1:100 000 GEOLOGICAL MAP SERIES

EXPLANATORY NOTES

BYNOE 5072

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Geophysics by B. A. Simons

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MAP
1:100 000 Geological Map of BYNOE (5072) in pocket.
Figure 1 Location of BYNOE.
ABSTRACT

The Bynoe 1:100 000 map sheet area (BYNOE*) was mapped by the Northern Territory Geological Survey (NTGS) during 1980.

The topography in the central and eastern parts of BYNOE is dominated by prominent ridges and low hills. In the western half of the area where Cainozoic sediments conceal older units the topography is undulating to flat.

The Archaean Rum Jungle Complex, which consists of mainly granite with remnant metasediments, occurs in the SE corner of BYNOE. The Complex is surrounded by Early Proterozoic sediments of the Mount Partridge, South Alligator, and Finniss River groups. The Rum Jungle Complex probably formed a basement high during the initial stages of Early Proterozoic sedimentation, which took place under fluvial and evaporitic conditions, followed later by shallow-marine and finally by deeper water clastic sedimentation. The Welltree Metamorphics in the western half of BYNOE, form part of the Litchfield Province and are considered to be metamorphosed sediments of the Pine Creek Geosyncline.

The Early Proterozoic sediments have been tightly folded and metamorphosed from subgreenschist facies in the east, to upper amphibolite facies in the west.

Late synorogenic to postorogenic granite intrusion was followed by a period of uplift and erosion. The Early Proterozoic sediments are unconformably overlain by Minor Middle Proterozoic, Mesozoic, and extensive Cainozoic sediments.

Uranium and base metal mineralisation occurs within the Mount Partridge Group adjacent to the Rum Jungle Complex and mining of uranium took place at Mount Burton. Extensive tin-tantalum mineralisation, associated with pegmatites in the Burrell Creek Formation, occurs in the West Arm–Bynoe Harbour–Mount Finniss area. In this area mining has taken place intermittently since 1886.

INTRODUCTION

General

This report contains a detailed description of the geology of BYNOE. The area was mapped by the Northern Territory Geological Survey (NTGS) during the 1980 field season using colour aerial photographs at 1:25 000 scale. Detailed traversing, outcrop mapping and stratigraphic drilling were involved.

The area was covered by regional airborne magnetic and radiometric surveys, which were flown for the NTGS in 1981. Gravity data were collected by the NTGS and combined with information from the Bureau of Mineral Resources, Geology and Geophysics (BMR) and private companies. Other detailed data, such as geologic descriptions plus gravity, magnetic and radiometric contour maps, and a listing of relevant investigations, are provided in Pietsch (1985b).

Location, access and land use

Bynoe is bound by latitudes 12°30’S, 13°00’S and longitudes 130°30’E, 131°00’E (Figure 1). The northern edge of the sheet area is approximately 3 km south of Darwin. Vehicle access to the permanently settled areas is gained by all-weather, unsealed roads. Tracks provide access elsewhere in the area during the dry season. The Berry Springs Nature Reserve lies on the eastern side of BYNOE. Cattle-raising is carried out on the Finniss River Station and on the Wagait Aboriginal Reserve, part of which lies in the southern portion of the area. There is a small Aboriginal community at Delissaville on Cox Peninsula.

Climate

BYNOE experiences a monsoonal climate with a wet season lasting from October to April. Most rain falls between December and March. The mean annual rainfall is 1600 mm and the lowest 1025 mm.

Temperatures are highest in the period from November to December, when the mean maximum is 34°C and the mean minimum is 27°C. The coldest month is July when the mean maximum is 30°C and the mean minimum is 19°C.

Geomorphology

The northern part of BYNOE lies within the catchment of the Finniss River, which meanders through extensive flood plains and paludal estuarine plains in the west. Elsewhere in BYNOE drainage is mainly into the Darwin and Bynoe Harbours. The topography ranges from mature, flat-lying and undulating to submature undulating and rugged in the central part of the area.

For the purpose of this survey, 7 geomorphic units are defined, in terms of geology, drainage and soil type. The units are Littoral Complex, Paludal Estuarine Plains, Alluvial Plains, Plateaux, Dissected Foothills, Dissected Uplands, and Undulating Granitic and Detrital Lowlands (Figure 2).

The Littoral Complex follows the irregular shorelines of Darwin and Bynoe Harbours, where the relatively quiet conditions allow dense stands of mangroves to grow on marine mud and clay. Open, fore shore areas of sand and shells are mainly confined to coasts facing the open sea. In places, treeless tidal flats occur on the landward side of the mangroves. The flats support communities of samphire and Sporobolus virginicus and consist of saline and calcic mud, clay and silt. Cheniers form adjacent to prominent points or landmasses facing the harbours and open sea.

Paludal Estuarine Plains, which penetrate inland along the Finniss River flood plain, form extensive, flat areas less than 7 m above sea-level. The plains are flooded seasonally and nonmarine, organic clay and silt overlie dark, marine Quaternary clays. The floodplains are mainly treeless and dominated by perennial, eperaceous herbs. However, thick clumps of paper-bark trees, mainly Hamadryas leucadendron, are common in low-lying parts of the plains. This land unit grades into the floodplains, incised channels and levee banks which comprise Alluvial Plains along the Finniss River and other, main drainage systems. The plains consist of Quaternary alluvium and colluvium with deep, sandy to silty soils which support open grassland and scattered trees.

Plateaux have developed over flat-lying Cretaceous sediments and show flat to rolling topography. The main soil types are loamy to sandy, yellow to red, gravelly soils and gravelly, red to yellow, loamy soils which support tall, open forest and woodland. Broad drainage channels are common and contain soils.*

* All references to 1:100 000 map sheet areas in this report are designated by the use of capital letters, eg. BYNOE.
Figure 2  Geomorphic units of BYNOE.

derived from colluvial sand, silt and clay, winnowed from the plateaux and deposited by sheetwash.

Undulating rubbly rises, interspersed with low hills and strike-ridges of poorly exposed, Early Proterozoic metasediments and metamorphics form Dissected Foothills, which rise to 45 m above sea-level. Dissected residuals of detrital laterite and remnant, lateritised benches of Cretaceous rocks are common on the rubbly rises. The soils, which are skeletal, gravelly and lateritic, overlie deeply-weathered rocks, and support stunted woodland, mixed scrub, palm forest, and leguminous–myrtaceous scrub. Detrital, lateritic breccias form along the edges of the Littoral Complex and Alluvial Plains. Shallow streams form a weakly dendritic drainage pattern.

Dissected Uplands, which rise to 110 m above sea-level, are formed by prominent, resistant, resistant ridges, low hills, and intermittent undulating rubbly rises. The ridges and hills are formed by tightly folded, N-S striking, Early Proterozoic arenites which produce a subparallel drainage pattern. The strike-ridges and hills have boulder-strewn slopes and rocky crests, with shallow, skeletal soils which support eucalypt woodland.

Undulating Granitic and Detrital Lowlands are underlain by granite and metamorphics, have a moderate to low relief, and are in an advanced stage of denudation. The sandy, podsolic, and in places lateritic, soils support palm scrub and low, open forest. The drainage pattern is commonly radial-dendritic with shallow, wide drainage channels.

Previous geologic investigations
The first recorded discovery of gold in the Darwin–Katherine area was made in BYNOE, along the Finniss River in 1865, but the find was of no economic significance. Mining began in 1886, after the discovery of tin in the Bynoe Harbour–West Arm area; mining of tin and tantalum still continues here.

Parkes (1892), Playford (1904) and Brown (1906, 1908) described the early mining activities in the Bynoe Harbour–West Arm area for the South Australian Government. Following the transfer of administration of the Northern Territory to the Commonwealth, Jensen (1914) investigated the Darwin area, and produced the first account of the geology in BYNOE. The earliest geologic work of regional importance was carried out by Noakes (1949) during reconnaissance mapping in the Darwin–Katherine region.

In 1949, uranium mineralisation was discovered at Rum Jungle. After this discovery, intensive geologic mapping and associated investigations were undertaken by private companies and BMR geologists in the quest for uranium and base metal mineralisation. Subsequently, the Mount Fitch and Mount Burton uranium and copper deposits and Brown’s lead deposit were discovered. Between 1953 and 1958, the BMR mapped the Darwin-Katherine region. This work was used to produce the Darwin 1:250 000 geologic map sheet (Malone, 1962) and the Tumbling Waters and Southport 1:63 360 geologic map sheets, which are relevant to BYNOE. Walpole and others (1968) presented a synthesis of these data.

The BMR also remapped about half of the Pine Creek Geosyncline at a 1:100 000 scale between 1971
and 1983. This remapping included the Rum Jungle area which lies in the SE part of BYNOE and it led to substantial changes in the stratigraphy developed previously by Walpole and others (1968); see Needham and others (1980) and Needham and Stuart-Smith (1985). Johnson (1974, 1977) compiled a progress report and preliminary map at 1:100 000 scale of the Rum Jungle area. Crick (1978, 1984) further modified the stratigraphy.

In the Rum Jungle area mineral exploration for uranium and base metals has continued into the present time, but discoveries in BYNOE were uneconomic. Apart from uranium in the Rum Jungle area, the main recent targets have been tin and tantalum. As a result, small mining ventures have developed in old workings and at new sites. Recently, however, uranium and base metals have been sought in the Bynoe Harbour area. Diamond drilling in BYNOE is summarised in Table 1.

REGIONAL GEOLOGIC SETTING

BYNOE lies in the NW part of the Pine Creek Geosyncline and includes the northern part of the Litchfield Province. (Figure 3). The stratigraphy adopted for the units of the Pine Creek Geosyncline was developed by the BMR. Table 2 outlines the stratigraphy of the Archaean to Early Proterozoic units within both tectonic units.

According to Needham and others (1980), the Pine Creek Geosyncline comprises mainly lutitic and arenaceous, Early Proterozoic sediments with tuffaceous intervals, deposited on late Archaean granites. In KOOLPINYAH, to the NE of BYNOE, the geosynclinal sediments rest unconformably on Archaean to Early Proterozoic metasediments (Piettsch, 1985).

The geosynclinal sediments accumulated in a single basin as a sequence up to 14 km thick and were deformed and regionally metamorphosed during the Top End Orogeny, of 1870-1780 Ma age (Needham and others, 1980, 1985). Tightly folded, subgreen schist facies metamorphics in the central part of the geosyncline grade into isoclinaly folded, amphibolite facies metamorphics to the east and west. The amphibolite facies metamorphics (Welltree Metamorphics) in western BYNOE form part of the Litchfield Province, which tectonically is the northern extension of the Halls Creek Mobile Zone.

Pre-orogenic and postorogenic, continental tholeiites and synorogenic to postorogenic granite intrude the Early Proterozoic rocks of the Pine Creek Geosyncline. Rocks of similar age in the Litchfield Province are intruded by the pre-orogenic mafic to ultramafic Wangi Basics (Piettsch, in preparation), and by synorogenic to postorogenic granites.

Flat-lying cover rocks of Middle Proterozoic, Palaeozoic and Mesozoic ages rest unconformably on the Early Proterozoic rocks in the geosyncline (Needham and others, 1980). By contrast, in the Litchfield Province folded and faulted Middle Proterozoic and faulted Palaeozoic rocks indicate continued tectonic activity well into Palaeozoic time.

STRATIGRAPHY

The stratigraphy of BYNOE is summarised in Table 3.

ARCHAEOAN

RUM JUNGLE COMPLEX (Ar)
The western part of the Rum Jungle Complex lies within the SE corner of BYNOE (Figure 4). Granite and minor gneiss, schist, metadiorite and banded iron formation form in this area scattered, low pavements, and boulder-strewn outcrops protrude through Cainozoic sandy soil.

Malone (1962) used the term 'Rum Jungle Granite' to describe porphyritic granite which he believed intruded adjacent sediments. Rhodes (1965) showed that Malone's 'granite' consisted of various igneous (mainly granitic) rocks and metasediments overlain unconformably by Early Proterozoic sediments. He subdivided the rock types of the complex into 6 main units in order of decreasing age, namely: schist and gneiss, granite gneiss, metadiorite, coarse granite, large-feldspar granite and leucogranite. Johnson (1977) added a banded iron formation to the complex, which in BYNOE occurs south of the Darwin River Dam at the margin of the complex. Table 4 outlines the rock types and stratigraphic relationships of the units within the Rum Jungle Complex.

Combined U-Pb zircon and Rb-Sr total rock ages from leucogranite show that the Rum Jungle Complex has a minimum age of 2400 Ma (Richards and others, 1966, 1977). Various granites intrude the metasediments, banded iron formation and metavolcanics, all of which may be equivalent to the Dirty Water Metamorphics in KOOLPINYAH (Piettsch, 1985). The Dirty Water Metamorphics overlies and were derived in part from Woolner Granite which has a U-Pb zircon age of 2675 ± 14 Ma (Williams and Compston, 1983).

The eastern margin of the Rum Jungle Complex is overlain unconformably by the Namoona Group. In BYNOE, the Crater Formation, which is the basal unit of the Mount Partridge Group, is unconformable on the western side of the complex. The Crater Formation contains boulders of banded iron formation and rare pebbles of granite plus arkosic sand derived from the complex. The contact between the Complex and sediments is usually sheared; where shearing is visible, the underlying granites are strongly foliated. At location GM 125694 the contact between granite and overlying locally derived arkose is well exposed and not sheared.

EARLY PROTEROZOIC

MOUNT PARTRIDGE GROUP
Shallow-water lutite, arenite, rudite and carbonate form the Mount Partridge Group, which mantles the Rum Jungle Complex (Figure 4). The basal arenite and rudite of the Crater Formation are overlain by carbonates of the Coomalie Dolomite. The Coomalie Dolomite passes upwards transitionally, through the dolomitic lutite of Whites Formation, into the overlying lutite and arenite of the Wildman Siltstone. The group is tightly folded and dips away from the Rum Jungle Complex.

Crater Formation (Epr)
The Crater Formation, which is mostly covered by a thin veneer of skeletal soil, crops out discontinuously on sporadic, low, rubbly rises. The lower portion consists of characteristic detrital components derived
<table>
<thead>
<tr>
<th>PROSPECT/MINE/LOCALITY/PROJECT</th>
<th>MAP LOCALITY REFERENCE NO.</th>
<th>AMG GRID REFERENCE</th>
<th>NO. OF DRILL HOLES</th>
<th>FORMATIONS</th>
<th>SPONSOR</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Finnis River Road</td>
<td>1</td>
<td></td>
<td>3</td>
<td>Eb, Ewts</td>
<td>NTGS</td>
<td>Lau and Pietsch (1981)</td>
</tr>
<tr>
<td>* Keswick Point (Bynoe Harbour)</td>
<td>2</td>
<td></td>
<td>6</td>
<td>Ewt, Ews, Egts</td>
<td>NTGS</td>
<td>Lau (1978)</td>
</tr>
<tr>
<td>* Regional Drilling</td>
<td>3</td>
<td></td>
<td>6</td>
<td>Es, Egts, Psk</td>
<td>NTGS</td>
<td>Pietsch (1982)</td>
</tr>
<tr>
<td>* Point Ceylon Area</td>
<td>5</td>
<td></td>
<td>4</td>
<td>Ewt, Ews, Egts</td>
<td>ACG</td>
<td>Porter (1985)</td>
</tr>
<tr>
<td>* Darwin East</td>
<td>6</td>
<td></td>
<td>3</td>
<td>Es</td>
<td>BMR</td>
<td>Van den Brock (1975)</td>
</tr>
<tr>
<td>Madigans Prospect</td>
<td>7</td>
<td>FL 978923</td>
<td>2</td>
<td>Pfbs</td>
<td>BMR</td>
<td>Hyde (1956)</td>
</tr>
<tr>
<td>Mount Finnis Mine</td>
<td>8</td>
<td>FL 937572</td>
<td>2</td>
<td>Pfbs</td>
<td>BMR</td>
<td>Summers (1957)</td>
</tr>
<tr>
<td>Berry Springs</td>
<td>9</td>
<td>GL 164944</td>
<td>2</td>
<td>Es</td>
<td>Mines Branch, Dept. of NTA</td>
<td>Barclay (1964)</td>
</tr>
<tr>
<td>Darwin River Dam</td>
<td>10</td>
<td>GL 138807</td>
<td>7</td>
<td>Epw, Epas</td>
<td>BMR</td>
<td>Magie and Barclay (1966)</td>
</tr>
<tr>
<td>Dolerite Ridge</td>
<td>11</td>
<td>GL 136625</td>
<td>14</td>
<td>Epw, Etdz</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
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<td>Dolerite Ridge East</td>
<td>12</td>
<td>GL 142627</td>
<td>2</td>
<td>Epw, Epis</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
<tr>
<td>Dolerite Ridge North Prospect</td>
<td>13</td>
<td>GL 122641</td>
<td>1</td>
<td>Epw</td>
<td>BMR</td>
<td>Hickey (1985b)</td>
</tr>
<tr>
<td>Mount Burton - Brown's Prospect</td>
<td>14</td>
<td>GL 137633</td>
<td>9</td>
<td>Epi, Epw, Epas</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
<tr>
<td>West Finnis Prospect</td>
<td>15</td>
<td>GL 124635</td>
<td>5</td>
<td>Epw, Es</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
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<td>East Finnis Prospect</td>
<td>16</td>
<td>GL 121656</td>
<td>4</td>
<td>Epw, Epas, Epis</td>
<td>BMR</td>
<td>Hickey (1985b)</td>
</tr>
<tr>
<td>Mount Burton Mine</td>
<td>17</td>
<td>GL 130642</td>
<td>19</td>
<td>Epw, Epas, Epis</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
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<td>Burton Creek Prospect</td>
<td>18</td>
<td>GL 128648</td>
<td>4</td>
<td>Epi, Epes</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
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<tr>
<td>Mount Burton North Prospect</td>
<td>19</td>
<td>GL 120644</td>
<td>6</td>
<td>Epw, Epas, Epis</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
<tr>
<td>Mount Fitch North Prospect</td>
<td>22</td>
<td>GL 115693</td>
<td>18</td>
<td>Epis, Epis, Epis</td>
<td>TEP</td>
<td>Hickey (1985b)</td>
</tr>
</tbody>
</table>

* Individual drill hole location shown on geological map.

Key to abbreviations in Table 1:

- **Pfs** — Burrell Creek Formation
- **Bs** — South Alligator Group
- **Bsk** — Kooldin Formation
- **Ets** — Acaoa Gap Quartzite
- **Epw** — Wildman Siltstone
- **Epi** — Whites Formation
- **Epc** — Coomalie Dolomite
- **Epr** — Crater Formation
- **Ewt** — Welltree Metamorphics
- **Ews** — Sweats Member
- **Egts** — Two Sisters Granite
- **ACG** — Australian Coal and Gold Holdings
- **IUEA** — Idemitsu Uranium Exploration Australia
- **NTA** — Northern Territory, Australia
- **TEP** — Territory Enterprises Pty, Ltd
- **UAL** — Urangesellschaft Australia Ltd
Figure 3  Regional geology — Litchfield Province and Pine Creek Geosyncline.
Table 2  Stratigraphy of Early Proterozoic pre-orogenic rocks* within the Pine Creek Geosyncline and the Litchfield Province.

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LITHOLOGY</th>
<th>THICKNESS (m)</th>
<th>STRATIGRAPHIC RELATIONSHIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIGHER-GRADE METAMORPHIC ROCKS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litchfield Province</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welltree Metamorphics</td>
<td>Quartz-feldspar-biotite gneiss, common graphite, garnet, sillimanite and andalusite; quartzite gneiss, marble, para-amphibolite and calc-silicate gneiss near base</td>
<td></td>
<td>? Metamorphic equivalent of Burrell Creek Formation and probably of lower units of the Pine Creek Geosyncline.</td>
</tr>
<tr>
<td>Unit Bc</td>
<td>Undifferentiated gneiss, schist, amphibolite and quartzite</td>
<td></td>
<td>? Relationship with other units not known; possibly older than Welltree Metamorphics.</td>
</tr>
<tr>
<td>Hermit Creek Metamorphics</td>
<td>Sillimanite gneiss; garnet-cordierite gneiss; biotite-quartz schist; mafic meta-igneous rocks</td>
<td></td>
<td>? Relationship with other units not known; possibly older than Burrell Creek Formation.</td>
</tr>
<tr>
<td>Pine Creek Geosyncline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myra Falls Metamorphics</td>
<td>Muscovite-biotite-feldspar-quartz schist and gneiss, with common amphibole, garnet and quartz-rich pods and bands</td>
<td></td>
<td>? Appears to grade into Nourlangie Schist to the west; may also be metamorphic equivalent of Cahill Formation.</td>
</tr>
<tr>
<td>Nourlangie Schist</td>
<td>Quartz-mica schist; mica-quartz schist; minor quartzite</td>
<td></td>
<td>? Metamorphic equivalent of the Wildman Siltstone, South Alligator Group and Burrell Creek Formation.</td>
</tr>
<tr>
<td>Cahill Formation</td>
<td>Mica-feldspar-quartz schist and quartz-mica schist with garnet, amphibole and kyanite in places; carbonaceous schist; crystalline dolomite-magnesite and calcisilicate gneiss near base</td>
<td>&gt;=3000</td>
<td>=3000 Apparently conformable on Kakadu Group; in places onlaps onto Archaean granite of Manambu Complex; lower member is both facies and metamorphic equivalent of Masson Formation; upper member equivalent of Mundoglie Sandstone.</td>
</tr>
<tr>
<td><strong>FINNISIRIVER GROUP (Flysch, 1500-1700 m)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chilling Sandstone</td>
<td>Quartz sandstone, ripple-marked and cross-bedded; minor conglomerate and siltstone</td>
<td>=6500</td>
<td>=6500 Conformable on Burrell Creek Formation.</td>
</tr>
<tr>
<td>Meeway Volcanics</td>
<td>Porphyritic acid lava; tuff</td>
<td>&lt;75</td>
<td>&lt;75 Uncertain relationship with Burrell Creek Formation; confined to SW.</td>
</tr>
<tr>
<td>Burrell Creek Formation</td>
<td>Greywacke; quartzite; siltstone; shale; conglomerate; argillite; felsic volcanics (Warr’s Volcanics); tuffaceous siltstone and arenite; acid and minor intermediate lavas; coarse ferruginous sedimentary breccia and conglomerate confined to the west</td>
<td>=3000</td>
<td>=3000 Gradational with underlying Mount Bonnie Formation; in contact with Coomalie Dolomite from Waterhouse Complex.</td>
</tr>
<tr>
<td>Muluk Mullok Volcanics</td>
<td>Spherulitic rhyolite</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SOUTH ALLIGATOR GROUP (Shallow-marine, chemical, volcanic 5000 m)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mount Bonnie Formation</td>
<td>Slate, carbonaceous in places; shale; phyllite; siltstone; greywacke; argillite; crystal tuff; tuffaceous chert; minor ferruginous siltstone with chert bands, lenses and nodules</td>
<td>&lt;500</td>
<td>&lt;500 Conformable and interbedded with Gerowie Tuff.</td>
</tr>
<tr>
<td>Gerowie Tuff</td>
<td>Black-green, cherty tuff; green argillite; pale-green; tuffaceous greywacke; minor, ferruginous chert, nodular siltstone, banded iron formation</td>
<td>&lt;750</td>
<td>&lt;750 Conformable and in places interbedded with Koolpin Formation and Shovel Billabong Andesite.</td>
</tr>
<tr>
<td>Shovel Billabong Andesite</td>
<td>Variolitic andesite</td>
<td>&lt;300</td>
<td>&lt;300 Flows near base of Gerowie Tuff.</td>
</tr>
<tr>
<td>Koolpin Formation</td>
<td>Ferruginous siltstone with chert bands and nodules; pyrite, carbonaceous shale; silicified dolomite; minor phylite, jasper and banded iron formation</td>
<td>&lt;1000</td>
<td>&lt;1000 Unconformable overlies older unit.</td>
</tr>
<tr>
<td>Kapalga Formation</td>
<td>Ferruginous siltstone; chert bands and nodules in places (commonly carbonaceous at depth); phyllite and greywacke; minor slate, arkose and sandstone; rare schist in NE</td>
<td>&lt;5000</td>
<td>&lt;5000 Eastern equivalent of the nonvolcanic components of South Alligator Group; unconformably overlies Wildman Siltstone and Mundoglie Sandstone.</td>
</tr>
<tr>
<td><strong>MOUNT PARTRIDGE GROUP (Fluvialite, chemical, shallow-marine, 5000 m)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildman Siltstone</td>
<td>Siltstone, in places carbonaceous at depth; red and cream, laminated siltstone; minor quartzite, quartz greywacke, dacite, rhyolite, andesite, basalt and tuff</td>
<td>&lt;2000</td>
<td>&lt;2000 Conformably overlies Mundoglie Sandstone; conformable and in place interfingers with Whites Formation; grades into Koolpinjah Dolomite; unconformably overlain by Koolpin and Kapalga Formations.</td>
</tr>
<tr>
<td>Whites Formation</td>
<td>Calcereous and/or carbonaceous, pyritic shale and argillite; calcilutite; silicified calcilutite; calcarenite; orthoquartzite, calcareous amphibolitic schist</td>
<td>&lt;500</td>
<td>&lt;500 Transitional sediments between Coomalie Dolomite and Wildman Siltstone.</td>
</tr>
<tr>
<td>Koolpinjah Dolomite</td>
<td>Dolomitic marble; dolomitic mica-schist; mica-quartz schist; sandy, intraclastic, dolomite limestone; calcareous quartzite</td>
<td></td>
<td>? Lateral facies equivalent of Coomalie Dolomite.</td>
</tr>
</tbody>
</table>
Table 2 (continued)

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LITHOLOGY</th>
<th>THICKNESS (m)</th>
<th>STRATIGRAPHIC RELATIONSHIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coomalie Dolomite</td>
<td>Dolomite-magnesite with algal structures and evaporite pseudomorphs in places; dolomite breccia; temolite schist; calcilutite</td>
<td>~300</td>
<td>Conformable on Crater Formation.</td>
</tr>
<tr>
<td>Crater Formation</td>
<td>Feldspathic sandstone; pebble conglomerate sandstone, pyritic in part; basal, ferruginous conglomerate in places</td>
<td>300-600</td>
<td>Unconformable on Celia Dolomite; onlaps Rum Jungle Complex in places; lateral equivalent of Mundogie Sandstone.</td>
</tr>
<tr>
<td>Mundogie Sandstone</td>
<td>Medium-grained to coarse-grained, commonly pebbly, quartz sandstone and orthoquartzite; quartz pebble conglomerate; siltstone; cross-bedded and graded; minor schist</td>
<td>2400</td>
<td>Unconformable on Masson Formation and Stag Creek Volcanics; facies variant of upper member of Cahill Formation.</td>
</tr>
<tr>
<td>NAMOONA GROUP (Shallow-marine, chemical, fluvial, less than 3500 m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stag Creek Volcanics</td>
<td>Mafic volcanic breccia; hawaiite; tuff; tuffaceous shale; tuffaceous greywacke</td>
<td>1000</td>
<td>Conformable at top of Masson Formation; restricted to South Alligator Valley.</td>
</tr>
<tr>
<td>Masson Formation</td>
<td>Ferruginous shale, mostly pyritic and carbonaceous at depth; fine-grained to coarse-grained calcareous and volcaniclastic greywacke; calcarenite; sandstone; limestone</td>
<td>3000</td>
<td>Lowest exposed unit in central part of Pine Creek Geosyncline; correlates with lower member of Cahill Formation in east and Celia Dolomite, Beestons Formation in the west</td>
</tr>
<tr>
<td>Celia Dolomite</td>
<td>Dolomite-magnesite, silicified or with algal structures in places; temolite schist; minor sandstone, arkose and carbonaceous sediments</td>
<td>&lt;300</td>
<td>Conformable on Beestons Formation.</td>
</tr>
<tr>
<td>Beestons Formation</td>
<td>Arkose; feldspathic sandstone; conglomerate; siltstone</td>
<td>&lt;200</td>
<td>Unconformable on Rum Jungle and Waterhouse complexes.</td>
</tr>
<tr>
<td>KAKADU GROUP (Fluvialite, 2000 m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mummurary Quartzite</td>
<td>Massive to friable gneiss orthoquartzite; minor schist</td>
<td>&gt;200</td>
<td>Eastern equivalent of Kudjumarndi Quartzite.</td>
</tr>
<tr>
<td>Mount Howship Gneiss</td>
<td>Very coarsely crystalline, white, feldspathic leucogneiss; minor schist; rare garnet and amphibole</td>
<td>&gt;2000</td>
<td>Eastern equivalent of Mount Basedow Gneiss.</td>
</tr>
<tr>
<td>Kudjumarndi Quartzite</td>
<td>Orthoquartzite; quartz gneiss; minor schist; rare cross-bedding, rare amphibole</td>
<td>150</td>
<td>Flanks and in places within accreted leucogneiss of Nanambu Complex.</td>
</tr>
<tr>
<td>Mount Basedow Gneiss</td>
<td>White-grey-pink, coarsely crystalline muscovite-biotite gneiss; granitoid gneiss; minor schist</td>
<td>&gt;1500</td>
<td>Transitional into accreted leucogneiss of Nanambu Complex.</td>
</tr>
</tbody>
</table>

*Excluding intrusives

from the underlying Rum Jungle Complex. Siltstone is not exposed although it commonly occurs in the upper part of the formation in BATCHelor (French, 1970). Near the SE corner of this sheet area, the formation attains an estimated thickness of 150 m, whereas at the Mount Fitz Prospect a 50 m-thick section of arkose is exposed. On the western wide of the Rum Jungle Complex, in BYNOE, the formation is made up of three principal rock types, namely haematite boulder conglomerate, quartzite and cross-bedded pebbly arkose.

Haematite boulder conglomerate is massive, poorly sorted and coarse-grained, and it contains moderately to well rounded pebbles and boulders in a matrix of poorly sorted sand, silt, fine haematite and mica. The clasts, which vary from slightly elliptical to oblate or prolate, consist mainly of banded iron formation with lesser quartzite, vein quartz and minor granite.

Quartzite consists mainly of medium-grained, angular to subangular quartz, and varying amounts of subangular to subrounded feldspar (to 15%) in a matrix of recrystallised silica, haematite and minor sericite. Pyrite casts are common. Associated with the quartzite, and in places with the haematite boulder conglomerate, are beds of brown, ferruginous, poorly sorted, coarse clastic rocks. These range from sandstone through gritty sandstone to pebbly conglomerate. The sandstone consists of subangular to subrounded quartz grains and grit plus subrounded to rounded pebbles of quartz, quartzite and minor banded iron formation in a matrix of silt, haematite, minor clay and sericite. In places, the pebbles are slightly elongate, parallel to foliation.

The pebbly arkose is commonly cross-bedded and contains pebbles of quartz, quartzite and granite in a typically coarse-grained, granite-derived arkosic matrix. Interbeds of slate have been intersected in drill core. The slate is chloritic and/or siliceous, commonly graphitic with accessory pyrite and chalcopyrite.

The haematite boulder conglomerate crops out from south of the Mount Fitz Prospect to the eastern edge of the sheet and is in sheared contact with the underlying granite. Pebbly arkose overlies the conglomerate in this area and granite to the north of the Mount Fitz Prospect: both sheared and non-sheared contacts have been noted between arkose and granite. Quartzite and associated pebbly sandstone occur above the haematite boulder conglomerate in the Mount Fitz Prospect–East Finniss River area.

Deposition of these sediments probably took place under fluvial conditions. The haematite boulder conglomerate is interpreted as an alluvial fan conglomerate by French (1970). The cross-bedded, pebbly arkose may
<table>
<thead>
<tr>
<th>UNIT, WITH MAP SYMBOL AND THICKNESS</th>
<th>FIELD RELATIONSHIP</th>
<th>DISTRIBUTION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAINIOZOIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUATERNARY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coastal alluvium (Qca)</td>
<td>Intertidal marine</td>
<td>Swash zone, tidal flats and mangrove areas</td>
<td>Intertidal-marine</td>
</tr>
<tr>
<td>Mud; silt; clay alluvium</td>
<td></td>
<td></td>
<td>Marine swash zone deposits</td>
</tr>
<tr>
<td>Cheners (Qcr) &lt; 3 m</td>
<td>Ridges generally parallel to present and past coastlines, perched on coastal alluvium</td>
<td>Coastal areas facing harbours and open sea conditions</td>
<td></td>
</tr>
<tr>
<td>Sand; shelly sand, coralline sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blacksoil plain (Qaf)</td>
<td>Adjacent to upper reaches of tidal inlets and rivers; grades seaward into coastal alluvium</td>
<td>Finniss River area</td>
<td>Estuarine to brackish; seasonal inundation</td>
</tr>
<tr>
<td>Clay; mud; silt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alluvium (Qa) &lt; 10 m</td>
<td>Stream channel deposits</td>
<td>Channels developed in drainage areas</td>
<td>Fluvial</td>
</tr>
<tr>
<td>Levee (Qai) &lt; 2 m</td>
<td>Transitional with Qa and overlies Qah, Qd</td>
<td>Fringing Finniss River</td>
<td>Fluvial, channel levee</td>
</tr>
<tr>
<td>Silt; sand; minor gravel</td>
<td>Sediment in broad drainages, lagoons and sloping fringes of estuarine and littoral area</td>
<td>Drainage areas</td>
<td>Unconsolidated sheet wash colluvium</td>
</tr>
<tr>
<td>Colliuvium (Qel) &lt; 4 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand; silt; clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TERTIARY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil (Czs) &lt; 5 m</td>
<td>Laterite-related soils generally developed over Cretaceous sediments; skeletal soils developed over Early Proterozoic metasediments</td>
<td>Widespread; well developed over Cretaceous sediments</td>
<td>Generally residual</td>
</tr>
<tr>
<td>Unconsolidated sand; ferruginous and clayey, sandy and gravelly soils; commonly containing limonite pisoliths</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laterite (Czl) &lt; 4 m</td>
<td>Trizonal laterite profile well developed over Cretaceous sediments and exposed at breaks in slope; detrital laterite at fringes of drainage areas</td>
<td>Common throughout</td>
<td>In situ and transported</td>
</tr>
<tr>
<td>Pisolic and mottled laterite; ferricrete; in situ and reworked remnants of standard laterite profile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MESOZOIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRETACEOUS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathurst Island Formation (Darwin Member) (Kid) 10 m</td>
<td>Flat lying; unconformable overlies Proterozoic units</td>
<td>North of Elizabeth River; eastern part of Cox Peninsula</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>Radiolarian claystone; basal conglomerate; glauconitic sandstone ferruginous at the surface; minor sandy claystone to west</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undivided (Jki) 10 m</td>
<td>Flat lying; unconformable overlies Proterozoic units</td>
<td>Bynoe Harbour area</td>
<td>Fluvial to paralic</td>
</tr>
<tr>
<td>Poorly sorted quartz sandstone; clayey sandstone; sandy claystone; conglomerate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRETACEOUS-JURASSIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petrel Formation (Jpk) 5 m</td>
<td>Flat lying; unconformable overlies Proterozoic units</td>
<td>Berry Springs area; west of Rum Jungle Complex</td>
<td>Fluvial to shallow marine</td>
</tr>
<tr>
<td>friable quartz sandstone; quartz pebble sandstone; quartz pebble conglomerate; ferruginous sandstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROTEROZOIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIDDLE PROTEROZOIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolmer Group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depot Creek Sandstone (Etd)</td>
<td>Unconformably overlies Early Proterozoic metasediments</td>
<td>Berry Springs area; SW of Rum Jungle Complex</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>Pink orthoquartzite and sandstone, commonly ripple marked</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EARLY PROTEROZOIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Sisters Granite (Egt)</td>
<td>Intrudes Efb and Ewt</td>
<td>Southern and western parts of BYNOE</td>
<td></td>
</tr>
<tr>
<td>Granite; granodiorite; adamellite; 1850Ma (Page and others, 1985)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zamu Dolerite (Edz)</td>
<td>Intrudes Rum Jungle Complex, Mount Partidge and South Alligator Groups; Metamorphic equivalent of Efb in part; faulted contact with Ec; intruded by Egt; unconformably overlain by Jki</td>
<td>Rum Jungle Complex</td>
<td>Western half of BYNOE</td>
</tr>
<tr>
<td>Basic intrusive: dolerite metamorphosed to amphibolite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welltree Metamorphics (Ewi)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz-feldspar-biotite gneiss, common garnet and sillimanite; quartzzite gneiss; quartzzite; minor quartz-feldspar-muscovite gneiss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIT, WITH MAP SYMBOL AND THICKNESS</td>
<td>FIELD RELATIONSHIP</td>
<td>DISTRIBUTION</td>
<td>DEPOSITIONAL ENVIRONMENT</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------------</td>
<td>--------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Sweets Member (Ews) &lt;600 m</td>
<td>Near base of Welltree Metamorphics</td>
<td>Western side of BYNOE</td>
<td></td>
</tr>
<tr>
<td>Marble, in places graphic; para-amphibolite; calc-silicate gneiss; quartz-feldspar-biotite gneiss</td>
<td>Faulted contact with Ewt, Ews and Egts; unconformably overlain by Jkl</td>
<td>Western side of BYNOE</td>
<td></td>
</tr>
<tr>
<td><strong>Unnamed unit (Ec)</strong></td>
<td>Conformably overlies and interfingers with South Alligator Group; intruded by Egts</td>
<td>Central and eastern parts of BYNOE</td>
<td>Turbidity flow in submarine fan environment</td>
</tr>
<tr>
<td>Burrell Creek Formation (Efh)</td>
<td>Unconformably overlies Mount Partridge Group; unconformably overlain by Jkp and Kld</td>
<td>North of Elizabeth River; Berry Springs area; west of Rum Jungle Complex</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>Shale, siltstone and phyllite; in places colour-banded; fine to very coarse sandstone; quartz arenite, sublitharenite, subarkose; quartzite; quartz-pebble conglomerate; minor graphic phyllite; quartz-mica schist and gneiss, to the west</td>
<td>Conformably overlies Ese Complex</td>
<td>North of Rum Jungle Complex</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>South Alligator Group</td>
<td>Basal member of Esk; unconformably overlies Ewp</td>
<td>North of Rum Jungle Complex</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td><strong>Undivided (Es)</strong></td>
<td>Conformably overlies Epi</td>
<td>Margin of Rum Jungle Complex; north of Elizabeth River</td>
<td>Shallow-marine subtidal</td>
</tr>
<tr>
<td>Saccharoidal quartzite (after carbonate); siltstone shale and phyllite, commonly carbonaceous, pyritic and, in places, chert-banded and siliceous</td>
<td>Member of Ewp</td>
<td>Margin of Rum Jungle Complex</td>
<td>Fluvial</td>
</tr>
<tr>
<td><em>Koolpin Formation</em> (Esk)</td>
<td>Conformably overlies Epc; unconformably overlain by Jkl</td>
<td>Margin of Rum Jungle Complex</td>
<td>Intertidal to subtidal</td>
</tr>
<tr>
<td>Shale and siltstone, commonly carbonaceous and pyritic</td>
<td>Conformable overlies Epr; unconformably overlain by Jkp</td>
<td>Margin of Rum Jungle Complex</td>
<td>Sabkha</td>
</tr>
<tr>
<td><strong>Wildman Siltstone (Epw)</strong></td>
<td>Unconformably overlies Ar</td>
<td>Margin of Rum Jungle Complex</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td>Shale and siltstone, colour banded and carbonaceous at depth; phyllite, in places carbonaceous; minor quartzite and quartz sandstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Acacia Gap Quartzite Member</strong> (Eps) 300 m</td>
<td>Conformably overlies Epi</td>
<td>Margin of Rum Jungle Complex; north of Elizabeth River</td>
<td>Fluvial</td>
</tr>
<tr>
<td>Quartzite, commonly pyritic; sandstone; interbedded shale and commonly carbonaceous</td>
<td>Member of Ewp</td>
<td>Margin of Rum Jungle Complex</td>
<td>Intertidal to subtidal</td>
</tr>
<tr>
<td><strong>Whites Formation</strong> (Epf) 70 m</td>
<td>Conformably overlies Epc; unconformably overlain by Jkl</td>
<td>Margin of Rum Jungle Complex</td>
<td>Sabkha</td>
</tr>
<tr>
<td>Slate and sericite schist, commonly graphic, pyritic and siliceous, in places dolomitic; minor quartzite</td>
<td>Conformable overlies Epr; unconformably overlain by Jkp</td>
<td>Margin of Rum Jungle Complex</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td><strong>Coomalie Dolomite</strong> (Epc) 250 m</td>
<td>Unconformably overlies Ar</td>
<td>Margin of Rum Jungle Complex</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td>Dolomitic marble and magnesite, in places chloritic and tremolitic, commonly silicified or lateritised at the surface; chloritic slate and sericite schist, commonly graphic (non-outcropping)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Crater Formation</strong> (Epr) 150 m</td>
<td>Unconformably overlain by Epr</td>
<td>Margin of Rum Jungle Complex</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td>Haematite boulder conglomerate; cross-bedded pebbly arkose; pebble conglomerate; quartzite; sandstone; minor slate (non-outcropping)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ARCHAEO</strong></td>
<td>Unconformably overlain by Epr</td>
<td>SE corner of BYNOE</td>
<td></td>
</tr>
<tr>
<td>Rum Jungle Complex (Ar)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucocratic granite; large-feldspar granite; coarse granite; metadiorite; granite gneiss; schist and gneiss; banded iron formation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correlate with pi-cross-bedded arenites of the Shirley area in BATECHLOR, which French (1970) interprets as point-bar deposits.

**Coomalie Dolomite (Epc)**

The Coomalie Dolomite was first described by Malone (1962) and later by Johnson (1974). Interbeds of arkose, shale and marble are common at the conformable boundary with the underlying Crater Formation. Outcrops are sparse, silicified, lateritised and generally poorly preserved, within ferruginous, partly kaolinitic, sandy soil. Silicified outcrops contain rare fragments of rhombic and bladed quartz, which are pseudomorphs after carbonate minerals and tremolite respectively. In places the low-lying, lateritic outcrops are gossanous after pyrite and chalcopyrite.

At the Mount Fitch Prospect the true thickness of the formation varies from 60 to 250 m. Paterson and others (1984) report a maximum thickness of 1000 m for the formation in the Embayment area in
Figure 4  Geologic and structural setting of BYNOE.
Table 4  Lithologies and relationships of units within the Rum Jungle Complex: after Rhodes (1965) and Johnson (1977).

<table>
<thead>
<tr>
<th>UNIT</th>
<th>DESCRIPTION</th>
<th>RELATIONSHIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ar7</td>
<td>Leuocratic granite: fine to medium, even crystalline adamellite; microcline, quartz, albite, chloritised biotite, minor muscovite; accessory apatite, magnetite, fluorite and zircon; pegmatite as sporadic veins, mainly microcline, quartz and minor muscovite.</td>
<td>Youngest member of the Complex; cut by quartz-tourmaline veins, pegmatite and amphibolite.</td>
</tr>
<tr>
<td>Ar6</td>
<td>Large-feldspar granite: adamellite; microcline (tabular or ovoid crystals to 7 cm long), quartz, plagioclase (albite to oligoclase and biotite); accessory magnetite, sphenite, apatite and fluorite; secondary muscovite, epidote and carbonate.</td>
<td>Intruded and veined by leuocratic granite and pegmatite; contains inclusions/remnants of schist, gneiss and diorite.</td>
</tr>
<tr>
<td>Ar5</td>
<td>Coarse granite: coarse, massive, even crystalline adamellite; microcline, quartz, plagioclase (albite to oligoclase and biotite); accessory fluorite.</td>
<td>Contains xenoliths of schist; cut by veins of leuocratic granite; grades into large-feldspar granite</td>
</tr>
<tr>
<td>Ar4</td>
<td>Metadiorite: Fine crystalline, massive; oligoclase, biotite and quartz with minor epidote, sphenite and magnetite.</td>
<td>Intrudes metamorphic rocks; intruded and veined by leuocratic granite; grades into and forms inclusions in large-feldspar granite.</td>
</tr>
<tr>
<td>Ar3</td>
<td>Granite gneiss: Medium to even crystalline, ranging from well banded to homogeneous; microcline, quartz, oligoclase, biotite and minor muscovite; accessory apatite, fluorite and zircon.</td>
<td>Contains inclusions of schist and gneiss; cut by leuocratic granite and pegmatite; appears to grade into the large-feldspar granite.</td>
</tr>
<tr>
<td>Ar2</td>
<td>Schist and gneiss: includes biotite gneiss, biotite-muscovite gneiss, biotite granofels, feldspathic gneiss, quartz-muscovite schist; quartz, microcline, plagioclase, biotite and muscovite in varying proportions; accessory sphenite, magnetite, fluorite, and pintused cordierite.</td>
<td>Inclusion in large-feldspar granite and coarse granite; occurs near margin of the Complex.</td>
</tr>
<tr>
<td>Ar1</td>
<td>Banded iron formation: banded, quartz-magnetite rock with magnetite partly altered to haematite.</td>
<td>Relationships with other units unclear; occurs near margin of the Complex; common as boulders in younger sedimentary rocks.</td>
</tr>
</tbody>
</table>

BATCHelor. The "Embayment" refers to a wedge-shaped mass of sediments near the SW margin of the Rum Jungle Complex displaced by the Giants Reef Fault (Figure 4).

Dolomitic marble and magnesite are predominant, with numerous lutite lenses rich in one or more of the following minerals: chlorite, tremolite and graphite. The lutites lens out laterally and are more abundant at both the base and top of the formation. The dolomitic marble is white, light-green to grey, and medium-grained to very coarse-grained. Magnesite is indistinguishable visually from dolomitic marble. According to Prichard (1976), magnesite occurs widely and is more prevalent at the surface. Domal, stratiform and conical stromatolites have been found, but appear to be restricted to BATCHELOR.

Chloritic and tremolitic alteration of the carbonates is common, while phlogopite, tourmaline, talc, graphite, chalcopyrite and pyrite are common accessories. Chlorite can form up to 40% of the rock, as fillings in shears and fractures, and as banded aggregates. Tremolite, which is more prevalent in rocks near the Embayment, occurs both as shear infill and scattered crystals. In places tremolite may replace as much as 80% of the original carbonate.

The lutes (chloritic slate and fine-grained sericite schist) have been observed only in drillcore. The lutes are commonly carbonateous and in places contain veins and irregular masses of carbonate. Fine-grained, lepidoblastic sericite is generally the main constituent of the sericite schist and it has intergrown with microcrystalline quartz which is elongate and parallel to the foliation. Small quantities of interleaved, very fine-grained biotite occur in places. The weak banding seen in the schist is due to variations in the relative concentrations of mica and quartz. The chloritic slates are fine-grained and consist of intergrown sericite, chlorite and quartz. Fine-grained, unoriented tourmaline is a minor but widespread accessory of all the lutes, together with sphenite, iron-oxides and opaques.
Crick and Muir (1980) recognised rhombohedral and bladed forms within the magnesite, which formed as pseudomorphs after halite and gypsum respectively. They referred also to relict anhydrite and halite forms to support their interpretation that the magnesite replaced evaporites. Bone (1983) contends that the magnesite is more likely of primary origin and that the crystal morphologies are related to the temperature of fluids involved in the recrystallising stage. The presence of stromatolites led Crick and Muir (1980) to interpret the depositional environment as intertidal to supratidal, analogous to that of a sabkha.

**Whites Formation (Epi)**

Whites Formation was first defined by Crick (1984). Previously, rocks of this formation were assigned to the Golden Dyke Formation (Malone, 1962; Johnson, 1977) and to the Masson Formation (Needham and others, 1980). The best exposures are found at the type locality, 2 km SE of Batchelor (Crick, in preparation).

In BYNOE, dark-grey to black slate and schist, commonly graphitic, pyritic and siliceous, plus minor fine-grained quartzite, crop out poorly in low, rubble rises and rubble-strewn pavements. The slates contain aligned sericite and minor chlorite or biotite intergrown with microcrystalline quartz. Schistose varieties are coarser grained. Graphite and opaque minerals occur as fine-grained to medium-grained stringers or as finely disseminated grains. Fine-grained pyrite is disseminated throughout and is probably the source of iron oxides in weathered exposures. In places, carbonate is present as irregular aggregates, disseminated crystals and as fracture-fill. Small, randomly oriented crystals of tourmaline are common. Fine-grained quartzite, stained with iron oxides, occurs as thin interbeds within the slates.

The thickness of the formation is difficult to determine due to its poor exposure. In the Mount Fitch area, drill intersections indicate a variable thickness of up to 70 m, but generally the thickness is less than 50 m. According to Crick (in preparation), the depositional environment is intertidal to subtidal and the unit represents a facies change from the intertidal to supratidal, evaporitic conditions which produced the Coomalie Dolomite.

**Wildman Siltstone (Epp)**

The unit was first described by Needham and others (1978), in the eastern part of the Pine Creek Geosyncline. The Wildman Siltstone crops out in the NE and SE corners of BYNOE and in the vicinity of the Darwin River Dam. Exposures in the north are confined to small, weathered outcrops at the base of escarpments formed by Cretaceous sediments. Elsewhere, outcrops are confined to low, rubble rises. The rocks have been folded tightly and, in the Darwin River Dam area, are isoclinal about subhorizontal to steeply plunging axes. Cleavage is well developed in the lutites and in outcrop forms a more prominent foliation than bedding.

In BYNOE, the Wildman Siltstone consists of the Acacia Gap Quartzite Member, which occupies the lower part of the formation, and siltstone, shale, phyllite and quartz sandstone. Colour-banded siltstone and shale occur predominantly above the Acacia Gap Quartzite Member, whereas dark-grey to black siltstone or phyllite are the main rock-types below the quartzite. The lutites, which form most of the unit, are deeply weathered and commonly form rubble outcrops. Coloured banding is caused by variations in the amount of iron-oxides and it is weakly developed as fine laminations less than 0.10 m thick parallel to bedding. At depth, the rock consists of alternating, light-grey and dark-grey, pyritic, carbonaceous bands.

In the vicinity of the Rum Jungle Complex, the rocks are phyllic and composed of partially to totally recrystallised fine-grained quartz, sericite and minor chlorite. The elongate quartz grains are weakly parallel to the foliation, which cuts the bedding. Accessory graphite occurs as minute particles in porphyroblastic quartz, as irregular masses and as interstitial granules. Pyrite occurs as very small cubes, lenses and veinlets and is more abundant in quartz-rich bands.

Quartz sandstone occurs as minor interbeds within siltstones in the NE part of the sheet. The sandstone is fine to medium-grained and consist of moderately sorted, subangular to subrounded quartz grains, minor lithic fragments and kaolinitised feldspar. The matrix of silt, sericite, haematite and clay makes up 10-30% of the rock volume. Thin interbeds of quartzite, generally only a few centimetres thick, also occur within the siltstone.

In BYNOE, the Wildman Siltstone and the Whites Formation are very similar. The latter is recognised only because of its dolomite content. The Wildman Siltstone is widespread in the central part of the Pine Creek Geosyncline, and is interpreted (Stuart-Smith and others, 1984b) as having been deposited in a shallow-marine, subtidal environment.

**Acacia Gap Quartzite Member (Epa)**

Malone (1962) first described the unit as the Acacia Gap Tongue Member of the Masson Formation. It was renamed the Acacia Gap Sandstone Member of the Masson Formation by Needham and others (1980), and the Acacia Gap Quartzite Member of the Wildman Siltstone by Crick (1983) in NOONAMAH. The member forms prominent, bush-strewn strike-ridges, with relief up to 60 m above the surrounding plains, to the north and west of the Rum Jungle Complex. Quartzite is the dominant rock type and forms blocks, well jointed beds, usually 0.5-10 m thick, which comprise 50-60% of the member. Interbedded, deeply weathered phyllite and minor sandstone are common but poorly exposed.

The quartzite is grey, and composed of medium- to coarse-grained well rounded quartz grains set in a siliceous matrix which commonly obliterates grain boundaries. Intersticial muscovite is common and minor, and granular graphite occurs in places. Disseminated medium- to coarse-grained, euhedral pyrite is represented at the surface by limonite-filled casts. The interbedded phyllite is both graphic and pyritic and indistinguishable from phyllite of the Wildman Siltstone. The thickness of the member is difficult to determine due to isoclinal folding. Crick (in preparation) estimates the thickness to range from 50-300 m.

**South Alligator Group**

North of the Elizabeth River carbonate and lutite of the South Alligator Group are exposed sparsely at breaks in slope along the margins of areas containing coastal and stream sediments. In the Berry Springs area similar rock types have been intersected in drill holes. West of the Rum Jungle Complex, fine-grained lutite which is carbonaceous in places, and minor, interbedded quartz arenite and subarkose, form low rubble rises and are
exposed in railway cuttings. In the above areas poor exposure prevents the establishment of a stratigraphic sequence and assignment of rock types to formations is not possible. North of Darwin River Dam, carbonaceous shale and siltstone of the Koolpin Formation, and ironstone breccia of the Koolpin Formations' basal Member (Ella Creek Member), occur stratigraphically above the Wildman Siltstone.

The South Alligator Group appears to thin appreciably to the west. The Getowie Tuff, which represents a period of widespread felsic, subaerial volcanism during deposition of the South Alligator Group, is prevalent to the east but has not been recognised in BYNBOE. West of the Rum Jungle Complex the South Alligator Group appears to be interbedded with sediments of the Burrell Creek Formation.

**Koolpin Formation (Esk)**
Carbonaceous shale and siltstone of the Koolpin Formation are exposed in several, small, rubble-covered hills, and they are deeply weathered, weakly banded and usually capped by ferricrete. In the Rum Jungle area, the siltstone and shale may attain a thickness of up to 200 m and in places contain pseudomorphs after gypsum (Crick, in preparation).

**Ella Creek Member (Esc)**
The Ella Creek Member was defined by Crick (in preparation) and the type section is at 12°48'S and 131°00'E. The unit is iron-rich at the surface and consists of a ferruginous breccia and a quartzite breccia.

The ferruginous breccia consists of angular clasts of saccharoidal quartzite and minor clasts of black shale in a massive, sandy to gritty, goethitic ironstone matrix. The quartzite breccia consists of tabular and spherical quartzite fragments in a limonitic silty matrix.

Part of this member was intersected in drillhole NTGS DDH 82/40. Below the surface fine-grained, saccharoidal quartzite is interbedded with black shale, siltstone, limonitic breccia and quartzite breccia.

The saccharoidal quartzite forms beds as thick as 5 m and consists of a fine-grained mosaic of granoblastic quartz stained with iron-oxides. Solution cavities are common and, in places, a brecciated appearance is imparted by limonite and secondary silica, infilling irregular cavities. Saccharoidal quartzite has been intersected in drillholes in the Berry Springs area and grades into dolomitic marble below the water table, suggesting that the quartzite of the Ella Creek Member similarly is a silicified dolomite.

The siltstone and shale are carbonaceous, pyritic, well laminated to massive and contain interbeds and lenses of saccharoidal quartzite. The saccharoidal quartzite component varies from minor to major.

Intervals of limonitic breccia, up to 0.5 m wide, are common and consist of angular clasts of black shale and tabular clasts of fine-grained, saccharoidal quartzite and chert in a limonitic matrix. The orientation of the clasts of black shale suggests that they are disjoined fragments of a convolute bed. Layers of fine-grained saccharoidal, quartzite breccia occur within the black shale. The breccia fragments are tabular to spherical and occur with clasts of black shale in a grey silt matrix. The tabular clasts in the enclosing shale are oriented parallel to bedding. The chert and quartzite fragments in both breccia types may represent desiccated and subsequently silicified evaporites or carbonates, which temporarily emerged during periods of deposition.

Lithologies of the Ella Creek Member indicate shallow water deposition. Crick (in preparation) interprets the unit as an Early Proterozoic regolith as it has features characteristic of present-day ferricrete, silcrete and calcrite. It appears, however, that some of the brecciation and ferruginisation at the surface are products of recent surificial lateritisation processes and cannot be taken as evidence for an ancient regolith.

**Undivided South Alligator Group (Es)**
North of the Elizabeth River and at Berry Springs, the carbonate rock has been silicified and occurs as fine-grained to medium-grained saccharoidal quartzite. The replacement texture can be recognised by a fine-grained mosaic of granoblastic quartz grains with coatings of iron oxides, and there are in places interspersed fragments of rounded, opalescent quartz. The saccharoidal quartzite, as observed in drillcore, changes to massive dolomitic marble at depth. The carbonate varies compositionally from pure calcite to dolomite (Lau, 1976) and is a common constituent of the South Alligator Group. Siltstone, shale and phyllite in these areas are commonly pyritic and carbonaceous, as reflected by the generally brown to dark-grey and occasionally purple colour in outcrop. In places, a weak banding is imparted by variations in the carbon content and by iron oxide pseudomorphs after pyrite. Minor chert occurs as thin laminae. Some very fine argillite is silicified, has a cherty appearance and weathers spherically. Owing to the limited areal extent and the highly weathered nature of the outcrops, structural features are difficult to record.

West of the Rum Jungle Complex, the sediments are mainly lutitic, in places ferruginous and carbonaceous and contain arenite interbeds. The sediments become increasingly phyllitic to the south. In the phyllite minor biotite occurs in places as very fine, unoriented flakes and is probably developed adjacent to quartz-tourmaline veins.

**Finniss River Group**
The Finniss River Group, as described by Walpole and others (1968), included the Burrell Creek Formation and the Noltenius Formation. The distinction between the two was based on the predominance of medium-grained to coarse-grained arenite and rudite in the Noltenius Formation whereas lutite and fine arenite were common to both units. Malone (1962) considered the Noltenius Formation to occupy the western marginal portion of the Pine Creek Geosyncline and to grade eastward into the Burrell Creek Formation. During mapping in DARWIN and BYNBOE no clearcut lithologic distinctions were found to warrant this differentiation and the term Noltenius Formation has been abandoned.

In BYNBOE the Finniss River Group is represented by the Burrell Creek Formation which occupies the central and most of the eastern part of the area. To the west the Burrell Creek Formation grades into the Welltree Metamorphics.

**Burrell Creek Formation (EfB)**
The Burrell Creek Formation consists of interbedded lutitic, arenaceous and rudaceous rocks which form
undulating hills, low ridges and prominent strike-ridges. Arenite predominates in outcrop, and comprises an estimated 30-40% of the formation; it also forms most of the prominent strike-ridges. The arenite content decreases towards the apparent base of the formation in the east, where lutite predominates. Coarse arenite and rudite are more prevalent to the west, most commonly occurring in the Finniss Range–Bulldog Pass area. Lutite crops out poorly on low ridges covered by skeletal soil, on rubble rises, in creek beds and in breakaways beneath extensive Cainozoic deposits. Graphite-rich interbeds occur in lutites in a zone 3-6 km wide trending north-south between Lucy Mine and Barrow Creek.

Sandstone of the Burrell Creek Formation typically forms brown and blocky beds 0.2-2.0 m thick, which are strongly jointed, commonly fractured, and quartz-veined. The sandstone is fine to very coarse-grained, unsorted to well sorted and varies in composition from quartzarenite to sublitharenite and subarkose. Sandstone usually consists of subangular to well rounded grains of quartz with sericitised and argillised feldspar and fragmental grains (fine-grained quartzite and argillised siltstone) in a matrix of silt, sericite, clay, and iron oxides. The matrix forms up to 40% of the rock volume and contains various amounts of secondary silica. Coarse-grained varieties usually have a higher matrix content. Authigenic and detrital tourmaline and minor graphite and zircon are accessories. Coarser sandstone, which in places grades into conglomerate contains varying amounts of quartz granules and pebbles, which are evenly distributed in massive varieties or well sorted in graded beds. The fine-grained to medium-grained sandstones are laminated and in places graded: the laminations are less than 2 mm thick and formed by variations in grain-size and composition. Cross-laminations and ripple-like structures are common in fine-grained sandstone. Medium-grained to coarse-grained quartzite is common throughout the sequence and has been derived from sandstones which had a closely packed fabric, now cemented by recrystallised silica.

Conglomerate within the Burrell Creek Formation forms beds and lenses up to 5 m thick, which in places may be composite intervals of several graded sets. Thicker beds are laterally persistent over several hundred metres, but thinner beds lens out over appreciably shorter distances. The conglomerate typically consists of a chaotic assemblage of subrounded to rounded quartz granules, pebbles, and in places, cobbles with subordinate lithic fragments (fine-grained quartzite and phylite) in a matrix similar to that of the sandstone. The gravel component varies from less than 30% to over 80%. Where the conglomerate is matrix-supported, the matrix is principally silty and clayey. To the west, the sandstones have been metamorphosed to weakly foliated quartzite and quartz-mica gneiss.

The massive, medium-grained to very coarse-grained sandstone contains concave, dish-like structures, and silicified pipes which have developed perpendicular to the bedding. These features have been interpreted as fluid escape structures. Convolute bedding, sole markings, flame structures, scours and fill structures, sand volcanoes and load casts are also common sedimentary features.

Commonly, the AE, BCE, and CE divisions of the Bouma sequence (Rupke, 1980) are preserved. Sandstone beds which texturally do not strictly fit the Bouma turbidite model are consistent with those of other gravitational mass-transport mechanisms, namely fluidised flow, grain flow, and debris flow (Reading, 1978). Sandstone deposited by fluidised flow is weakly to non-graded with flame and load structures common on the base. Fluid escape structures occur in the middle and upper parts of the bed. Grain-flow beds are massive, have sharp upper and lower contacts and sole marks at the base. Faint swirled laminae and diffuse flat laminae occur throughout, and lutite clasts are randomly distributed. Sandstone and conglomerate which are massive, unsorted, and also have matrix-supported clasts, are interpreted as debris flow deposits. Based on textural and sedimentary structures, the sediments of the Burrell Creek Formation in BYNOE formed by deposition in a submarine fan environment, in which turbidity flow was the main mechanism of sediment transport.

Beds of siltstone, shale and phylite vary in thickness from less than 0.10 m to more than 10 m, and are typically brown, grey or colour-banded in outcrop. Colour-banding is due to varying concentrations of fine-grained iron oxides along bedding laminae, which range in thickness from 1-5 mm. The shale consists of clay and very fine sericite, which imparts a slight sheen in places, and of iron oxides, which form a matrix enclosing quartz grains in siltstone. Slaty cleavage is moderately to well developed and bedding is displayed by colour bands and variation in grain size from fine sand to clay. The siltstone is moderately laminated and rarely ripple-marked.

The Burrell Creek Formation increases in metamorphic grade westward from subgreenish facies siltstone, phyllite and sandstone, to upper greenish facies gneiss and schist. Sedimentary features and lithologies, typical of the lower-grade units of the Burrell Creek Formation, can be recognised until the sillimanite isograd is approached, whereafter these features are obliterated by recrystallisation. Gneiss and schist in the sillimanite zone are assigned to the Welltree Metamorphics. There is no evidence that the Welltree Metamorphics consist of older basement. The arenaceous as well as the lutitic units along the western margin of the formation are moderately to strongly foliated. The quartz-muscovite matrix of the metaarenites is completely recrystallised, whereas complete recrystallisation of the quartz grains has taken place only at higher grades. The original grain shapes and sedimentary textures, however, are preserved.

The metalutites are represented by phyllite, fine-grained quartz-muscovite schist and quartz-muscovite-biotite schist. Biotite occurs as well-aligned flakes, intergrown with muscovite and quartz in schist on the western margin of the formation, and as randomly oriented late porphyroblasts in quartz-muscovite schist in contact aureoles near granites. Banding on micro and macro scales, defined by varying concentrations of mica and quartz, relates to original compositional layering in the phyllites. Carbonaceous rocks usually contain less than 5% but sometimes up to 20% graphite, concentrated in thin layers parallel to original bedding. Authigenic tourmaline is a common accessory in the metalutites and a major component along contacts with some pegmatites and quartz veins. Andalusite and porphyroblasts of garnet are common accessories.
WELLTREE METAMORPHICS (Ewt)
The Welltree Metamorphics occur in the western half of BYNOE and consist mainly of quartzofeldspathic schist and gneiss with a lower member (Sweets Member) of marble, calc-silicate rock, para-amphibolite and quartzofeldspathic gneiss. Other than in several hills at the head of The Brooks Creek, where quartzite crops out, exposure is very poor. The surficial rocks usually have been deeply weathered, hence stratigraphic and most lithologic information is from drillcore.

A sequence of predominantly quartz-feldspar-biotite-muscovite gneiss and schist, in place, grades laterally into, and is interlayered with, quartzitic gneiss and quartzite. The quartzofeldspathic rocks contain minor graphite, garnet, sillimanite and cordierite, and accessory zircon, pyrite and pyrrhotite, rare apatite, monazite, and sphene. The quartzitic gneiss is fine-to-medium-grained and has poor compositional banding. The remainder of the rocks are medium- to coarse-grained and compositionally banded.

Andesine-oligoclase is the dominant plagioclase, but does not co-exist with albite. Microcline is often prophyroblastic, but usually subordinate to plagioclase.

Biotite is a common but usually minor constituent of the quartzitic gneiss. In quartz-feldspar-biotite-muscovite rocks, biotite constitutes up to 30% of the rock and imparts a strong schistosity. Muscovite, where present, is usually subordinate to biotite. Where muscovite is the major or only mica present the plagioclase is more likely to be albite.

Porphyroblasts of garnet, in places identified as almandine, and sillimanite, are common. Where both cordierite and sillimanite occur, sillimanite is subordinate. Fractures coated with chlorite-calcite, and quartz-calcite veins are common.

 Pegmatites, ranging from several centimetres to over 0.50 m in width, are mainly conformable with the gneissic banding. In detail, the margins are irregular and contain inclusions of gneiss.

The quartzite is almost pure and consists mainly of coarse-grained to very coarse-grained, strained, interlocking, irregular quartz grains. The quartz grains generally occur in elongate masses which impart a weak foliation. Banding due to variations in grain size also exists. Fine-grained, weakly aligned, muscovite forms up to 10% of the rock. Well-foliated graphite is common, usually in fine laminae and often embedded in quartz patches. Accessory minerals are calcite, plagioclase, diopside, apatite, sphene, zircon, pyrite and pyrrhotite. The secondary minerals chlorite and muscovite-sericite are widespread throughout the formation.

Sweets Member (Ews)
Sweets Member occurs at the base of the Welltree Metamorphics in BYNOE and consists of quartzofeldspathic gneiss, calc-silicate rocks, para-amphibolite, marble and ultramafics. The upper boundary is gradational and is marked either by the presence of diopside-rich intervals within the quartzofeldspathic gneiss, or by the first appearance of amphibolite bands. The quartzofeldspathic gneiss, common to the Welltree Metamorphics, persists throughout Sweets Member, where it is distinctly graphitic, in places calcareous, and grades vertically into calc-silicate gneiss. The lowermost known rocks of this member are intruded by granite.

The member is more than 500 m thick. The lowest unit, identified in drillcore, consists predominantly of marble at least 400 m thick, which is overlain by a unit which consists mainly of para-amphibolite with a maximum thickness of 100 m. The contact between these units is ill-defined and gradational.

The marble unit contains bands of both calc-silicate and calc-silicate gneiss which increase in number toward the base. Thin layers of quartzofeldspathic gneiss and para-amphibolite occur throughout the unit.

The para-amphibolite unit contains calc-silicate gneiss throughout. Thin marble and calc-silicate bands occur near the base of the unit, whereas quartzofeldspathic gneiss, in places quartzitic, is common near the top of the unit.

Exposures of marble are rare but where present are silicified and vuggy. At depth the rock is massive, medium to coarsely crystalline, commonly stylolitic, and mainly dolomitic. Magnesite and calcitic marbles occur in places. Disseminated, subparallel flakes of graphite and phlogopite are common, and one or more of teneolite and diopside may be present. Talc usually forms subparallel flakes and, in place, thin bands: diopside and teneolite occur as disseminated crystals and discrete bands. Accessory minerals are quartz, sphene, potash feldspar, zoisite, pyrite, pyrrhotite, chondrodite, magnetite and chlorite.

The calc-silicates and calc-silicate gneiss typically contain the mineral assemblage hornblende/actinolite/talc ± phlogopite ± diopside ± calcite ± quartz. Garnet, sphene, cummingtonite, epidote, graphite, pyrrhotite and pyrite are common, but occur in minor amounts. Chlorite, sercite and serpentine occur as alteration products. The calc-silicate gneiss is composed of varying amounts of quartz, microcline, oligoclase-andesine and biotite, with diopside as the most common calc-silicate mineral. Where phlogopite or teneolite-actinolite is predominant, a strong schistosity is developed.

Para-amphibolite is characteristically fine-grained and well banded, although coarse-grained, massive varieties do occur. The para-amphibolite is typically composed of hornblende + feldspar ± quartz ± biotite ± diopside. The feldspar is oligoclase-andesine, and rarely labradorite. Diopside, quartz and biotite, if present, occur in varying amounts within discrete bands. Common accessories are pyrrhotite, magnetite, and graphite with minor sphene, apatite, epidote leucoxene and calcite. Chlorite and sercite occur in places as alteration products. Mineralogic banding, gradational contacts with calc-silicates, and the presence of graphite, indicate that the amphibolite is a metasediment.

Non-outcropping ultramafics have been intersected by drillholes in the Point Ceylon area (Porter, 1985). According to Porter the ultramafics consist of dark-green to black, fine-to-coarse-grained, serpentined, teneolite-olivine rock, in which the olivine content is generally 40-60%. Chlorite, phlogopite, garnet, haematite and calcite are accessories.

The ultramafics occur within Sweets Member where they appear to grade into teneolite-actinolite rich calc-silicates and amphibolite rich in teneolite-actinolite. Their stratigraphic position within the member is unknown. These rocks are interpreted as being metamorphic derivatives of original carbonate rocks, but petrologic and chemical data are inconclusive. Alternatively, the rocks may represent an intrusive of pyroxenitic to peridotitic composition, related to the Wangi Basins, which occur in REYNOLDS RIVER to the south.
UNIT Ec

Unit Ec is not exposed in BYNOE but probably exists beneath a thin cover of Cretaceous sediments to the west of Tom Turners Fault. This inference is based on the observation that, in FOG BAY, Tom Turners Fault separates this unit from Sweets Member of the Welltree Metamorphics to the east. Furthermore, magnetic features in BYNOE are consistent with those over this unit in FOG BAY.

The relationships of Unit Ec to the Welltree Metamorphics and to rocks of the Pine Creek Geosyncline are unknown. Based on the interpretation of gravity data in FOG BAY, Simons (in Hickey, 1985a) stated that Unit Ec may be part of a thick sequence of metasediments and mafic igneous rocks which possibly accumulated in a rift-like structure.

In FOG BAY Unit Ec consists of biotite gneiss with subordinate amphibolite and very small amounts of marble and quartzite, which exhibit gradational contacts with each other (Hickey, 1985a). The composition of the biotite gneiss is: quartz + oligoclase-andesine (rarely albite) + microcline + biotite ± muscovite ± garnet ± sillimanite. The gneissic foliation is well developed and the metamorphism is mainly of amphibolite grade. Trondhjemitic rocks of similar composition to the biotite gneiss, are weakly foliated and exhibit intrusive contacts with the gneissic rocks. The trondhjemite is probably an anatectic derivative of the biotite gneiss.

Mafic to ultramafic intrusive igneous rocks consisting of mica-peridotite, pyroxenite, serpentinite, norite and eclogite, occur within the biotite gneiss (Pearcey, 1985). This suite probably has affinities with the Wangi Basics (Pietsch, in preparation) exposed further to the south in the Litchfield Province.

INTRUSIVE IGNEOUS ROCKS

Zamu Dolerite (Edz)

This unit was named by Ferguson and Needham (1978) and comprises predominantly mafic intrusives of the South Alligator River area and other mafic intrusives and minor felsic derivatives emplaced as conformable, tabular bodies into the Pine Creek Geosyncline, before deformation and metamorphism took place. Regionally, rocks of this unit are orthopyroxene-normative, with a mainly continental tholeiitic composition (Ferguson and Needham, 1978).

The Zamu Dolerite in BYNOE is poorly exposed as rubbly ridges or as scattered boulders. The dolerite intrudes Whites Formation, Wildman Siltstone and rocks of the South Alligator Group. Rhodes (1965) reported that dykes of dolerite cut the youngest intrusive phase of the Rum Jungle Complex.

West of the Rum Jungle Complex and within the South Alligator Group, the dolerite is dark greyish-green, fine-grained to medium-grained, and has a relict subophitic texture. Actinolite constitutes up to 50% of the rock and occurs as randomly oriented subidioblastic and idioblastic pseudomorphs after augite. Labradorite occurs as randomly oriented, tabular and lath-shaped grains that have been incipiently to almost completely saussuritised. Opaques are probably titanomagnetite, ilmenite and sulphide minerals; these occur as fine, scattered anhedral to euhedral crystals.

Two Sisters Granite (Egts)

The Two Sisters Granite forms a discordant, irregular batholith which lies within FOG BAY, ANSON, REYNOLDS RIVER and BYNOE. It crops out in the SW corner of BYNOE and as stocks within the Welltree Metamorphics and Burrell Creek Formation. Gravity lows beneath the Welltree Metamorphics and the Burrell Creek Formation, and the presence of corresponding contact aureoles, indicate the subsurface existence of granite to the north and NE of the exposed granite. The contact aureole in the Burrell Creek Formation is up to 15 km wide. The gravity data shows that the Roberts Creek Granite is part of the Two Sisters Granite and consequently the term Roberts Creek Granite has been discarded.

The margins of the granite are mainly obscured by sandy soil but a faulted contact with the Burrell Creek Formation marked by quartz veins and breccia, is exposed on the eastern side of the batholith. Outcrops occur as rock pavements and low rubbly rises separated by extensive areas of sandy soil.

The batholith consists of pink and grey medium to coarsely crystalline, moderately foliated to unfoliated granite, adammellite, granodiorite and minor porphyritic granite.

Some phenocrysts of potash feldspar, up to 8 mm long, with a common grain-size of 2-4 mm occur in rocks of granitic composition, whereas in the Bynoe Harbour area, some coarse varieties have an average crystal size of 12 mm. Quartz, potash feldspar (including microcline), plagioclase (albite-oligoclase), biotite and minor muscovite are the main constituents of the granite and granodiorite rock types. Post-crystalline deformation, under conditions of tectonic stress, has resulted in the partial or total recrystallisation of large quartz crystals into finer-grained aggregates. In places feldspar has been fractured and partly recrystallised, and larger mica flakes have been bent and/or fractured. Muscovite-sericite replaces feldspar; chlorite partly replaces biotite, and in places muscovite is strongly altered to sericite. Where the alteration is thorough, numerous intersecting quartz veins cause local silicification of the rock.

Unfoliated granitoids contain accessory zircon, and traces of hornblende and sphene.

Accessory garnet, pyrite, zircon and pyrhotite plus rare braunnerite, sillimanite, apatite and monazite occur within the foliated varieties, which usually have an adammellite-grandioritic composition. The foliation, which strikes between 340° and 010°, is mainly formed by the alignment of biotite and, to a lesser extent, by parallel elongation of quartz and feldspar. Compositional banding, formed by variations in microcline, plagioclase and biotite contents, is common in the foliated varieties. The contact between foliated and nonfoliated rocks is gradational and may represent an intrusive contact modified by subsequent metamorphism.

On the basis of compositional banding and mineralogical criteria, the foliated granitoids are deemed to be S-type. Their distinctive mineralogical features (Ferguson and others, 1980) are the absence of hornblende, the presence of garnet and sillimanite, and the common occurrence of sulphides (pyrrhotite and pyrite).
Pegmatite
Veins and lenticular bodies of pegmatite occur within the Burrell Creek Formation and the Welltree Metamorphics. Within the former the pegmatites may have been formed by magma injection whereas those within the Welltree Metamorphics may have developed as a result of partial fusion. Pegmatites in the Burrell Creek Formation are confined to the contact aureole with the granites. The pegmatites are distributed irregularly, are generally concordant with the foliation and have also been intruded along bedding planes although some are discordant to bedding. The veins may be 2 to 3 m long and less than 1 m wide, or they may be more than 150 m long and over 60 m wide. They generally have sharp contacts with the country rock. The country rock is hornfelsed and commonly contains large andalusite crystals and fine tourmaline.

Many pegmatites in the Burrell Creek Formation are complex and exhibit pronounced zoning, typified by the succession, from the wall to the core, of quartz-muscovite, quartz-feldspar-muscovite, feldspar ± quartz, quartz. Tourmaline, cassiterite and tantalite are common accessories, while albigenyte and lepidolite occur sporadically.

Pegmatites within the Welltree Metamorphics consist of quartz, microcline-perthite, albite and minor muscovite and biotite, with accessory garnet, tourmaline and zircon. Chlorite and muscovite have formed as alteration minerals. These pegmatites contrast with the pegmatites in the Burrell Creek Formation, as zoning is absent as are tin and tantalum.

MIDDLE PROTEROZOIC

Tolmer Group

Depot Creek Sandstone (Ptd)
This formation was described by Walpole and others (1968) as the lower member of the Buldiba Sandstone. Dundas and others (1986) dispersed with the term Buldiba Sandstone and gave formation status to the Depot Creek Sandstone.

In BYNOE, the Depot Creek Sandstone crops out in the lower reaches of the Darwin River and south of the Rum Jungle Complex. It consists of clean, pink, fine-grained to coarse-grained sandstone and orthoquartzite which are commonly ripple-marked and contain thin beds and lenses of quartz conglomerate. The quartz grains in the sandstone are generally well rounded, less than 1 mm in diameter and are cemented in a matrix of secondary silica. The grain boundaries are coated with fine haematite which imparts the diagnostic pink colour to the sandstone. Based on regional correlations by Sweet (1977), the age of the Depot Creek Sandstone is between 1620 Ma and 1200 Ma.

MESOZOIC

Flat-lying Mesozoic sediments of late Jurassic and Cretaceous age overlie Early Proterozoic rocks in the NW and NE parts of BYNOE. Skwarko (1966) mapped the latter as Mullaman Beds. Hughes (1978) divided the Mullaman Beds in the northern part of the Northern Territory into the Petrel Formation and the Bathurst Island Formation. Both formations occur in BYNOE; however, in the Bynoe Harbour area they have not been differentiated.

JURASSIC–CRETACEOUS

Petrel Formation (JKp)
Numerous, small, isolated outcrops of sandstone and conglomerate, less than 4 m thick, occur in the Berry Springs area. The sandstone is massive, friable and consists of poorly sorted, rounded quartz grains up to 5 mm across, set in a sandy matrix which is commonly ferruginous and in places siliciﬁed. Conglomeratic layers occur within the sandstone; these contain rounded quartz pebbles 5 to 50 mm in diameter. Shale clasts and rounded, fine-grained quartzite pebbles are common but minor components. Although no fossils have been found in this area, these rocks are lithologically identical to the fluvial and shallow-marine, Late Jurassic to Neocomian rocks of the Petrel Formation found elsewhere in the NW part of the Northern Territory (Hughes, 1978).

Undivided Mesozoic (JKI)
In the Bynoe Harbour–Indian Island area, deeply weathered and lateritised sandstone and conglomerate are exposed in intertidal rock ledges and low coastal cliffs. Basal conglomerate is overlain by sandstone and sandy claystone which are both commonly conglomeratic. Massive, immature conglomerate beds and lenticular beds of limonitic sandstone occur within the sandstone and sandy claystone.

The basal conglomerate has developed in situ, on the underlying metamorphic and granitic rocks. It consists of unsorted, angular, quartz grains and weathered mica in a mottled, iron-rich, clayey matrix. Larger fragments of vein quartz occur also, virtually in situ.

Above the basal conglomerate, the sandstone varies markedly in maturity and consists of very poorly sorted to well sorted, fine to very coarse, subangular to subrounded quartz grains in a clayey matrix which constitutes up to 50% of the rock. The clayey matrix varies from 50-80% in sandy claystone. Within the sandstone, conglomeratic layers contain varying amounts of rounded granule- to cobble-sized quartz clasts and usually grade upward into sandstone or sandy claystone. Well sorted sandstone is usually medium-grained, commonly laminated, in places cross-bedded, and is more abundant within the sequence north of Bynoe Harbour.

Massive, immature conglomerate beds up to 3 m thick and usually lenticular occur in coastal cliffs on Indian Island. These are distinguished from other rudaceous units by their immature and chaotic nature. They consist of an unsorted assemblage of angular, granule to cobble-sized, quartz gravel in an unsorted, ferruginous, sandy to clayey matrix. Distinctive, brown, medium-grained to coarse-grained, well sorted sandstone, consisting of rounded quartz grains in a limonitic cement occurs in lenticular beds, either within the massive conglomerate or adjacent to it.

In view of the compositional and spatial relationships, the sediments are interpreted as alluvial deposits, formed over an undulating, deeply weathered surface. The chaotic conglomerate probably represents sheet wash or debris flow, whereas the other sediments are indicative of alluvial plain and channel deposits. The dominance of fine-grained, distal and clay-rich sandstone in the north indicates a change to a paralic and shallow-marine environment marginal to the shallow-marine deposits of the Darwin Member. This is seen in DARWIN, where claystone of the Darwin Member
grades to the west and south into sandy claystone, trough cross-bedded, clayey sandstone and laminated, cross-bedded sandstone.

Cretaceous

**Bathurst Island Formation**

**Darwin Member (Kld)**

This is the lowermost unit of the Bathurst Island Formation, deposited on an uneven surface of Early Proterozoic rocks. In BYNOE, the member forms plateaux covered by sand and ferricrete to the north of East Arm, and it is also present in the West Arm–Bynoe Harbour area, where it has a maximum thickness of 10 m. All lithologies within the member are exposed in cliffs in the Woods Inlet–West Arm area. Elsewhere, the claystone and sandstone of the member are exposed in low, coastal, fringing cliffs, escarpment edges and breaks in slope.

A basal polymict conglomerate is present, ranging in thickness from 0.5-4.0 m and it consists of locally derived granules and cobbles of angular to rounded quartz and angular lithic fragments, set in a matrix of sand, silt and clay. Overlying the conglomerate is a ferruginous sandstone bed with a maximum thickness of 1 m. The sandstone is exposed in the cliffs north of West Arm and probably lenses out to the west and south. It is a very ferruginous, fine-to-medium-grained, porous, siliceous sandstone. Silica, and iron oxides after glauconite, form cellular walls which cement the quartz grains together. In fresh drillcore the rock is composed of 40-90% glauconite grains, 10-60% rounded quartz grains, generally less than 5% detrital muscovite, and minor fragments offeldspar in a silt and clay matrix.

Claystone and minor silty claystone are the dominant components of the Darwin Member in BYNOE. Fresh claystone, as intersected in drillholes in DARWIN and KOOLPINYAH, is composed of montmorillonite plus minor carbonaceous material, pyrite and shell fragments. Deep, lateritic weathering has changed the montmorillonite to kaolinn and involved also dissolution and redeposition of iron oxides and silica, imparting the typically colourful and mottled appearance to exposures. Lateritisation also produces a surficial capping. In places silification produces a moderately hard variety of claystone which is referred to as porcellanite.

The claystone is rich in radiolaria tests and contains abundant belemnite casts, usually confined to beds less than 0.2 m thick. Bioturbated beds with a disorderly array of worm burrows are developed in the claystone 5-6 m above the Early Proterozoic basement. The bioturbated beds are several metres thick and contain numerous subvertical burrows up to 0.60 m long and 15 mm in diameter. Minor nodules, possibly containing phosphorite, occur within the bioturbated horizons. In the southern and western parts of Cox Peninsula, the claystone changes gradually to sandy claystone which contains varying amounts of very fine to very coarse, subrounded to rounded quartz grains in a clay matrix.

Berger (in Hughes, 1978) suggested an Aptian age for the Darwin Member. Foraminifera collected from the Darwin Member in offshore wells, including Petrel No. 1, Flat Top No. 1 and Newby No. 1, have also been dated as Aptian (Hughes, 1978).

The dominance of clay over silt and sand and the presence of glauconite, montmorillonite and carbonaceous material suggest that the sediments of the Darwin Member were deposited in a moderately reducing, alkaline, neritic, marine environment, bordering a land mass of low relief. The fluctuation of the sea level is indicated by the presence of bioturbated beds and phosphorite nodules which developed in periods of shallow water.

CAINÓZOIC

Cainozoic sediments form an extensive veneer over much of the area. They consist of Tertiary to Quaternary soil and laterite plus Quaternary marine and nonmarine sediments.

**Tertiary-Quaternary**

**Soil (Czs)**

No attempt has been made to subdivide the soil types. Loamy to gravelly, lateritic soils usually form over Cretaceous sediments. Sand and gravel lithosols overlie most of the Early Proterozoic metasediments and, where the cover is thin, structures in the underlying weathered bedrock can still be seen on aerial photographs. The soil which overlies granitic and high grade metamorphic rocks is unconsolidated and sandy.

**Laterite (Czl)**

During Upper Cretaceous to Middle Tertiary time the land surface was subjected to intense chemical weathering, leading to lateritisation. The standard trizonal laterite profile (Whitehouse, 1940) is commonly observed in the area and is developed best over Cretaceous sediments. It consists of an upper pisolithic ferruginous zone grading downward through a mottled zone to a pallid zone. Exposure, weathering and erosion of this profile in BYNOE have given rise to "weathering laterite" and porcellanite in the Cretaceous claystone.

"Weathering laterite" is found where the mottled zone was exposed and then indurated by reintroduction of iron oxides and silica. Porcellanite forms where the pallid zone has been exposed and intense silification has occurred. Detrital laterite has formed mainly from reworked material cemented by a ferruginous matrix. It generally forms as benches in low-lying areas which fringe drainage depressions and marine flats, as pavements in the dissected plains over Early Proterozoic rocks, and in dissected areas on the Cretaceous plateau. The positions of the benches suggests that they formed in a period of higher stream levels, probably in early Quaternary times.

Pisolitic laterite consists dominantly of ironstone pisoliths up to 10 mm in diameter set in a cement of iron oxides and quartz grains. The laterite occurs as the ferricrete capping at the top of the trizonal profile and it is exposed as pavements, some of which are more resistant and upstanding on cliff edges and at breaks in slope. In BYNOE, it is up to 4 m in thickness and has formed over clayey sandstone and sandy claystone in instances where the porous and clayey nature of the rocks allows ready passage for iron oxides and provides a good medium for deposition. Structures and fabric of the parent rock are obliterated.
Mottled-zone laterite represents the middle portion of the standard laterite profile, consisting of red-brown and white, ferruginised, leached and highly weathered claystone, silstone and clayey sandstone. In places, a honeycomb structure occurs. The zone grades upwards into ferruginous pisolitic laterite and merges downward into the pallid zone of essentially white, kaolinitic rock. Concretionary laterite is a laterite of pedogenic origin which is forming actively as ferruginous motting in poorly drained colluvium and as ironstone nodules in soils. This type of laterite is most commonly formed in low-lying, sandy fringe areas of drainage depressions.

Quaternary

Marine deposits

Coastal alluvium (Qca) Intertidal, marine alluvium consists of poorly sorted quartz sand, shell, limonite and lithic fragments deposited in the swash zone. Mud, clay and silt occur on the tidal flats. Mangrove swamps are common and consist of black, shelly, marine mud. Clay pans and sandy flats occur in areas inundated less frequently by tidal flows.

Beach rock Beachrock consists of tabular, broken slabs of conglomerate. Quartz sand, shell fragments, limonite, lithic fragments and coral are bonded by a carbonate cement. Beach rock occurs at the landward edge of beaches and in places beneath sand ridges.

Cheniers (Qcr) Cheniers form within mangrove areas where they usually extend from prominent land masses and points which face the open sea or main harbours. The cheniers are strands and sandy shell-ridges perched on intertidal mudflats. Radiocarbon ages range from 2350±120 BP, to 670±110 BP, for ridges in DARWIN (Hickey, 1981), which probably are of about the same age as those in BYNOE.

Nonmarine deposits

Blacksoil plains (Qaf) The upper reaches of the saline mud flats grade into estuarine and paludal blacksoil plains along the Finniss River. These plains are inundated by brackish water during wet seasons when some mixing of salt and fresh water occurs. Stands of paperbark grow in perennially wet areas, which consist of a surface layer of organic-rich, clayey silt overlying clay. The seasonally exposed flats consist of brown to dark-grey, organic-rich clay which develops polygonal, shrinkage-cracks during dry seasons.

Colluvium (Qcl) The undulating nature of the topography has resulted in the formation of broad drainage areas rather than clearly defined drainage channels. Sand, silt and clay have been deposited in these areas by sheetwash and have been mapped collectively as colluvium.

Colluvium has also developed on slopes of less than 2°, generally marginal to estuarine and littoral areas. Fringing water-winnowed sand and silt concentrated toward the base of the slope by sheetwash is usual.

Alluvium (Qa) Alluvium, consisting of rock fragments, sand, silt and clay has been deposited in drainage channels. Perched gravel terraces, which are now lateritised, occur in places along the channel edges.

Levee banks (Qal) Levee banks are deposited beside the fluvial channels during overbank flow. They form narrow ridges parallel to the channel and diminish rapidly in size towards the adjacent floodplain. The banks consist of fine to coarse sand, silt, clay and minor gravel. Sedimentary structures include planar and cross stratification, together with graded bedding represented by upward fining of gravel to fine sand.

METAMORPHISM

The metamorphic events in BYNOE are described separately for rock types within the following units: Rum Jungle Complex, Early Proterozoic metasediments, Welltree Metamorphics, Unit Ec, and Two Sisters Granite (Figure 5).

Four or possibly five metamorphic events, and several phases of hydrothermal activity and metasomatism have occurred, and are summarised in Table 5.

The sequence of metamorphic events is:

Event 1. Early regional metamorphism of sedimentary units before granite intrusion; confined to the Archaean Rum Jungle Complex.

Event 2. Regional metamorphism which occurred during the early part of the Top End Orogeny (Needham and others, 1985) and produced subgreen-schist to upper amphibolite metamorphism within the Early Proterozoic metasediments. The formation of the medium-grade Welltree Metamorphics took place during this regional event. The metamorphism of unit Ec and Welltree Metamorphics are probably coeval. However, a Rb-Sr age of 2002±42 Ma obtained from rocks of unit Ec indicates that earlier metamorphism of this unit may have taken place.

Event 3. Contact metamorphism associated with the intrusion of the Two Sisters Granite.

Event 4. Late, low-grade regional metamorphism, which was dominantly an hydrothermal event, is evident within the Early Proterozoic metasediments, Two Sisters Granite, Welltree Metamorphics and Unit Ec.

Rum Jungle Complex The metamorphic grade reached amphibolite facies conditions (Rhodes, 1965). Minor retrograde metamorphic alteration has affected the granite gneiss and metadiorite, as indicated by secondary epidote in biotite and oligoclase, and secondary albite in oligoclase (Rhodes, 1965). The retrograde metamorphism probably occurred during the early part of the Top End Orogeny. Where shearing is intense in granite at the margin of the complex, plagioclase has been almost completely seritized and veins of quartz and quartz-microcline cut the fractured mineral grains.

Early Proterozoic metasediments The metasediments include those of the Mount Partridge, South Alligator and Finniss River groups. Metamorphic grade increases progressively westward across the area, from subgreen-schist facies in the east, through the greenschist facies and biotite zones to the sillimanite zone in the west. The distribution of the isograds is shown in Figure 6.

In the east, the subgreen-schist facies rocks retain their original sedimentary textures, generally with little metamorphic recrystallisation. Lutites are well cleaved and in places contain fine-grained sericite. Arenites are commonly silicified and usually fractured and quartz-veined. Local biotite, andalusite and minor tourmaline have formed close to younger pegmatite or quartz veins. Where pegmatites are abundant, luteite is commonly altered to fine-grained muscovite schist. Pebbles in conglomerates are often slightly flattened.
<table>
<thead>
<tr>
<th>UNIT</th>
<th>LITHOLOGY</th>
<th>REGIONAL PROGRADE METAMORPHISM</th>
<th>CONTACT METAMORPHISM</th>
<th>RETROGRADE METAMORPHISM/HYDROTHERMAL ALTERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MINERAL ASSEMBLAGE/INDICATOR MINERALS</td>
<td>FACIES/AGE</td>
<td>MINERAL ASSEMBLAGE/INDICATOR MINERALS</td>
</tr>
<tr>
<td>Rum Jungle Complex</td>
<td>Schist and gneiss</td>
<td>Q+Mcl+Olge+Biot ±Musc</td>
<td>Lower to middle amphibolite</td>
<td>Pre-2400 Ma$^1$</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Granite gneiss</td>
<td></td>
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<tr>
<td></td>
<td>Meta-diorite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Proterozoic metasediments</td>
<td>Lutite/arenite</td>
<td>Q+Musc-Ser±Clt (partial recrystallisation)</td>
<td>Subgreenschist</td>
<td>1870 Ma$^{20}$</td>
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<tr>
<td></td>
<td>Marble</td>
<td>Do±Tr+Tc±Calc</td>
<td>Middle to upper greenschist</td>
<td>1870 Ma$^{20}$</td>
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<tr>
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<td>Dolerite</td>
<td>Act+Epd+Ser</td>
<td>Subgreenschist</td>
<td>1870 Ma$^{20}$</td>
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<td></td>
<td>Metalutite/meta-arenite</td>
<td>Q+Musc±Biot±Fs</td>
<td>Lower Greenschist</td>
<td>1870 Ma$^{20}$</td>
</tr>
<tr>
<td></td>
<td>Schist/meta-arenite</td>
<td>Q+Biot+Musc±Fs</td>
<td>Middle to upper greenschist</td>
<td>1870 Ma$^{20}$</td>
</tr>
<tr>
<td>Welltree Metamorphics</td>
<td>Gneiss schist</td>
<td>Q+Ab±Mcl±Musc±Biot</td>
<td>Upper greenschist</td>
<td>1870 Ma$^{20}$</td>
</tr>
<tr>
<td></td>
<td>Q+Olge-Ands+Mcl+Biot±Musc</td>
<td>Lower to middle amphibolite</td>
<td>1870 Ma$^{20}$</td>
<td>Q,Mcl,Grnt, ?Sill, ?Cord, Musc, Biot</td>
</tr>
<tr>
<td></td>
<td>Q+Olge-Ands+Mcl+Biot±Sill±Alm (±Cord)</td>
<td>Middle to upper amphibolite</td>
<td>1870 Ma$^{20}$</td>
<td>Q,Mcl,Grnt, ?Sill, ?Cord, Musc, Biot</td>
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<tr>
<td>Calc-Silicate/Calc-Silicate gneiss</td>
<td>Tre-Act±Di ±Q±Grnt</td>
<td>Middle amphibolite</td>
<td>1870 Ma (^{(80)} )</td>
<td>Ser,Serp,Preh, Zoi</td>
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<tr>
<td>Para-amphibolite</td>
<td>Q+Olgc-Ands +Di±Md±Tre ±Grnt</td>
<td>Middle amphibolite</td>
<td>1870 Ma (^{(80)} )</td>
<td>Q,Clt,Ab,Musc, Lower greenschist</td>
</tr>
<tr>
<td>Hb+Olgc-Ands ±Biot±Q±Epd</td>
<td>Middle amphibolite</td>
<td>1870 Ma (^{(80)} )</td>
<td>Ser,Clt</td>
<td>Lower greenschist</td>
</tr>
<tr>
<td>Hb+Lab±Di ±Biot</td>
<td>Middle to upper amphibolite</td>
<td>1870 Ma (^{(80)} )</td>
<td>1850 Ma (^{(4)} ) Ser,Clt</td>
<td>Lower greenschist</td>
</tr>
<tr>
<td>Marble</td>
<td>Do(Calc)±Phlog ±Tc±Tre±Q</td>
<td>Upper greenschist to lower amphibolite</td>
<td>1870 Ma (^{(80)} ) Di,Zoi,Grnt, Q,Scap,Chon Hornblende-bornefels</td>
<td>1850 Ma (^{(4)} ) Clt,Antig,Ser, Preh</td>
</tr>
<tr>
<td>Unit</td>
<td>Gneiss and Schist</td>
<td>Q+Olgc-Ands +Mel+Biott±Sill ±Grnt</td>
<td>Middle amphibolite</td>
<td>1870 Ma (^{(80)} ) or 2000 Ma (^{1})</td>
</tr>
<tr>
<td>Two Sisters Granite</td>
<td>adamellite, granodiorite</td>
<td></td>
<td></td>
<td>Q,Ser,Clt</td>
</tr>
</tbody>
</table>

Key to abbreviations used in Table 5:

- Act — acinolite
- Ab — albite
- Aim — almandine
- Andl — andalusite
- Ands — andesine
- Antig — antigorite
- Biot — biotite
- Calc — calcite
- Clt — chlorite
- Chon — chondrodite
- Cord — cordierite
- Di — diopside
- Do — dolomite
- Epd — epidote
- Fs — feldspar
- Grnt — garnet
- Hb — hornblende
- Lab — labradorite
- Mel — microcline
- Musc — muscovite
- Olgc — olgoclace
- Phlog — phlogopite
- Pin — pinite
- Preh — prehnite
- Q — quartz
- Scap — scapolite
- Ser — sercite
- Serp — serpentine
- Sill — sillimanite
- Tc — talc
- Tou — tourmaline
- Tre — tremolite
- Zoi — zoisite

1. Age of Rum Jungle Complex granites (Richards and others, 1977)
2. The Top End Orogeny (1870-1780 Ma). (a) Nimbuhwah Event 1870 Ma (Needham and others, 1985), (b) Late event 1780 Ma (Page and other, 1985; Geochronology section, this report).
3. Rb-Sr isotope age, Unit Be (Geochronology section, this report).
4. Age of granite intrusion in the Litchfield Province (Page and others, 1985).
Adjacent to the Rum Jungle Complex, the metasediments of the Mount Partridge Group and part of the South Alligator Group, have been metamorphosed to greenschist facies. The grade generally varies locally but increases toward the Embayment. Lutites vary from slate to fine-grained schist. The general mineral assemblage is quartz + muscovite ± chlorite. The quartz grains are extensively recrystallised, commonly elongate parallel to foliation and often exhibit strained extinction. Biotite is a patchy, minor constituent, and is usually partly altered to chlorite. Arenites are commonly veined by quartz and have been partially to completely recrystallised, while pebbles in conglomerate are commonly deformed to obliterate and prolate shapes. The replacement of pyroxene by actinolite and saussuritisation of labradorite occurs within the Zanu Dolerite.

At the Mount Pitch Prospect and in the Embayment, the assemblage dolomite ± tremolite ± talc ± calcite occurs in places. This assemblage is stable from middle greenschist to lower amphibolite facies and is of anomalously higher metamorphic grade than the grade of the interbedded metasediments.

The greenschist facies isograd (Figure 6) was mapped on the basis of metamorphic texture, as the rocks here consist of a quartz-rich flysch sequence. The lutite in the sequence is too fine-grained for the identification of the greenschist facies index minerals and the coarser grained rocks are too quartz-rich for the growth of these minerals.

Within the greenschist facies zone the lutite has been recrystallised to fine-grained schist. The arenite is moderately to strongly foliated, with a recrystallised matrix of fine muscovite (sericite), granoblastic quartz and minor feldspar. The quartz fragments of the arenite are only partly recrystallised. In conglomerate, the pebbles are moderately to strongly deformed to obliterate or prolate shapes. In this zone the mineral assemblage of the lutite and arenite is quartz + muscovite ± feldspar.

The biotite zone is marked by first appearance of biotite oriented parallel to the foliation. Original bedding with schist is represented by folded parallel colour bands. Arenite is completely recrystallised but relit sedimentary textures are retained. The regional metamorphic mineral assemblage is quartz + biotite + muscovite ± feldspar ± andalusite ± garnet. Andalusite or in places possibly sillimanite, occurs as small, elliptical porphyroblasts up to 2 mm in diameter, oriented parallel to foliation. The porphyroblasts have been partly to totally pseudomorphed by quartz and randomly oriented muscovite and biotite.

Metasediments of the Burrell Creek Formation are in contact with the Two Sisters Granite, and hornfelsed in an aureole up to 15 km wide. The presence of andalusite defines the extent of the contact aureole. The mineral assemblage is quartz + muscovite + biotite + andalusite. Within the subgreenschist and lower greenschist facies metamorphics, the later contact minerals developed mainly in metalutite. Muscovite is present in rocks adjacent to pegmatite, as weakly to randomly oriented, medium-to coarse-grained flakes. Biotite occurs as medium to coarse, randomly oriented grains which in places constitute up to 20% of the rock. Andalusite crystals have disrupted and curved the initial foliation. In rocks near pegmatite
the andalusite crystals are commonly as large as 20 mm. In the middle to upper greenschist facies metamorphics, within the contact aureole, the first generation of andalusite crystals have been partially replaced by quartz, muscovite and biotite, and in places subsequently overgrown by the second generation of andalusite. Remnant, folded trains of foliated biotite formed by the earlier, regional metamorphic event are occasionally evident as inclusion trials in the second-generation andalusite crystals.

Late, low-grade, dominantly hydrothermal metamorphism is evident in the Early Proterozoic metasediments. Muscovite and feldspar have been partly altered to sericite, and minor chlorite has formed after biotite. The second-generation andalusites have been partly to completely replaced by quartz and muscovite. Tourmaline is intergrown with the quartz and muscovite, which indicates that tourmalisation of the metasediments was a late stage event.

Quartz-tourmaline veining and associated tourmalisation affect both the Rum Jungle Complex and the surrounding sediments. The veins radiate from the basement complex and tourmaline mineralisation extends well into the country rock. At the Mount Fitch Prospect scapolitisation of dolomitic rocks is associated with the veining. According to Pagel and others (1984), hydrothermal activity, associated with tectonic activity occurred after both the tourmaline phase, and deposition of the Depot Creek Sandstone. The mineralising solutions, which were responsible for uranium mineralisation in the area, were confined mainly to tectonic structures in the Early Proterozoic rocks. A number of alteration minerals, including chlorite, haematite, magnesite, silica, tourmaline, rutile, apatite and staurolite were introduced in two phases of hydrothermal activity (Pagel and others, 1984).

Welltree Metamorphics Polyphase metamorphism is evident, in which pervasive medium-grade regional metamorphism was followed by contact metamorphism and late, low-grade regional metamorphism.

The mineral assemblages and textures of the first event are typical of upper greenschist to upper amphibolite facies regional metamorphism. Typical mineral assemblages for the various lithologies are shown in Table 5.

Other than the lenticular assemblage containing albite, the assemblages are characteristic of amphibolite facies regional metamorphism. The restriction of calamite to the higher-grade assemblage in lilies and the presence of sillimanite and cordierite rather than kyanite, suggest a high-temperature, intermediate pressure regime.

During intrusion of the Two Sisters Granite, the Welltree Metamorphics in the contact aureole reached hornblende-hornfels facies. Quartz and microcline were introduced and veins of quartz-fluorite and quartz-calcite formed during the mylonitisation and brecciation which accompanied the intruding granite. The introduction of sulphide minerals such as sphalerite, galena, chalcopyrite and pyrrhotite, occurred at this time.

Marble at the granite contact contains a 'skarn-type' mineral assemblage, typically consisting of diopside, zoisite, scapolite, garnet and quartz, with minor sphalerite, sphene and chondrodite. Scapolite and chondrodite replace earlier metamorphic silicates. On
the eastern side of the Welltree Metamorphics, un- 
oriented, bladed sillimanite within strongly aligned, 
elongate pseudomorphed porphyroblasts may re- 
present recrystallisation on remnant nuclei of the 
elier sillimanite which was formed during regional 
metamorphism.

Late-stage lower greenschist facies metamorph- 
ism, which overprints both the regional and contact 
events, is widespread. Within the lutitic and quartzo- 
feldspathic rocks, albite is veined by carbonate, 
suggesting it replaces higher-temperature calcic plagi- 
ocline. Chlorite + muscovite (sericite) ± phoe 
the common retrograde assemblage, while ‘metamor- 
phic’ pyrochlore is commonly altered to secondary 
pyrite. Calcium and magnesium silicates in the contact 
aureoles contain secondary sericite, serpentine, preh- 
nite, chlorite and antigorite; and feldspar has been 
locally altered to zoisite.

Unit Ec The gneissic rocks of Unit Ec contain quartz  
+ andesine-oligoclase + microcline + biotite ±  
sillimanite ± garnet, indicative of the middle to upper 
amphibolite facies of regional metamorphism. Re- 
trograde sericite and chlorite occur in places. Minor 
porphyroblastic albite may have formed from higher 
temperature feldspar.

Two Sisters Granite Partial recrystallisation of large 
quartz grains to finer-grained aggregates plus fracturing 
and partial recrystallisation of some of the potash 
feldspar are evident in the foliated granite. Some 
biotite aggregates are bent and partially recrystallised. 
This deformation and recrystallisation is a localised 
event and precedes later hydrothermal alteration.

Hydrothermal alteration caused mild to intense 
alteration of feldspar, biotite, and of muscovite to 
sericite and chlorite. Where the alteration is intense, 
secondary quartz and sericite pervade the rock, as well 
as forming numerous intersecting veins.

STRUCTURE

The structural setting of BYNOE is shown in Figure 4. 
Rum Jungle Complex and marginal sediments The 
schist, gneiss and granite gneiss of the Rum Jungle 
Complex are strongly folded with a general east-west 
strike. According to Rhodes (1965), a 320° foliation 
occurrs throughout the Complex. The marginal sedi- 
ments belong to the Mount Partridge Group and dip 
outward from the complex at angles ranging from 40°- 
60°.

Near Darwin River Dam, isoclinal folds in the 
Acacia Gap Quartzite Member plunge at about 45° to 
the NW.

South of the Mount Fitch Prospect, foliation in the 
granites and metasediments follows their mylonitised 
contact. In the sediments, the long and intermediate 
axes of deformed pebbles lie within the foliation, which 
dips outward from the granites of the Complex.

Williams (1963) identified four periods of deforma- 
tion within the sediments adjacent to the Rum 
Jungle Complex. The first was gentle, east-west fold- 
ing, which was followed by major deformation. The 
latter event produced tight to open folds about north-
trending axes. Axial-plane foliation associated with 
the major deformation remains the prominent cleavage 
in lutitic sediments. Subsequent, monoclinal folding sub- 
parallel to the major deformation, offset the fold limbs, 
rotated the foliation surface and was synchronous with 
the development of second generation mica, giving a 
weak cleavage. A late period of monoclinal folding 
about steeply plunging axes resulted in flexuring of the 
earlier folds in a general east-west direction. Williams 
considered that early east-west folds, or a vertical 
component to the east-west monoclinal folding was 
responsible for the doming of the Rum Jungle Complex.

Stephenson and Johnson (1975) state that the 
polyphase deformation disappears radially outward 
from the complex. They associate the polyphase folds 
with diapiric intrusion of the complex, which caused 
overprinting of the regional fabric near the complex.

Paterson and others (1984) refer to four, mainly 
ductile deformation phases in the Embayment occur-
ing prior to the deposition of Depot Creek Sandstone. 
The first phase was the development of mylonite inter-
preted as the basal zone of a tectonic slide. This was 
followed by upright north-south folding, east-west 
folding, and finally NW and SW megakinks.

Barrell Creek Formation In BYNOE, two genera-
tions of folding (F1 and F2) are evident in rocks of 
subgreenschist facies regional metamorphic grade, 
within the Barrell Creek Formation (Figure 7).

The F1 folds appear to be doubly-plunging, attenu-
ated, tight to isoclinal folds. They developed a weak 
axial-plane cleavage, S1, best developed in F1 folds 
hinges, and recognisable only where the F1 trend is at a 
high angle to F2.

F2 produced a steeply-dipping, cleavage, S2, trend-
ing approximately 310-340°. In BYNOE, this cleavage is 
more widespread than is S1, but again, tends to be 
restricted to areas where the F2 folds are prominent.

Of importance to the full understanding of the 
structural interpretation of the F1 folds are prolate 
pebbles within the Barrell Creek Formation con-
glomerates. These pebbles are elongate and parallel to 
the F1 axes and, indicate uniaxial extension. The 
prolate pebbles were probably stretched during the F2 
event, and F1 fold axes were rotated to their very steep 
plunges by simple shearing. During F2, the F1 folds 
were wrenched dextrally in a zone of broadly dis-
tributed strain. The timing of the F2 event is unknown, 
but may have taken place during movements on the 
Tom Turners-Giants Reef wrench fault system, which 
extends south through the Litchfield Province.

Metasediments of greenschist facies regional 
metamorphic grade within the Barrell Creek Forma-
tion exhibit mineralogical and textural banding which is 
original bedding. Parallel growth of phyllosilicate 
minerals produced the dominant foliation, which in 
places is parallel to bedding. This foliation trends 
approximately 340-020°. A second foliation observed 
only in phyllite and schist is parallel to the axial planes 
of tight folds produced by intracrustal orogenic 
vagination of 
Welltree Metamorphics. Due to poor exposure, the 
structural interpretation of the Welltree Metamorphics 
is based mainly on small-scale structures, the distribu-
tions of units within drillcore and on regional magnetic 
patterns. The dominant folds, outlined by the distribu-
tion of Sweets Member consist of doubly plunging, 
overturned, isoclinal folds trending NW and NE. These 
pech at approximately 60-70° to the west parallel to 
more open folds which have a wavelength of 1.0- 
1.5 km.

Compositional banding forms the oldest preserved 
surface in the Welltree Metamorphics and may re-
present original bedding. The parallel growth of
phylosilicate minerals, generally at a low angle or parallel to banding, produced the dominant, steeply dipping foliation.

**Faulting**
Radial faults are common along the SW margin of the Rum Jungle Complex and continue for short distances in both directions away from the granite-sediment contact. In places, the sediments are displaced laterally along the faults. Paterson and others (1984) state that during and after deposition of the Depot Creek Sandstone, several periods of semiductile to brittle events took place in the Rum Jungle area.

Faults in the Bynoe Harbour area postdate intrusion of the Two Sisters Granite and in FOG BAY and ANSON have deformed and, in places, preserved infaulted remnants of Middle Proterozoic sediments. The faults have been mapped according to sporadic outcrops of silicified fault breccia, the distribution of magnetic features, and other corroborative features evident in drillcore. The main directions of faulting are NNE, NW and east. The NNE-trending faults, including one in the Burrell Creek Formation, display dextral movements of less than 1 km and in places, a vertical component. Vertical movement on one such fault north of Finniss River Station is south-side down. Tom Turner Fault is a major dextral wrench fault which extends for at least 150 km to the south (Hickey, 1985) with intense shearing and possible step faulting over a 1-2 km wide zone.

Where it is exposed along the western edge of the Two Sisters Granite, the contact with the Burrell Creek Formation is faulted, and a fabric parallel to the fault is well developed in both units.

Malone (1962) proposed a major north-south trending fault zone, the Finniss Fault zone (renamed the Mount Fitch Fault by Walpole and others, 1968), a few kilometres west of the Rum Jungle Complex. He suggested the fault was active during and after the deposition of the Finniss River Group and locally influenced sedimentation of the group. Crick (in preparation) states that a considerable section of the Mount Partridge Group and the entire South Alligator Group are absent to the west of the Rum Jungle Complex. He accounts for this by invoking considerable west and SW downthrow of up to several kilometres, on the Mount Fitch Fault. Sediments of the South Alligator Group however, have been recognised.
to the west of the Rum Jungle Complex during NTGS mapping of the area. There is no field evidence of a major fault zone. The absence of a considerable section of the Mount Partridge Group, including the Acacia Gap Quartzite Member, for several kilometres north of the Mount Fitch Prospect, suggests that considerable erosion of the Mount Partridge Group took place prior to the deposition of the South Alligator Group. The concept that erosion rather than faulting accounts for the absence of part of the Mount Partridge Group is reasonable because a regional unconformity has been recognised at the base of the South Alligator Group by Stuart-Smith and others (1980). They report that within the Pine Creek Geosyncline the Mount Partridge Group was uplifted, folded and subsequently eroded prior to the deposition of the South Alligator Group. On the western side of the Rum Jungle Complex, the unconformable boundary between the two formations is concealed, but marked by a change in photo lineament pattern, which is predominantly NS in the South Alligator Group, and mainly EW in the Mount Partridge Group.

The Cretaceous sediments have generally undergone minor warping. Dips rarely exceed 85°, except in areas north of the Elizabeth River, where doline development in underlying carbonate rocks has caused localised depression. Joint sets are well developed on wave-cut platforms.

GEOPHYSICS

Gravity
The Bouguer anomaly map of BYNOE (Figure 8) was compiled from gravity data supplied by Urangesellschaft Australia Pty Ltd (UGA), the BMR and the NTGS. Gravity stations were read along major roads and tracks in BYNOE, and additional detailed helicopter surveys along the southern and western edges of the mapsheet area provided sufficient information for interpretation at 1:100 000 scale. Reprocessing of this data was carried out by the NTGS using the 1967 International Latitude Correction and an average rock density of 2.67 t/m³.

The general positive value of the Bouguer anomaly contours over BYNOE is in keeping with a similar observation for the remainder of the Pine Creek Geosyncline. This has been interpreted by Tuck and others (1980) as representing dense metasediments over less dense basement.

By far the most distinctive feature on the Bouguer map is a trough which trends roughly north-south. The lowest Bouguer anomaly values occur south of the Finniss River and correspond to the subcropping Two Sisters Granite. The contours indicate that the granite extends west into FOG BAY, and to the east forms a stock of the Two Sisters Granite (known previously as the Roberts Creek Granite), which intrudes the Burrell Creek Formation. The central and northern parts of the gravity trough indicate the presence of granite beneath a thin layer of metasediment in this region.

The western edge of BYNOE is marked by a
Magnetics
A contour map of the Total Magnetic Intensity (TMI) of BYNOE (Figure 9) has been produced from data obtained in 1981, from north-south flight lines 300 m apart at a mean terrain clearance of 100 m by Austrex Pty Ltd for the NTGS. The results are available from the Northern Territory Department of Mines and Energy as 1:250 000 and 1:100 000 TMI contour maps, 1:100 000 TMI profiles and flight path maps, and as digital records on magnetic tape. An interpretation of the TMI contour map is shown in Figure 10.

In BYNOE the magnetic contour pattern is marked by a fairly featureless central area, with zones of considerable complexity on either side. This central area coincides with low Bouguer anomaly values and represents nonmagnetic metasediments overlying granitic material.

In the north a negative, linear, magnetic feature cuts across the central, magnetically flat area. Similar, linear features elsewhere in the Pine Creek Geosyncline have been interpreted as thin, near-vertical dolerite dykes (Pietsch, 1985). Modelling indicates that the depth to the top of the dyke is 10-50 m. Isotopic dating of dykes near Mount Bundey was inconclusive, with both Palaeozoic (Newton, 1980) and Proterozoic (Tucker and others, 1980) ages being recorded.

The dyke in BYNOE is truncated at its eastern end by a poorly defined north-south lineament which also displaces a WNW-trending dyke in DARWIN (Pietsch, 1983). It is uncertain whether the dyke continues to the west, because of the complex magnetic pattern found there. However, the dyke may be related to a similar, negative, linear feature noted in FOG BAY (Hickey,
Figure 10 Magnetic interpretation of BYNOE.

1984). A NW-trending sinistral fault (A-B, Figure 10) appears to offset this dyke near Rankin Point.

Area I (Figure 10) is distinguished by a complex magnetic pattern. Drilling of the magnetic features by Idemitsu Uranium Exploration Aust. Pty Ltd (UEA), shows that they are caused by the magnetic characteristics of Sweets Member of the Welltree Metamorphics. The areas of weaker magnetic response within Area I may represent nonmagnetic granitoid pods and infolded nonmagnetic metasediments.

Within Area I, displacement of the magnetic pattern is evident. A variation in rock type between Indian Island and the mainland in FOG BAY (Hickey, 1984) indicates the possibility of a fault which controls this displacement along C-D (Figure 10).

The magnetic pattern, associated with Sweets Member, extends north to DARWIN, indicating that the member continues offshore from Cox Peninsula. The eastern edge of this northern extension shows an abrupt change in magnetic pattern which coincides with the location of Tom Turners Fault.

The southern continuation of Sweets Member is interrupted by the Two Sisters Granite. The higher total magnetic intensities south of Sweets Lookout lie within the inferred boundaries of the Two Sisters Granite. Since the granite has low magnetic intensity this response is probably caused by unexposed rafts of magnetic metasediments or amphibolites of Sweets Member, within the granite.

A triangular area of less complicated magnetic contours (Area II, Figure 10) has a similar magnetic pattern to Unit Ec in FOG BAY to the west (Hickey, 1984). The boundary between Area II and Area I may be controlled by Tom Turners Fault in the east and by the fault along C-D in the north.

A linear, magnetic high (Area III, Figure 10) lies within the nonmagnetic sediments of the Burrell Creek Formation and probably represents a magnetic unit within the formation. The magnetic pattern of this area suggests that north-south folding of the Burrell Creek Formation has occurred with the fold axes plunging to the north. A similar pattern around the eastern margin of the Two Sisters Granite in the south of BYNOE probably has the same magnetic source.

The SE corner of BYNOE is distinguished by a complicated magnetic contour pattern related to the Rum Jungle Complex. The Complex itself (Area IV, Figure 10), consists of areas of varying magnetic character, demonstrating the varied geology. The magnetic contours indicate that some degree of east-west faulting may also have taken place.

The Rum Jungle Complex is bordered by a series of strong, linear, magnetic features coinciding with the outcrop and inferred subcrop of the Mount Partridge and South Alligator groups (Area V, Figure 10). Although the magnetic contour pattern of the Acacia Gap Quartzite Member suggests that this unit has been truncated by the inferred Mount Fitch Fault (Crick, 1984), the magnetic pattern of the South Alligator Group clearly indicates that this unit extends across the proposed fault.

The magnetic contours of that part of Zone V between the Two proposed east-west faults (Figure 10), indicate that the South Alligator Group is at a greater depth here, suggesting that the area between the two faults has been downthrown.
The extreme SE corner of BYNOE coincides with the Embayment. The magnetic contour pattern indicates that the South Alligator Group may subcrop immediately to the west of the Embayment.

Area VI (Figure 10) in the NE corner of BYNOE represents an area of increased TMI and may coincide with subcropping South Alligator Group.

The 'bullseye' feature at locality E (Figure 10), north of the Rum Jungle Complex, indicates a magnetic source at a depth of 3-4 km. Similar features in KOOLPINYAH have been interpreted as magnetic units within the Dirty Water Metamorphics which overlie nonmagnetic basement at depths of 2-4 km (Pietsch, 1985).

**Radiometrics**

An airborne radiometric survey was carried out for the NTGS in conjunction with the magnetic survey, using a 50 litre NaI crystal. The results are available from the Northern Territory Department of Mines and Energy as Total Count Contours at scales of 1:250 000 and 1:100 000, as 1:100 000 multiplots, and as digital records on magnetic tape.

A low total count occurs over BYNOE with numerous, isolated contour closures. In general, the pattern follows geomorphic features such as saline coastal flats, swamps, dams, blacksoil plains and rivers, rather than subcropping geology (Figure 11).

Higher radiometric values are associated with the eastern branch of the Finniss River in the SE corner of BYNOE. These values are caused by radio-elements in the Rum Jungle Complex being transported into the river system. East of Sweets Lookout, and downstream from the Rum Jungle area, a high total count is associated with radio-elements within the blacksoil plains adjacent to the Finniss River. Other isolated areas of high count on the blacksoil plains occur over the Two Sisters Granite.

The SE corner of BYNOE is marked by a high total count (up to 50 ur) and a complex contour pattern. This represents the high radio-element content and complicated geology of the Rum Jungle Complex. The northern edge of the Rum Jungle Complex is covered by the Darwin River Dam, but north of this, a zone of slightly higher total count can be detected. This zone borders the dam and extends south, coinciding with the inferred subcrop of the South Alligator Group.

A similar high total count in the NE corner of BYNOE occurs within the exposed South Alligator Group rocks and distinguishes this group for the Mount Partridge group and the Burrell Creek Formation.

A poorly defined area of high total count occurs between Point Patience and Rankin Point. The higher radio-element content probably represents higher potassium levels associated with intrusions of granitoids and pegmatites.

**GEOCHRONOLOGY**

Dating, using Rb-Sr and Sm-Nd isotopic techniques was carried out on several metamorphic rocks from the Welltree Metamorphics and Unit Ec. The studies were carried out in 1983 for the NTGS by WAITAID, Perth. The Rb-Sr data can only be considered preliminary.
**Welltree Metamorphics**

**Rb-Sr data**
Samples of biotite gneiss, biotite schist and diopside gneiss obtained from drill core were dated. The freshest core was selected; however, very minor chloritisation of biotite and sericitisation of felspar have been observed in some samples.

A Rb-Sr whole rock age of 1784±101 Ma was obtained. According to de Lacer (written communication) this age probably represents a metamorphic or “reset” age.

Page and others (1985), from studies of granitoids in the Litchfield Province, conclude that the granitoids were emplaced at about 1850 Ma, and were affected by greenschist- to amphibolite-facies regional metamorphism (1770±15 Ma) some 50-80 Ma after igneous crystallisation.

The Rb-Sr isochron age of 1784±101 Ma must be considered in the light of three metamorphic events which could have caused isotope resetting. The first event, regional metamorphism, took place during the early stages of the Top End Orogeny (the Nimbuwah event of 1870 Ma, as described by Needham and others, 1985) and preceded contact metamorphism due to granite intrusion at 1850 Ma. The 1770±15 Ma age (Page and others, 1985) probably represents the third event, which was dominantly hydrothermal, lower-grade, regional metamorphism.

**Sm-Nd data**
A model Sm-Nd age of 2150±40 Ma was obtained from a sample of unaltered biotite gneiss. The figure is an estimate of the mantle extraction age of the components of the biotite gneiss.

**Unit Pc**

**Rb-Sr data**
Biotite gneiss and amphibolite samples obtained from drill core were used for Rb-Sr whole-rock analysis. Both fresh and slightly altered (sericitised and chloritised) samples were used. No clear pattern emerged in the isochron date and it is evident that the rocks have been disturbed with respect to Rb and Sr. Two possible isochrons were constructed. The first fit suggests an age of 2002±42 Ma and the second fit suggests an age of 1792±197 Ma. The best fit age of 2002±42 Ma is preferred, with evidence of resetting at 1792±197 Ma. As with the Welltree Metamorphics, rocks of Unit Pc have undergone severall periods of metamorphism which could cause isotope resetting. The model 1 age (2002±42 Ma) suggests however, that a metamorphic event may have taken place before the Top End Orogeny.

**Sm-Nd data**
A model Sm-Nd age of 2280±40 Ma was obtained from a sample of unaltered biotite gneiss. This age and that obtained from the Welltree Metamorphics (2150±40 Ma) are older than, but close to the age of mantle fractionation processes in northern Australia, which, according to Page and others (1985), occurred at around 2000 to 2100 Ma.

**GEOLOGIC HISTORY**

Most deposition, tectonism, igneous activity, and all metamorphism occurred during the Proterozoic.

The Mount Partridge and South Alligator groups were deposited in shallow-water environments under alternating continental and shallow-marine conditions, which changed to deeper water during the deposition of the Finiss River Group and part of the Welltree Metamorphics.

The paralic sediments of the Crater Formation were deposited as molasse facies, at the margin of the recently uplifted Rum Jungle Complex. Carbonate and interbedded carbonate lutite of the overlying Coomalie Dolomite was deposited under intertidal and supratidal conditions (Crick and Muir, 1980) in the vicinity of the Rum Jungle Complex. Shallow-water littoral and subtidal deposits of the Wildman Siltstone transgressed the Coomalie Dolomite. Whites Formation is a variable group of carbonate and in places dolomitic sediments which represents the transition from Coomalie Dolomite to the Wildman Siltstone. Deposition of the Acacia Gap Quartzite Member occurred in a shallow-marine environment within the south-western part of the area occupied by the Wildman Siltstone.

Uplift, folding and considerable erosion preceded deposition of the South Alligator Group. Sediments of this group were deposited after a shallow-marine transgression. Felsic, subaerial volcanism during this stage resulted in the deposition of tuff to the east of BYNOE. Deepening of the geosyncline allowed the deposition of the Burrell Creek Formation in a submarine-fan environment by mass gravity flow processes. The Burrell Creek Formation is generally conformable on the South Alligator Group. West of the Rum Jungle Complex, where much of the South Alligator Group is absent, deposition of part of the Burrell Creek Formation probably took place contemporaneously with that of the South Alligator Group.

At least part of the lenticic and arenaceous, quartzofeldspathic assemblage of the Welltree Metamorphics is equivalent to the Burrell Creek Formation. Marble, carbonate and interbedded sandstone of the lower unit (Sweets Member) was probably deposited in a shallow marine to fluvial environment similar to that of the lower sequences of the Mount Partridge Group which are marginal to the Rum Jungle Complex.

At the close of sedimentation of the Finiss River Group, tholeiitic basalt sills of the Zamu Dolerite intruded the Mount Partridge and South Alligator groups and also the granite of the Rum Jungle Complex. This was followed closely by deformation, metamorphism, and the intrusion of synorogenic granite into the Early Proterozoic sediments of the Pine Creek Geosyncline and the Litchfield Province, between 1870 and 1780 Ma. Upliging of the Rum Jungle Complex either by diapiric emplacement due to the introduction of younger (unknown) granite diapirs (Stephenson and Johnson, 1975), or as a result of polyphase folding, took place at this time.

Erosion followed the termination of the orogeny. The arenites of the Depot Creek Sandstone were deposited by shallow seas during the Middle Proterozoic. The main period of faulting postdates the deposition of the Depot Creek Sandstone.
Table 6  Recorded mineral production and ore reserves (to December 1985) within BYNOE*.

<table>
<thead>
<tr>
<th>MINE/PROSPECT/MINING AREA</th>
<th>RESERVES (mt)</th>
<th>ORE (kt)</th>
<th>GRADE (%)</th>
<th>CONCENTRATE Sn (l)</th>
<th>Ta (l)</th>
<th>U3O8 (l)</th>
<th>Cu (l)</th>
<th>Pb (kt)</th>
<th>Zn (kt)</th>
<th>Sn, Ta (l)</th>
<th>Ag (t)</th>
<th>Au (kg)</th>
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<td>Mount Fitch Prospect</td>
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<td>0.042</td>
<td>0.60</td>
<td>1500</td>
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<tr>
<td>Brown's Deposit</td>
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<td>12g/t</td>
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**PRODUCTION PERIOD**

<table>
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<tr>
<th>West Arm-Bynoe Harbour-Mount Finniss area</th>
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<th>15</th>
<th>17.4</th>
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<tbody>
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<td></td>
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<tr>
<td>West Arm-Bynoe Harbour-Mount Finniss area</td>
<td>1958-1985</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**

| 515 | 15 | 1514.5 | 1811 | 1107 | 61.5 | 110 | 224 | 17.4 |

* Sources: Crohn (1968), Berkman (1970), Needham (1981), Berkman and Fraser (1980) and Northern Territory Department of Mines and Energy records.

Dolerite dykes are likely to be associated with linear magnetic features as in KOOLPINYAH, where intrusion of the dykes probably took place during the Palaeozoic.

Mesozoic sedimentation began with development of fluvial to paralic conditions in the Late Jurassic leading to the deposition of the Petrel Formation (Neocomian). A shallow marine transgression from the northwest followed during the Early Cretaceous (Aptian) when the fine argillitic sediments of the Darwin Member were deposited. Since late Cretaceous or Early Tertiary times, terrestrial conditions have dominated and deep, chemical weathering has produced extensive laterite soils.

**ECONOMIC GEOLOGY**

Tin, tantalum, and minor gold, lithium and thorium mineralisation occurs in the West Arm-Bynoe Harbour-Mount Finniss area. Uranium, copper, lead and zinc mineralisation is hosted by Early Proterozoic metasedimentary rocks adjacent to the Rum Jungle Complex.

*Tin and tantalum*

Details of the tin-tantalum mineralisation and individual prospects are given by Summers (1957) and Crohn (1968).

Tin and tantalum mineralisation occurs within pegmatites which intrude the Burrell Creek Formation. More than 90 mines and prospects have been worked, by underground and open cut methods. Some eluvial deposits have been worked, but no true alluvial deposits of economic grade were proven.

Recent exploration in the area has concentrated on the evaluation of alluvial deposits, and the weathered zones of large pegmatites some of which were previously mined. Currently the only operating mine, Mount Finniss, produces approximately 10-15 tonnes of tin and tantalum per year, from a large pegmatite.

Production figures for tin and tantalum in the West Arm-Bynoe Harbour-Mount Finniss area are given in Table 6. These figures are known to be incomplete.

**Uranium and base metals**

Descriptions of the uranium and base metal deposits and prospects in the Rum Jungle area are given by Crohn (1968), Berkman (1968), Fraser (1980), Berkman and Fraser (1980), Needham (1981), and Pagel and others (1984). Production figures and mineral reserves from these sources are given in Table 6.

Uranium and copper mineralisation occurs at the Mount Burton Mine and at the Mount Fitch and Mount Fitch North prospects near the contact between dolomite and graphitic slate. At the Mount Burton Mine, the oxidised zone contained mainly torbernite and malachite, with minor chalcocite and native copper. All of the copper ore was obtained from the oxidised zone. Pitchblende, pyrite and chalcopyrite occurred below the weathered zone and diminished rapidly below 30 m.

At the two Mount Fitch prospects, primary uranium mineralisation occurs as disseminated amorphous oxides within carbonaceous schist and in narrow, friable, clayey carbonaceous bands and also as anastomosing veinlets in the matrix of magnetitic breccia (Berkman and Fraser, 1980). Low-grade copper mineralisation occurs as malachite, chalcocite and native copper in residual breccias (Berkman and Fraser, 1980).

Brown's Deposit occurs in sheared graphitic, sericitic and pyritic shale, close to the contact with dolomite. Cerussite, malachite and pyromorphite occur in the top 30 m, whereas finely divided galena and very little chalcopyrite, sphalerite, linnaeite, covellite and gersdorffite occur below this depth (Fraser, 1980).

Anomalous uranium and base metal surface values were obtained at Dolerite Ridge, 2 km west of Brown's Deposit.
Gold
The only mine in the area to have recorded significant gold production is the Golden Boulder, discovered in 1906, approximately 3.5 km SSW of Observation Hill. Reported production was 17.6 kg of gold (Crohn, 1968).

Iron ore deposits
Beetson's deposit is located on gossanous ironstone ridges. Coarse sand and a shallow shaft expose irregularly alternating bands of dense haematite, cavernous hematite and goethite within Early Proterozoic metasediments.

Amblygonite (lithium)
Amblygonite occurs at Picketts Mine in the Finnis River area. Analysis of the mineral showed 47% P₂O₅, 35% Al₂O₃ and 7.9% Li (Crohn, 1968). Total recorded production from this locality was about 64 tonnes, mostly obtained in 1906 and 1924-1925.

Radioactive minerals
Madigans Prospect in the Charlotte River area consists of thorium minerals in fracture zones of ferruginous sandstone. Beach sands in the northern side of Bynoe Harbour contain monazite.

Crushed rock and sand
At present, the source of crushed rock for construction and road making purposes is the Acacia Gap Quartzite Member. In previous years the Darwin River Quarry, near the Darwin River Dam, supplied crushed rock from this member. Small amounts of sand were obtained from the Blackmore River.

Groundwater
Groundwater supply is the main source of water in the settled rural area, mainly in the Berry Springs–Darwin River Dam area. Production rates for bores in this area vary markedly. The best supplies are obtained from Early Proterozoic units containing cavernous dolomite, joints or fault zones. Where deep pre-Cretaceous, brecciated regolith has developed over the dolomite, excellent water supplies are obtained. The pre-Cretaceous regolith is the possible aquifer which supplies Berry Springs.

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APPENDIX

Definitions of new stratigraphic units in BYNOE

WELL TREE METAMORPHICS

Derivation of name: Welltree Station (130°32'00'E, 13°12'30'S) on Reynolds River 1:100 000 Sheet (5071).

Distribution: The unit forms very poor outcrop on the Darwin, Bynoe, Fog Bay, Reynolds River and Anson 1:100 000 sheet areas.

Type locality: Discontinuous outcrop of schist and gneiss approximately 3 km northwest of Wangi homestead on the Reynolds River 1:100 000 sheet. Outcrop extends in a northwest zone between 130°37'6"E, 130°37'24"E, 13°09'6"S.

Lithology: Quartz-feldspar-biotite-gneiss in places containing graphite and magnetite; quartz-feldspar-mica schist; quartzitic gneiss. The schist and gneiss both commonly contain garnet and porphyroblasts of sillimanite or andalusite.

Thickness: Unknown.

Members: Sweets Member — Marble, in places graphitic; para-amphibolite; diopside gneiss; quartz-feldspar-biotite gneiss.

Relationships and boundary criteria: Lies to the west of metasediments of the Burrell Creek Formation (contacts obscured). It is intruded by granite dated at 1850 Ma (Page and others, 1985). Faulted to the west by Tom Turners Fault, against 1850 Ma granite and undifferentiated gneiss. The southern extension is obscured by Cambrian sediments. The northern extension is obscured by Cretaceous sediments.

Age and evidence: Early Proterozoic.

1. Age of the crustal formation of original components is 2150±40 Ma (de Lacter, written communication).

2. Metamorphic event dated at 1784±101 Ma (de Lacter, written communication).

3. Intruded by granite dated at 1850 Ma (Page and others, 1985).

Synonymy:

1. Referred to by Berkman (1980) as undifferentiated quartz-mica schist.


SWEETS MEMBER (of the Welltree Metamorphics).

Derivation of name: Sweets Lookout, (130°54'42"E, 12°53'36"S) on Bynoe 1:100 000 Sheet (5072).

Distribution: Bynoe, Fog Bay, Anson and Reynolds River 1:100 000 sheet areas. Very poor, to non-outcropping.
Type Section: In drill hole LKN20, coordinates FL657820, intersected between 70 m and 420 m. Core is currently held by Idemitsu Uranium Exploration Australia Pty Ltd and on expiration of tenement will be held by the Northern Territory Department of Mines and Energy, Darwin.
Lithology: Marble, in places graphitic; para-amphibolite; calc-silicate; diopside gneiss; quartz-feldspar-biotite gneiss in places graphitic.
Thickness: Greater than 500 m.
Relationship and boundary criteria: The member occurs within the Welltree Metamorphics. Top unit consists of diopside-tremolite gneiss containing amphibolite bands. The bottom unit consists of marble. The member's amphibolite and marble content distinguishes it from the Welltree Metamorphics.
Age and evidence: Early Proterozoic —
1. It occurs as a member within the Welltree Metamorphics.