources, Australia, Record* 1970/15 (unpublished).

WINCHELL, A. N., 1951—ELEMENTS OF OPTICAL MINERALOGY. PART II. DESCRIPTIONS OF MINERALS. 4th edition. *Wiley, New York.*

YEATES, A. N., CROWE, R. W. A., TOWNER, R. R., WYBORN, L. A. I., & PASSMORE, V. L., 1975—Notes on the geology of the Gregory Sub-basin and adjacent areas of the Canning Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* 1975/77 (unpublished).

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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GEOLOGY OF THE GRANITES-TANAMI REGION, NORTHERN TERRITORY AND WESTERN AUSTRALIA

by

D.H. BLAKE, I.M. HODGSON, & P.C. MUHLING

APPENDIX: DEFINITIONS OF FORMALLY NAMED ROCK UNITS EXPOSED IN THE GRANITES-TANAMI REGION

THE GRANITES-TANAMI BLOCK

Tanami Complex (Blake & others, 1975)

Derivation of name:	Tanami, an abandoned gold mining settlement, 19°57'S, 129°42'E, Tanami 1:250 000 Sheet area.
Distribution:	Birrindudu, Tanami, Billiluna, Lucas, and The Granites 1:250 000 Sheet areas.
Names and lithological affinities of constituent units:	Killi Killi Beds, Mount Charles Beds, Nanny Goat Creek Beds, Nongra Beds, Helena Creek Beds; low grade regionally metamorphosed sedimentary and volcanic rocks; all units contain greywacke and some volcanics.
Thickness:	Not known; probably several thousand metres; base not exposed.
Age:	Early Proterozoic, correlated with Halls Creek Group.
Fossils:	None known.
Relations:	Overlain unconformably by Pargee Sandstone, Supplejack Downs Sandstone, Birrindudu Group, Redcliff Pound Group, and Antrim Plateau Volcanics. Intruded by Proterozoic granites.
Synonomy:	Part previously termed Tanami Metamorphic Series (Jensen, 1915); in Western Australia previously mapped as Halls Creek Metamorphics (Casey & Wells 1964) and undivided Halls Creek Group (Dow & Gemuts, 1969).

Killi Killi Beds (Blake & others, 1975)

Derivation of name:	Killi Killi Hills, on the Northern Territory - Western Australia border at latitude 19°45'S, Tanami and Billiluna 1:250 000 Sheets.
Distribution:	Tanami, Billiluna, Lucas, and The Granites Sheet areas.
Lithology:	Schistose greywacke, lithic arenite, siltstone, mudstone; minor quartzite, banded chert, basalt, dolerite, gabbro, acid volcanics.
Reference area:	At 19°13'30"S, 128°54'30"E, 5 km south of Mount Stubbins, Gardner Range, Billiluna Sheet area, where the main rock types of the unit are well exposed in a series of tight folds.
Thickness:	Probably several thousand metres.
Age:	Early Proterozoic.
Relations:	Part of the Tanami Complex. Probably stratigraphically equivalent to the other units of the complex from which it is separated geographically. Unconformably overlain by Pargee Sandstone, Birrindudu Group, and Redcliff Pound Group; intruded by Proterozoic granites.
Synonomy:	Previously mapped in Western Australia as Halls Creek Metamorphics (Casey & Wells, 1964) and Halls Creek Group (Dow & Gemuts, 1969).

Mount Charles Beds (Blake & others, 1975)

Derivation of name:	Mount Charles, 19°50'00"S, 129°50'40"E, 22 km northeast of Tanami, Tanami 1:250 000 Sheet area.

Distribution:	Tanami and The Granites Sheet areas.
Lithology:	Thin-bedded to laminated chert, silicified siltstone; subordinate phyllitic to schistose greywacke, siltstone and shale, quartzite, gossanous quartz-ironstone, jaspilite, altered basalt, acid porphyry.
Reference area:	Vicinity of Mount Charles, Tanami Sheet area, where thinly interbedded chert, quartzite and phyllite, and basalt and greywacke, are exposed.
Thickness:	Probably several thousand metres.
Age:	Early Proterozoic.
Relations:	Part of the Tanami Complex. Probably stratigraphically equivalent to other units of the complex, from which it is separated geographically. Overlain unconformably by Pargee Sandstone, Birrindudu Group, Redcliff Pound Group and Antrim Plateau Volcanics; intruded by Proterozoic granites.
Synonomy:	Part mapped as Tanami Metamorphic Series by Jensen (1919).

<u>Nanny Goat Creek Beds</u> (Blake & others, 1975)

Derivation of name:	Nanny Goat Creek, the main tributary of Wilson Creek, northeast part of Tanami 1:250 000 Sheet area.
Distribution:	Northeast part of Tanami Sheet area.
Lithology:	Acid porphyry, basalt, tuff; minor greywacke, lithic arenite, phyllitic to schistose shale and siltstone, banded chert.

Reference area: Along latitude 19 06'10"S for two kilometres eastwards from the Tanami-Hooker Creek track, Tanami Sheet area. Here vertically cleaved acid porphyry crops out to west of interbedded sandstone, greywacke, shale, and siltstone, and amygdaloidal basalt.

Thickness: Probably several thousand metres.

Age: Early Proterozoic.

Relations: Part of the Tanami Complex. Probably stratigraphically equivalent to other units of the complex, from which it is separated geographically. Overlain unconformably by Supplejack Downs Sandstone and Gardiner Sandstone; probably intruded by Winnecke Granophyre.

Synonomy: None.

<u>Nongra Beds</u> (Blake & others, 1975)

Derivation of name: Nongra Lake, $18^{o}12'$S, $129^{o}45'$E, Birrindudu 1:250 000 Sheet area.

Distribution: Birrindudu and probably Tanami Sheet areas.

Lithology: Phyllitic shale, siltstone, greywacke, and lithic arenite; banded chert, tuff, acid porphyry.

Reference area: At $19^{o}42'50''$S, $129^{o}43'10''$E, 48 km southeast of Birrindudu homestead, Birrindudu Sheet area, where steeply to vertically dipping phyllite, arenite, chert, and acid porphyry are exposed.

Thickness: Probably several thousand metres.

Age: Early Proterozoic.

Relations: Part of the Tanami Complex. Probably stratigraphically equivalent to other units of the complex, from which it is separated geographically. Overlain unconformably by Gardiner Sandstone.

Synonymy: None.

Helena Creek Beds (Blake & others, 1975)

Derivation of name: Helena Creek, 18°15'S, 130°15'E, Birrindudu 1:250 000 Sheet area.

Distribution: Northeast part of Birrindudu Sheet area.

Lithology: Greywacke, tuff, phyllite, conglomerate, lithic arenite, acid porphyry.

Reference area: 35 km east of Nongra Lake, between points 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, where massive, closely jointed tuff, thin-bedded to laminated tuff, porphyry, and hornfels crop out.

Thickness: Probably over 1000 m.

Age: Early Proterozoic.

Relations: Part of the Tanami Complex. Geographically isolated from other units of the complex. Probably overlain unconformably by Antrim Plateau Volcanics; intruded by the Winnecke Granophyre.

Synonymy: None.

Mount Winnecke Formation (Blake & others, 1975)

Derivation of Name: Mount Winnecke, $15^{\circ}46'06''$S, $130^{\circ}19'50''$E, Birrindudu Sheet area.

Distribution: Birrindudu and Tanami Sheet areas.

Lithology: Sublithic arenite, tuffaceous sandstone and siltstone, acid lava; minor conglomerate, laminated tuff, lapilli tuff, mudstone, and agglomerate.

Type section: Across north side of structural basin north of Mount Winnecke, from $18^{\circ}37'55''$S, $130^{\circ}21'20''$E to $18^{\circ}42'40''$S, $130^{\circ}27'10''$E. Section consists of southerly dipping tuffaceous sandstone (200 m). overlain successively by lithic sandstone (1820 m), tuffaceous sandstone and siltstone (280 m), lithic sandstone (140 m), tuffaceous sandstone (140 m), lithic sandstone (1220 m), porphyritic acid lava (520 m), lithic sandstone (230 m), and acid lava (250 m): total thickness 4800 m.

Thickness: At least 4800 m.

Age: Late Early Proterozoic; acid lavas isotopically dated at 1808 $\pm$ 15 m.y. (Page & others, 1976).

Fossils: None known.

Relations: Intruded by Winnecke Granophyre; overlain possibly conformably by Supplejack Downs Sandstone, and in the Black Hills area probably unconformably by Gardiner Sandstone; unconformably overlain by Cambrian rocks east of the Winnecke Range.

Synonomy: Mapped as Mount Winnecke Sandstone by Traves (1955); renamed Mount Winnecke Formation because of voluminous acid volcanics in the sequence.

<u>Supplejack Downs Sandstone</u> (Blake & others, 1975)

Derivation of name: Supplejack Downs homestead, 19°17'00"S, 129°56'15"E, Tanami Sheet area.

Distribution: Northeast part of Tanami Sheet area.

Lithology: Sublithic arenite, quartz arenite, shale, and siltstone.

Type section: Across southern end of a strike ridge 11 km east of Supplejack Downs homestead, at 19°16'50"S, 130°02'45"E. Here 100 m of westerly dipping, medium bedded, medium-grained arenites are exposed.

Thickness: At least 1300 m.

Age: Late Early Proterozoic.

Fossils: None known.

Relations: Overlies Mount Winnecke Formation, possibly conformably, and is unconformable on Nanny Goat Creek Beds; overlain unconformably by Antrim Plateau Volcanics and probably also by Gardiner Sandstone.

Synonomy: None.

Pargee Sandstone (Blake & others, 1975)

Derivation of name: Pargee Range, 19°35'S, 129°15'E, Tanami Sheet area.

Distribution: Tanami, Billiluna, and The Granites Sheet areas.

Lithology: Sublithic arenite, lithic arenite, quartz arenite, conglomerate, and greywacke.

Type section: For 800 m along a gully between 19°38'20"S, 129°12'30"E, and 19°38'30"S, 129°12'15"E, west of the Pargee Range, Tanami Sheet area. Here 700 m of cross-bedded, medium to coarse-grained arenites and interbeds of pebble conglomerate are exposed, dipping 70° southwest.

Thickness: At least 1500 m.

Age: Late Early Proterozoic.

Fossils: None known.

Relations: Unconformable on Killi Killi Beds and Mount Charles Beds of the Tanami Complex; unconformably overlain by Gardiner Sandstone.

Synonomy: None.

Winnecke Granophyre (Traves, 1955; Blake & others, 1975)

Derivation of name: Winnecke Creek, 18°45'S, 130°20'E, Birrindudu Sheet area.

Distribution: East part of Birrindudu and northeast part of Tanami Sheet areas.

Type area: At $18^{o}46'$S, $130^{o}12'$E, on the west side of the Tanami-Hooker Creek track to the north of Winnecke Creek, where the Winnecke Granophyre is particularly well exposed.

Lithology: Biotite granophyre, biotite adamellite, acid porphyry.

Relations: Intrudes Mount Winnecke Formation, and probably also Nanny Goat Creek Beds and Helena Creek Beds of the Tanami Complex; overlain by Antrim Plateau Volcanics.

Age: Late Early Proterozoic; isotopically dated at 1802 $\pm$ 15 m.y. (Page & others, 1976).

Synonomy: None.

The Granites Granite (Hodgson, 1976)

Derivation of name: The Granites, an abandoned gold-mining settlement, $20^{o}33'30''$S, $129^{o}21'30''$E, The Granites Sheet area.

Distribution: East part of The Granites Sheet area and western margin of adjoining Mount Solitaire Sheet area.

Type area: Prominent tors and groups of spheroidal boulders 1 km S of The Granites,, at $20^{o}34'30''$S, $129^{o}21'10''$E.

Lithology: Pink and grey porphyritic and non-porphyritic biotite adamellite; minor pegmatite and aplite; locally foliated.

Age: Late Early Proterozoic or early Carpentarian: isotopically dated at 1780 $\pm$ 24 m.y. (Page and others, 1976).

Relations:	Intrudes the Mount Charles Beds of the Tanami Complex; overlain by Muriel Range Sandstone.
Synonomy:	None.

<u>Slatey Creek Granite</u> (Blake & others, 1977)

Derivation of name:	Slatey Creek, 19°19'S, 128°145'E, Billiluna Sheet area.
Distribution:	East part of Billiluna Sheet area.
Type area:	Scarp at 19°22'S, 128°41'30"E, where unweathered muscovite and muscovite-biotite adamellite are exposed, intrusive into Killi Killi Beds, and overlain by 30 m of Lewis Range Sandstone.
Lithology:	Porphyritic and non-porphyritic mainly medium to fine-grained muscovite, biotite-muscovite, and biotite adamellite; minor biotite granodiorite, pegmatite and aplite veins.
Age:	Late Early Proterozoic or early Carpentarian; isotopically dated at 1770 ± 62 m.y. (Page & others, 1976).
Relations:	Intrudes the Killi Killi Beds of the Tanami Complex; overlain by Gardiner Sandstone and Lewis Range Sandstone.
Synonomy:	Mapped as part of the Lewis Granite by Casey & Wells (1964).

<u>Lewis Granite</u> (modified after Casey & Wells, 1964)

Derivation of name:	Lewis Range, 20°05'S, 128°30'E, Lucas Sheet area.

Distribution: Northeast part of Lucas Sheet area.

Lithology: Muscovite and muscovite-biotite adamellite; minor biotite adamellite, biotite granodiorite; pegmatite and aplite veins common.

Type area: Hill 1 km west-northwest of Point Nelligan, at $20^{o}11'30''S$, $128^{o}38'00''E$, northeast side of Lewis Range, Lucas Sheet area, where the main varieties of the Lewis Granite are well exposed.

Age: Early Carpentarian; isotopically dated at 1720 ± 8 m.y. (Page & others, 1976).

Relations: Intrudes the Killi Killi Beds of the Lower Proterozoic or Archaean Tanami Complex; overlain by Carpentarian Gardiner Sandstone and Adelaidean Lewis Range Sandstone.

Synonomy: Previously included all granite cropping out in Billiluna and Lucas Sheet areas (Casey & Wells, 1964).

HALLS CREEK PROVINCE

Halls Creek Group (Dow & Gemuts, 1969)

Derivation of name: Halls Creek township, $18^{o}14'S$, $127^{o}41'E$, Gordon Downs Sheet area.

Distribution: Southeast and southwest Kimberley region, WA.

Constituent formations and lithological affinities: Ding Dong Downs Volcanics, Saunders Creek Formation, Biscay Formation, and Olympio Formation; low grade regionally metamorphosed sedimentary rocks (mainly greywacke and siltstone) and basic and acid volcanic rocks.

Thickness:	Probably several thousand metres.
Age:	Early Proterozoic; older than 1961 ± 27 m.y. and probably younger than 2200 m.y. (Page, 1976).
Fossils:	None known.
Relations:	Overlain unconformably by Early Proterozoic and Carpentarian sedimentary rocks; intruded by Early Proterozoic granites.
Synonomy:	Halls Creek Metamorphics of Traves (1955).

<u>Biscay Formation</u> (Dow & Gemuts, 1969)

Derivation of name:	Bay of Biscay Hills, 17°48'S, 128°05'E, Dixon Range Sheet area.
Distribution:	East Kimberley region, including west part of Gordon Downs Sheet area.
Lithology:	Basic volcanics and intrusive rocks.
Reference area:	Core of Biscay Anticlinorium, Dixon Range Sheet area.
Thickness:	Unknown because of isoclinal folding; probably 1000 m.
Age:	Early Proterozoic.
Relations:	Part of Halls Creek Group. Conformable between Saunders Creek Formation below and Olympio Formation above.

Olympio Formation (Dow & Gemuts, 1969)

Derivation of name: Olympio Creek, 35 km north-northeast of Halls Creek, Dixon Range Sheet area.

Distribution: East Kimberley region, including northwest part of Billiluna and west part of Gordon Downs Sheet areas.

Lithology: Mainly schistose to phyllite greywacke, siltstone, shale.

Reference area: Middle reaches of Parton River, north of Saunders Creek area, Dixon Range Sheet area.

Thickness: Unknown, probably several thousand metres.

Age: Early Proterozoic; metamorphism isotopically dated at 1961 ± 27 m.y. Conformably on Biscay Formation; part of Halls Creek Group.

Relations: Overlain unconformably by Carpentarian Mount Parker Sandstone in Billiluna and Gordon Downs Sheet areas.

ARUNTA BLOCK

Arunta Complex (Mawson & Madigan, 1930)

Derivation of name: Arunta, a central Australian aboriginal tribe.

Distribution: Arunta Block, central Australia, including parts of Stansmore, Webb, The Granites, Highland Rocks, and Lake Mackay Sheet areas.

Lithology: Low to high-grade regional metamorphic rocks; quartzite, schist and gneiss in The Granites-Tanami region.

Thickness:	Unknown; probably several thousand metres.
Age:	Early Proterozoic; older than regional metamorphisms dated at about 1800 m.y. and 1700 m.y. (Stewart, 1976).
Relations:	In The Granites-Tanami region, overlain unconformably by Redcliff Pound Group, Heavitree Quartzite, and probably Pollock Hills Formation; intruded by Mount Webb Granite and unamed granites.

<u>Pollock Hills Formation</u> (new name)

Derivation of name:	Pollock Hills, 22°50'S, 127°40'E, Webb Sheet area.
Distribution:	Pollock Hills, southwest part of Webb Sheet area.
Lithology:	Porphyritic acid lava, lithic and sublithic arenite and tuffaceous sandstone; minor tuffaceous siltstone and conglomerate, lapilli tuff, agglomerate.
Type section:	Across part of the Pollock Hills, from 22°50'S, 127°40'E (base) to 22°49'S, 127°38'E (top), where acid lava is overlain by 600 m of westerly dipping, medium to thin-bedded lithic and sublithic arenite and tuffaceous sandstone.
Thickness:	Probably over 1000 m.
Age:	Carpentarian; acid lava isotopically dated at 1510 $\pm$ 240 m.y. and, when combined with Mount Webb granite, 1526 $\pm$ 25 m.y. (Page & others, 1976).

Fossils: None found.

Relations: Inferred to be unconformable on Arunta Complex; intruded by Mount Webb Granite; overlain unconformably by Heavitree Quartzite.

Synonomy: None.

Mount Webb Granite (Blake, 1977)

Derivation of name: Mount Webb, 22°56'30"S, 128°08'30"E, Webb Sheet area.

Distribution: South part of Webb Sheet Area.

Lithology: Medium to coarse-grained biotite adamellite, locally containing either hornblende or augite or both, commonly foliated; minor aplite veins.

Type area: Prominent tor at 22°50'00"S, 127°50'30"E, 32 km west-northwest of Mount Webb, formed of unweathered weakly foliated biotite adamellite, cut by sparse aplite veins.

Age: Carpentarian; isotopically dated at 1520 ± 40 m.y. (Page & others, 1976).

Relations: Intrudes Arunta Complex and Pollock Hills Formation; cut by basic dykes; overlain by Heavitree Quartzite.

Synonomy: None.

BIRRINDUDU BASIN

Birrindudu Group (Blake & others, 1975)

Derivation of name: Birrindudu homestead, 18°23'30"S, 129°26'30"E, Birrindudu Sheet area.

Distribution: Birrindudu, Tanami, The Granites, Billiluna and Lucas Sheet areas.

Constituent formations and lithological affinities: Gardiner Sandstone, Talbot Well Formation, Coomarie Sandstone; predominantly sublithic arenite and quartz arenite, although the middle unit also contains much stromatolitic chert.

Thickness: At least 6000 m.

Age: Carpentarian; isotopic data for glauconite from Gardiner Sandstone indicate age of about 1560 m.y.

Relations: Unconformable on Tanami Complex, Pargee Sandstone, various granites, and probably Supplejack Downs Sandstone, Mount Winnecke Formation and Winnecke Granophyre; overlain unconformably by Redcliff Pound Group and Antrim Plateau Volcanics.

Synonomy: None.

Gardiner Sandstone (Blake & others, 1975)

Derivation of name: Gardner Range, Billiluna and Tanami 1:250 000 Sheet areas.

Distribution: Tanami, Birrindudu, The Granites, Billiluna and Lucas Sheet areas.

Lithology: Sublithic arenite; subordinate quartz arenite, conglomerate, shale, siltstone, glauconitic sandstone; dolomitic sandstone at one locality.

Type section: At Larranganni Bluff, 19°33'45"S, 128°57'45"E, Billiluna Sheet area. Described by Casey & Wells (1964); consists of basal conglomerate 12 m thick overlain in turn by 36 m of partly micaceous laminated arenite, 30 m of flaggy arenite and minor interbedded shale, and 18 m of cross-bedded ripple-marked arenite.

Thickness: Maximum exposed about 3000 m.

Age: Carpentarian; isotopic K-Ar and Rb-Sr data on glauconite indicate age of about 1560 m.y. (Page & others, 1976).

Fossils: None known.

Relations: Part of the Birrindudu Group. Unconformable on Tanami Complex, Pargee Sandstone, Slatey Creek Granite, Lewis Granite, unnamed granites, and probably also Mount Winnecke Formation, Supplejack Downs Sandstone, and Winnecke Granophyre; overlain conformably by Talbot Well Formation, and unconformably by Redcliff Pound Group and Antrim Plateau Volcanics.

Synonomy: Gardiner Beds of Casey & Wells (1964).

Talbot Well Formation (Blake & others, 1975)

Derivation of name: Talbot Well, 19°33'50"S, 129°55'20"E, Tanami Sheet area.

Distribution: Birrindudu, Tanami, The Granites, Billiluna and probably Lucas Sheet areas.

Lithology: Chert, which is commonly stromatolitic, sublithic arenite, laminated siltstone and shale, cherty arenite, limestone.

Type section: West side of the Supplejack Range, Tanami Sheet area, at 19°16'45"S, 129°54'00"E, where about 200 m of stromatolitic chert overlies some 10 m of thinly interbedded shale, siltstone and flaggy arenite; which lie conformably on quartz arenite of the Gardiner Sandstone.

Thickness: Maximum exposed about 300 m.

Age: Carpentarian.

Fossils: Stromatolites.

Relations: Part of the Birrindudu Group. Conformable on Gardiner Sandstone and conformably overlain by Coomarie Sandstone.

Synonomy: None.

Coomarie Sandstone (Blake & others, 1975)

Derivation of name: Coomarie Range, and Coomarie Spring, 19°41'00"S, 128°46'35"E Tanami Sheet area.

Distribution: Birrindudu, Tanami, and Billiluna Sheet areas.

Lithology: Sublithic arenite; minor quartz arenite, siltstone, shale.

Type section: At latitude 19°15'S, across the western limb of the syncline between longitudes 129°12'10"E and 129°13'10"E, Tanami Sheet area, where about 170 m of medium-grained sublithic arenite, dipping 10° west, is separated by a sand plain, 700 m wide, from an overlying more steeply dipping sequence, about 500 m thick, of fine to medium-grained arenites and minor interbedded shale.

Thickness:	About 2500 m.
Age:	Carpentarian.
Fossils:	None known.
Relations:	Youngest unit of the Birrindudu Group. Conformable on Talbot Well Formation, and unconformably overlain by Antrim Plateau Volcanics.
Synonomy:	None.

Limbunya Group (Sweet & others, 1974)

Derivation of name:	Limbunya pastoral lease, Limbunya Sheet area.
Distribution:	Extends southwards from Limbunya Sheet area into northeast part of Birrindudu Sheet area.
Lithology:	Carbonate and fine-grained clastic sedimentary rocks; minor coarse clastics. Medium to fine-grained sublithic arenite, quartz arenite, and possibly minor conglomerate and stromatolitic chert in Birrindudu Sheet area.
Thickness:	At least 400 m in Birrindudu Sheet area.
Age:	Probably Carpentarian
Fossils:	Stromatolites
Relations:	Overlain unconformably by Antrim Plateau Volcanics in Birrindudu Sheet area; unconformable on Inverway Metamorphics and Bunda Grit and overlain unconformably by Wattie Group to north.

Baines Beds (Blake & others, 1977)

Derivation of name: Baines Hills, 19°20'S, 128°08'E. Billiluna Sheet area.

Distribution: Baines Hills and Elsey Hills, Billiluna Sheet area.

Lithology: Quartz arenite, sublithic arenite, greywacke, lithic arenite, conglomeratic sublithic arenite.

Reference area: The Baines Hills, between 19°22'12"S, 128°08'12"E and 19°22'40"E, where medium to fine-grained quartz arenite and sublithic arenite about 1000 m thick are exposed.

Thickness: At least 1000 m.

Age: Probably Carpentarian.

Fossils: None found.

Relations: Unconformably overlain by Palaeozoic rocks of the Canning Basin, and probably by Lewis Range Sandstone; base not exposed.

Synonomy: Mapped as Kearney Beds by Casey & Wells (1964).

Ima Ima Beds (Blake & others, 1977)

Derivation of name: Ima Ima Pool, 19°18'S, 127°53'E, on Sturt Creek, Billiluna Sheet area.

Distribution: Northwest part of Billiluna and southwest part of Gordon Downs Sheet areas.

Lithology: Sublithic arenite, quartz arenite.

Reference area: 10 km north-northeast of Wolf Creek Meteorite Crater, at 19°05'S, 127°50'E, where an exposed sequence about 450 m thick, consisting of sublithic arenite and minor interbeds and lenses of pebble conglomerate, dips southeast.

Thickness: At least 1000 m.

Age: Probably Carpentarian.

Fossils: None known.

Relations: Not known, as outcrops are separated by sand plains from outcrops of other Precambrian rock units.

Synonomy: Mapped as Kearney Beds by Casey & Wells (1964) in Billiluna Sheet area and as Gardiner Beds by Gemuts & Smith (1968) in Gordon Downs Sheet area.

Lake Willson Beds (Blake & others, 1977)

Derivation of name: Lake Willson, 19°23'S, 128°16'E, Billiluna Sheet area.

Distribution: North-central part of Billiluna Sheet area.

Lithology: Chert, commonly stromatolitic; sublithic arenite, shale, siltstone.

Reference area: At 19°19'S, 128°12'E, on the Sturt Creek - Balgo track, where about 150 m of interbedded chert and sublithic arenite dips 70° northwest.

Thickness: At least 150 m.

Age: Probably Carpentarian.

Fossils: Stromatolites.

Relations: Overlain probably conformably by Pindar Beds; base not exposed.

Synonomy: Mapped as Gardiner Beds by Casey & Wells (1964).

Pindar Beds (Blake & others, 1977)

Derivation of name: Pindar Yard, 19°05'S, 128°16'15"E, beside Jawilga Pool on Sturt Creek, Billiluna Sheet area.

Distribution: North-central part of Billiluna Sheet area.

Lithology: Quartz arenite, sublithic arenite.

Reference area: About 2 km southwest of the northern Palm Springs in the Denison Range, at 19°16'S, 128°17'E, where a thickness of about 300 m is exposed.

Thickness: At least 300 m.

Age: Probably Carpentarian.

Fossils: None known.

Relations: Probably conformable on Lake Willson Beds, and unconformably overlain by Denison Beds.

Synonomy: Mapped as Gardiner Beds and Kearney Beds by Casey and Wells (1964).

Redcliff Pound Group (Hodgson, 1976)

Derivation of name:	Redcliff Pound, 21°35'S, 128°45'E, Stansmore Sheet area.
Distribution:	Billiluna, Lucas, Stansmore, Webb, The Granites and Highland Rocks Sheet areas.
Constituent formations and lithological affinities:	Lewis Range Sandstone, Muriel Range Sandstone, Munyu Sandstone, Murraba Formation, Erica Sandstone; all consist mainly of sublithic arenite and quartz arenite.
Thickness:	Maximum exposed is about 1000 m, at Redcliff Pound.
Age:	Late Adelaidean, correlated with Heavitree Quartzite and Bitter Springs Formation, which are probably younger than 1000 m.y. (Wells, 1976).
Relations:	Unconformable on Tanami Complex, Pargee Sandstone, various granites, and Birrindudu Group; overlain possibly conformably by Hidden Basin Beds and unconformably by Palaeozoic units.
Synonomy:	None.

Munyu Sandstone (Blake & Yeates, 1977)

Derivation of name:	Munyu Hills, 21°47'S, 129°08'E, Highland Rocks Sheet area.
Distribution:	Highland Rocks, Stansmore and Webb Sheet areas.
Lithology:	Poorly sorted quartz arenite; minor well-sorted quartz arenite, sublithic arenite, conglomerate, limestone lenses with chert laminae.

Type section: Across a strike ridge at 21°55'00"S, 128°55'00"E, Stansmore Sheet area, where quartz arenite about 400 m thick dips 45° north.

Thickness: At least 400 m.

Age: Late Adelaidean.

Fossils: None.

Relations: Unconformably on Arunta Complex and unnamed granite; inferred to be overlain conformably by Murraba Formation, and unconformably by Pedestal Beds; lateral equivalent of Lewis Range and Muriel Range Sandstones.

Synonomy: Mapped as Gardiner Beds by Casey & Wells (1964).

Muriel Range Sandstone (Hodgson, 1976)

Derivation of name: Muriel Range, 20°46'S, 129°30'E, The Granites Sheet area.

Distribution: The Granites and eastern most part of Lucas Sheet areas.

Lithology: Sublithic arenite and quartz arenite, mainly thin-bedded with bedding plains crowded with shale pellets; minor shale, siltstone, conglomerate, breccia, arkose.

Type section: Across the Inningarra Range, The Granites Sheet area, from 20°45'10"S, 129°38'45"E to 20°47'00"S, 129°54'30"E, where a sequence about 450 m thick of sublithic arenite and quartz arenite is exposed, dipping gently south.

Thickness: At least 450 m.

Age: Late Adelaidean.

Fossils: None known.

Relations: Part of Redcliff Pound Group. Unconformable on Tanami Complex, Pargee Sandstone and granites; inferred to be overlain conformably by Murraba Formation in west, and unconformably by Palaeozoic and Cretaceous units; lateral equivalent of the Lewis Range and Munyu Sandstones.

Synonomy: Mapped as Phillipson Beds by Casey & Wells (1964) in Lucas Sheet area.

Lewis Range Sandstone (Blake & others, 1977)

Derivation: Lewis Range, northeast part of Lucas Sheet area.

Distribution: Lucas and Billiluna Sheet areas.

Lithology: Quartz arenite, mainly medium to fine-grained, well-sorted and medium bedded; minor sublithic arenite, conglomerate (at base), siltstone: shale pellets generally uncommon.

Type section: Lewis Range, at 20°13'00"S, 128°38'00"E, 1.5 km southwest of Point Nelligan, where a sequence about 20 m thick is exposed on the side of a cuesta; the basal 3 m, consisting of poorly sorted pebbly quartz arenite with conglomeratic lenses overlying Lewis Granite is succeeded by 17 m of medium-grained quartz arenite, showing low-angle cross-bedding.

Thickness: Maximum exposed about 400 m.

Age: Late Adelaidean.

Fossils: None known.

Relations: Part of Redcliff Pound Group. Unconformable on Tanami Complex, Slatey Creek Granite, Lewis Granite, unnamed granites, and Gardiner Sandstone; inferred to be overlain conformably by Murraba Formation; lateral equivalent of Munyu and Muriel Range Sandstones.

Synonomy: Mapped as Kearney Beds and Phillipson Beds by Casey & Wells (1964).

<u>Murraba Formation</u> (Blake & Yeates, 1977)

Derivation of name: Murraba Ranges, 21°15'S, 128°45'E, Stansmore Sheet area.

Distribution: Exposures confined to Lucas, Stansmore, and Highland Rocks Sheet areas.

Lithology: Interbedded chert-granule conglomerate, sublithic arenite, quartz arenite, siltstone, shale, mudstone, pebble conglomerate, and dolomite; mainly thin-bedded, laminated.

Type section: East side of Redcliff Pound, Stansmore Sheet area, at 21°36'30"S, 128°45'30"E, where a succession 350 m thick dips 20° - 30°W, conformably underlying Erica Sandstone; the section consists of 160 m of thin-bedded to laminated sublithic arenite, overlain successively by 110 m of thin-bedded sublithic arenite containing shale pellets, 10 m of quartz arenite, and 70 m of thinly interbedded sublithic arenite and chert-granule conglomerate.

Thickness: At least 800 m at Redcliff Pound.

Age: Late Adelaidean.

Fossils: None known.

Relations: Part of Redcliff Pound Group. Conformably overlain by Erica Sandstone and inferred to be conformable on Munyu, Muriel Range and Lewis Range Sandstones; overlain unconformably by Palaeozoic and Cretaceous beds.

Synonomy: Mapped as Gardiner Beds and Phillipson Beds by Casey & Wells (1964).

<u>Erica Sandstone</u> (Blake & Yeates, 1977)

Derivation of name: Erica Range, $21^{\circ}05'$S, $129^{\circ}30'$E, Stansmore Sheet area.

Distribution: Billiluna, Lucas, Stansmore, and Highland Rocks Sheet areas.

Lithology: Sublithic arenite, mainly medium-bedded, cross-bedded, well-sorted, medium to fine-grained, with a clay matrix; minor quartz arenite, flaggy micaceous arenite, siltstone, shale; rare conglomeratic arenite and glauconitic sandstone.

Type section: Across the main cuesta of the Erica Range, from $21^{\circ}05'50''$S, $128^{\circ}30'00''$E, to $21^{\circ}07'00''$S, $128^{\circ}29'00''$E, where a sequence about 400 m thick of sublithic arenite is exposed.

Thickness: Maximum exposed about 700 m.

Age: Late Adelaidean.

Fossils: None.

Relations: Part of Redcliff Pound Group. Conformable on Murraba Formation; overlain possibly conformably by Hidden Basin Beds.

Synonomy: Mapped as Gardiner Beds and Phillipson Beds by Casey & Wells (1964).

<u>Hidden Basin Beds</u> (Blake & Yeates, 1977)

Derivation of name: Hidden Basin, a broad depression containing Lake Wills and Lake Hazlett, Stansmore Sheet area.

Distribution: Stansmore and Webb Sheet areas.

Lithology: Quartz arenite, sublithic arenite; minor shale, siltstone.

Reference area: At $21^{o}40'$S, $128^{o}25'$E, 25 km southwest of Lake Hazlett, where 1800 m of quartz arenite and sublithic arenite is overlain to the west by 280 m of thinly interbedded shale, siltstone and sublithic arenite, overlain in turn by 150 m of glassy quartz arenite.

Thickness: At least 3000 m.

Age: Late Adelaidean.

Fossils: None known.

Relations: Overlies, possibly conformably, Erica Sandstone; overlain unconformably by Palaeozoic sediments.

Synonomy: Mapped as part of the Gardiner Beds by Casey & Wells (1964).

Denison Beds (Blake & others, 1977)

Derivation of name: Denison Range, 19°15'S, 128°20'E, Billiluna Sheet area.

Distribution: Denison Range, Billiluna Sheet area.

Lithology: Quartz arenite; subordinate sublithic arenite with abundant shale pellets.

Reference area: Southeast part of Denison Range, south of Pyramid Hill, where 5 m of thin-bedded sublithic arenite overlies about 15 m of medium-grained quartz arenite, which overlies in turn about 10 m of thick-bedded quartz arenite showing contorted lamination.

Thickness: About 30 m.

Age: Probably late Adelaidean.

Fossils: None known.

Relations: Probably unconformable on Pindar Beds and conformably overlain by Jawilga Beds.

Synonomy: Mapped as Gardiner Beds by Casey & Wells (1964).

Jawilga Beds (Blake & others, 1977)

Derivation of name: Jawilga Pool, 19°05'00"S, 128°16'40"E, on Sturt Creek, Billiluna Sheet area.

Distribution: Between the Denison Range and Baines Hills, Billiluna Sheet area.

Lithology: Medium to fine-grained sublithic arenite, chert conglomerate.

Reference area: At 19°14'30"S, 128°16'30"E, on west side of the Denison Range, where a sequence about 130 m thick is exposed in a narrow fault-bounded zone.

Thickness: At least 130 m.

Age: Probably late Adelaidean.

Fossils: None known.

Relations: Only contacts exposed are faulted; probably conformable on Denison Beds, and conformably overlain by Boee Beds.

Synonomy: Mapped as Gardiner Beds by Casey & Wells (1964).

Boee Beds (Blake & others, 1977)

Derivation of name: Boee Pool, 19°10'45"S, 128°07'00"E, on Sturt Creek, Billiluna Sheet area.

Distribution: East side of the Baines Hills, Billiluna Sheet area.

Lithology: Medium to fine-grained sublithic arenite, subordinate conglomerate and conglomeratic arenite.

Reference area: Northwest from 19°29'30"S, 128°02'20"E, Billiluna Sheet area, where 120 m of sublithic arenite is separated by a sand plain to the west, a few hundred metres wide, from overlying conglomeratic arenite and conglomerate.

Thickness: At least 350 m.

Age: Probably late Adelaidean.

Fossils: None found.

Relations: Contacts not exposed; probably conformable on Jawilga Beds.

Synonomy: Mapped as Kearney Beds by Casey & Wells (1964).

UNNAMED BASIN IN NORTHWEST

Mount Parker Sandstone (Dow & Gemuts, 1969)

Derivation of name: Mount Parker, 17°11'S, 128°18'E, highest point in the Osmond Range, Dixon Range Sheet area.

Distribution: East Kimberley region, including Billiluna Sheet area.

Lithology: Quartz arenite; minor sublithic arenite, conglomerate, siltstone.

Type section: In Osmond Range, Dixon Range Sheet area.

Thickness: About 300 m.

Age: Probably Carpentarian.

Fossil: None known.

Relations: Unconformable on Halls Creek Group; overlain conformably by Bungle Bungle Dolomite.

Synonomy: Mapped as Kearney Beds in Billiluna Sheet area by Casey & Wells (1964).

Bungle Bungle Dolomite (Dow & Gemuts, 1969)

Derivation of name:	Bungle Bungle outcamp, at 17°21'S, 128°21'E, on Turner station, Dixon Range Sheet area.
Distribution:	East Kimberley region, including Billiluna Sheet area.
Lithology:	Mainly dolomite, dolomitic shale; chert (silicified dolomite), silicified oolite, cherty ironstone, lithic arenite, greywacke, siltstone, and shale in Billiluna Sheet area.
Type section:	In Osmond Range, Dixon Range Sheet area.
Thickness:	About 300 m in Billiluna Sheet area.
Age:	Probably Carpentarian.
Fossils:	Stromatolites, microfossils (Diver, 1974).
Relations:	Conformable on Mount Parker Sandstone; overlain unconformably by Wade Creek Sandstone.
Synonomy:	Mapped as Kearney Beds in Billiluna Sheet area by Casey & Wells (1964).

Wade Creek Sandstone (Dow & Gemuts, 1969).

Derivation of name:	Wade Creek in the Osmond Range, Dixon Range Sheet area.
Distribution:	East Kimberley region, including Billiluna Sheet area.
Lithology:	Mainly medium-grained sublithic arenite; minor siltstone, shale.

Type section:	Osmond Range, Dixon Range Sheet area.
Thickness:	Probably at least 800 m.
Age:	Adelaidean; shale from Osmond Range isotopically dated at 1128 $\pm$ 110 m.y.
Fossils:	None known.
Relations:	Unconformable on Bungle Bungle Dolomite; inferred to be overlain unconformably by Duerdin Group in Billiluna and Gordon Downs Sheet areas.
Synonomy:	Mapped as Kearney Beds in Billiluna Sheet area by Casey & Wells (1964).

<u>Duerdin Group</u> (Dow & Gemuts, 1969)

Derivation of name:	Duerdin Creek, 18°30'S, 127°55'E, Gordon Downs Sheet area.
Distribution:	East Kimberley and Victoria River regions, including Billiluna Sheet area.
Constituent formations and lithological affinities:	Redbank Yard Formation, Ranford Formation; contain glacigene rocks.
Thickness:	Probably over 500 m.
Age:	Late Adelaidean; isotopically dated at about 700 m.y. (Plumb & Derrick, 1975).
Fossils:	None known.
Relations:	Inferred to be unconformable on Wade Creek Sandstone in Billiluna Sheet area; overlain unconformably by Albert Edward Group.

Synonymy: None.

Redbank Yard Formation (Blake & Yeates, 1977)

Derivation of name: Redbank Yard on Wolf Creek, at $19^{o}04'00''$S, $127^{o}47'00''$E, Billiluna Sheet area.

Distribution: Northwest corner of Billiluna Sheet area.

Lithology: Conglomerate, sublithic arenite; minor dolomite.

Type section: At $19^{o}07'$E, $127^{o}36'30''$E, 16 km west-southwest of Redbank Yard, where a sequence 330 m thick dips 20^{o} south; it consists of 200 m of polymictic conglomerate overlain by 130 m of medium to very coarse sublithic arenite.

Thickness: At least 330 m.

Age: Late Adelaidean.

Fossils: None.

Relations: Part of Duerdin Group, and considered to be stratigraphic equivalent of the Moonlight Valley Tillite (Dow & Gemuts, 1969); inferred to be unconformable on Wade Creek Sandstone to the west, and to be overlain conformably by Ranford Formation to the east.

Synonymy: Mapped as part of Kearney Beds by Casey & Wells (1964).

Ranford Formation (Dow & Gemuts, 1969)

Derivation of name: Mount Ranford, $17^{o}28'$S, $128^{o}12'$E, Dixon Range Sheet area.

Distribution:	East Kimberley and Victoria River regions, including Billiluna Sheet area.
Lithology:	Thin-bedded siltstone and shale, sublithic arenite, dolomitic sandstone.
Type section:	Moonlight Valley, Dixon Range Sheet area.
Thickness:	Probably about 200 m in Billiluna and Gordon Downs Sheet areas.
Age:	Late Adelaidean.
Fossils:	None known.
Relations:	Inferred to overlie conformably Redbank Yard Formation in Billiluna Sheet area; overlain unconformably by Albert Edward Group.
Synonomy:	Mapped as Kearney Beds in Billiluna Sheet area by Casey & Wells (1964).

Albert Edward Group (Dow & Gemuts, 1969)

Derivation of Name:	Albert Edward Range, Gordon Downs Sheet area.
Distribution:	East Kimberley, including Billiluna Sheet area.
Constituent formations and lithological affinities:	Mount Forster Sandstone, Elvire Formation, Boonall Dolomite, Timperley Shale, Nyuless Sandstone, Flat Rock Formation; conformable sequence of probably shallow marine sedimentary rocks.
Thickness:	Probably over 2000 m.

Age: Late Adelaidean; isotopically dated at about 650 m.y. (Plumb & Derrick, 1975).

Relations: Unconformable on Duerdin Group; overlain unconformably by Antrim Plateau Volcanics.

Synonomy: Mapped as Kearney Beds in Billiluna Sheet area by Casey & Wells (1964).

<u>Mount Forster Sandstone</u> (Dow & Gemuts, 1969)

Derivation of name: Mount Forster, 17°58'S, 128°12'E, Dixon Range Sheet area.

Distribution: East Kimberley region, including Billiluna Sheet area.

Lithology: Quartz arenite, sublithic arenite; minor conglomerate.

Type section: Brim Creek, 18°15'S, 128°00'E, Albert Edward Range, Gordon Downs Sheet area.

Thickness: About 200 m.

Age: Late Adelaidean.

Fossils: None known.

Relations: Part of Albert Edward Group. Unconformable on Ranford Formation; conformably overlain by Elvire Formation.

<u>Elvire Formation</u> (Dow & Gemuts, 1969)

Derivation of name: Elvire River, Gordon Downs Sheet area.

Distribution:	East Kimberley region, including Billiluna Sheet area.
Lithology:	Shale, siltstone; minor lithic arenite.
Thickness:	390 m in Billiluna Sheet area.
Age:	Late Adelaidean.
Fossils:	None known.
Relations:	Part of Albert Edward Group. Conformable between Mount Forster Sandstone below and Timperley Shale (Billiluna Sheet area) or Boonall Dolomite (Gordon Downs Sheet area) above.

Boonall Dolomite (Dow & Gemuts, 1969)

Derivation of name:	Boonall Yard, 18°12'S, 128°14'E, Gordon Downs Sheet area.
Distribution:	East Kimberley region; not present in Billiluna Sheet area.
Lithology:	Dolomite; minor dolomitic conglomerate, dolomite breccia.
Thickness:	Up to 60 m.
Age:	Late Adelaidean.
Fossils:	Stromatolites.
Relations:	Part of Albert Edward Group. Conformable between Elvire Formation below and Timperley Shale above in Gordon Downs Sheet area.

Timperley Shale (Dow & Gemuts, 1969)

Derivation of name:	Mount Timperley, 18°29'S, 128°00'E, Gordon Downs Sheet area.
Distribution:	East Kimberley region, including Billiluna Sheet area.
Lithology:	Shale and siltstone; minor thinly interbedded lithic arenite.
Thickness:	Over 1000 m.
Age:	Late Adelaidean.
Fossils:	None known.
Relations:	Part of Albert Edward Group. Conformable between Elvire Formation (Billiluna Sheet area) or Boonall Dolomite (Gordon Downs Sheet area) above and Nyuless Sandstone below.

Nyuless Sandstone (Dow & Gemuts, 1969)

Derivation of name:	Nyuless Creek, 18°16'S, 128°07'E.
Distribution:	East Kimberley region; not exposed in Billiluna Sheet area.
Lithology:	Fine to medium-grained quartz-rich arenite.
Thickness:	About 35 m.
Age:	Late Adelaidean.
Fossils:	None known.

Relations: Part of Albert Edward Group. Conformable between Timperley Shale above and Flat Rock Formation below.

Flat Rock Formation (Dow & Gemuts, 1969)

Derivation of name: Flat Rock Yard, 18°28'S, 128°05'E, Gordon Downs Sheet area.

Distribution: East Kimberley region; tentatively identified in Billiluna Sheet area.

Lithology: Sublithic arenite, generally dolomitic, and interbedded siltstone and shale.

Thickness: Probably over 1000 m.

Age: Late Adelaidean.

Fossils: None known.

Relations: Part of Albert Edward Group. Conformable on Nyuless Sandstone; unconformably overlain by Antrim Plateau Volcanics.

AMADEUS BASIN

Heavitree Quartzite (Joklik, 1955; Wells, 1970)

Derivation of name: Heavitree Gap, Alice Springs, Alice Springs Sheet area.

Distribution: Northern margin of Amadeus Basin, including Webb Sheet area.

Lithology: Quartz arenite, sublithic arenite; minor siltstone, conglomerate, greywacke.

Type locality: Heavitree Gap, Alice Springs.

Thickness: Maximum about 500 m in Webb area.

Age: Late Adelaidean; younger than 1076 ± 50 m.y. (Marjoribanks & Black, 1974), and probably younger than 1000 m.y. (Wells, 1976).

Fossils: None known.

Relations: Unconformable on Arunta Complex, Pollock Hills Formation and Mount Webb Granite in Webb Sheet area; overlain conformably by Bitter Springs Formation.

Bitter Springs Formation (Ranford & others, 1966; Wells & others, 1970)

Derivation of name: Bitter Springs, Alice Springs Sheet area.

Distribution: Northern margin of Amadeus Basin, including Webb Sheet area.

Lithology: Mainly dolomite and limestone; minor chert and quartz arenite in Webb Sheet area.

Type locality: Bitter Springs Gorge, Alice Springs Sheet area.

Thickness: At least 300 m in Webb Sheet area.

Age: Late Adelaidean; probably younger than 1000 m.y.

Fossils: Stromatolites, microfossils.

Relations: Conformable on Heavitree Quartzite; upper contact not exposed in Webb Sheet area.

Synonomy: Bitter Springs Limestone of Joklik (1955).

NGALIA BASIN

Vaughan Springs Quartzite (Nicholas, 1971; Wells & others, 1972)

Derivation of name:	Vaughan Springs at Mount Doreen homestead, Mount Doreen Sheet area.
Distribution:	Ngalia Basin, including Lake Mackay Sheet area.
Lithology:	Mainly quartz arenite; also conglomerate locally at base, and siltstone, shale, and glauconitic sandstone (Treuer Member).
Type section:	Not yet defined.
Thickness:	Locally over 2000 m.
Age:	Late Adelaidean; glauconite isotopically dated at about 1300 m.y. (Cooper & others, 1971), but formation is probably younger than 1000 m.y., as it is correlated with Heavitree Quartzite.
Fossils:	None known.
Relations:	Unconformable on Arunta Complex metamorphics and unnamed granite; top eroded in Lake Mackay Sheet area.

PHANEROZOIC

Antrim Plateau Volcanics (Traves, 1955; Bultitude, 1976)

Derivation of name:	Great Antrim Plateau, hilly dissected volcanic country east of the Elvire River and south of the Hardman Basin, east Kimberley region.
Distribution:	Victoria River, east Kimberley and The Granites-Tanami regions, including Gordon Downs, Birrindudu, Tanami and The Granites Sheet areas.

Lithology: Tholeiitic basalt lava; minor chert and sandstone.

Type locality: Not yet defined.

Thickness: Maximum recorded 1500 m.

Age: Probably Early Cambrian.

Fossils: Stromatolites.

Relations: Unconformable on late Adelaidean (Albert Edward Group) and older Precambrian rocks; unconformably overlain by Middle Cambrian sediments north of The Granites-Tanami region.

<u>Lucas Formation</u> (Hodgson, 1976)

Derivation of name: Lake Lucas, 20°56'S, 128°50'E, Lucas Sheet area.

Distribution: Lucas, Stansmore, The Granites, and Highland Rocks Sheet areas.

Lithology: Calcareous and non-calcareous sandstone, siltstone and mudstone; minor limestone and dolomite.

Type section: Cliff on east side of Lake Dennis, at 20°53'30"S, 28°56'00"E, Lucas Sheet area. The sequence exposed here, from top to bottom, is 2.5 m calcrete overlying 3 m calcareous mudstone, 2 m sandstone, 2 m mudstone, 0.3 m sandstone, 2 m mudstone, 1.5 m sandstone and 1 m mudstone.

Thickness: Probably over 1000 m locally.

Age: Probably Palaeozoic.

Fossils:	Possible unidentifiable spore and some minute spheres of uncertain affinities.
Relations:	Inferred to be unconformable on Redcliff Pound Group; overlain by Pedestal Beds, the contact probably being a low-angle unconformity.
Synonomy:	Lucas Beds of Casey & Wells (1964).

<u>Pedestal Beds</u> (Hodgson, 1976)

Derivation of name:	Pedestal Hills, 20°35'S, 129°17'E, The Granites Sheet area.
Distribution:	Lucas, Stansmore, Webb, The Granites, Highland Rocks, and Lake Mackay Sheet areas.
Lithology:	Sandstone; minor conglomerate, siltstone, shale.
Reference area:	At 20°22'10"S, 129°29'00"E, 5 km east of Macfarlanes Peak Bore, The Granites Sheet area, where 20 m of sandstone and minor thin siltstone interbeds dip 10-15° south.
Thickness:	Maximum exposed about 500 m.
Age:	Probably Palaeozoic.
Foss.'s:	None known.
Relations:	Unconformable on Tanami Complex, Arunta Complex, granite, Redcliff Pound Group, and Hidden Basin Beds; overlie Antrim Plateau Volcanics and Lucas Formation, probably unconformably; top eroded.
Synonomy:	None.

Angas Hills Beds (Blake, 1977)

Derivation of name:	Angas Hills, 22°50'S, 128°10'E, Webb Sheet area.
Distribution:	Southern part of Webb Sheet area.
Lithology:	Conglomerate, sandstone; minor mudstone.
Reference section:	Cliff at 22°51'00"S, 128°12'30"E, Webb Sheet area, where 12 m of coarse pebble conglomerate with thin lenses of sandstone is overlain by 24 m of sandstone with thin interbeds of mudstone.
Thickness:	About 300 m.
Age:	Probably Palaeozoic.
Fossils:	None found.
Relations:	Unconformable on Arunta Complex, Heavitree Quartzite and probably Bitter Springs Formation; top eroded.
Synonomy:	None.

Chuall Beds (Blake & Yeates, 1977)

Derivation of name:	Chuall Pool, 19°10'00"S, 128°09'30"E, on Sturt Creek, Billiluna Sheet area.
Distribution:	Vicinity of Sturt Creek homestead, Billiluna Sheet area.
Lithology:	Micaceous quartzose to lithic sandstone.
Reference area:	At 19°10'40"S, 128°11'30"E, 4 km southeast of Sturt Creek homestead, Billiluna Sheet area.

Thickness:	Maximum at least 140 m.
Age:	Probably Palaeozoic.
Relations:	Inferred to be unconformable on Lake Willson Beds and Pindar Beds; top eroded.
Synonomy:	None.

<u>Hazlett Beds</u> (Veevers & Wells, 1961)

Derivation of name:	Lake Hazlett, 21°30'S, 128°40'E, Stansmore Sheet area.
Distribution:	Eastern central part of Stansmore Sheet area.
Lithology:	Quartzose sandstone, siltstone, claystone.
Reference area:	At 21°38'00"S, 128°43'30"E, southwest of Redcliff Pound, Stansmore Sheet area.
Thickness:	About 10 m.
Age:	Probably Mesozoic.
Fossils:	None known (radiolaria reported by Veevers & Wells is not confirmed).
Relations:	Unconformable on Redcliff Pound Group; top eroded.
Synonomy:	None.

<u>Larranganni Beds</u> (Blake & others, 1975)

Derivation of name:	Larranganni Bluff, 19°33'S, 129°00'E, southern end of the Gardner Range, Tanami and Billiluna Sheet areas.

Distribution:	Tanami, Billiluna, and The Granites Sheet areas.
Lithology:	Quartzose sandstone; minor siltstone, conglomerate.
Reference area:	At 19°33'45"S, 129°00'00"E, 0.5 km south of Larranganni Bluff, Tanami and Billiluna Sheet areas, where 8 m of flat-lying sandstone and minor conglomerate overlie steeply dipping Killi Killi Beds.
Thickness:	Maximum about 8 m.
Age:	Probably Mesozoic.
Fossils:	None known.
Relations:	Unconformable on Killi Killi Beds, Gardiner Sandstone, Antrim Plateau Volcanics, and probably Slate Creek Granite; top eroded.

GEOLOGY OF

THE GRANITES–TANAMI REGION

NORTHERN TERRITORY AND WESTERN AUSTRALIA

1979

SCALE 1:500 000

Transverse Mercator Projection

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1968 by A. T. Wells, T. G. Evans, T. Nicholas, BMR
1971 by D. H. Blake, I. M. Hodgson, P. A. Smith, BMR
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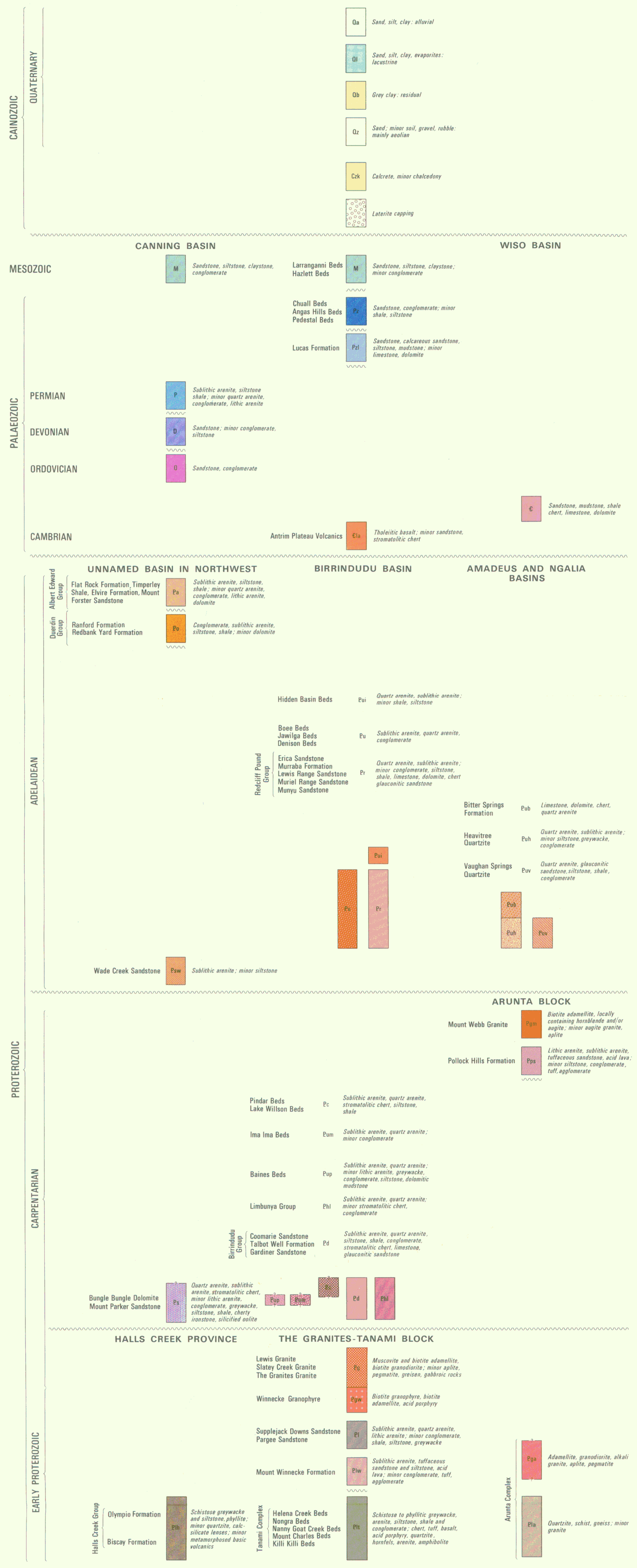
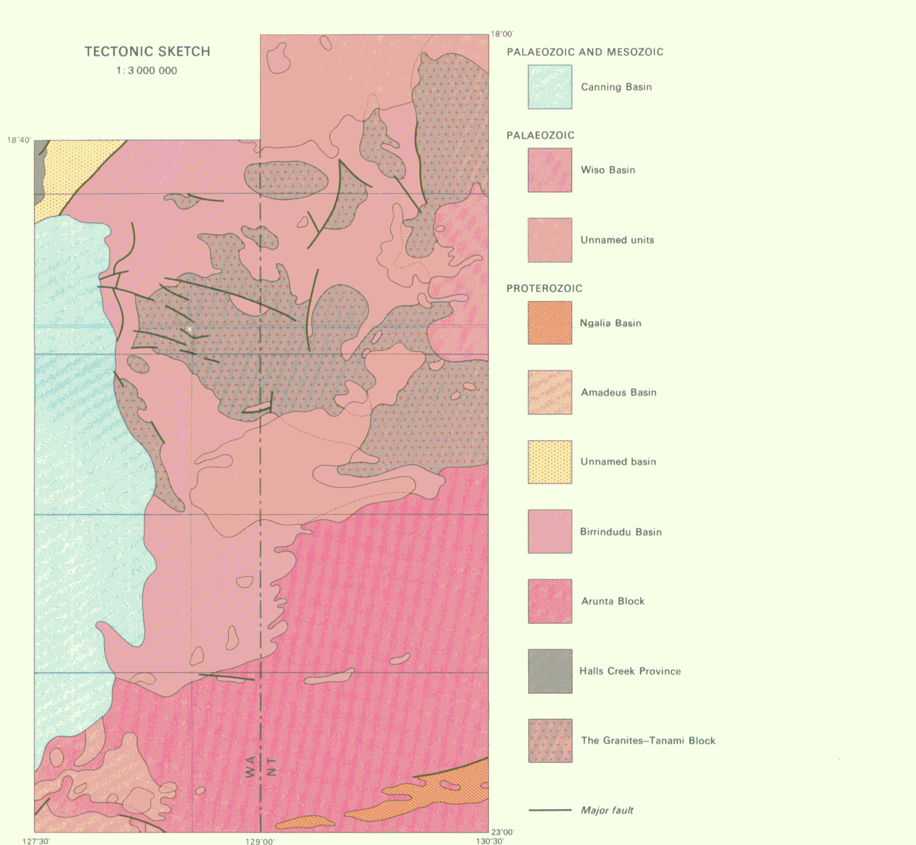
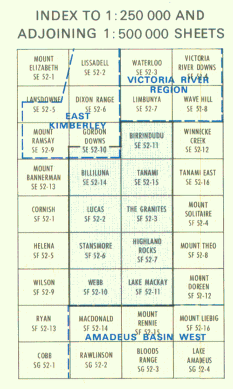
Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. or the Geological Survey of Western Australia, Perth



TECTONIC SKETCH



INDEX TO 1:250 000 AND ADJOINING 1:500 000 SHEETS



LOCALITY MAP

THE GRANITES–TANAMI REGION 1:500 000