<table>
<thead>
<tr>
<th>CAPE SCOTT SD52-7</th>
<th>PINE CREEK SD52-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREENWOOD 4970</td>
<td>DALY RIVER 5070</td>
</tr>
<tr>
<td>MOYLE 4969</td>
<td>TIPPERARY 5170</td>
</tr>
<tr>
<td>PORT KEATS</td>
<td>WINGATE MOUNTAINS 5069</td>
</tr>
<tr>
<td>SD52-11</td>
<td>JINDUCKIN 5169</td>
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<tr>
<td>FITZMAURICE 4968</td>
<td>FERGUSSON</td>
</tr>
<tr>
<td></td>
<td>RIVER SD52-12</td>
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<tr>
<td></td>
<td>BARWOLLA 5068</td>
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<td></td>
<td>FLORA 5168</td>
</tr>
</tbody>
</table>

1:100 000 GEOLOGICAL MAP SERIES

EXPLANATORY NOTES

WINGATE MOUNTAINS 5069

C. J. EDGOOSE, G. M. FAHEY and J. E. FAHEY

Government Printer of the Northern Territory
Darwin 1989
Figure 1  Locality map.
ABSTRACT

WINGATE MOUNTAINS* (Sheet 5069) was mapped by the Northern Territory Geological Survey (NTGS) during 1983 using 1:25 000 colour aerial photographs. A supplementary airborne magnetic and radiometric survey was carried out the following year.

The physiography of the western half of the sheet area is dominated by the flat, elevated surface of the Wingate Plateau and the rugged mountains which form foothills to the plateau in the northern half of the sheet area. All of the drainage forms part of the catchment of the Daly River to the north.

The NW part of WINGATE MOUNTAINS is formed of Early Proterozoic* medium to low grade Hermit Creek Metamorphics which form a continuous sequence with the higher grade rocks to the north in DALY RIVER. The younger Finniss River Group, also Early Proterozoic, has only faulted contacts with the Hermit Creek Metamorphics in the sheet area. The Finniss River Group comprises the Burrell Creek Formation with the Berinka Volcanics near its base, and the massively thick Chilling Sandstone.

The Hermit Creek Metamorphics and the Finniss River Group were intruded successively by Early Proterozoic basic rocks (Wangi Basics) and late- to post-orogenic granitoids (Murra-Kamangee Granodiorite, Allia Creek Granite and Soldiers Creek Granite).

Middle Proterozoic sedimentary sequences (Tolmer and Auvergne Groups) dominate the eastern half of the sheet area, and unconformably overlie Early Proterozoic metasedimentary rocks and granites. A Middle Proterozoic acid intrusive (Ti-Tree Granophyre) forms stocks and sills within the Finniss River Group near the western margin of the sheet area. Scattered remnants of a Late Proterozoic glucigenic sequence, the Unya Formation, rest unconformably on Early and Middle Proterozoic rocks.

Early Cambrian basalts and minor sedimentary rocks are extensively exposed in the SE part of the sheet area where they underlie the Cretaceous capping which forms the escarpment of the Wingate Plateau. These Cretaceous sedimentary rocks, preserved on the Wingate Plateau and outlying remnants, are part of a once very extensive Tertiary peneplain land surface.

INTRODUCTION

Location, access and climate

WINGATE MOUNTAINS (Sheet 5069) covers the area between 14° 00' and 14° 30'S and 130° 30' and 131° 00'E centred 220 km south of Darwin (Figure 1). It includes a number of small abandoned tin mines (Collah, Muldiva-Buldiva tin fields) and a small abandoned gold mine (Fletchers Gully). Although the area is used for cattle grazing there is no permanent settlement. The abandoned Fish River Station homestead is used only occasionally by musterers and station workers. Most of the area lies within the Fish River Pastoral Lease (CL(P)98) except for vacant crown land south of Collah Waterhole.

Vehicle access in the east of the sheet area is provided by the road to the Fish River Station homestead, and by the track to Collah Waterhole. The Fish River Station homestead road is reached via crossing the Daly River either at Beeboom crossing to the NE in TIPPERARY or the Ooloo crossing to the east in JINDUCKIN. Both of these crossings are impassable during the wet season. Vehicle access to the northern and NW portions of the sheet is gained via the track to Fletchers Gully gold mine and subsidiary rough bush tracks. Vehicle access to the Wingate Plateau, which occupies about 40% of the sheet area, is denied because of the rugged foothills and steep escarpments which mark its edge. There are two airstrips in WINGATE MOUNTAINS; one at Fish River Station homestead and another at Collah Waterhole; the latter is badly damaged by erosion gullies.

The climate is tropical inland (Department of National Development, 1952-60) and almost all of the annual rainfall of about 1350 mm falls during the period from November to March.

Geomorphology

There are three major geomorphic divisions in WINGATE MOUNTAINS: Laterised mesa surfaces, Escarpments and dissected hills, and Eutalial lowlands (Figure 2).

Laterised mesa surfaces

Laterised mesa surfaces, which are remnants of a thin, once extensive Tertiary peneplain developed over a sheet of Cretaceous sediments, cover almost one half of WINGATE MOUNTAINS. This area is part of the extensive plateau which divides the Daly and Fitzmaurice River systems. Hays (1968) refers to this surface as the "Tennant Creek Surface". Sandy, deeply laterised soils have developed on the Cretaceous rocks and these support an open eucalypt forest which is notably taller and denser than the forest in other geomorphic regions. Numerous springs and soaks occur on the plateau and associated with these areas are plant communities of the monsoon forests (Christian and Stewart, 1953) including the Carpentaria palm.

Escarpments and dissected hills

The escarpments and dissected hills cover an extensive area of WINGATE MOUNTAINS and comprise mainly Proterozoic igneous, metamorphic and sedimentary rocks. The escarpments form the flanks of the mesas and usually consist of a small scarp topping a steep, talus-sloven slope.

* All references to 1:100 000 map sheet areas in this report are designated by the use of capital letters, eg. WINGATE MOUNTAINS.

+ In this report the Proterozoic is subdivided as follows: Early Proterozoic (2500 to 1700 Ma), Middle Proterozoic (1700 to 1000 Ma), and Late Proterozoic (1000 to 570 Ma).
In the north, flat-lying Cretaceous rocks have largely been removed permitting the formation of dissected hills from the tightly folded Early Proterozoic metamorphic and igneous rocks and the more gently folded Middle Proterozoic sedimentary rocks.

Soils in this division are dominantly skeletal. However, where they have accumulated between rock outcrops, they support open woodland, shrubs and grasses.

Eluvial lowlands
This division includes generally eluvial covered ground adjacent to the escarpments and dissected hills. Most of the eluvial lowlands are formed over Early Proterozoic granitic, volcanic and metamorphic rocks. There are some small areas in the south-central part of the sheet area where lowlands have formed on flat-lying Proterozoic sediments and in a larger area in the NE where they have developed over gently dipping Proterozoic rocks and minor Cambrian sediments and volcanics.

Previous Investigations
H.Y.L. Brown made the first geologic observations in WINGATE MOUNTAINS when he described “highly metamorphic siliceous and micaceous rocks in the ranges and granite in the valleys” in the area around Fletchers Gully gold mine (Brown and Bisedow, 1906).

The first published geologic map which covered WINGATE MOUNTAINS was the Fergusson River 1:250 000 map and accompanying explanatory notes (Randal, 1962). Prior to this, work by Ellis (1926 a, b and c), Hossfeld (1937 a and b), Noakes (1949) and White and others (1962) expanded the geologic knowledge of the region.

The Bureau of Mineral Resources (BMR) mapped the Victoria River region between 1967 and 1970 and produced several publications (Sweet and others, 1974; Sweet, 1977), including a second edition of the 1:250 000 Fergusson River sheet and explanatory notes (Pontifex and Mendum, 1972).

Details of mineral exploration by mining companies and prospectors prior to 1968 are scanty and are recorded only in government reports and newspaper extracts. Since 1968, a number of companies have held exploration licences in WINGATE MOUNTAINS. Most commodities, including diamonds and uranium, have been exploration targets. A summary of geologic investigations including details of geologic mapping, drilling, geochemical and geophysical surveys together with references to relevant reports is given in NTGS Exploration Series Maps - WINGATE MOUNTAINS.

STRATIGRAPHY

The stratigraphy of WINGATE MOUNTAINS is summarised in Table 1.

Petrographic details given in this report are based principally upon petrologic descriptions of thin sections by the Australian Mineral Development Laboratory (AMDEL) (in Edgoose and others, 1984a).
Figure 3  Regional tectonic setting of WINGATE MOUNTAINS.
REGIONAL GEOLOGIC SETTING

WINGATE MOUNTAINS lies in the SW part of the Pine Creek Geosyncline, and includes the SE extremities of the Litchfield Province (Figure 3). To the south the sheet area includes the NE margin of the Victoria Basin, and in the east, small outlying sub-basins of the extensive Cambrian Daly Basin.

The Litchfield Province consists of Early Proterozoic, low to high grade metamorphics, and granitoids. In this southern part of the province, the metamorphics form basement to the younger units of the Pine Creek Geosyncline developed along its western margin.

The geosynclinal sediments accumulated in a single basin, forming a sequence up to 14 km thick which was deformed and metamorphosed during the 1870-1780 Ma Top End Orogeny (Needham and others, 1985). This event was retrograde in its effect on the metamorphics in the south of the Litchfield Province. Pre-orogenic basic rocks and synorogenic to post-orogenic granitoids intruded the rocks of both the western Pine Creek Geosyncline and Litchfield Province.

Tectonically, the Litchfield Province forms a continuum with the Halls Creek Mobile Zone to the SW. The major faults that link the two provinces played an important role in the development of the western margin of the Pine Creek Geosyncline. Later subsidence along these faults initiated and subsequently deformed the Middle Proterozoic basins of the Fitzmaurice Mobile Zone, Tolmer Group, and Victoria Basin, and opened up the Palaeozoic Daly and Bonaparte Basins (Figure 3). Undeformed Mesozoic rocks form a thin cover sequence that probably once blanketed the entire region.

EARLY PROTEROZOIC

Hermit Creek Metamorphics (Ph)

The Hermit Creek Metamorphics are of very limited extent in WINGATE MOUNTAINS (Figure 4). The scattered, isolated exposures on the NW edge of the sheet area are probably roof pendants in the Murra-Kamangee Granodiorite. The exposures constitute the most SE outcrops of this extensive but poorly outcropping unit which is interpreted to underlie approximately 1000 km² in WINGATE MOUNTAINS, MOYLE, GREENWOOD and DALY RIVER (Figure 5). The outcrops in WINGATE MOUNTAINS form part of the transition between the high grade sequence to the north in DALY RIVER and the low grade sequence to the west and SW in MOYLE. This regional decrease in metamorphic grade can be traced in a westerly and SW direction across the area occupied by the Hermit Creek Metamorphics. The rocks in WINGATE MOUNTAINS constitute a sequence of lower to upper amphibolite facies pelitic and psammitic gneisses. Metabasites, which form a major proportion of the higher grade sequence to the north, have not been recognised in this area. This may indicate that their intrusion was related to high grade metamorphic conditions.

Early workers (White and others, 1962; Malone, 1962; Walpole and others, 1968) assigned the Hermit Creek Metamorphics an Archaean age on the basis of the structural and metamorphic differences from adjacent Early Proterozoic rocks of the Pine Creek Geosyncline. Sweet (1977) recognised the Hermit Creek Metamorphics as having undergone an amphibolite facies metamorphism followed by a greenschist facies retrogression which he correlated with the 1870-1780 Ma Top End Orogeny in the Pine Creek Geosyncline. NTGS work supports Sweet's interpretation. More recently, Hammond and others (1984) proposed a two-fold subdivision of the metamorphics into retrogressed and non-retrogressed high-grade sequences. NTGS field and petrologic work finds that such a subdivision is untenable (Piech and Edgcooe, 1988) as the retrogression across the sequence is essentially non-uniform in nature. The rocks in WINGATE MOUNTAINS fall into Hammond's retrogressed subdivision for which he retained the name Hermit Creek Metamorphics.

The age of the Hermit Creek Metamorphics is poorly defined. Rb/Sr whole rock and mica age determinations from WINGATE MOUNTAINS give results of 1770±27 Ma and 1803±27 Ma. As the metamorphics have been intruded by the Murra-Kamangee Granodiorite, dated at 1853±33 Ma (Page and others, 1984), then these dates have clearly been isotopically re-equilibrated. A metamorphic sequence in the north of the province, the Fog Bay Metamorphics, gave a Rb/Sr age of 2002±42 Ma and a 2280±40 Ma Sm/Nd model age (Hickey, 1985). These dates reflect an earlier cycle of sedimentation and metamorphism, represented in the south by the Hermit Creek Metamorphics, that occurred in the Litchfield Province prior to the development of the Pine Creek Geosyncline in this western area at least. The Sm/Nd model age for the Fog Bay Metamorphics shows that mantle extraction of rocks in this earlier cycle occurred during the Early Proterozoic and not in the Archaean, as many earlier workers believed (Walpole and others, 1968; Sweet and others, 1974).

Correlations between the Hermit Creek Metamorphics and the Tickalaria Metamorphics of the Halls Creek Mobile Zone have been made by several workers (Sweet, 1977; Dundas and others, 1987). These correlations were based on similarities in lithology, metamorphic and tectonic history, age, and the structural continuity between the two areas. More recent geochronology in the Halls Creek Mobile Zone (Page and Hancock, 1988) indicates that the Tickalaria metamorphic event and Top End Orogeny were roughly contemporaneous. Both events postdate the formation of the Hermit Creek Metamorphics.

The pelitic and psammitic rocks in WINGATE MOUNTAINS are dominantly quartz-feldspar-biotite gneisses and schists. Quartz and feldspar generally form a granuloblastic mosaic of both coarse and fine grains which are usually concentrated in coarser and finer bands and probably reflect original bedding. Aligned biotite flakes define a clear foliation. Feldspars are generally unwinde and are commonly argillised and sericitised. It is presumed that both K-feldspar and plagioclase are present. Narre pelitic and twinning in plagioclase indicates a composition in the andesine range.

Some samples show compositional layering highlighted by rich layers of aligned biotite flakes, much of which is extensively chloritised. Garnet, sillimanite, cordierite and rarer andalusite occur in varying proportions. Poikiloblastic masses of garnet, now largely converted to an ultra-fine mesh of clay and chlorite, are common and generally occur in layers up to 2 mm thick parallel to the foliation. The garnet appears to have replaced feldspar but merely enclosed the quartz and some of the biotite. Sillimanite does not occur in garnetiferous rocks, and feldspar often replaces dense swaths of the fine fibrolitic mineral. Cordierite occurs in association with garnet in some pelitic gneisses. Accessory minerals include zircon,
Figure 4  Solid Geology of WINGATE MOUNTAINS.
Figure 5  Regional geologic setting of WINGATE MOUNTAINS.
<table>
<thead>
<tr>
<th>UNITS, MAP SYMBOL, LITHOLOGY, THICKNESS</th>
<th>FIELD RELATIONSHIP</th>
<th>DISTRIBUTION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAINozoic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quaternary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alluvium (Oa) 3 m</td>
<td>River and creek channel deposits</td>
<td>Drainage areas</td>
<td>Fluvial</td>
</tr>
<tr>
<td>Sand, silt, clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colluvium (Qcl) 3 m</td>
<td>Deposits of broad drainage areas, shallow depressions</td>
<td>Drainage areas</td>
<td>Sheet-wash</td>
</tr>
<tr>
<td>Sand, silt, clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tertiary</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil (Csz) 30 m</td>
<td>Generally skeletal deposits, lateritic over Cretaceous sediments</td>
<td>Widespread</td>
<td>Residual</td>
</tr>
<tr>
<td>Unconsolidated sand, gravel, clayey and silty sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laterite (CzL)</td>
<td>Occurs as small, scattered boulders in lateritic soils</td>
<td>Wingate Plateau</td>
<td>In situ</td>
</tr>
<tr>
<td>Insitu and reworked nodular, concretionary, pisolitic and mottled laterite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talus and Scree (CzT) 2 m</td>
<td>Developed on slopes below escarpments on Wingate Plateau and outlying remnants, and on slopes of fault ridges</td>
<td>Widespread in SE</td>
<td>Terrestrial</td>
</tr>
</tbody>
</table>

| **Mesozoic**                           |                    |              |                          |
| Cretaceous                             |                    |              |                          |
| Undivided Cretaceous (K) 40 m          | Unconformably overlies Pfc, Pfb, Ptd, Paa, C1a | Wingate Plateau and outlying remnants | Fluvial, in part may be shallow-marine |
| Laterised sandy and silty siliceous claystone; immature clayey quartzarenite; common basal quartz pebble conglomerate | | | |

Unconformity

| **Palaeozoic**                          |                    |              |                          |
| Cambrian                               |                    |              |                          |
| Daly River Group                       |                    |              |                          |
| Tindall Limestone (C mt)               | Unconformably overlies Pth, C1 | NE of WINGATE MOUNTAINS near Fish River | shallow-marine |
| Grey and beige dolomitic limestone, algal and cherty in part | | | |

| Early Cambrian                         |                    |              |                          |
| Antrim Plateau                         | Unconformably overlies Pgs, Paa, Puu, Unconformably overlain by-C mt, K | Eastern side of WINGATE MOUNTAINS | Flood basalt |
| Volcanics (C la)                       | Up to 80 m. Basalt, massive and vesicular, quartz or clay infilling vesicles; interlayered micaceous siltstone or mudstone; lateritised carbonate rocks; lenticular interlayered and cross-cutting dykes of flaggy, feldspathic quartzarenite | | |

| Undivided sediments (C l)              | Unconformably overlies Pgs, Paa, Puu, overlain by C1a, K | East-central and SE parts of WINGATE MOUNTAINS | Shallow-marine |
| Quartzarenite; ferruginous siltstone; silicified carbonate rock (limestone?) |                    |              |                          |

Unconformity
<table>
<thead>
<tr>
<th>UNIT, MAP SYMBOL, LITHOLOGY, THICKNESS</th>
<th>FIELD RELATIONSHIP</th>
<th>DISTRIBUTION</th>
<th>DEPOSitional ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROTEROZOIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LATE PROTEROZOIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniya Formation (Puu)</td>
<td>Unconformably overlies Pgs, Paa, Pad, unconformably overlain by Cia, K</td>
<td>SE part of WINGATE MOUNTAINS</td>
<td>Glacial</td>
</tr>
<tr>
<td>up to 137 m. Diamictite; glaciolacustrine arenite and siltstone with dropstones; glacifluvial conglomerate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MIDDLE PROTEROZOIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ti-Tree Granophyre (Egi)</td>
<td>Intrudes Pfb, Pfb, Pbw</td>
<td>NW part of WINGATE MOUNTAINS</td>
<td></td>
</tr>
<tr>
<td>Altered and sheared granophyre; granophytic adamellite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AUVERGNE GROUP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinkerton Sandstone (Zap)</td>
<td>Conformable on Pad</td>
<td>Southern part of WINGATE MOUNTAINS</td>
<td>Fluvial</td>
</tr>
<tr>
<td>at least 40 m. Quartzarenite, flaggy to well-bedded, cross bedded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saddle Creek Formation (Pad)</td>
<td>Conformable on Paa</td>
<td>SE part of WINGATE MOUNTAINS</td>
<td>Fluvial</td>
</tr>
<tr>
<td>at least 210 m. Quartzarenite, flaggy to massive, with large scale cross bedding, ripple marks, and slump structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angalarri Siltstone (Paa)</td>
<td>Unconformable on Pgs</td>
<td>SE part of WINGATE MOUNTAINS</td>
<td>shallow-marine</td>
</tr>
<tr>
<td>at least 160 m. Siltstone, fissile, red brown to pale green; some dolomite and dolomitic siltstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOLMER GROUP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hinde Dolomite (Pth), at least 900 m. Dolomite; stromatolitic dolomite; ferruginous quartzarenite</td>
<td>Conformable on Pts</td>
<td>NE part of WINGATE MOUNTAINS</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td><strong>STRAY CREEK SANDSTONE (Pts)</strong></td>
<td>Conformable on Ptd</td>
<td>NE part of WINGATE MOUNTAINS</td>
<td>Shallow-marine to fluvial</td>
</tr>
<tr>
<td>about 800 m. Quartzarenite, flaggy, micaceous, ripple marked and cross bedded, siderite marker horizon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DEPOT CREEK SANDSTONE (Ptd)</strong></td>
<td>Unconformable on Pgs, Pgs, Pfb</td>
<td>Eastern part of WINGATE MOUNTAINS</td>
<td>Fluvial</td>
</tr>
<tr>
<td>about 400 m. Quartzarenite, massive to thick-bedded; rare thin quartz gravel and pebble layers; thin basal conglomerate in places</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EARLY PROTEROZOIC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allia Creek Granite (Ega)</td>
<td>Intrudes Pfb</td>
<td>North-central edge of WINGATE MOUNTAINS</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Biotite adamellite, often coarsely porphyritic with large phenocrysts of microcline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soldiers Creek Granite (Egs)</td>
<td>Intrudes Pfb</td>
<td>SE corner of WINGATE MOUNTAINS</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Muscovite leucogranite, coarse-grained with greisen veins; muscovite-tourmaline pegmatite with cassiterite mineralization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIT, MAP SYMBOL, LITHOLOGY, THICKNESS</td>
<td>FIELD RELATIONSHIP</td>
<td>DISTRIBUTION</td>
<td>DEPOSITIONAL ENVIRONMENT</td>
</tr>
<tr>
<td>----------------------------------------</td>
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</tr>
<tr>
<td><strong>Murra-Kamangee</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granodiorite (Pgmk)</td>
<td>Intrudes Ph, Pbv</td>
<td>NW corner of WINGATE MOUNTAINS</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Biotite granodiorite; tonalite; often garnetiferous, weakly to moderately foliated, contains numerous xenoliths, 1852±33 Ma U/Pb</td>
<td>Faulted against Pfc, Pfb, Pbiv</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wangi Basics</strong> (Pbv)</td>
<td>Intrudes Ph, Pfb, Pfc</td>
<td>Scattered across NW quadrant and central WINGATE MOUNTAINS</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Altered and metamorphosed basic to intermediate igneous rocks: felsic gabbro; quartz gabbro; dolerite; quartz dolerite; quartz diorite; anorthosite; intruded as stocks and sills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FINNIS RIVER GROUP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Volcanics</strong> (Pfcv) about 400 m. Altered rhyodacite, rhyolite, banded tuff</td>
<td>Intercalated in Pfc</td>
<td>NW central part of WINGATE MOUNTAINS</td>
<td>Volcanic</td>
</tr>
<tr>
<td><strong>Chilling Sandstone</strong> (Pfc) about 7000 m. siliceous, micaceous, ripple marked and cross bedded</td>
<td>Conformably overlies and interfingers with Pfb</td>
<td>NW quadrant of WINGATE MOUNTAINS</td>
<td>Shallow-marine, fluvial</td>
</tr>
<tr>
<td><strong>Burrell Creek Formation</strong> (Pfb) Phyllite; andalusite phyllite; quartz-mica schist; andalusite-quartz-mica-feldspar schist; quartzarenite; submature micaceous quartzarenite; immature quartzarenite, micaceous and feldspathic; gritty quartzarenite or quartz grit; andalusite hornfels; quartz conglomerate ± clasts of phyllite, quartzarenite, acid volcanic rocks (Berinka Volcanics)</td>
<td>Intruded by Pbiv, Pga, Pgmk, Pgs, Pgi. Overlain by Pfc, overlain unconformably by Ptd</td>
<td>NW quadrant of WINGATE MOUNTAINS; linear belt extending to the SE</td>
<td>Deeper marine-turbidites</td>
</tr>
<tr>
<td><strong>Berinka Volcanics</strong> (Pfbv) Metamorphosed to altered spherulitic dacite; sheared lithic tuff; agglomerate; silicified-sericitised feldspar crystal tuff; porphyritic rhyodacite; interlayered siltstone and mudstone</td>
<td>Interlayerd near base of Pfb</td>
<td>NW part of WINGATE MOUNTAINS</td>
<td>Volcanic</td>
</tr>
<tr>
<td><strong>Hermit Creek Metamorphics</strong> (Pb) Schist and gneiss, low to high grade metamorphic rocks, retrogressed</td>
<td>Infruded by Pgmk, interpreted to unconformably underlie Pfb</td>
<td>NW corner of WINGATE MOUNTAINS</td>
<td>Flysch?</td>
</tr>
</tbody>
</table>

*Unconformity*
apatite and leucoxene. In the higher grade rocks leucocratic layers may outline tight, pytymatic folds which suggests some partial melting may have occurred (Plate 1). One outcrop on the northern edge of the sheet area consists of steeply dipping alternating bands of psammitic and pelitic gneiss which reflect original bedding (Plate 2). The psammitic bands are finer grained and consist of biotite quartzite. The pelitic bands are composed of sillimanite, cordierite, K-feldspar, quartz and biotite. This rare outcrop scale indication of original bedding in the Hermit Creek Metamorphics suggests that the sequence, at least in part, represents a metamorphosed flysch.

FINNIS RIVER GROUP

The Finnis River Group represents the closing stages of sedimentation in the Pine Creek Geosyncline. This youngest sequence of the Geosyncline forms its western margin, and is the only representative of the thick geosynclinal pile in WINGATE MOUNTAINS. The Finnis River Group is represented in the sheet area by two formations: the Burrell Creek Formation and the interfinger and overlying Chilling Sandstone. The Burrell Creek Formation contains the Berinka Volcanics towards its base.

Burrell Creek Formation (Pfb)

The area in WINGATE MOUNTAINS now shown as Burrell Creek Formation was previously mapped entirely as “Noltenius Formation” (Pontifex and Mendum, 1972). The Noltenius Formation was characterised as a more rudaceous proximal facies of the Finnis River Group which was deposited to the west of, and synchronously with, the more pelitic distal facies Burrell Creek Formation. In DALY RIVER the two formations were found to be difficult to distinguish lithologically and, as a consequence, the Noltenius Formation was discarded as a mappable unit and the entire sequence was mapped as Burrell Creek Formation (Dundas and others, 1987). To maintain uniformity between 1:100 000 map sheet areas, the name “Noltenius Formation” is replaced by “Burrell Creek Formation” in WINGATE MOUNTAINS. In the SE of WINGATE MOUNTAINS, there is a prominent NW- to SE- trending ridge made up of sometimes brecciated siliceous meta-quartzarenite, part of which was previously mapped as Middle Proterozoic Tolmer Group Depot Creek Sandstone. This ridge has also been included in the Burrell Creek Formation.

In WINGATE MOUNTAINS the Burrell Creek Formation is a major outcropping unit and forms ranges of rugged dissected hills. In the NW of the sheet area the formation splits into two “arms” which wrap around a broad synclinorium (Figure 4). The “western arm” con-

Plate 1 Leucocratic veins outlining contorted, pytymatic layering in pelitic gneiss, Hermit Creek Metamorphics.

Plate 2 Alternating coarse-grained and fine-grained bands reflect originally psammitic and pelitic sedimentary layering in gneiss, Hermit Creek Metamorphics.
tinues into MOYLE whilst the “eastern arm” becomes partially truncated by the Early Proterozoic Soldiers Creek Granite and overlain by Cretaceous sedimentary rocks before continuing into the central to SE part of the sheet area.

The Burrell Creek Formation is composed of interbedded phyllite, schist, immature quartzarenite (“greywacke”), grit and conglomerate. In its more westerly exposures the formation also contains lenses and interbeds of siliceous submature to mature quartzarenite; where these are mappable, they are shown as Chilling Sandstone.

The formation was deposited in the Pine Creek Geosyncline around 1880 to 1870 Ma (P. Stuart-Smith, pers. comm.). It then underwent a period of regional metamorphism and deformation during the 1870 to 1780 Ma Top End Orogeny (Needham and others, 1985), which produced upright north-trending tight to isoclinal folding with accompanying low grade metamorphism (up to lowermost greenschist facies). Typical metamorphic minerals are sericite and chlorite. Intrusion of the late Early Proterozoic Soldiers Creek and Allia Creek granites contact metamorphosed the formation. Later dextral transcurrent movement along the Giants Reef Fault system steepened plunges on the fold axes and locally produced kinking of the S1 cleavage in the phyllites (see STRUCTURE).

In the “eastern arm” of the Burrell Creek Formation the dominant rock types are phyllite and micaceous meta immature (feldspathic) quartzarenite with minor meta quartz grit and conglomerate lenses. Sedimentary features include convolute bedding, graded bedding, sole marks, and scour and fill structures (Plate 3). The rock types, along with the sedimentary features, indicate deposition by turbidity currents in a submarine environment. Within the western “arm” the formation contains a high proportion of quartz grit, conglomerate and submature to mature quartzarenite. Typical sedimentary features here are planar lamination, cross bedding, graded bedding, scour and fill structures, rare ripple marks, and some convolute bedding (phyllites). The rock types and associated sedimentary features indicate that, in this area, the sediments were deposited in a shallow water marine environment. Given the structural geometry (see STRUCTURE), this is indicative of a SW-directed lateral facies change from a predominantly deep water flysch sequence (“eastern arm”) to a predominantly shallow water environment (“western arm”). In the “western arm” a lateral and vertical transition to the platform sequence, represented by the Chilling Sandstone, is also noted. This vertical transition to the Chilling Sandstone also occurs in the east, however here it is more abrupt and probably represents the platform sequence transgressing back over the deep water sediments (Figure 6).

Figure 6  Relationship between units of the Finnis River Group.
For further description the Burrell Creek Formation has been divided into four areas (Figure 7).

Area 1
In this area the Burrell Creek Formation is made up of interbedded (meta) conglomerate, quartz grit, submature to mature quartzarenite, micaceous immature quartzarenite, and phyllite.

The conglomerates contain mainly pebble- to cobble-sized clasts of vein quartz and, in addition, may contain angular to subrounded clasts of siliceous phyllite, fine- to medium-grained quartzite, and acid volcanic. The acid volcanic clasts have probably been derived from the nearby Berinka Volcanics which occur stratigraphically below the conglomerate horizons, towards the base of the Burrell Creek Formation. Some of the conglomerates display graded bedding and scour and fill structures.

The quartz grits are composed dominantly of medium- to granule-sized grains, are generally poorly sorted, and are commonly silicified. Noted sedimentary structures are graded bedding and reversed graded bedding.

The phyllite, as elsewhere throughout the Burrell Creek Formation, is well cleaved and is composed of various combinations of quartz, muscovite, sericite and chlorite. The mineral assemblages indicate lowermost greenschist facies metamorphism.

In this area the Burrell Creek Formation is intruded by a number of basic sills of the Early Proterozoic Wangi Basics, and is faulted against the Early Proterozoic Murra-Kamangee Granodiorite.

Area 2
In this area the Burrell Creek Formation is well-exposed and forms a range of rugged dissected hills (Figure 7).

The Formation is composed mainly of interbedded phyllite and micaceous meta fine- to coarse-grained immature feldspathic arenite ("meta greywacke"). In addition there occur interbeds of meta submature quartzarenite, micaceous meta immature quartzarenites with coarse- to granule-sized ("meta grits"), and micaceous meta pebble and cobble quartz conglomerate. Observed sedimentary features are convoluted bedding, graded bedding, sole marks, and scour and fill structures.

The Early Proterozoic Allia Creek Granite has contact metamorphosed the metasedimentary rocks of the Burrell Creek Formation and forms a wide aureole defined by porphyroblastic andalusite development.

The Burrell Creek Formation is, in this area, unconformably overlain by the Middle Proterozoic Tolmer Group, Early Cambrian Antrim Plateau Volcanics, and Cretaceous sedimentary rocks.

Area 3
In the Buldiva-Muldiva Tin Mine area the Burrell Creek Formation is composed of west- to NW-striking interbedded schist, phyllite, meta pebbly grit, and micaceous meta coarse- to medium-grained quartzarenite. The formation is intruded and contact metamorphosed by the Soldiers Creek Granite, with porphyroblastic andalusite developed within the contact zone.

Area 4
In this area the Burrell Creek Formation is composed mainly of interbedded phyllite, schist and micaceous meta immature (feldspathic) quartzarenite.

The Soldiers Creek Granite has contact metamorphosed the metasedimentary rocks of the Burrell Creek Formation; "knotted" andalusite schist, which is sometimes crenulated, and andalusite-biotite hornfels occur near and at the contact. The metapsammitic rocks near the contact contain a high proportion of mica of probable contact metamorphic origin.

The Burrell Creek Formation has also been intruded by a medium-sized stock composed of gabbro and diorite of the Wangi Basics. Although there is no discernable alteration of the metasedimentary rocks near the contact, which is nowhere clearly exposed, there is a marked effect on the structure. The interbedded phyllites and meta immature quartzarenites which lie on the eastern margin of the stock, sandwiched between it and the Soldiers...
Creek Granite, strike approximately north and have probably been deflected from their regional NW strike by the intrusion of the basic body.

The Burrell Creek Formation in this area is overlain with an angular unconformity by the Angalarri Siltstone, Uniya Formation and Cretaceous sedimentary rocks; the contacts, however, are not well exposed.

**Berinka Volcanics (P/br)**

The term Berinka Volcanics was first used by Randal (1962) to describe rhyolites, tuffs and agglomerates which crop out in the NW of WINGATE MOUNTAINS. Randal considered the volcanics to overlie the "Noltenius Formation" (Burrell Creek Formation). Walpole (1968) briefly described the volcanics and suggested that they may be interbedded with the Noltenius Formation. Later BMR mapping supported Walpole's suggestion that the volcanics are interbedded, or intertongue, with the Noltenius Formation (Pontifex and Mendum, 1972; Sweet and others, 1974; Sweet, 1977). These later workers mapped a granophyre which Walpole and others (1968) had included in the Berinka Volcanics as part of the younger Ti-Tree Granophyre. Acid volcanics to the west, in MOYLE, were also included in the Berinka Volcanics by these later workers (Morgan, 1972; Sweet and others, 1974).

In WINGATE MOUNTAINS the Berinka Volcanics crop out over an area of approximately 16 km² in the NW of the sheet area (Figure 4). Here they form rugged hills and ridges and consist of extrusive volcanic rocks and some thin interbeds of argillaceous sedimentary rocks.

In outcrop the volcanics are usually weathered, medium to dark grey-green, massive rocks, often with a lighter coloured mottling. Within the vicinity of the Giants Reef Fault they are strongly sheared, foliated and highly weathered. Under these conditions they are indistinguishable in hand specimen from foliated meta immature quartzarenites of the Burrell Creek Formation.

Field relationships suggest that the volcanics are interbedded with, and occur towards the base of, the Burrell Creek Formation. Clasts of Berinka Volcanics occur in conglomerates of the Burrell Creek Formation stratigraphically above the volcanics, and phylmites of the Burrell Creek Formation occur stratigraphically below the volcanics. The Ti-Tree Granophyre and Early Proterozoic Wangi Basins intrude both the Berinka Volcanics and Burrell Creek Formation.

The Berinka Volcanics are considered to be co-magmatic with the acid to intermediate Warr's and Mulluk Mulluk volcanics mapped in DALY RIVER (Dundas and others, 1987). Chemically and mineralogically the three suites are similar and, although to some extent their depositional environments differ, they appear to reflect a single period of volcanism initiated at the onset of Finniss River Group sedimentation along the western margin of the Pine Creek Geosyncline.

The Berinka Volcanics in WINGATE MOUNTAINS are linked by the Giants Reef Fault system to an elongate body of acid volcanics in MOYLE which have
also been assigned to the Berinka Volcanics (Edgoose and others, 1988). The distance between the two bodies is about 10 km, the approximate lateral displacement on the Giants Reef Fault (Dundas and others, 1987), indicating that they originally formed one tectonic body.

The volcanics comprise spherulitic dacite, porphyritic dacite, porphyry rhyolite, lithic and feldspathic tuffs and agglomerates. They have undergone hydrothermal alteration and low-grade regional metamorphism which has produced sericitisation and argillisation.

The tuffs are dominantly composed of quartz, chlorite, feldspar, sericite and opaque minerals. Most of the quartz or siliceous fragments can be identified as relict pyroclasts, and often appear to be aggregated in groups which may reflect a crude pyroclastic layering or sorting due to reworking. Some quartz is phenocrystic although very few grains show good crystal outlines. In some specimens, a cherty quartz mosaic probably reflects devitrification of glass fragments.

Most of the feldspar has been replaced by sericite. Some grains show phenocrystic form, although the alteration makes specific identification difficult. Some feldspar forms mineral grains while elsewhere it forms composites typical of a pyroclastic origin. The groundmass is composed of fine quartz, chlorite and feldspar forming a turbid mesh. Some coarser chlorite clusters probably represent glass alteration products or altered accidental lithic fragments. There are indications in some samples that the original groundmass may have been ignimbritic. Minute veinlets of sericite form patterns reminiscent of perlitic cracking textures. The rhyolites and rhyodacites, always very altered, are generally porphyritic or microporphyritic in quartz and feldspar. The feldspar is predominantly altered plagioclase and where identification is possible, it is in the oligoclase range. The groundmass is a microgranular mesh of quartz, plagioclase, chlorite and opaques. Some slightly coarser patches of chlorite are probably replacing ferromagnesian minerals. Most specimens contain 37% of lithic contaminants of quartzofeldspathic and mafic composition.

Most of these rocks are spherulitic or microspherulitic in texture. The spherules consist of very fine feldspar, commonly of more than one type, with sericite forming a fine-grained secondary phase. Some also contain a core of quartz or quartz finely intergrown with feldspar. Some samples show evidence of having originally been glassy but are now recrystallised and devitrified to a spherulitic texture.

The extremely variable texture of the groundmass and the size and sorting of the pyroclastic fragments in the tuffs indicate in many instances that they may have been deposited under shallow fluvial conditions, with later episodic reworking. The thin interbeds of argillaceous sediments show that a relatively quiet sedimentary environment prevailed at times, possibly in restricted areas that were isolated by extrusion of the volcanics. It is postulated that shallow-water to subaerial conditions prevailed during eruption.

The predominance of quartzarenites in the Burrell Creek Formation overlying the volcanics indicates that deposition following the extrusion of the Berinka Volcanics was occurring in a shallow environment, transitional to the platform sediments of the Chilling Sandstone.

**Chilling Sandstone (Efe)**

The name “Chilling Sandstone” was first used by Randal (1962) and Malone (1962) to describe the quartzarenite conformably overlying the “Noltenius Formation” (Burrell Creek Formation) of the Finniss River Group in the NW of WINGATE MOUTAINS. Walpole and others (1968) designated the type section for the Chilling Sandstone to lie in the syncline between the Fletchers Gully gold mine and Chilling Creek. The name “Chilling Sandstone” was retained by Pontifex and Mendum (1972), Morgan and others (1970), Sweet and others (1974), and Sweet (1977); however in WINGATE MOUNTAINS the limit of the Chilling Sandstone was extended to include part of what had been previously mapped as Middle Proterozoic Depot Creek Sandstone (Randal, 1962; Walpole and others, 1968). Hammond and others (1984) renamed the Chilling Sandstone the “Chilling Creek Formation” and incorporated this formation into a new group, informally named the Wingate Group, erected because of an inferred unconformity between the Chilling Sandstone and the underlying Burrell Creek Formation. Detailed studies by the NTGS show that the Chilling Sandstone is conformable and intertongues with the Burrell Creek Formation. Thus the new “Wingate Group” is discarded and the original name of “Chilling Sandstone” is retained. However, in contrasts, to Walpole and others (1968) and later BMR workers (Sweet and others, 1974), the NTGS has, on the basis of the interfingering relationship between the Chilling Sandstone and Burrell Creek Formation, incorporated the Chilling Sandstone into the Finniss River Group.

The Chilling Sandstone crops out and is well exposed over an area of about 210 km² in the NW of WINGATE MOUNTAINS where it forms part of the Wingate Plateau (Figure 4). The moderately- to steeply dipping sequence is about 7000 m thick and is composed mainly of well-bedded, medium-grained mature quartzarenite and micaceous submature quartzarenite. Macro-scale trough cross bedding is extremely well preserved (Plate 4) indicating an upright sequence.

Towards the base of the sequence, near the contact with the underlying Burrell Creek Formation, interbeds of phyllitic micaceous siltstone and phyllite occur with in-

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**Plate 4 Cross bedding in quartzarenite, Chilling Sandstone.**
creasing frequency. These show the transitional nature of the contact between the two formations (Figure 8).

The upper part of the Chilling Sandstone contains an interbed, about 375 m thick, of rhyolitic volcanics with at least one possibly dacitic member. The volcanic unit (Efcv) contains spherulitic devitrified rhyolitic rocks as well as a probable pyroclastic unit that, in thin section, contains clasts of flow-banded rhyolite and country rock. The dacitic unit is deeply weathered but contains primary amphibole, possible altered primary orthopyroxene, and subhedral quartz.

The Chilling Sandstone is intruded by sills of gabbro and dolerite of the Early Proterozoic Wangi Basics, and by sills and stocks of the Middle Proterozoic Ti-Tree Granophyre. This intrusive relationship is confirmed by the occurrence of rafts of quartzarenite within the granophyre. The sandstone is faulted against the Middle Proterozoic Angalarri Silstone and is unconformably overlain by Cretaceous sedimentary rocks.

A narrow, prominent ridge of quartzarenite, which lies in the NW of WINGATE MOUNTAINS and extends SW into MOYLE, has been assigned to the Chilling Sandstone. The quartzarenite here dips at moderate to steep angles towards the SE and is separated from the underlying Early Proterozoic Murra-Kamangee Granodiorite by an inferred low-angle thrust fault. The Chilling Sandstone is a platform sequence, as first suggested by Walpole and others (1968). As such it is in marked contrast with the underlying dominantly felsicly Burrell Creek Formation. The "Chilling Platform" straddled the margin of the deep water sedimentary basin in which the sediments of the Burrell Creek Formation were deposited.

The Chilling Sandstone is a possible source for the quartzarenites of the Middle Proterozoic Moyle River Formation found to the west in MOYLE.

**INTRUSIVE IGNEOUS ROCKS**

**Wangi Basics (Bbb)**

In WINGATE MOUNTAINS the Wangi Basics are composed of fresh to metamorphosed, basic to inter-

mediate intrusives forming two large stocks and numerous sills.

The largest stock, in the NW of the sheet area, extends into MOYLE and covers an area of 28 km². Here the basic rocks form boulder-strewn hills with characteristic red-brown soils. Exploration by Mobil Energy Minerals Australia (O'Connor, 1983) showed that the stock consists mainly of quartz gabbro, some gabbro-norite and minor anorthosite and troctolite. NTGS mapping and petrologic studies confirm that the most common rock type is a medium-to coarse-grained quartz gabbro, with minor fine-grained gabbro or dolerite. Although in hand specimen the gabros appear fresh, thin section studies show they are altered hydrothermally or by low grade (greenschist facies) metamorphism.

The gabros are composed of plagioclase, clinopyroxene and/or orthopyroxene, and amphibole. Commonly plagioclase is altered, at least in part, to sericite, chlorite, calcite and epidote; pyroxene is partially or wholly replaced by fibrous amphibole (tremolite-actinolite). Some samples also contain primary igneous hornblende.

Although contacts are obscured, the stock is inferred to intrude the Early Proterozoic Hermit Creek Metamorphics, Burrell Creek Formation and Berinika Volcanics. The stock is clearly older than the 1850-1840 Ma Murra-Kamangee Granodiorite (Page and others, 1984), as evidenced by xenoliths of basic rocks within the granodiorite and thin veins of granitic material within the stock, at or near the contact. The Ti-Tree Granophyre also intrudes the gabbro - thin veins of granophyre occur within the gabbro, and the contact between the two is marked by a hybridised granophyre, forming an altered hornblende-quartz diorite.

In the NW of WINGATE MOUNTAINS a number of basic sills intrude the metasedimentary rocks of the Burrell Creek Formation and the Chilling Sandstone. In the immediate vicinity of the sills, which are up to 6 km long and 200 m wide, the country rock is indurated. The sills consist of medium-to coarse-grained gabbro and minor quartz dolerite. Thin sections show that the rocks are composed of pyroxene, plagioclase, and minor am-

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**Figure 8** Transition between the Burrell Creek Formation and the Chilling Sandstone.
phibole, sericite, clay, biotite, quartz, iron oxides and opaques. All of the samples show evidence of alteration: plagioclase is partially or wholly altered to sericite and clay; pyroxene is similarly altered to actinolite/tremolite, chlorite, clay or epidote. Some of the pyroxene is intergrown and overgrown with hornblende. Petrology suggests that there have been two stages of alteration: a late-magnetic recrystallisation of some of the pyroxene to hornblende under conditions of decreasing temperature and a later hydrothermal alteration, possibly with accompanying greenschist facies metamorphism. It was probably during the later alteration event that accessory pyrite was introduced.

A basic to intermediate stock, about 8 km$^2$ in area, lies in the centre of the SE portion of WINGATE MOUNTAINS where it is exposed in boulder-strewn hummocky rises. It consists of medium-grained quartz-bearing diorite and gabbro, and some dolerite. The gabbro and diorite are composed mainly of plagioclase (labradorite, andesine) and hornblende with minor quartz, biotite and iron oxides. They show evidence of having undergone low grade metamorphism, with accompanying hydrothermal alteration: plagioclase is partially or wholly replaced by sericite, clay, epidote and calcite; hornblende is sometimes altered to actinolite/tremolite, biotite is variably chloritised. Secondary pyrite may also be present. The stock intrudes the metasedimentary rocks of the Burrell Creek Formation and is intruded by the Soldiers Creek Granite, as shown by xenoliths of gabbro within the granite, and veins of granite within the gabbro.

The age constraints of the Wangi Basics in WINGATE MOUNTAINS, as in the adjoining sheet area DALY RIVER (Dundas and others, 1987), are given by the field relationships, as outlined, which show they have intruded the Burrell Creek Formation and have been intruded by the Murra-Kamangee Granodiorite. The Burrell Creek Formation has a probable maximum age of 2000 Ma in its western extent and the Murra-Kamangee Granodiorite is dated at 1852±33 Ma (Page and others, 1984). These dates suggest that the Wangi Basics were intruded between 2000 and 1840 Ma and are thus probable correlative of the early Proterozoic Zamu Dolerite of the Pine Creek Geosyncline (Needham and others, 1980).

However, it should be noted that there is no upper age constraint on the basic sills which intrude the Burrell Creek Formation and Chilling Sandstone in the NW of WINGATE MOUNTAINS. They have been assigned to the Wangi Basics on the basis of similar mineralogy and state of alteration, rather than to the Middle Proterozoic Murrenja Dolerite which intrudes the Moyle River Formation in ANSON and MOYLE (Fahey and Edgoose, 1986; Edgoose and others, 1989). In addition to the above, elsewhere in the Litchfield Province the Murrenja Dolerite is restricted to the western side of Tom Turners Fault.

GRANITOIDS

There are three granite bodies in WINGATE MOUNTAINS; the Murra-Kamangee Granodiorite in the NW, the Allia Creek Granite in the north, and the Soldiers Creek Granite in the SE-central part of the sheet area. The granitoids are distinguished on the basis of their mineralogical and textural differences.

Radiometric age determination, using the U/Pb method on zircon and xenotime obtained from samples of the Murra-Kamangee Granodiorite in MOYLE, gave a crystallisation age of 1852±33 Ma (Page and others, 1984). Rb/Sr whole rock data on samples of Murra-Kamangee Granodiorite from DALY RIVER gave a radiometric age of 1770±16 Ma (Page and others, 1984). This age probably reflects hydrothermal alteration associated with the intrusion of younger granitoids (Allia Creek Granite, Soldiers Creek Granite).

Rb/Sr mineral and whole rock age determinations on samples from the Allia Creek and Soldiers Creek granitoids have yielded ages of 1780±80 Ma (Riley, 1980) and 1760±27 Ma (Edgoose and others, 1984a) respectively.

Murra-Kamangee Granodiorite (Pgmk)
The Murra-Kamangee Granodiorite is defined from its type area in MOYLE (Edgoose and others, 1989). In WINGATE MOUNTAINS the granodiorite is well exposed and crops out over a total area of approximately 100 km$^2$ in the NW of the sheet area. It continues northwards into DALY RIVER, NW into GREENWOOD, and westwards into MOYLE.

The Murra-Kamangee Granodiorite crops out as groups of boulders and tors scattered across eolian rises and the edges of floodplains. It comprises mainly biotite tonalite and granodiorite with minor adammellite. The most common rock type is weakly foliated, xenolithic, medium- to coarse-grained biotite tonalite. It is composed mainly of quartz, plagioclase and biotite forming a typical allitromorphic mosaic. Minor minerals include muscovite, sericite and chlorite; accessory minerals are garnet, apatite, zircon, tourmaline and opaques.

The rock contains a relatively high percentage of quartz (30-40%) which is commonly strained and displays heavily sutured intergranular boundaries. Many of the quartz crystals contain inclusions of other minerals. Biotite is the dominant mica, forming 10% to 15% of the rock; it is often markedly pleochroic and displays variable alteration to chlorite. Biotite clots are ubiquitous and probably represent altered garnets. Tourmaline is generally found in accessory amounts only; however, it may form up to 3% of the rock and appears to have been among the last components to crystallise. It was possibly introduced during a final pegmatitic phase. This final phase may have also been water-rich, contributing to the alteration of the plagioclase and biotite.

Granodiorites and adammellites are generally medium-grained and composed mainly of quartz, plagioclase, orthoclase and biotite, with minor garnet, muscovite, sericite and tourmaline, and accessory zircon, apatite and opaques. Granodiorites and adammellites vary little from the tonalites except for increasing K-feldspar which usually exists as late stage subhedral poikilocrysts giving a porphyritic texture to the rock. These poikilocrysts are distributed throughout a medium-grained allitromorphic mosaic of quartz and plagioclase.

The Murra-Kamangee Granodiorite contains numerous country rock xenoliths. The most common xenoliths are garnet-biotite-feldspar-quartz metasediments derived from the Hermit Creek Metamorphics. Other xenoliths include vein quartz, and metabasic igneous rocks. Cognate xenoliths are less common and consist of garnetiferous tonalitic gneiss with diffuse margins.

The Murra-Kamangee Granodiorite has intruded the Early Proterozoic Wangi Basics and Hermit Creek Metamorphics. Its age of 1852±33 Ma indicates that it is younger than the Burrell Creek Formation and Chilling
Sandstone, however the relationships in WINGATE MOUNTAINS are not clear because of faulting near the contact.

The relationship with the Wangi Basics is evidenced by veins and pods of granodiorite within the basics and xenoliths of basics within the granodiorite at or near the contact. The intrusive relationship with the metasedimentary rocks of the Hermit Creek Metamorphics is demonstrated by the numerous country rock xenoliths within the granodiorite that are readily recognisable as gneisses of the Hermit Creek Metamorphics. Field relationships in MOYLE and DALY RIVER also demonstrate this relationship (Edgoose and others, 1989; Dundas and others, 1987). On the western margin of the sheet area, the Murra-Kamangee Granodiorite is separated from the Early Proterozoic Chilling Sandstone by a low-angle thrust fault.

Allia Creek Granite (Pga)
The Allia Creek Granite, which occupies about 50 km² in the north-central part of the sheet area, was originally named the Allia Granite by Randal (1962). Since that time, however, the body has been called the Allia Creek Granite in most publications (e.g. Walpole and others, 1968; Morgan and others, 1970). These earlier workers included in the Allia Creek Granite a smaller area of outcrop which lies in DALY RIVER and about eight kilometres north of the main exposure. On the basis of differences in texture and mineralogy, the smaller northern exposure has been assigned to a separate intrusive named the Jammine Granite (Dundas and others, 1987). The division of these two granites is further supported by differences in their geochemistry (De Ross, 1987).

The Allia Creek Granite crops out as low boulders and pavements, and occasionally forms tors up to 1.5 m high. Many of the exposures are distinctive because of porphyritic feldspars which may be up to 60 mm in length (Plate 5). These phenocrysts often display a crude platy alignment defining a flow structure which appears to parallel the margin of the granite and dip steeply towards the centre. Randal (1962) described the granite as essentially a biotite-muscovite granodiorite which he believed to be related to the “Litchfield Complex”. Pontifex and Mendum (1972) described the Allia Creek Granite as relatively poor in potash feldspar in comparison to the Soldiers Creek Granite.

Thin section examination shows the porphyritic crystals to be tabular microcline showing typical cross-hatched twinning. Plagioclase composition probably lies in the oligoclase range and it is of subordinate importance, invariably showing intense alteration to sericitised clay minerals. The quartz is clear in section but most crystals show signs of strain. Spectacular pleochroic biotite occurs in clusters of small flakes, commonly associated with apatite and zircon prisms. Muscovite flakes are rare. The high potassium content of the rock suggests it was crystallised from a magma that was augmented by hydrothermal potassium-bearing fluids. This contrasts strongly with the description of the “potash-poor Allia Creek Granite” by Pontifex and Mendum (1972). Graphic intergrowths of quartz and feldspar suggest that the final stages were pegmatitic.

The most recent age determination of the Allia Creek Granite (muscovite, whole rock, feldspar) gave a Rb/Sr date of 1780±80 Ma (Riley, 1980). The fairly large range of error in this age determination limits its usefulness, as the granite could be both syntectonic or post-tectonic. Ferguson and others (1980) describe granites in the Pine Creek Geosyncline that produce contact metamorphism as late orogenic, i.e. the country rock would be “cold” enough to record a thermal overprint from the intruding body. The Allia Creek Granite intruded and hornfelsed the Burrell Creek Formation producing andalusite-muscovite schists which may also contain garnet and cordierite and veins of pegmatite which are common within the Burrell Creek Formation near the contact with the granite. Rafts of Burrell Creek Formation metasedimentary rocks, up to several hundred metres across, also occur within the area of exposure of the granite.

Soldiers Creek Granite (Pgs)
The Soldiers Creek Granite is exposed over about 120 km² in the SE quadrant of the sheet area. The granite was first named by Hossfeld (1937b), although both alluvial and hard rock mining of tin in the granite took place from as early as 1922 (see ECONOMIC GEOLOGY). The granite forms a distinctive pattern on aerial photographs because of the numerous greisen veins which form intersecting linear ridges up to 20 m in height above the surrounding plain. On this plain the granite is well exposed as weathered and crumbling pavements and boulders. The granite is extensively greisenised and altered, with very few fresh outcrops. Its eastern extent is unknown because of the Middle Proterozoic cover rocks of the Tolmer Group. Cover rocks also obscure the southern and western margins but geophysical evidence suggests that the granite is very extensive to the south. The unconformity between the granite and the Tolmer Group can be observed on the north face of the ridge which extends eastward from Collah Waterhole. In the area west of the waterhole, Early Cambrian Antrim Plateau Volcanics form a thin sheet over the granite, and its westernmost exposure is overlain by Early Cambrian
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cesery rocks. Elsewhere the Uniya Formation occurs as isolated patches resting on the granite.

The rocks consist predominantly of variably greisenised granite, with similarly altered adamellite and granodiorite. Numerous xenoliths up to 30 cm in diameter occur throughout the granite. Near the margins there are some large roof pendants and rafts of Burrell Creek Formation country rock, and hybrids of granite and country rock have formed. A moderate (up to about 1 km wide) metamorphic aureole in the Burrell Creek Formation is marked by the development of coarse muscovite in phylilitcs and, locally, the growth of porphyroblastic andalusite. Numerous greisen and pegmatitic veins have invaded the metasediments for several hundred metres from the granite contact. All of the above features indicate that the Soldiers Creek Granite represents the roof zone of a high level intrusive.

Most commonly the rock is a variably altered and locally greisenised coarse- to medium-grained leucocratic porphyritic granite with microline phenocrysts. The phenocrysts are less coarse than those in the Allia Creek Granite, being generally of the order of 10 mm in length.

Quartz, orthoclase, microcline and plagioclase form an allotriomorphic mosaic with a granular or granitoid texture. The K-feldspars are generally the dominant mineral species and the plagioclase is typically of oligoclase composition. Biotite and muscovite are commonly intergrown but both also occur as single grains and in small aggregates. Muscovite is commonly coarser-grained than biotite. Almost all of the granite shows some degree of late stage alteration and greisenisation. The plagioclase is variably altered to fine sericite and, in some instances, kaolinitisation has occurred. Biotite is partly or completely altered to chlorite and iron oxide. Much of the muscovite is hydrothermal in nature. In more altered samples, K-feldspar has also been converted to sericite and quartz.

The granite near the Fish River Fault and parts of the Collah Fault has been extensively sheared in addition to the pervasive alteration. Most of the components have been replaced by strained, euhedral crystals of allotriomorphic quartz. The abundance of coarse muscovite in the granite increases near the margins of the greisen veins. The vein assemblages consist of quartz, sericite and muscovite, and clearly represent granitic rocks in which all the feldspars have been replaced by sericite and which have been invaded by coarse-grained muscovite and quartz. Some greisens still retain coarse altered K-feldspar. Cassiterite and, more commonly, specularite occur in these greisen veins.

Cassiterite was mined at Collah from the eluvials derived from weathered greisen veins within the granite. At Muldiva and Buldiva mines to the north, the cassiterite occurs in greisen veins invading phylilitcs of the Burrell Creek Formation.

MIDDLE PROTEROZOIC

TOLMER GROUP

The Tolmer Group occupies about one quarter of the area of WINGATE MOUNTAINS. It is a sequence of arenite, siltstone and dolomite up to 1600 m thick, deposited in a shallow-water to intertidal environment. The group unconformably overlies the Early Proterozoic Burrell Creek Formation and the Allia Creek and Soldiers Creek granitcs. It is unconformably overlain by the Cambrian Antrim Plateau Volcanics and the Cambrian Daly River Group. The contact with the Auvergne Group is not exposed. However, the Bullita and Wattie groups of the Victoria River Basin have been correlated with the Tolmer Group (Sweet, 1977) and as the Auvergne Group is younger than these groups the contact is assumed to be unconformable. Generally the Tolmer Group is undeformed with only gentle folding associated with faulting.

NTGS mapping has resulted in changes to the previous geologic map of the area (Pontifex & Mendum, 1972). The major change is the inclusion in the Hinde Dolomite of rocks previously mapped as Waterbag Creek Formation. In DALY RIVER (Dundas and others, 1987), arenites mapped as Waterbag Creek Formation were reassigned to the Hinde Dolomite because they were found to be interbedded with carbonate rocks normally assigned to the Hinde Dolomite. A similar situation exists in WINGATE MOUNTAINS. In addition, the chert band which marks the boundary between the Waterbag Creek Formation and the Hinde Dolomite (Sweet and others, 1974), has not been recognized in this area. A maximum age for the Tolmer Group is defined by a Rb/Sr radiometric age of 1780±80 Ma for the unconformably underlying Allia Creek Granite (Riley, 1980). A possible minimum age of about 1200 Ma is given by correlation with the Wattie and Bullita Groups of the Victoria River Basin (Sweet, 1977).

Depot Creek Sandstone (Etd)

The Depot Creek Sandstone is the basal formation of the Tolmer Group and is estimated to be approximately 400 m thick. It crops out in a linear NW-trending belt in the eastern portion of the sheet area, and generally the formation dips shallowly eastward except where affected by faulting.

In the north of the sheet area, the Depot Creek Sandstone forms an easterly-dipping platform capping the Burrell Creek Formation and the Allia Creek Granite. The unconformity is well exposed in escarpments formed around the edges of the plateau. In the south, along the ridge that trends east from Collah Waterhole, a palaeoweathering profile is evident in the Soldiers Creek Granite immediately below the quartzarenites of the Depot Creek Sandstone.

The Depot Creek Sandstone in WINGATE MOUNTAINS is a massive to blocky, red to pale pinkish orange, medium- to coarse-grained, quartzarenite. It displays abundant ripple marks and cross bedding; surface silification is widespread. Coarser layers are often interbedded with the arenites and pebbles occur in single layers or outlining cross beds. A cross bedded basal boulder conglomerate with rounded boulders of quartzarenite, up to 300 mm diameter, set in an arenite matrix, overlies the Burrell Creek Formation and Soldiers Creek Granite approximately 5 km north of Collah Waterhole. Towards its top the formation becomes more thinly bedded; this is quite apparent in the Fish River Gorge.

The contact with the Stray Creek Sandstone is conformable and is very difficult to determine in the field. However, both units have distinct photo patterns - the Depot Creek Sandstone is strongly jointed and has a blocky pattern whereas the Stray Creek Sandstone is more thinly bedded and has a distinct "ribbon" pattern as a result of parting along bedding planes.

Drainage is controlled by jointing producing some spectacular gorges. The Fish River forms such a gorge where it flows through the Depot Creek Sandstone.
Stray Creek Sandstone (Pts)
The Stray Creek Sandstone forms a gently dipping sequence about 300 m thick conformably overlying and to the east of the Depot Creek Sandstone. In the NE of the sheet area Stray Creek Sandstone crops out poorly in the centre of a shallow dome where it is flank ed by gently dipping Hinde Dolomite.

In WINGATE MOUNTAINS the basal part of the Stray Creek Sandstone consists of well-bedded, medium-grained clean quartzarenites, identical to the Depot Creek Sandstone, which rapidly grade up into flaggy, micaceous quartzarenites. The sequence becomes finer-grained, more silty and more micaceous towards the top. Consequently these fissile sandstones and siltstones crop out poorly. Commonly the finer-grained quartzarenites are glauconitic or chloritic, imparting a dark grey-green colour to the rocks. They are generally thin-bedded and laminated, and bedding surfaces often show mud cracks, mud flakes and current lineations. The sedimentary structures preserved in the coarser units include symmetrical and asymmetrical ripple marks, and ubiquitous cross bedding. The sandstone forming the ridge east of Collah Waterhole is unique in that it displays extensive convolute and slump bedding—these features have been observed nowhere else in the Stray Creek Sandstone. A siderite horizon about 2 m thick forms an isolated outcrop west of Jogi Creek at GR 068245. This siderite unit forms an important marker horizon near the top of the sequence in DALY RIVER (Dundas and others, 1987) where it is much more extensive. Further outcrops of siderite are reported from the Stray Creek Sandstone south of Lilyarba Creek, near the eastern edge of the sheet area (Peter Rush, BHP, pers. comm.). The outcrops are usually massive, coarse-grained and heavily oxidised. The beds of quartzarenite above this massive band contain coarse grains of siderite decreasing in abundance up sequence.

Hinde Dolomite (Pth)
The Hinde Dolomite crops out sporadically on the plains east of the Stray Creek Sandstone and, east of Lilyarba Creek, forms low hills which rise up to 80 m above the level of the plains. It consists of up to at least 900 m of pink and grey, flaggy dolomite, stromatolitic dolomite (particularly in the basal section), cherty dolomite, marl, chert, ferruginous quartzarenite, siltaceous quartzarenite and reddish siltstone. It has generally gentle dips of 5° to 10° towards the ENE.

The base of the sequence is clearly marked by an abrupt change from the flaggy micaceous and silty quartzarenites of the Stray Creek Sandstone to the dolomites of the Hinde Dolomite. The dolomites form both flaggy and blocky outcrops and vary from crystalline to finely crystalline often containing thin silty dolomite laminae and thicker layers. The stromatolites, where present, are large colonial varieties, identified as *Inzeria tjonmese* Krylov from samples elsewhere in the sequence (Cloud and Semikhatov, 1969). The siltstones are predominantly dolomitic, vary from black to yellow-brown or reddish in colour, and crop out poorly due to their fissile nature. Quartzarenites vary from relatively clean medium-grained white to pale grey rocks, to reddish brown silty or ferruginous rocks. They often contain halite casts, mud flakes, and pits left by the weathering out of coarsely-grained carbonate. Chert occurs as massive beds and as replacement veins in dolomite.

Where faults occur within the Hinde Dolomite, e.g. on the eastern flank of the domal structure in the NE, and on the western margin of the sheet area, coarse breccias have developed. The breccias consist of angular fragments of dolomite, chert and lesser quartzarenite in a ferruginous matrix that may be calcareous in part.

**AUVERGNE GROUP**

Rocks belonging to the Auvergne Group are poorly exposed but nevertheless cover an extensive area in the SE quadrant of WINGATE MOUNTAINS. The group consists of the Angalarri Siltstone, the Saddle Creek Formation, and the Pinkerton Sandstone in the sheet area. The exposures in WINGATE MOUNTAINS mark the northermmost extent of the Auvergne Group which forms a part of the Late Proterozoic Victoria Basin sequence.

**Angalarri Siltstone (Paa)**
The Angalarri Siltstone is the oldest formation of the Auvergne Group to crop out in WINGATE MOUNTAINS. It is very poorly exposed but forms an extensive unit in the SE portion of the sheet area. Generally the siltstone is exposed in rubbly outcrops on the flanks of the Wingate Plateau, below the Cretaceous escarpment.

The siltstone consists predominantly of red-brown, extremely fissile siltstone with minor interbeds of grey-green siltstone. Thin (usually less than 10 cm) beds of very fine, immature red-brown quartzarenite occur throughout the sequence. In outcrops north of Jarong Spring, there are also a few thin horizons of pale grey laminated dolomite, and some dolomitic siltstones. However, the Angalarri Siltstone is generally notable for its lithological uniformity over a large area.

No contacts between the Angalarri Siltstone and older rock units are exposed. Where it is not capped by younger units such as the Uniya Formation, Antrim Plateau Volcanics or Cretaceous sediments, the siltstones form low, rounded, rubble-covered hills and gentle valleys. In situ outcrop is rare as the siltstone weathers readily and forms a thick talus of fissile fragments. Some outcrops can be seen in the heads of gullies on ridges protected with a younger capping. These outcrops are flat-lying and usually fractured, making it very difficult to collect representative samples.

The sandstone consists of angular iron-stained quartz grains set in a very fine-grained ferruginous matrix of quartz and clay. The rock is usually moderately well sorted with a random orientation of the angular quartz grains.

The maximum thickness of siltstone that can be determined from outcrop in WINGATE MOUNTAINS is about 50 m. Sweet and others (1974) report a maximum thickness for the unit of 500 m in the Mount Thymman area (Delamerie 1:250 000 sheet area). NTGS DDH 83/1 was terminated in Angalarri Siltstone after passing through 160 m of reddish-brown siltstone, some layers of which had been reduced to a greenish-grey colour (Figure 9).

On the SE flank of the fault ridge that runs east from Collah Waterhole, the Angalarri Siltstone appears to overlie the Stray Creek Sandstone of the Tolmer Group although the contact is not exposed. The Stray Creek Sandstone on the ridge dips moderately to steeply to the SSW while the nearest exposure of Angalarri Siltstone is flat-lying or dips shallowly to the NE. This suggests that some faulting of the Tolmer Group may have occurred prior to deposition of the Angalarri Siltstone.
Saddle Creek Formation (Ead)
The Saddle Creek Formation crops out as a relatively narrow east-west striking band in the south-central part of the sheet area, and in a small exposure at the southern end of the Fish River Fault. The strike of the main body swings around to the south at its western end. There is also a narrow, bench-forming outcrop of north-trending sandstone on the western edge of the Wingate Plateau.

The Saddle Creek Formation conformably overlies the Angalarri Siltstone, although this relationship is not seen in the sheet area where the Saddle Creek Formation is exposed in benches and small cliffs on the flanks of broad valleys which cut down into poorly outcropping Angalarri Siltstone.

Sweet and others (1974) describe the Saddle Creek Formation as consisting of a basal quartzarenite sequence and an upper sequence dominated by siltstone. In WIN-GATE MOUNTAINS, only the basal quartzarenite occurs. The dominant feature of the sandstone in outcrop is the massive cross bedding and common slump and contorted bedding structures. North of Jarong Spring, where a creek cuts through the small scarp of Saddle Creek Formation, massive cross beds at least 10 m long and 2-3 m thick are overlain by a 1 m thick bed containing abundant contorted bedding.

Along strike, to the west the outcrop becomes massive with beds in excess of 1-2 m in thickness. Smaller scale cross bedding and some slumping, flame structures and distorted bedding are still in evidence.

About 1 km north of Jarong Spring, a glacial pavement is preserved on the quartzarenite of the Saddle Creek Formation. The transport of the glacier over these rocks has left a striated, moulded surface on which some impressions of chatter marks still remain. The pavement is only a few square metres in area and, in the absence of surface silicification, it is not as well preserved as the pavements in DALY RIVER (Dundas and others, 1987). The pavement is overlain by poorly exposed diamictite and glaciofluvial sandstone of the Uniya Formation. The absence of the Saddle Creek Formation over most of the SE corner of WINGATE MOUNTAINS, where the Angalarri Siltstone is directly overlain by the Uniya Formation or the Antrim Plateau Volcanics, may be attributed to removal by glacial activity during this Late Proterozoic glaciation.

The quartzarenites which are faulted against and conformably overlie the Depot Creek Sandstone on the ridge that trends east from Collah Waterhole have been assigned to the Stray Creek Sandstone largely on the basis of this apparently conformable relationship. However, in outcrop these rocks bear many similarities to the Saddle Creek Formation, showing such structures as distorted and convoluted bedding, slump structures, and cross bedding. These features are uncommon in the normally well bedded quartzarenites of the Stray Creek Sandstone.

In thin section, the quartzarenites consist of subangular to subrounded interlocking quartz grains, often arranged in coarser and finer layers which in hand specimen give the rock a laminated appearance. Lithic fragments and mineral grains such as biotite and feldspar form a small proportion of the rock and indicate a granitic provenance. Both coarser and finer beds are generally poorly sorted.

Pinkerton Sandstone (Pap)
The Pinkerton Sandstone is exposed on the southern margin of the sheet area where erosion has dissected the cover of Cretaceous rocks that form the Wingate Plateau. No contacts with older rocks can be observed, but the Pinkerton Sandstone is inferred to conformably overlie the Saddle Creek Formation as it does further south into the Victoria Basin (Morgan and others 1970). The exposures on the southern margin of the sheet area have largely been identified as Pinkerton Sandstone on the basis of earlier BMR mapping in this region and to the south (Pontifex and Mendum, 1972).

The exposures consists of narrow benches of well-bedded to flaggy pale grey to white quartzarenite and silty quartzarenite. Abundant cross bed sets occur throughout the sequence, and some beds contain halite casts. About 30-40 m of sediments are exposed in this area - the formation has a maximum thickness of 100 m in the Auvergne 1:250 000 sheet area.

Ti-Tree Granophyre (Egi)
The Ti-Tree Granophyre crops out in the centre, central west and NW of WINGATE MOUNTAINS. In the west it forms narrow sills up to 3 km long and 300 m thick intruding the Burrell Creek Formation and the Chilling Sandstone. In the NW a small body of approximately 1.5 km² intrudes the Berinka Volcanics, the Burrell Creek Formation and the Wangi Basics and in the centre of the sheet area, several larger stocks of Ti-Tree Granophyre intrude the Chilling Sandstone.

The Ti-Tree Granophyre is red-brown to pale red-brown when weathered and medium to dark pinkish-grey or pinkish grey-green when fresh. Texturally and compositionally variable, it consists of altered and sheared granophyre, altered porphyritic granophyre, altered sericitised granophyre, altered porphyritic microadamellite and granophyro adamellite. It contains fine- to medium- and occasionally coarse-grained phenocrysts of quartz and feldspar in a groundmass of micrographic, generally spherulitic intergrowths of quartz and feldspar. Minor minerals include chlorite, biotite, leucocene, epidote (saxsuturised), calcite, muscovite, hornblende and opaques. All samples show extensive deuteric alteration; the feldspars have undergone clay-sericite alteration and chlorite has replaced the ferromagnesian minerals. Petrological work indicates that the granophyre is possibly a hydrous differentiate of a siliceous alkaline intrusive with granodioritic affinities.

A granophyre sill in contact with a sill of Wangi Basics (GR 418666) is distinguished by an unusually high content of hornblende. This is probably the result of contamination by basic material during intrusion of the sill.

In the NW (GR 418666) there are veins of granophyre intruding the Wangi Basics. In this general area there are also veins of granophyre intruding the Berinka Volcanics. Recent drilling by CEC has confirmed this intrusive relationship (Simpson and Dennis, 1986). Thus the maximum age for the Ti-Tree Granophyre is Early Proterozoic but younger than the deposition and later metamorphism of the Pine Creek Geosyncline rocks. Evidence in MOYLE indicates that the Ti-Tree Granophyre intrudes the Middle Proterozoic Moyle River Formation, thus placing its age at no older than Middle Proterozoic.

U/Pb isotopic dating of samples of Ti-Tree Granophyre failed to produce any decisive results. Possible crystallisation ages of 1805±4 Ma and 390±9 Ma were obtained. However, it is likely that there was contamination of the very small zircon concentrate which was separated from the rock (Edggoose and others, 1984b).
about 3 km SW of Collah Waterhole (GR 079079), in the area designated by Sweet and others (1974) as the type locality for the Jarong Conglomerate: this is now the parastratotype for the Uniya Formation. Other exposures occur 17 km SW and 45 km NE of Collah Waterhole, 1 km north of Jarong Spring, and near the Collah Fault at GR 985120.

At the parastratotype there is an exposure about 60 m thick comprising alternating diamicite, glaciolastrine and glaciofluvial beds. The outcrop consists of small cliffs of diamicitic with only vague indications of layering, larger cliffs of rhythmitite containing dropstones (Plate 6) and other small cliffs of mainly glaciolastrine rocks with narrow beds of diamicite. Bedding generally dips shallowly to the south. Boulders up to one metre across, some of which are polished and striated (Plate 7), occur as glaciofluvial drift on the hill slope.

The glaciofluvial and glaciolastrine rocks have numerous dropstones and the arenite layers (usually coarse) vary from well sorted to unsorted. Some layers have localised cross bedding and pebbles other than dropstones are found randomly distributed throughout the otherwise evenly bedded arenite layers.

The diamicite is typically unsorted with a low proportion of matrix. The pebbles or boulders are mainly light pink quartzite, probably originating from the Depot Creek and Stray Creek sandstones of the Tolmer Group which outcrop about 2 to 3 km to the north. A polished and striated pavement is sometimes preserved on the moderately south-dipping Stray Creek Sandstone in this area. The striations are oriented north-south but the direction of movement could not be determined. Other clasts include immature arenite and phyllite (Burrall Creek Formation), dolomite (Tolmer Group) and granite (Soldiers Creek Granite). The matrix is a mixture of argillaceous and arenaceous material comprising quartz with lithic fragments.

The actual thickness of the Uniya Formation in the parastratotype was probably greater than that exposed at present as the lower slopes are covered with polished and striated boulders and pebbles and the Cretaceous overlying the formation has a basal conglomerate which contains pebbles from the diamicite in a coarse ferruginous arenite matrix. A thickness of 137.2 m of Uniya Formation was proved in drillhole NTGS 83/1, 2 km south of Collah Waterhole. The succession shown in the drillhole consists entirely of matrix-supported diamicite with numerous clasts, up to 0.3 m diameter, set in a matrix of dark brownish-red siltstone (Figure 9). The colour of these siltstones and the very gradational contact between the Uniya Formation and the underlying Angalarri Siltstone indicates the siltstone was a major provenance for the glaciogenic rocks.

About 2 km² of Uniya Formation crops out below the scarp of the Wingate Plateau 17 km SW of Collah Waterhole. The formation, which is overlain by Cretaceous sediments and basalts of the Early Cambrian Antrim Plateau Volcanics is up to 20 m thick and composed of glaciolastrine siltstones, which contain occasional pebble-size dropstones of quartzarenite and chert interbedded with probable glaciofluvial pebble to cobble conglomerate and micaceous feldspathic medium-grained quartzarenites. The conglomerates contain subrounded to rounded, sometimes striated, quartzarenite clasts.

A hill formed of poorly exposed Uniya Formation overfies a glacial pavement about 1 km north of Jarong Spring. The outcrop consists of scattered, rounded
erratics of stromatolitic dolomite, laminated dolomite, quartzite, basic igneous rocks, granite and metasediments, up to 1 m but generally in the order of 300 mm, in diameter. Minor outcrop of immature fine silty arenite which displays prominent soft sediment deformation occurs near the summit of the hill. The thickness of the formation in this area is estimated at about 20 m. The sequence overlies a small, poorly preserved glacial pavement formed on shallow dipping quartzarenites of the Saddle Creek Formation. Although not polished, the pavement is smooth with striations trending 10°-20° and some chatter marks still evident.

The formation occurs as a talus of erratics under the Cretaceous capping of the mesas and buttes to the north and NE of Jarong Spring. Although not exposed, it overlies the Angalarri Silstone, presumably unconformably, and is usually thin, since in many instances exposures of the silstone are found only a few metres below the base of the Cretaceous cap. The erratics forming the talus vary greatly in size; the largest is several metres in diameter (Plate 8). To the east, near the Collah Fault, the formation overlies the Angalarri Silstone and the Soldiers Creek Granite. In this area, a 10 m thick exposure of massive unsorted pebble conglomerate dips to the south, and represents a rapidly transported and deposited sediment of glaciofluvial origin.

A small exposure of Uniya Formation occurs below the scarp and immediately to the north of a prominent mesa in the east-central region of WINGATE MOUNTAINS (GR 908170). Here it is composed of flat-lying glaciofluvial cross-beded arenites and rubble of sometimes striated cobble- to boulder-sized erratics of granite, schist, gneiss and quartzite. About 2 km to the NNW of this exposure there is an extensive surface scree of numerous sub-rounded cobble- to boulder-sized erratics of ripple-marked siliceous medium-grained quartzarenites.

**Figure 9** Drill log of NTGS diamond drillhole 83/1.

**PALAEOZOIC**

**CAMBRIAN**

**Undivided sedimentary rocks (C1)**

Sedimentary rocks which overlie Proterozoic units and which stratigraphically underlie or are equivalent to the Antrim Plateau Volcanics have been assigned to undivided sedimentary rocks of Early Cambrian age. These rocks form narrow outcrops abutting the Fish River Fault.
and scattered exposures in an eluvial plain to the east of the fault in the central eastern part of the sheet area. The sedimentary rocks unconformably overlie the Soldiers Creek Granite and the Depot Creek Sandstone, although no contacts are exposed. They are overlain by a small outlier of Tindall Limestone at GR 035155.

The lithologies comprising this sequence include quartzarenite, ferruginous siltstone, and silicified carbonate rock (probably limestone). Outcrops are sparse, deeply weathered and generally flat-lying or have shallow depositional dips.

These sedimentary rocks represent a transitional and shelf marine sequence deposited in a restricted, elongate shallow basin. It is likely that this basin was formed by movement on the Fish River Fault in the Late Proterozoic. Post-Cambrian faulting is apparent but restricted as Cambrian sedimentary rocks are preserved on both sides of the Fish River Fault.

Antrim Plateau Volcanics (C 1a)
The Antrim Plateau Volcanics form an extensive unit in the southern half of the sheet area, generally consisting of poor, rubbly exposures underneath the scarp of Cretaceous rocks around the edges and the outliers of the Wingate Plateau. They are dominantly composed of vesicular and amygdaloidal basalt but also contain numerous interbeds of quartzarenite and some minor interbeds of limestone and rest with an angular unconformity on the Soldiers Creek Granite, the Angalarri Siltstone, and the Uniya Formation. Much of this unit is covered by the extensive Cretaceous sediments which form the surface of the Wingate Plateau.

The volcanics consist of medium-grained, greenish-grey and reddish-brown basalt. They are somewhat altered, sometimes olivine-bearing, and commonly consist of plagioclase phenocrysts set in a fine matrix of pyroxene and plagioclase laths. In the highly vesicular rocks, the vesicles are infilled with quartz, amphibolite, barite and carbonates. Some of the outcrops are so coarsely vesicular and the infillings of quartz so prominent that they superficially resemble quartz-pebble conglomerates.

The lenses and horizons of sedimentary rocks within the volcanics largely consist of medium-grained, well-bedded quartzarenites, which are commonly feldspathic. The most prominent sedimentary feature is cross bedding. Where the rocks are overlain by basalt they are well indurated whereas elsewhere they are friable and weather easily.

The surfaces of some of the quartzarenite lenses are grooved and undulating as the result of hot lava flowing over the bedding surface. They may also exhibit a spidery network of fine but prominent veins of limonitic quartzarenite. The exact nature of this veined surface is not understood.

Numerous sedimentary dykes composed of baked, feldspathic quartzarenite range from a few centimetres to a metre or so in thickness (Plate 9). Thin interbeds of limestone occur at a few isolated localities south of Collah. They consist of cryptocrystalline grey and mottled limestone similar to the Tindall Limestone and indicate that the volcanics were, at least partially, extruded into a shallow marine environment.

The maximum known thickness of the volcanic and sedimentary sequence is 103 m in drillhole NTGS 83V1 (Figure 9). Here, the sequence consists of three individual flows of medium-grained basalt. The maximum outcrop thickness of the sequence is about 80 m.

Plate 9 Sandstone dyke, approximately 1 m wide, in Antrim Plateau Volcanics.

Daly River Group

Tindall Limestone (C mt)
The Tindall Limestone crops out in two small areas in WINGATE MOUNTAINS - an area of slightly elevated ground 10 km north of the Fish River Station homestead and on a hill 6 km NNW of Collah Waterhole. It is the only representative of the Daly River Group in WINGATE MOUNTAINS. The Tindall Limestone is a two-tone buff and brownish-grey crystalline rock. It has a uniform grey colour on the weathered surface, but a mottled appearance on fresh surfaces. The buff coloured areas are fine-grained and the brownish-grey areas are coarser grained. Thin sections from similar outcrops in DALY RIVER show the brownish-grey areas to consist of granular aggregates of calcite and the buff coloured areas to consist of fine granular dolomite. The northern outcrop lies within a remnant sub-basin of mainly unexposed Cambrian rocks. Although only a metre or so thick and of very limited extent, the outcrop is well jointed and its surface is grooved, etched and fluted as a result of weathering.

Mesozoic

Cretaceous (K)
Cretaceous sedimentary rocks form the most extensive unit in WINGATE MOUNTAINS. They form the surface of the receding Wingate Plateau but exposures are largely confined to the dissected edges and outlying mesas and buttes of the plateau. Erosion has exposed some of the sequence on the plateau surface but most Cretaceous rocks in the sheet area are masked by superficial deposits.

The outcrops generally consist of vertical cliffs and scarp on the plateau margin in which they unconformably overlie rocks of the Finiss River, Tolmer and Auvergne groups, the Antrim Plateau Volcanics, the Uniya Formation, the Soldiers Creek Granite and the Ti-Tree
Granophyre. The unconformity is commonly marked by a thin basal conglomerate containing clasts up to cobble size of the underlying rock types. The thickness of this conglomerate can be a few metres but it is generally less than a metre. The clasts are usually rounded to well-rounded and are set in a limonitic matrix of coarse quartzzrenite. These conglomerates are interpreted to be channel or braided stream deposits developed on a partially peneplained land surface.

Friable, clayey, mottled arenite which is commonly strongly ferruginised, is the dominant rock type overlying the conglomerates. Mottled, ferruginous claystone and fairly clean, friable white quartzzrenite also occur, the latter being particularly prevalent on the surface of the Wingate Plateau. Minor porcellanite was found at Priors Knob, an isolated butte east of Muldva and Buldva mines.

At locality GR 975138, the cast of a fossil leaf was found in ferruginous sandy claystone. This fossil, and the basal boulder beds, indicate that at least part of the Cretaceous sequence in WINGATE MOUNTAINS is non-marine.

The thickness of the Cretaceous sequence is difficult to estimate because loose rubble on the slopes below the scarps usually obscures the contact with underlying units. It appears that the rocks were deposited on a slightly undulating erosion surface. The Wingate Plateau is receding in a SW direction, and it is likely that Cretaceous rocks covered the whole of the sheet area at one time.

The sequence was previously referred to as the “Mullaman Beds” (Skwarko, 1966; Morgan and others, 1970) until Hughes (1978) totally revised the Cretaceous stratigraphy for the northern part of the Northern Territory. The rocks in WINGATE MOUNTAINS probably correlate with Hughes’ Late Jurassic to Middle Cretaceous sequence.

CAINozoic

Approximately 60% of the bedrock in WINGATE MOUNTAINS is covered by unconsolidated Cainozoic deposits which form a large part of the surface of the Wingate Plateau as well as forming floodplains and lowlands over the rest of the sheet area. The deposits are subdivided into Eluvial soils (Czs), Laterite (Czl), Talus and Scree (Czt), Alluvium (Qa), Colluvium (Qcl). Eluvial soils (Czs) are the most extensively developed deposits. On the Wingate Plateau, these soils are lateritic and clay-rich, becoming sander where they have formed over the cleaner quartzzrenites. Small outcrops of psilolite laterite have formed on the plateau surface but are not of mappable extent. A denser vegetation cover than is noted elsewhere in the sheet area attests to the deeper soil profile developed on the plateau.

Where they have formed over granitic and sedimentary rocks, the soils on the lowlands consist of sandy and gravelly deposits. Over metamorphic rocks, due to an increase in the clay fraction, the soils are dominantly orange-red clayey sands and loams. Deeper red loamy soils have formed over the basic intrusives, and these are easily distinguished by an accompanying increase in density of vegetation. On the uplands, immature skeletal soils are predominant although even these have not developed to a great extent as most unconsolidated material is washed to lower ground during the heavy rains of the wet season.

Laterite (Czl), does not form mappable outcrops in WINGATE MOUNTAINS. As described in the previous section, the soils of the Wingate Plateau have a distinct lateritic component and small outcrops of laterite occur within these soils.

Talus and scree (Czt) are the deposits which mantle the slopes of fault ridges and the slopes below the scarp of the Wingate Plateau. The scree on the fault ridges usually consists of vein quartz and fault breccia. On the slopes of the plateau it consists predominantly of the Cretaceous rocks which form the overlying scarp or, where the Cretaceous cap is thin, it may include talus of the underlying rock unit.

QUATERNARY

Alluvium (Qa) is the predominant Quaternary deposit in WINGATE MOUNTAINS. It covers extensive areas in the NE of the sheet area where the land surface is very mature and numerous creeks flow into the north-flowing Fish River, a tributary of the Daly River. This area forms the southern limit of the extensive floodplain of the Daly River. In the NW and central north, widespread alluvial deposits are associated with the north-flowing Muldva and Chilling creeks. Extensive alluvial deposits also occur along drainage systems on the Wingate Plateau, particularly near plateau margins which are being actively dissected. The deposits range from coarse cobble and boulder alluvials and sand where they occur within the drainage channels, to sand, silt and clay where they occur as overbank deposits from the regular flooding during the wet season.

Colluvium (Qcl) occurs more commonly away from the margins of the Wingate Plateau where erosion is less active and fine silt, clay and some sand accumulates in lowlying, swampy areas.

In the lowlands, colluvial deposits of silt and clay occur along the edges and in the heads of some alluvial floodplains where sheetwash of fine material from the surrounding, more elevated areas, is the dominant erosional mechanism.

METAMORPHISM

The earliest recognised metamorphic event in WINGATE MOUNTAINS is recorded in the rocks of the Hermit Creek Metamorphics. This event produced multiple deformation and high grade (up to granulite facies) metamorphism in the Hermit Creek Metamorphics to the north in DALY RIVER (Dundas and others, 1987). The intensity of metamorphism decreases in a southerly and SW direction, so that the sequence in WINGATE MOUNTAINS is constituted largely of rocks of medium (amphibolite facies) and low (upper greenschist facies) grade.

Metamorphism occurred under low pressure and high temperature conditions. The growth of garnet in preference to cordierite in the rocks of this area, in contrast to those in the north, may reflect a local increase in pressure conditions. This metamorphic episode is characterised by the growth of garnet + sillimanite + biotite + feldspar (K-feldspar and plagioclase) + quartz mineral assemblages in schists and gneisses, the development of compositional banding, and the parallel alignment of minerals, particularly phyllosilicates, defining a strong foliation (S1). Compositional banding often outlines small, pytymatic folds suggesting the accompanying deformation was multi-phase. No details of the age of this early metamorphism are known. It occurred prior to the
deposition of the Finniss River Group and the development of the Pine Creek Geosyncline in this western area at least.

The Hermit Creek Metamorphics are invariably retrogressed to lower greenschist facies. In the lower greenschist prograde rocks the level of alteration is therefore such that it could be effected by mild hydrothermal processes, however in the medium prograde rocks (upper greenschist to amphibolite facies) a distinct retrogressive metamorphic event can be recognised. This second, retrogressive event is attributed to the low grade metamorphism accompanying the 1870-1780 Ma Top End Orogeny in the adjacent Pine Creek Geosyncline. The rocks of the Finniss River Group were mildly metamorphosed (very low to low grade) by the Nimbuwah Event (1870-1850 Ma), the earliest stage of the Top End Orogeny. A penetrative slaty cleavage ($S_1$) is developed in the pelitic units and is defined by the parallel growth of phyllosilicate minerals. In the more quartz-rich rocks, some recrystallisation and grain growth of quartz has occurred, but the effects of metamorphism are not generally manifest. Metamorphism in the Wangi Basins is non-uniform. Some samples show little more than weak alteration, while others show replacement of pyroxenes by hornblende amphibole and some degree of recrystallisation.

Contact metamorphism is apparent in many areas in WINGSATE MOUNTAINS. The Allia Creek and Soldiers Creek Granites have conspicuous contact aureoles in the Burrell Creek Formation. No contact effects of the Murra-Kamangle Granodiorite can be observed in either the Hermit Creek Metamorphics or the Finniss River Group rocks. Porphyroblastic andalusite is the most common contact feature in the Burrell Creek Formation surrounding the Allia Creek Granite. Biotite, cordierite, sillimanite, rare garnet and tourmaline also occur. Contact effects of the granite can be seen for several kilometres suggesting that it lies at a shallow level below much of the Burrell Creek Formation in the NW and north-central parts of the sheet area. The Soldiers Creek Granite has produced coarse-grained mica-richfeldspar schist in the contact zone, and has hornfelsed more quartz-rich sediments. Pneumatolytic alteration, related to the greisenisation of the granite, has also affected the surrounding Burrell Creek Formation.

Widespread but patchy alteration or retrogression of both regional and contact metamorphic mineral assemblages occurs in rocks of the Finniss River Group. Most andalusite, muscovite and feldspar is altered to a fine mesh of sericite, and biotite has altered to chlorite. This pervasive event is proposed as being largely hydrothermal or metasomatic in nature and may be recorded in the 1800-1780 Ma Rb/Sr dates that have been attained for the Hermit Creek Metamorphics (Dundas and others, 1987) and many of the granites in the Litchfield Province and western Pine Creek Geosyncline (Page and others, 1984). These dates mark the close of the Top End Orogeny and this hydrothermal event may be coincident with the intrusion of late granites during this orogenic episode.

STRUCTURE

The structure of WINGSATE MOUNTAINS is dominated by the large syncline in the Finniss River Group and the Giants Reef Fault Zone which cuts across the NW corner of the sheet area. The fault zone is a northwesterly continuation of major faults in the Halls Creek and Fitzmaurice Mobile Zones.

Folding

The exposure of Hermit Creek Metamorphics is too weathered and scattered to allow any conclusions to be drawn about the style of folding that accompanied the first, prograde, period of metamorphism. As discussed under METAMORPHISM, tight pytmgmatic style folding observed in some compositionally banded gneisses suggests that the deformation during this event was multi-phase in part. Elsewhere the banding reflects original sedimentary layering that is unfolded at outcrop scale although two metamorphic foliations, defined by the parallel alignment of mineral species, are present.

The Chilling Syncline is a large (smallest amplitude about 2.5 km) non-uniform structure whose eastern and western limbs differ markedly in their response to the compressional forces which operated during folding. The eastern limb consists of steeply dipping beds of both Chilling Sandstone and Burrell Creek Formation which are tightly folded into parasitic folds whose axes largely parallel the axis of the major structure. These folds are tight to isoclinal, non-symmetrical structures with a relatively consistent north-south orientation. This is the fold style typical of the Burrell Creek Formation throughout the Pine Creek Geosyncline, produced in response to east-west compressional forces during the Top End Orogeny. A prominent axial plane foliation, $S_1$, is well developed in pelitic units in the Burrell Creek Formation and in the rare pelitic intervals in the Chilling Sandstone. In the more quartz-rich rocks, particularly the Chilling Sandstone, non-pervasive spaced fracture cleavages or cataclastic shatter zones parallel to axial traces have developed.

Where the fold closure can be clearly seen, the Chilling Syncline plunges southwards at about 70°. The plunge shallows southwards along the axial trace until the fold trace resolves into a series of sub-parallel anticlinal and synclinal axes. A regionally extensive anticlinal axis, the Muldiva Anticline, lies to the east of and sub-parallel to the Chilling Syncline. The Fletchers Gully Gold Mine lies on the axial trace of this fold.

There are no subordinate folds on the western limb of the Chilling Syncline. Beds dip steeply and consistently to the SE and SSE. No reversal of younging directions or shatter zones which might indicate the presence of isoclinal fold axes parallel to bedding, or repetition of the sequence by thrusting along bedding planes, were mapped. A second period of folding is evident in rocks of the Finniss River Group. This folding episode is related to the major period of wrench-style faulting in the Giants Reef Fault Zone with the only mappable $F_2$ fold axes being drag folds located on fault traces west and SW of the Chilling Syncline. A sill of Ti-Tre Granophyre has been folded with the enclosing beds of Burrell Creek Formation and Chilling Sandstone in one of these folds. The age of the Ti-Tre Granophyre demonstrates that this second period of folding belongs to a tectonic episode younger than the Top End Orogeny. The $F_3$ folding has produced the steep plunges and changes in direction of $F_1$ fold axes - e.g., the doubly-plunging, sinuous Muldiva Anticline and the sinuous axial trace of the Chilling Syncline.

In the area north of the closure of the Chilling Syncline, intense buckling and kinking of pelitic beds of the Burrell Creek Formation has occurred because of a competence differential between these more plastic beds and the adjacent blocks of rigid quartzite during folding movements. Minor crenulation cleavage is locally de-
Figure 10  Magnetic contours of WINGATE MOUNTAINS.

developed in this area and in the closures of F2 drag structures. Some stretching lineations noted in contact metamorphic andalusites along the Muldiva Anticline support the proposition that the F2 folding occurred after the intrusion of the Allia Creek Granite, i.e. after the Top End Orogeny.

Faulting
The major faults in the sheet area are the Giants Reef Fault Zone in the NW corner and the Fish River and Collah faults in the SE quadrant. The Giants Reef Fault Zone consists of numerous sub-parallel splay faults on the western margin of the sheet area which coalesce into the major fault trace of the Giants Reef Fault to the north.

Evidence in WINGATE MOUNTAINS and adjacent areas indicates that the Giants Reef Fault coincides in position with zones of earlier faulting that had an influence on the development and sedimentation along the western margin of the Pine Creek Geosyncline. The Henschke Breccia in MOYLE shows that at least one earlier period of movement followed the cratonisation of the Hermit Creek Metamorphics (Edgoose and others, 1989). The presence of the Berinka Volcanics and coarse clastic sediments in the Finniss River Group in its western outcrops are related to this earlier tectonism which saw the opening of the Pine Creek Geosyncline and the development of the Litchfield Province as a western foreland to the geosyncline. Movement on the ancestral Giants Reef Fault may have occurred at the close of deposition of the Mt Partridge Group, resulting in the regional unconformity at its top. Sagging further east allowed the accumulation of the South Alligator Group distal volcanics and chemical sediments, to which the Berinka Volcanics may be related. This suggests that the Finniss River Group is diachronous in part and that the western margin of the geosyncline is stepped to the east (Figure 6), accounting for the absence of the older geosynclinal sediments on the western side of the geosyncline.

The fault traces are generally outlined and healed by massive quartz veining although some mylonitic shear zones also occur, particularly in the igneous rocks. A dextral displacement of about 10 km on the Giants Reef Fault is indicated by the displacement on the northern extension of the Chilling Syncline.

A NE-trending, sinistral splay fault bisects the Chilling Syncline. North of this fault the syncline becomes a north-plunging smaller amplitude fold which is truncated by the Giants Reef Fault at its northern end. The continuation of this fold lies to the north in DALY RIVER. The consistent topographic elevation of the base of the Chilling Sandstone across these faults demonstrates negligible vertical displacement has occurred.

A probable low angle thrust fault, parallel to the trend of the Giants Reef Fault, forms the contact between rocks of the Pine Creek Geosyncline and the Murra-Kamangee Granodiorite on the western edge of the sheet area. This fault continues SW into MOYLE where the faulted nature of the contact is indicated by shearing in the underlying granite, brecciation and recrystallisation in the overlying quartzite, and the planar nature of the contact over several kilometres. The fault plane dips at about 35° to the SE, parallel to bedding in the quartzite. There is no indication of the magnitude of
the displacement on this fault, as the absence of the Burrell Creek Formation could be explained by its interfingering relationship with the Chilling Sandstone in this area.

Movement on the Fish River Fault initiated the development of the shallow basin on its eastern flank and the subsequent influx of Early - Middle Cambrian sediments. However, south of Collah Waterhole, the Fish River Fault has placed Unija Formation against Antrim Plateau Volcanics showing that, in this area at least, some Post-Cambrian movement took place. Post-Cambrian movement is also evident on the Collah Fault near Collah Waterhole, where extensive, spidery quartz veining occurs in the basalt of the Antrim Plateau Volcanics. Further NW a prominent fault ridge of vein quartz marks the fault trace along the contact between the Burrell Creek Formation and the Soldiers Creek Granite. The ridge east of Collah Waterhole provides evidence for Late Proterozoic faulting.

**Figure 11**  Total count radioelement contours of WINGATE MOUNTAINS.

The magnetic pattern over WINGATE MOUNTAINS is generally fairly flat, with gentle gradients of 5 nT/km or less, reflecting minor differences in the top of the magnetic basement (Figure 11).

A small complex area in the NW contains anomalies with amplitudes up to 650 nT, much higher than elsewhere in the region. This area, on the border with MOYLE, coincides with mapped outcrops of Wangi Basins. Other, smaller magnetic anomalies directly to the south and the SE of the main complex coincide with mapped sills of Wangi Basins. The largest of these anomalies is reported by Hill (1981) to be caused by magnetite-bearing basic igneous intrusives of Zamu Dolerite, here referred to as Wangi Basins.

The NE-trending Giants Reef Fault passes between the major complex of Wangi Basics and the sills where another fault is interpreted to branch off the main fault with only a slight divergence.

The Antrim Plateau Volcanics occur in scattered outcrops in WINGATE MOUNTAINS and are characterised by numerous small closures with amplitudes of usually not more than 25 nT. One such area, approximately 7 km wide, is located in the NW. It is enclosed by curved boundary lines on both the eastern and the western side. The southern part is offset from the rest of the area by a NE-trending sinistral fault with an apparent horizontal displacement of 5 km.

Another quite conspicuous area of Antrim Plateau Volcanics is located in the SE corner of the sheet area. This area is enclosed on three sides and in particular the eastern side by almost linear boundaries. Although not mapped as such, the linear nature of the northern and

GEOPHYSICS (By T.L.R. Findhammer)

**Magnetics**

The magnetic data on WINGATE MOUNTAINS was acquired in 1984 by Aerodata Holdings Ltd. The results of this airborne survey are available as located, corrected data on magnetic tape, as stacked profiles at 1:100 000 scale, and as contoured data at 1:250 000 and 1:100 000 scale. The contoured data is in total magnetic intensity, with the 1980 IGRF removed. The stacked profiles have a base value of 47550 nT.
western boundaries indicate that they may be block faulted. The eastern boundary coincides with the Fish River Fault trending NW at 330°, and faulting Soldiers Creek Granite against Antrim Plateau Volcanics. The fault then continues north to a position roughly 2 km north of the Muldiva mine. At this point the fault is possibly displaced approximately 4 km to the SW by a cross fault, and then continues further NW as a subtle magnetic lineament. The three small, elongated magnetic anomalies close to the Muldiva mine are located in an area of Antrim Plateau Volcanics.

A further magnetic lineament trending 300° passes through the block of Antrim Plateau Volcanics in the SE. This feature ends against a relatively large “thumbprint” magnetic anomaly, the source of which is probably a mafic plug in the shape of a prism. Model calculations indicate a depth to the top between 1.5 and 2 km.

The small anomalies directly to NW of this plug are due to the mafic rocks of the Wangi Basics exposed in that area.

In the SW of the sheet area another large “thumbprint” magnetic anomaly can be observed. It too is probably caused by a mafic plug similar to the one to the east. Model calculations based on maximum gradients indicate a similar depth to the top of the body.

Radiometrics

Radiometric data for WINGATE MOUNTAINS was acquired in 1984 and processed in 1985 by Aerodata Holdings Ltd. The results of this airborne survey are available as located, corrected data on magnetic tape, as stacked profiles for thorium and potassium, and as contoured total radioelement data at 1:100 000 scale. The contoured data is in ppm equivalent uranium or units of radioelement concentration (μR), the stacked profiles in ppm equivalent thorium and percent potassium.

Most of WINGATE MOUNTAINS shows a low level of radioactivity. The total radioelement concentration is generally below 6 μR (Figure 12).

The highest values observed are between 18 and 22 μR and occur over the Soldiers Creek Granite in the east-central part of the sheet area.

Another small area with values at 12-18 μR is located in the north-central part of the sheet area and coincides with the Allia Creek Granite. Both granites are known to be rich in K-feldspars, e.g. microcline. Moreover the Soldiers Creek Granite has undergone extensive greisenisation resulting in an abundance of potassium mica and K-feldspar. The stacked profiles over these areas clearly show that the major contribution to the radioelement contours is made by potassium rather than thorium. A relatively narrow zone of values between 6 and 10 μR connects the two granites. This is possibly due to the siltstones and shales of the Burrell Creek Formation whose boundary with the Chilling Sandstone is quite clearly marked in the contours.

An area of Ti-Tree Granophyre is also recognisable in the contours although it does not stand out as well as

Figure 12  Bouguer anomaly contours of WINGATE MOUNTAINS.
the granites. The stacked profiles show that potassium is the main contributor to the overall anomaly.

The Murra-Kamangee Granodiorite in the NW is not discernable in either the total radiocarbon contour map or in the potassium or thorian stacked profiles.

The SW quarter of WINGATE MOUNTAINS appears to have a higher background than the rest of the sheet. Numerous small closures with values between 10 and 14 μV can be observed in this area of predominantly Cretaceous clayslates and arenites. In this area, however, the contribution is from thorium rather than potassium and it is likely that this is a result of monazite being fixed in lateritic soils developed on the surface of the Wingate Plateau.

Gravity
The gravity information for WINGATE MOUNTAINS is very limited and consists entirely of BMR data. A total of 53 stations are located in the area. Twenty-six of these stations are from a helicopter survey on a grid of approximately 11 km centres. The other 27 recordings were made during a short (19 km) road survey in the NW part of the sheet area. The contours, as presented in Figure 13, are taken from the 1:500 000 gravity map in the Proceedings of the International Uranium Symposium on the Pine Creek Geosyncline (Ferguson and Goleby, 1980).

The information is insufficient for a detailed interpretation. However, the larger regional features are in excellent agreement with the known geology.

The high of 150 um/sec² in the NW coincides with the mapped position of the Wangi Basins.

The low of -120 um/sec² is located over the Allia Creek Granite and indicates that this granite extends under the sediments to the north and east.

The low of -240 um/sec² is related to the Soldiers Creek Granite. This granite is relatively thin where it crops out but thickens to the SE under the sediments of the Tolmer Group.

The Bouguer anomaly low of -150 um/sec² in the NE is probably also a granite, hidden under the Hinde Dolomite. This low is probably caused by an eastern extension of the Allia Creek Granite. It is separated from the Soldiers Creek Granite by a ridge of relatively high values.

The contours in the southern and SE part of the region indicate that the Soldiers Creek Granite may form part of a much larger granitic complex in the south.

NE-trending contours in the NW coincide with the position of the Giants Reef Fault, south of the Wangi Basins. Further north these contours tend northerly into DALY RIVER.

GEOLGIC HISTORY

The deposition of the argillaceous and arenaceous sediments now represented by the Hermit Creek Metamorphics is the earliest recorded geologic event in WINGATE MOUNTAINS. Metamorphism and deformation of the metamorphics was followed by faulting and uplift resulting in the formation of a western foreland to the Pine Creek Geosyncline.

The deposition of sediments and extrusion of the submarine acid volcanics of the Finniss River Group began about 1880 Ma and continued to about 1870 Ma when the Top End Orogeny commenced.

The Finniss River Group sedimentation was probably largely controlled by subsidence associated with faulting along the basin margin. The local concentration of acid volcanics (the Berinka Volcanics), and the deposition of coarse conglomerates is further evidence of growth faults along the western basin margin. To the west in MOYLE the Burrell Creek Formation (lower Finniss River Group) was deposited in a predominantly shallow-water marine environment. An eastward lateral facies change to a deeper water fshy environment, regionally more typical of the Burrell Creek Formation, is apparent in WINGATE MOUNTAINS. This indicates that the Burrell Creek Formation was deposited both on the continental margin bordering a deep marine basin (Pine Creek Geosyncline) and within that basin. The sediments of the Burrell Creek Formation pass vertically and laterally into the quartzarenites of the Chilling Sandstone (upper Finniss River Group) platform sequence.

Between 1880 Ma and 1870 Ma the Hermit Creek Metamorphics and the Finniss River Group were intruded by stocks and sills of igneous rocks of the Wangi Basins. This was followed by low grade (sub-greenschist facies) regional metamorphism and deformation, coincident with the 1870 Ma to 1780 Ma Top End Orogeny, during and possibly just after which the Murra-Kamangee Granodiorite and the Allia Creek and Soldiers Creek granites were emplaced. The Top End Orogeny retrogressed and produced the dominant S-f fabric in the Hermit Creek Metamorphics and resulted in tight to isoclinal, upright folding in the Finniss River Group. In the NW of the sheet area, most of this tight folding forms parasitic structures on the limbs of the broad Chilling Syncline.

Erosion exposed the granites and Early Proterozoic rocks during the Middle Proterozoic, prior to deposition of the Tolmer and Auvergne groups. A broad, shallow basin which transgressed from near-shore shallow-marine to intertidal or supratidal environments accumulated 1600 m of Tolmer Group rocks. The Auvergne Group accumulated on the stable Stuart Shelf in a shallow-marine and fluvial environment. After lithification of the sediments, a period of generally SE- to SW-directed compressional stress caused folding, north- to NE-trending wrench and minor thrust faulting in the Giants Reef Fault Zone, and localised shearing. Prior to this compressional event, sills and stocks of Ti-Tree Granophyre were emplaced. Field evidence indicates that the Fish River and Collah Faults were initiated during this period of major tectonism.

The Uniya Formation is the northernmost known occurrence of the Late Proterozoic glaciation recorded in southern, central and NW Australia. Deposition of the Uniya Formation followed a period of erosion after the close of the major tectonic episode. It is likely that the glaciation consisted of small, localised terrestrial ice sheets which resulted in only thin, scattered deposits and had little erosional effect on the topography of the area.

The basaltic lavas of the Antrim Plateau Volcanics, with associated sedimentary lenses, cover a large area from REYNOLDS RIVER south to the East Kimberley region. They are regarded as the subterranean flood basalts, although there was some relief on the ancient land surface onto which they were extruded - usually in a series of flows.

In the Late Proterozoic to Early Cambrian some gentle subsidence allowed the formation of shallow basins in which accumulation of elastic sediments was followed by
dominantly shelf carbonate deposits in the Middle Cambrian.

The ensuing period of erosion continued until the Early Cretaceous marine transgression. During the Early Tertiary, (epiogenic) uplift was followed by peneplanation; and the resultant erosion surface (Tennant Creek Surface of Hays, 1968) is now preserved on the Wingate Plateau and outlying remnants.

ECONOMIC GEOLOGY

Gold
Gold was mined at Fletchers Gully (GR 822393) from 1905 to 1940, with a total recorded production of 70 kg. Approximately 10 kg of this was won from alluvial workings. The gold occurs in quartz veins in the core of an anticline (Muldiva Anticline) in contact metamorphosed slate, phyllite and metaquartzite of the Burrell Creek Formation, adjacent to the Allia Creek Granite. The veins are associated with both shear and tension gashes, and vary from about 0.6 cm to nearly 1 m in width (Walpole and others, 1968). The Allia Creek Granite was probably either the source of the mineralization or the heat source which mobilised mineralising fluids. The slates at the mine are graphic in part and this may have played a role in the concentrating of gold in the quartz veins.

Tin
Minor tin was worked in some small pegmatite veins in the vicinity of Fletchers Gully giving production figures of 4.3 t of tin concentrate. At Behrin's Prospect, located north of Fletchers Gully and close to Muldiva Creek, cassiterite is disseminated in a greisen within the Allia Creek Granite and some alluvial deposits were worked in the early 1900s. There is no record of the production for this area.

At Muldiva and Buldiva Mines, the tin occurred in greisen and pegmatite veins developed in the Burrell Creek Formation adjacent to the Soldiers Creek Granite. During the 1920s these veins were mined, as well as alluvial and fluvial deposits. At Buldiva, some tin was also won from the base of the Cretaceous plateau-forming sequence, where it formed a palaeoplacer deposit in a conglomerate largely derived from the underlying granite.

Alluvial tin at Collah, approximately 20 km to the SSE, was discovered in 1922 and worked intermittently since that time (Walpole and others, 1968). Most production came from shallow alluvial pockets in creeks, and eluvial scrapes. There are numerous greisens and quartz-tourmaline veins in the granite in this area which presumably form the source of the cassiterite although no lode deposits have been discovered.

Total recorded production form Buldiva, Muldiva and Collah is 46 t of tin concentrate.

Uranium
A brecciated fault zone at GR 705205 within the Ti-Tree Granophyre was identified as containing minor amounts of uranium (Walker, 1970). A uranium-bearing shear zone in the Allia Creek Granite was identified by radiometrics. Further sampling found only small amounts of uranium (Manning, 1982; 1983).

Water
WINGATE MOUNTAINS contains plentiful supplies of surface water. Fish River, Snape Creek, Allia Creek and Muldiva Creek are perennial, spring-fed watercourses. Many smaller creeks in the sheet area contain water until the latter part of the dry season. The sandstone units of all ages are reasonably good aquifers and there are numerous springs, largely concentrated in the edges and foothills of the Wingate Plateau. On the plateau itself, there are many low-lying swampy areas which are spring-fed from the Cretaceous sandstone and remain all year round. Water at the abandoned Fish River homestead was supplied by bore.

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