1:100 000 GEOLOGICAL MAP SERIES

EXPLANATORY NOTES

DARWIN 5073

B. A. PIETSCH
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# MAP

1:100 000 Geological Map of Darwin (5073) in pocket
Figure 1  Locality map.
ABSTRACT

The Darwin 1:100 000 map sheet area was mapped by the Northern Territory Geological Survey (NTGS) during 1979 using 1:25 000 colour aerial photography. The area was covered by regional airborne magnetic and radiometric surveys which were flown for the NTGS in 1981.

DARWIN* has a mature topography of low relief. The present-day physiographic features formed mainly during the Middle to Late Cretaceous time. Subsequent deep chemical weathering produced a well developed laterite profile.

The basement rocks have been assigned to the Early Proterozoic. They consist of metasediments of lower greenschist facies assigned to Mount Partridge Group, South Alligator Group and Finniss River Group on Shoal Bay Peninsula, and schist and gneiss of upper greenschist to amphibolite facies on Cox Peninsula. Metamorphism occurred during the Pine Creek Orogeny at about 1800 m.y.† and was followed by the intrusion of dolerite dykes with a strong magnetic signature. Cretaceous sediments were subsequently deposited upon the eroded Proterozoic basement.

Mining activity is confined to the excavation of sand, gravel and aggregate for construction purposes.

INTRODUCTION

General

This report contains a detailed description of the geology of DARWIN (sheet 5073). The majority of outcrop consists of Lower Cretaceous sediments. Basement rocks which are assigned to Early Proterozoic are very poorly exposed. The area was mapped during the 1979 field season by B. A. Pietsch and G. C. Lau. Colour aerial photography at 1:25 000 scale which was flown in 1974, 1975 and 1979 was used for mapping purposes. Investigations involved detailed geological traverses, outcrop mapping and stratigraphic drilling. Detailed data, such as logs of stratigraphic drilling and water bores, petrology, distribution of building resource materials and listings of relevant previous investigations are provided by Pietsch (1983).

Stratigraphic subdivision and nomenclature of Early Proterozoic stratigraphy follow those of Needham and others (1980) for the Pine Creek Geosyncline. Table 1 outlines the stratigraphy of the Early Proterozoic units.

Location

DARWIN is bounded by latitudes 12° 00’S and 12° 30’S and longitudes 130° 30’E and 131° 00’E (Figure 1).

The city of Darwin, situated on the southern part of the sheet is the capital of the Northern Territory. It is serviced by interstate and international shipping and airlines. All weather road access from the south is provided by the sealed Stuart Highway.

*All references to 1:100 000 map sheet areas in this report are designated by the use of capital letters, e.g. DARWIN.
†A long period of deformation and metamorphism possibly began at 1870 m.y. and culminated at about 1800 m.y. (Needham and others, 1980b).

Climate

DARWIN has a monsoonal climate with a wet season lasting from October to April. Most rain falls between December and March. The mean annual rainfall is 1614 mm, as determined by measurements made over the last 42 years by the Bureau of Meteorology. The highest recorded annual rainfall is 2644 mm and the lowest is 1025 mm.

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

Vegetation

Vegetation on the upland areas is mostly open forest, mixed forest and scrubby open forest. The common species are Eucalyptus miniata, Eucalyptus tetrodonta, Eucalyptus blesseri and Eucalyptus foelscheana with an understorey of shrubs such as Grevillea, Melaleuca, Tristania and in places Cycas media and Calytrix. On the footslopes to low swampy areas, low forest dominates. The main species are Eucalyptus polycarpa, Eucalyptus papuana, Pandanus, Livistona and scattered Melaleuca. Intermittent clumps of mixed rainforest species occur in wet, but well drained areas.

The estuarine plains consist of largely treeless areas dominated by cyperaceous perennial herbs. Thickly clumped stands of Melaleuca leucadendron and Melaleuca argenta are supported within depressions that remain swampy for an extended period of the year. The upper reaches of the saline mud-flats are vegetated by Sporobolus virginicus and minor patches of samphires. Forests of mangroves, of which there are 24 species in DARWIN, dominate along tidal channels.

Previous Investigations

Numerous local investigations by the NTGS, the Mines Branch of the Northern Territory Administration, Bureau of Mineral Resources and various other groups have been carried out in the past. These investigations usually related to construction work, groundwater, mineral assessment, environmental control, and general geological assessment.

The earliest geological work of importance dealt with the Cretaceous rocks, from which radiolarians were collected in the 1880’s from cliff sections near Darwin. This work was described by Hinde (1893). Brown (1895; 1906) collected ammonites and other fossils from cliff sections near Darwin, and Etheridge (1907) identified them as of Early Cretaceous age.

Noakes (1949), during reconnaissance mapping in the Katherine-Darwin region, dealt mainly with the stratigraphy of the Cretaceous rocks. He considered plant-bearing sandstones and minor silstone units south of DARWIN to be conformably overlain by argillaceous units best developed in coastal cliff sections. Those sediments were assigned to the Mullaman Group, which he considered to be of Lower Cretaceous age. The Cretaceous sediments in the cliff sections were named the Darwin Formation.

The discovery of uranium at Rum Jungle in 1949, resulted in intensive geological mapping and evaluation of the Pine Creek Geosyncline. From 1953 to 1958, the Bureau of Mineral Resources carried out a program of regional mapping in the Katherine-Darwin area. This included the main fieldwork used to produce the Darwin geological 1:250 000 map sheet (Malone, 1962).
<table>
<thead>
<tr>
<th>UNIT</th>
<th>LITHOLOGY</th>
<th>THICKNESS (metres)</th>
<th>STRATIGRAPHIC RELATIONSHIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Burrell Creek</td>
<td>Siltstone, shale, greywacke siltstone; greywacke increases to west. Interbedded volcanics near base</td>
<td>Approximately 3000</td>
<td>Gradational into Kapalga Formation; in contact with Coomalie Dolomite near Waterhouse Complex</td>
</tr>
<tr>
<td>Formation</td>
<td></td>
<td></td>
<td>Overlies Burrell Creek Formation, confined to Katherine area</td>
</tr>
<tr>
<td>&quot;Unit Ea&quot;</td>
<td>Undifferentiated quartz-feldspar-mica schist, in places granitised</td>
<td>Unknown</td>
<td>Metamorphic equivalent, at least in part, of Burrell Creek Formation</td>
</tr>
<tr>
<td>&quot;Unit Eb&quot;</td>
<td>Undifferentiated schist and gneiss, in places, graphitic, minor quartzite</td>
<td>Unknown</td>
<td>Probably a member of Unit Ea</td>
</tr>
<tr>
<td>*SOUTH ALLIGATOR GROUP (Shallow-marine chemical, volcanic, 5000 m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kapalga Formation</td>
<td>Ferruginous siltstone, chert bands and nodules in places, commonly carbonaceous at depth, minor tuff</td>
<td>Less than 5000</td>
<td>Mainly conformable and in places interbedded with Gerowie Tuff, apparently unconformable onto Koolpin Formation north of South Alligator Valley</td>
</tr>
<tr>
<td>Gerowie Tuff</td>
<td>Black-green cherty tuff, green argillite, pale green tuffaceous greywacke, minor ferruginous chert nodular siltstone and banded iron formation</td>
<td>Less than 750</td>
<td>Conformable and in places interbedded with Koolpin Formation</td>
</tr>
<tr>
<td>Shovel Bilabong</td>
<td>Variolitic andesite</td>
<td>Less than 1000</td>
<td>Flows near base of Gerowie Tuff</td>
</tr>
<tr>
<td>Anodesite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koolpin Formation</td>
<td>Ferruginous siltstone with chert bands and nodules, pyritic carbonaceous shale, silicified dolomite, minor phyllite, jasper and banded iron formation</td>
<td>Less than 1000</td>
<td>Angular unconformity to disconformity at base</td>
</tr>
<tr>
<td>MOUNT PARTRIDGE GROUP (Fluvial, chemical, shallow-marine, 5000 m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nourlangie Schist</td>
<td>Quartz-mica schist, mica-quartz schist, minor quartzite</td>
<td>Unknown</td>
<td>Metamorphic equivalent of Wildman Siltstone and possibly Burrell Creek Formation, locally unconformable on Cahill Formation upper member</td>
</tr>
<tr>
<td>*Wildman Siltstone</td>
<td>Siltstone, in places carbonaceous at depth, red and cream laminated siltstone, minor quartzite and quartz greywacke</td>
<td>1000</td>
<td>Conformable on Mount Hooper Sandstone and Muncogie Sandstone and Whites Formation in Rum Jungle area, correlates with Nourlangie Schist</td>
</tr>
<tr>
<td>*Acacia Gap</td>
<td>Quartz, sandstone and feldspathic sandstone with pyritic carbonaceous siltstone and quartz siltstone interbeds</td>
<td>0-1200</td>
<td>Conformable near base of Wildman Siltstone</td>
</tr>
<tr>
<td>Quartzite Member</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites Member</td>
<td>Calcareous and/or carbonaceous pyritic shale and argillite; calcilutite, silicified calcilutite, calcarenite, rare para- and orthoquartzites and calcareous amphibolitic schist</td>
<td>Unknown</td>
<td>Transitional group of sediments, conformably overlying Coomalie Dolomite</td>
</tr>
<tr>
<td>Coomalie Dolomite</td>
<td>Dolomite, magnesite, dolomite breccia, tremolite schist, calcilutite, with algal structures and evaporite pseudomorphs in places</td>
<td>Approximately 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>Rests unconformably on Celia Dolomite; onlaps onto Rum Jungle Complex in places. Lateral equivalent of Muncogie Sandstone</td>
</tr>
<tr>
<td>Mount Hooper Sandstone</td>
<td>Medium quartz sandstone and quartzite with some chert fragments, siltstone, phyllite, feldspathic quartzite, pebbly in places, chert-pebble conglomerate.</td>
<td>Less than 5000</td>
<td>Contains pebbles of silicified carbonate probably derived from Cahill Formation lower member; facies variant of Cahill Formation upper member</td>
</tr>
</tbody>
</table>
Skwarko (1962) carried out extensive studies of the Cretaceous rocks in the northern part of the Northern Territory, including Darwin. He retained the term Mullaman Beds for all Cretaceous sediments, as previously used by Bureau of Mineral Resources geologists. Hughes (1978) included the Cretaceous rocks of Darwin in his study of the geology and mineral occurrences of Bathurst Island, Melville Island and Cobourg Peninsula. He divided the Mullaman Beds of the northern part of the Northern Territory into two units. A lower, predominantly arenaceous unit is correlated with the Petrel Formation, and an overlying argillaceous unit is assigned to the Darwin Member of the Bathurst Island Formation. The evolution of nomenclature for Cretaceous sediments is given in Table 2.

Physiography

Darwin consists of two land masses separated by Darwin Harbour. Both areas have a mature topography of flat to undulating plains rising less than 45 m above sea level.

For the purpose of this survey, five terrains or land units are defined in terms of geology, drainage and soil type. These terrains are the littoral complex, the paludal estuarine plains, the ephemeral and perennial lagoons and broad drainage channels, the plateau, and the dissected southern plains (Figure 2).

The physiography of Darwin is included in the study of the Katherine-Darwin region by Christian and Stewart (1953) and can be correlated with physical regions described by Williams (1969). Correlation of the various physiographic units is given in Table 3.
<table>
<thead>
<tr>
<th>Author</th>
<th>Lithological assemblage 'argillaceous'</th>
<th>Lithological assemblage 'arenaceous'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radiolarian claystone, silty claystone, siltstone, fine argillaceous sandstone, minor conglomerate</td>
<td>Fine to coarse quartzose sandstone, minor conglomerate, claystone</td>
</tr>
<tr>
<td>Etheridge (1907), Whitehouse (1928)</td>
<td>Point Charles Beds used to describe the fossiliferous strata at Point Charles near Darwin. Also referred to as 'Point Charles strata', 'Point Charles deposit' and 'Point Charles beds'</td>
<td></td>
</tr>
<tr>
<td>Noakes (1949), Sullivan &amp; Iten (1952), Traves (1955)</td>
<td>Darwin Formation best developed in the coastal sections around Darwin and correlated by Noakes with radiolarian siltstone throughout the Katherine-Darwin region</td>
<td>Unnamed formation of plant-bearing sandstone</td>
</tr>
<tr>
<td>Skwarko (1966)</td>
<td>Darwin Area, Inland Belt Unit B and Unit C (the distinction between Units B and C corresponds to the division within the Darwin Member between the lower argillaceous fine sandstone and conglomerate and the upper claystone)</td>
<td>Inland Belt Unit A</td>
</tr>
<tr>
<td>BMR Geologists (1962-1972)</td>
<td>The name Mullaman Group was changed to Mullaman Beds to comply with Section 27 of the Australian Code of Stratigraphic Nomenclature</td>
<td>Petrel Formation</td>
</tr>
<tr>
<td>Hughes (1978)</td>
<td>Darwin Member of Bathurst Island Formation</td>
<td></td>
</tr>
<tr>
<td>This Report</td>
<td>Darwin Member of Bathurst Island Formation includes sandy claystone and clayey sandstone facies variants in Darwin Member on the western side of Cox Peninsula</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2  Physiographic terrains of DARWIN.

<table>
<thead>
<tr>
<th>Land Units (This Report)</th>
<th>Physical Regions (Williams, 1969)</th>
<th>Land Units (Christian and Stewart, 1953)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Littoral complex</td>
<td>Coastal Plains</td>
<td>Littoral</td>
</tr>
<tr>
<td>Paludal estuarine plains</td>
<td>Koolpinyah surface</td>
<td>Charles Point, Koolpinyah and Bynoe</td>
</tr>
<tr>
<td>Ephemeral and perennial lagoons and broad drainage channels</td>
<td>Plateau</td>
<td>Bynoe</td>
</tr>
<tr>
<td>Plateau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissected southern plains</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Littoral complex**
This terrain contains beach sands, cheniers and mangrove forests, plus both saline and calcic sand, and silt and clay of intertidal flats.

**Paludal estuarine plains**
These are poorly-drained estuarine mud flats and seasonally-swampy areas which support stands of paperbarks and grasses resistant to brackish water. Sediment is deposited during seasonal inundation and consists of organic silt and clay. The plains are generally less than 3 metres above the high-tide level.

**Ephemeral and perennial lagoons and broad drainage channels**
This terrain consists of broad low-lying areas both on plateau areas and on the dissected southern plains. The soil consists of colluvial sand, silt and clay winnowed from upland areas and deposited by sheetwash action.

**Plateau**
A plateau is developed over flat-lying Cretaceous sediments and has uniform to gradual slopes. Gravelly and sandy soils are predominant, and a well-developed trizonal laterite profile is common. At the fringes of this unit, the top part of the trizonal sequence is usually stripped away.
Dissected southern plains
These plains are undulating and generally consist of shallow and skeletal soils and rubble developed on deeply weathered Lower Proterozoic rocks.

Geomorphological history
Evidence of geomorphic processes can be traced back to pre-Cretaceous time when an undulating land surface existed, with lutitic and arenaceous units providing higher relief than carbonate rocks.

An extensive veneer of sediments was deposited from an encroaching sea during Aptian time in the Lower Cretaceous period. During Albian time, uplift probably caused a regression of the sea to the north-west and exposed the sediments to a long period of erosion which formed the main, present-day, physiographic features. Van den Brock (1974) postulates that the formation of dolines, which are common in DARWIN, began at this time.

According to Hughes (1978), tectonism in the Early Tertiary produced a minor, north-west tilting of the Bathurst Island Formation and the subsequent renewal of fluvial erosion until Late Tertiary time. These processes further altered the physiographic features by removing part of the early, thick, laterite profile from now low-lying areas and instigated the formation of broad drainage channels. Drainage channels such as Corrawara Creek and Woods Inlet on Cox Peninsula and many smaller creeks on Shoal Bay Peninsula probably formed at this time.

The Quaternary period was marked by fluvial and colluvial deposition. Ferricrete benches at the break in slope around the margins of broad drainage areas are probable remnants of an older laterite surface which has been etched by streams in Quaternary time.

Evidence for higher sea levels in Holocene time is provided by perched cheniers at the Cameron Beach area according to Hickey (1981). Low cliffs to 3 m high are preserved in outcrops of Lower Cretaceous rocks on the periphery of Leanyer Swamp.

STRATIGRAPHY
REGIONAL GEOLOGICAL SETTING
The low-grade metasedimentary rocks in DARWIN are part of the assemblage of mainly lutitic and arenaceous Early Proterozoic* sediments of the Pine Creek Geosyncline. The high-grade metamorphic rocks can in part be tentatively correlated with the Pine Creek Geosyncline Early Proterozoic assemblage. The generalised geology of DARWIN is shown in Figure 3. The stratigraphy has been related to that developed by the Bureau of Mineral Resources (Needham and others, 1980b) during systematic 1:100 000 remapping of about half the Pine Creek Geosyncline area during the 1970's and early 1980's.

Sediments and interlayered tuffs of Early Proterozoic age were deposited over ?late Archaean complexes now exposed as three main granitic complexes (Figure 4). Sedimentation took place in one basin and deposition occurred under alternating continental and shallow-marine environments, according to Stuart-Smith and others (1980b). Regional deformation and metamorphism took place at about 1870 to 1800 m.y. The tightly-folded strata in the central part of the Pine Creek Geosyncline are metamorphosed to greenschist facies, and grade into isoclinally deformed amphibolite-facies metamorphic rocks to the west and east.

Pre- and post-orogenic continental tholeiites and post-orogenic granite diapirs intrude the rocks of Early Proterozoic age. Flat-lying cover rocks of Middle Proterozoic (post 1800 m.y.), Palaeozoic and Mesozoic ages rest unconformably on these rocks. This indicates tectonic stability since early Middle Proterozoic time. The regional geological setting of DARWIN is shown in Figure 5.

In DARWIN the rocks assigned to the Early Proterozoic can be subdivided on the basis of metamorphic grade. Cox Peninsula is underlain by upper greenschist to amphibolite facies quartzofeldspathic and mica schists, gneiss and minor quartzite. The Shoal Bay Peninsula consists of lower greenschist facies metasediments. The stratigraphy is summarised in Table 4. Figure 6 outlines the Early Proterozoic stratigraphy diagrammatically.

EARLY PROTEROZOIC
MOUNT PARTRIDGE GROUP (Pp)
Lutitic and arenaceous metasediments of the Mount Partridge Group crop out poorly in the eastern part of the area. Exposed units within the group are the Wildman Siltstone and the Acacia Gap Quartzite Member. The latter is a reliable marker horizon to which the stratigraphic position of other units can be referred. The polyvariant term ‘greywacke’ used commonly by previous authors has been discarded as it is a definitive term widely based on aspects such as source area, texture, and depositional environment. It cannot be used in a precise compositional or textural context. Sandstone classifications are made according to the scheme established by Folk (1980).

Whites Formation (Ppi)
Whites Formation, the basal unit of the Mount Partridge Group in DARWIN, is not exposed, and its presence in the north-east of the area has been inferred from drill core. BMR DDHZ, grid reference GM 126352, intersected massive, black, dolomitic slate. This lithology is equatable with siltstone and shale, commonly carbonaceous, calcareous and pyritic, intersected by drill-holes in KOOLPINYAH and NOONAMAH located to the west of outcropping Acacia Gap Quartzite. Lithologically and stratigraphically these units are equivalent to Whites Formation as described by Needham and others (1980a). In the Rum Jungle area, Whites Formation constitutes a transitional and variable group of sediments between the Coomalie Dolomite and the Acacia Gap Quartzite (Figure 7).

Wildman Siltstone (Ppw)
Exposures of Wildman Siltstone are confined to small weathered outcrops at the base of escarpments formed in Cretaceous sediments south of the Stuart Highway, and as stream-edge subcrop near Noogoo Swamp. The Wildman Siltstone in DARWIN overlies Whites Formation. According to Stuart-Smith and others (1981), Wildman Siltstone in MARY RIVER to the east

*The term ‘Early Proterozoic’, as used in this report, refers to part of the Proterozoic that is older than 1800 m.y.
conformably overlies Mundogie Sandstone, where lithologies assigned to Whites Formation have lensed out.

Well cleaved siltstone, shale and phyllite, which comprise over 60 percent of outcrop, are interbedded with quartz sandstone. The lutitic rocks are soft and deeply weathered, often cropping out as semi-rubble. Colour banding caused by variations in the amount of iron oxide, is weakly developed in places as fine laminations, which are less than 5 mm thick and parallel to bedding. The predominant lutitic rock types are shale and fine grained phyllite. Several cored drill holes, located in this formation, (Van den Broek, 1974) intersected very weathered mudstone. Only minor interbeds or separate outcrops of siltstone were noted.

Quartz sandstone, classified compositionally as quartz arenite, is fine to medium grained, consisting of moderately-sorted, subangular to subrounded quartz grains, minor lithic fragments, and kaolinsed and sericitised feldspar. The proportion of matrix varies from 10 to 30 percent and consists of silt size quartz grains, abundant sericite, haematite and clay.

Cleavage is well developed in the lutitic units and in outcrop dominates over bedding, which is usually difficult to discern. Alignment of metamorphic sericite flakes imparts a strong foliation to phyllitic rocks.

**Acacia Gap Quartzite Member (Ppa)**

This member is characterised in outcrop by low, rounded boulders of quartzite protruding through Cainozoic sediments. Currently operating quarries near Milners Creek provide the best exposures. The Acacia Gap Quartzite Member can be traced from the Rum Jungle Special Sheet area to DARWIN. In the Rum Jungle Special Sheet area, it has been mapped as an interbedded member near the base of the Wildman Siltstone by Crick (1981). No exposed relationship has been observed between these units in DARWIN, but, on the basis of cuttings from water-bores, the quartzite occupies a position near the base of the Wildman Siltstone.

Where exposed, the Member consists predominantly of arenaceous units interbedded with 30 to 50 percent lutite. Quartzite is the dominant rock type consisting of coarse-grained quartz in a siliceous matrix which has obliterated grain boundaries. Pyrite casts infilled with iron oxide are common, along with scattered irregularly filled cavities to 10 mm in width. Individual beds range in thickness from less than 0.5 m to 6.0 m.

Interbedded arenites are fine to coarse-grained. Some sandstone beds contain well sorted and rounded quartz grains in a minor silt and clay matrix. Many sandstone beds are poorly sorted with 25 to 90 percent subrounded to subangular quartz grains in a matrix of silt size quartz, clay, minor iron oxide and lithic fragments. In places, clay occurs as an alteration product of feldspar. Fissile, commonly pyritic, purple to buff siltstone and grey shale form narrow interbeds less than 0.5 m wide within the arenites.

Individual beds can be traced for 500 m along the length of the quarry pits with only moderate variations in thickness.

**SOUTH ALLIGATOR GROUP (Ps)**

A corridor of carbonate and pelitic sediments of the South Alligator Group trends north-south from Buffalo Creek to Marlowes Lagoon, and south to the Elizabeth
<table>
<thead>
<tr>
<th>ERA/PERIOD</th>
<th>GROUP</th>
<th>UNIT</th>
<th>MAP SYMBOL</th>
<th>THICKNESS</th>
<th>DESCRIPTION</th>
<th>FIELD RELATIONSHIP</th>
<th>DISTRIBUTION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAINOZOIC</td>
<td>Quaternary</td>
<td>Coastal alluvium</td>
<td>Qca</td>
<td></td>
<td>Mud. silt, clay</td>
<td>Intertidal marine alluvium</td>
<td>Swash zone, tidal flats and mangrove areas</td>
<td>Intertidal marine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Black-soil plain</td>
<td>Qaf</td>
<td></td>
<td>Clay. mud. silt</td>
<td>Adjacent to upper reaches of tidal inlets.</td>
<td>Northern Shoal Bay Peninsula (Micketts Ck and King Ck areas), Northern Cox Peninsula</td>
<td>Estuarine brackish water, Sediments deposited during seasonal inundation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colluvium</td>
<td>Qcl</td>
<td>less than 3 m</td>
<td>Sand. silt, clay</td>
<td>Sediment deposited in broad drainage areas, lagoons, and sloping fringes of estuarine and littoral areas</td>
<td>Associated with drainage areas</td>
<td>Unconsolidated sheet wash colluvium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alluvium</td>
<td>Qa</td>
<td>less than 2 m</td>
<td>Gravel, sand, silt</td>
<td>Stream channel deposits</td>
<td>Throughout area where channels have developed in drainage areas</td>
<td>Fluvial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cheniers</td>
<td>Qcr</td>
<td>less than 3 m</td>
<td>Sand, shelly sand, coral fragments</td>
<td>Ridges generally parallel to coastline, perched on marine alluvium</td>
<td>In coastal areas facing open sea conditions</td>
<td>Marine — swash zone deposits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Talus and scree</td>
<td>Qs</td>
<td></td>
<td>Unconsolidated claystone, sandstone, and clayey sandstone rubble</td>
<td>Scree and talus at the base of cliffs formed by Cretaceous sediments</td>
<td>Western side of Woods Inlet</td>
<td>Continental</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beach rock</td>
<td>Qcb</td>
<td>less than 2.5 m</td>
<td>Sand, shells, coral fragments and limonite pisolites in a calcareous cement</td>
<td>Cemented beach sand at top of beach lines and commonly underlying cheniers</td>
<td>Intermittent along beaches throughout the area</td>
<td>Intertidal to subtidal marine</td>
</tr>
<tr>
<td>Tertiary</td>
<td></td>
<td>Soil</td>
<td>Czs</td>
<td>less than 3 m</td>
<td>Unconsolidated sand, clayey sand, ferruginous clayey sand, soil commonly containing limonite pisolites</td>
<td>Laterite-related soils generally developed over Cretaceous sediments, skeletal soils developed over Lower Proterozoic meta-sediments</td>
<td>Widespread, well developed over Cretaceous sediments</td>
<td>Generally residual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laterite</td>
<td>Czi</td>
<td>less than 4 m</td>
<td>Nodular, concretionary pisolitic and vermiculomottled laterite; ferricrete</td>
<td>Trizonal laterite profile well developed over Cretaceous sediments and exposed at break in slope; detrital laterite fringes drainage areas</td>
<td>Common throughout the area. Well developed in-situ laterite on cliff edges and escarpments in west Cox Peninsula area</td>
<td>In-situ and transported</td>
</tr>
<tr>
<td>Era</td>
<td>Formation/Group</td>
<td>Unit</td>
<td>Description</td>
<td>Location</td>
<td>Environment</td>
<td></td>
<td></td>
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<tr>
<td>MESOZOIC</td>
<td>Bathurst Island Formation (Darwin Member)</td>
<td>KI'd</td>
<td>Radiolarian claystone, sandy claystone, clayey sandstone, quartz sandstone, ferruginous sandstone, basal conglomerate</td>
<td>Cox Peninsula and extensive areas of Shoal Bay Peninsula</td>
<td>Shallow-marine to paralic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROTEROZOIC</td>
<td>Finniss River Group</td>
<td>Burrell Creek Formation</td>
<td>Siltstone, shale, sandstone, quartz arenite, sublitharenite, quartz pebble conglomerate</td>
<td>Western and southern part of Shoal Bay Peninsula</td>
<td>Turbidity current in submarine fan environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>South Alligator Group</td>
<td>Es</td>
<td>Ferruginous siltstone, siltstone &amp; shale in places carbonaceous and/or silicified; pyritic carbonaceous shale in places silicified; minor chert banded siltstone and carbonate rocks</td>
<td>North-south corridor between Buffalo Creek and Marlowes Lagoon</td>
<td>Shallow-marine, chemical and volcanic</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Mount Partridge Group</td>
<td>Wildman Siltstone</td>
<td>Siltstone, in places colour banded, silty sandstone (quartz arenite, sublitharenite) with minor colour banding, minor quartzite</td>
<td>Eastern and south-eastern part of area</td>
<td>Shallow marine</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Mount Partridge Group</td>
<td>Acacia Quartzite</td>
<td>Quartzite, commonly pyrite, sandstone with interbedded siltstone</td>
<td>Tightly folded beds in eastern part of area</td>
<td>?Fluvial</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Whites Formation</td>
<td>Ppi</td>
<td>Siltstone and shale commonly pyritic carbonaceous and calcareous</td>
<td>Not outcropping on sheet area - intersected by water bores</td>
<td>Shallow-marine, chemical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unassigned Metamorphics</td>
<td>Pa</td>
<td>EA</td>
<td>Undifferentiated quartz-feldspar-mica schist, in places granitised</td>
<td>Metamorphic equivalent, at least in part, of Burrell Creek Formation</td>
<td>Central and eastern Cox Peninsula. Outcrops at base of cliffs on east coast</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pb</td>
<td>Pb</td>
<td>Undifferentiated schist and gneiss, in places graphitic; minor quartzite</td>
<td>Inferred faulted contact with Unit PA. Probable member of Unit PA</td>
<td>Western extremity of Cox Peninsula. Very poor outcrop</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
River in BYNOE. Outcrop is sparse and confined to small, usually rubbly exposures fringing coastal and stream alluvium south of the Stuart Highway. Waterbore cuttings have confirmed the presence of similar sediments north of the highway.

These sediments are assigned to the South Alligator Group because of their stratigraphic position between the Mount Partridge and Finniss River Groups, and on lithological similarities with the Group elsewhere in the Pine Creek Geosyncline. Needham and others (1980b) defined the South Alligator Group as a distinctive assemblage of iron-rich sediments, carbonate and tuff. The lowest unit (Koolpin Formation) is mostly pyritic, carbonaceous shale which commonly contains chert bands and nodules, algal carbonate and banded iron formation. The overlying tuff unit (Gerowie Tuff) crops out as well-bedded cherty rocks with devitrified skins. The upper unit (Kapalga Formation) is a transitional suite containing Koolpin and Gerowie rock types, interbedded with sandstone and siltstone comparable with the Finniss River Group lithologies. Insufficient field relationships exist in DARWIN to
Figure 5  Regional geological setting of DARWIN.

Geological boundaries
Concealed geological boundaries
Fault
Magnetic lineaments
K Cretaceous
P Permian
Pt Tolmer Group
Pf Finiss River Group
Ps South Alligator Group

Ep Mt Partridge Group
Em Manton Group
Ea Quartz mica, feldspar schist
Eb Gneiss, schist, graphic in part, marble
Ec Gneiss, para amphibolite, quartzite
Eg Carpentarian Granite
A Archean Complex
Figure 6 Diagrammatic outline of Early Proterozoic stratigraphy of DARWIN.

subdivide the Group into the Formations established by Needham (1980b).

The similarities observed in DARWIN and BYNOE include the dominance of carbonate, and pyritic carbonaceous shale and siltstone, the presence of silicified (cherty) argillaceous sediments and distinctive chert banding and lensing within commonly ferruginous siltstone.

Carbonate rocks
Carbonate rocks are now represented in outcrop as fine to medium-grained saccharoidal 'quartzite', occasionally observed as interbeds with siltstone and shale. The paucity of exposure precludes any determination of the thickness of individual carbonate beds. Fine-grained granoblastic quartz grains are in places interspersed with medium grained opalescent grains, with grain boundaries obscured by silica overgrowths. Iron oxide is present as grain coatings, incipient granular spots, and pseudomorphs after pyrite. Thin partings, interpreted as bedding planes, follow the general outcrop trend. Veinlets of quartz in places drusy and crystalline with associated limonite, are common.

Several core drill holes (Van den Broek, 1974) intersected carbonate rocks beneath surficial Mesozoic sediments near Marlowes Lagoon. At depth silification is less intense and the rock changes from saccharoidal 'quartzite' to massive carbonate. Compositonally the carbonate varies from almost pure calcite to completely dolomitised carbonate. The distribution of carbonate outcrops and frequency of intersection in drill holes (BMR CH 2.7) suggests that carbonate is a common constituent of the South Alligator Group. In the South Alligator Valley, Walpole (1968) described the Koolpin Formation as consisting of two main members, namely discontinuous algal reefs and a pyritic carbonaceous siltstone with beds, lenses and nodules of silicified dolomite. Similarities probably exist within the South Alligator Group between DARWIN and the South Alligator Valley with respect to the amount of carbonate in the total section. The origin of carbonate in DARWIN is unknown as no sedimentary features have been seen.

Siltstone, shale, phyllite
Siltstone, shale and phyllite are commonly carbonaceous and pyritic, reflected by the generally brown to dark grey, and occasionally purple colour of outcrop. Pyrite casts occur as fine, disseminated, commonly cubic, iron-oxide filled cavities. In places a weak banded appearance may be imparted by the iron oxide pseudomorphs. Minor chert occurs as thin laminae. In one location the chert is spotted and tuff-like in appearance. Some of the very fine argillaceous rocks are silicified, have a cherty appearance, and weather

Figure 7 Schematic facies relationships of the Mount Partridge Group between Rum Jungle and Koolpinyah.
and Noltenius Formation. The distinction between the two units was based on the prevalence of medium to coarse-grained arenite and rudite in the Noltenius Formation. Lutite and fine arenite were common to both units. Malou (1962) considered the Noltenius Formation to occupy the western margin of the Pine Creek Geosyncline and to grade eastward into the Burrell Creek Formation. In the course of investigation in DARWIN and BYNOE no clear cut lithological distinctions exist to warrant the differentiation, and all units are mapped as Burrell Creek Formation.

Burrell Creek Formation (Elb)
The Burrell Creek Formation is the youngest Early Proterozoic sedimentary unit in DARWIN. It is exposed on the southern side of Shoal Bay Peninsula at the base of cliffs and escarpments formed in Cretaceous sediments, and in low-lying areas as a rubbly outcrop. Resistant arenaceous and rudaceous lithologies form small islands south of Quarantine Island.

A gradational conformity between this formation and the South Alligator Group exists in the Pine Creek Geosyncline. In DARWIN part of the contact is inferred as faulted.

In DARWIN the formation consists of interbedded lutite, arenite and rudite. The sediments fine to the west where rudites disappear and arenites become less frequent and finer-grained.

The total thickness has not been estimated due to poor outcrop, tight folding and lack of marker horizons.

Shale, siltstone and phyllite
Lutites, consisting of shale, siltstone, and phyllite, comprise an estimated 60 to 70 percent of outcrop and possibly greater than 80 percent of the formation. At Winnellie very weathered commonly light grey, buff, mauve and weakly colour-banded shale and siltstone are exposed. The colour banding is due to varying concentrations of fine-grained iron oxide following bedding laminae.

Essentially the rocks consist of clay, very fine incipient sericite which imparts a slight sheen in places, and iron oxide, which in the siltstone acts as a matrix to silt size quartz grains. Slaty cleavage is moderately to well developed and dominates over bedding in outcrop.

The majority of lutites are phyllitic and crop out as typically brown, strongly-foliated, metamorphic equivalents of shale and siltstone (Plate 1).

Bedding is displayed by weak colour bands and variations in grain size from fine sand to clay.

Sandstone
North and south of Reichardt Creek beds of quartz sandstone, conglomerate and phyllite are prominent. They range in width from less than 10 cm to several metres. Fine interbeds of one rock type in more massive beds of another are common.

Quartz sandstones vary markedly in grain size from very fine to very coarse-grained, with coarser units commonly containing up to 20 percent of quartz granules. The degree of sorting decreases from moderate to very poor, inversely with increasing grain size. Roundness varies from subangular to rounded. The quartz content ranges from less than 40 to greater than 90 percent in a matrix consisting of clay, silt-size quartz grains, fine iron oxide and sericite. Subordinate components such as lithic fragments and feldspar

Plate 1 Foliation in Burrell Creek Formation phyllite at Stokes Hill Wharf area.
Note near-vertical bedding and cross-cutting quartz veinlets parallel to foliation direction.

Plate 2 Scour-and-fill structure at the base of a granular sandstone bed in the Burrell Creek Formation on Quarantine Island.

conchoidally. Both siltstone and shale are phyllitic in places where fine grains of aligned, metamorphic sericite flakes have developed. In one location adjacent to an inferred fault, the siltstone is schistose in character.

Owing to the limited extent and highly weathered nature of the outcrops, structural features are difficult to discern and too few in number to infer any regional trends.

FINNIS RIVER GROUP
The Finniss River Group, as described by Walpole and others (1968), comprised the Burrell Creek Formation
generally constitute less than five percent of the non-matrix fraction. The lithic fragments consist of fine-grained, silicified sandstone and phyllite, which are probably derived from within the Formation. Feldspar is much less prevalent and is represented by clasts of kaolinite which have sharp angular boundaries. Detrital tourmaline grains are a minor but widespread constituent. The abundant granoblastic sericite in the matrix is metamorphically derived and the alignment of flakes imparts a moderate to weak foliation to the sandstone. The recrystallisation of some arenesite to quartzite is probably due to metamorphic redistribution of silica in the matrix. The sedimentary structures present are graded bedding in sandstone, normal and inverse graded bedding in granular sandstone and minor ripple marks in fine-grained sandstone. Scour and fill structures at the base of coarser units are common (Plate 2).

Conglomerate
Conglomerate forms beds and lenses up to six metres thick near Quarantine Island. Thicker beds are laterally persistent over several hundred metres, but thinner beds, generally less than two metres thick, lens out over appreciably shorter distances, and in places are abruptly terminated by younger beds. The conglomerate typically consists of a chaotic assemblage of subrounded to rounded quartz granules, pebbles, and in places cobbles with subordinate lithic elements in an unsorted matrix of sand, silt, mud, iron oxide and sericite. The gravel component varies from less than 30 percent to 80 percent. Where the conglomerate is matrix-supported, the matrix consists essentially of silt and mud. The lithic fragments are generally sub angular, fine-grained quartzite and phyllite, probably derived from a proximal source. Sericite imparts a moderately strong foliation to the rocks with higher matrix content. Detrital tourmaline is a minor but common constituent.

Scour-and-fill structures are common. Normal and inverse graded bedding occurs in the subaqueous debris-flow-type conglomerates.

UNASSIGNED METAMORPHIC ROCKS
Unit Ea
This unit of quartz-mica schists which underlies most of Cox Peninsula occurs as very weathered intermittent and sinuous exposures at the base of cliffs formed in Cretaceous sediments in the Talc Head–Woods Inlet, and northern Shoal Bay areas. The extent of this unit has been established mainly from drill holes.

North of Woods Inlet, relict sedimentary bedding consisting of grain-size variations and weak colour banding at an angle to foliation is preserved in fine-grained, quartz-mica schist. The lack of feldspar observed in outcrop is due either to surface weathering or to the fact that the metamorphism was insufficient to form feldspar. The relict bedding closely resembles that in coarse phyllite of the Burrell Creek Formation on Shoal Bay Peninsula, where a subtle increase in metamorphic grade from east to west occurs. The schist north of Woods Inlet is interpreted as a higher grade equivalent of the coarse phyllite, suggesting that Ea, at least in part, is a metamorphic equivalent of the Burrell Creek Formation.

Fresh samples of this unit were obtained from three cored holes drilled across the northern part of Cox Peninsula (NTGS DRP DDH 2, 3 and 4). Most of the quartz grains in the sample from the eastern hole (NTGS DRP DDH 2) were petrologically described as being almost completely unstrained. Some grains show residual strain and have boundaries which are less annealed. To the west (NTGS DRP DDH 3), two successive generations of quartz are evident in thin section. One distinctive type consists of elongate grains which have been fractured and partially resealed. The second type occurs as irregular to rounded particles, with embayed margins. Although no physical evidence remains it is assumed that these two generations have replaced an earlier type which was crystallised in equilibrium with biotite. Muscovite is the dominant mica in NTGS DRP DDH 2. In contrast biotite is the dominant mica in core from the the western holes. The crystal form of biotite is often poor and it shows much evidence of disruption, alteration and replacement by a pale yellow-brown chlorite. Muscovite occurs within patches of biotite, probably as a replacement product.

The feldspars are generally altered, but plagioclase, orthoclase and microcline are recognisable. Trace relationships of the feldspar in DRP DDH 3 are complex. Shattered and highly altered feldspar occurs within areas of biotite in a relationship which suggests equilibrium of crystallisation. Other grains of plagioclase identified by polysynthetic twinning have usually disrupted biotite and are assumed to have been introduced later. A third feldspar consists of fresh microcline which contains inclusions of relic, very altered, older feldspar, and rounded blebs of incipient quartz. In the western hole (NTGS DRP DDH 4), elongate porphyroblasts to 5 mm long of potash feldspar, including microcline, are commonly parallel to the foliation. These contain numerous oriented inclusions of biotite and a few inclusions of quartz.

Pale lenticular aggregates, 4–8 mm long and 2–3 mm wide, composed almost entirely of fibrous sillimanite, constitute up to 15 percent of the rock in the western hole. The outer zones of the aggregates have been invaded by quartz which has crystallised across some of the sillimanite.

Unit Eb
This unit crops out on the northern fringe of Shoal Bay at the base of cliffs and on a wave-cut platform. Outcrop of extremely weathered gneiss and schist consists of quartz, yellow to buff talcose clay which in part retains feldspar particle shapes, and brown decomposed mica. Dark grey, graphite-rich clay zones occur in the weathered gneiss.

Quartzite, which is strongly dissected by large quartz veins, crops out as a resistant stack on the beach. These rocks have been assigned to Unit Eb because of their graphite content and strong magnetic response. These characteristics are concordant with those of a group of metamorphic rock types interpreted as being a member of Unit Ea in BYNOE.

Isoclinal folding is evident in the schist, and quartz veining in the quartzite strikes in a northerly direction adjacent to the inferred position of Tom Turner’s Fault, which forms the boundary between Units Ea and Eb.

INTRUSIVE IGNEOUS ROCKS
Dolerite
Non-outcropping dolerite was intersected by drill holes at two locations, both corresponding with regional
magnetic lineaments. On Quarantine Island dolerite intrudes Burrell Creek Formation sandstone (Lau 1974a), where sediments in a narrow contact aureole (less than 1 m wide) have been partly silicified.

The dolerite is dark greenish-grey, fine to medium-grained, with a subidiomorphic, granular, igneous texture. Plagioclase is the principal mineral constituting 60 to 70 percent of the rock, with augite and minor (less than 5 percent) ilmenite, serpentine, and mesostasis. Plagioclase occurs as idiomorphic to subidiomorphic calcic and sodic zoned grains with saussuritised centres, and as partly saussuritised labradorite laths. Clinopyroxene is typically a very pale brown augite, which is subidiomorphic and subophitic, and in places twinned. Ilmenite forms as fine scattered intergrowths between clinopyroxene and feldspar laths. Serpentine, possibly after olivine or pyroxene, occurs as subidiomorphic grains, in altered feldspar and along veins. The interstitial mesostasis consists of xenomorphic quartz, potassic feldspar, and minor sphene, pyrite and calcite.

On north-east Shoal Bay Peninsula, water bore RN 5848 intersected altered dolerite. Plagioclase constitutes 50 to 55 percent of the rock and is partly replaced by epidote and/or zoisite. Secondary amphibole, chlorite and biotite are the other major components. Amphibole and mica have probably replaced pyroxene. Epidote/zoisite is mainly an alteration product, but there are some aggregates of primary epidote in interstices. Opaque iron-titanium oxide and leucoxene are minor constituents.

**Pegmatite**

Abundant pegmatite veins intrude Unit Ea and several occur in the Burrell Creek Formation on the western extremity of Shoal Bay Peninsula. The veins range in

width from less than 20 cm to more than 50 cm and are generally parallel to the direction of foliation. Some crosscutting quartz and tourmaline-rich veins also occur.

The pegmatite is generally coarse-grained and consists of quartz, feldspar, muscovite and accessory tourmaline. The source is probably the inferred granite underlying Cox Peninsula.

**MESOZOIC**

In DARWIN there is no evidence of post-orogenic Proterozoic or Palaeozoic strata.

**CRETACEOUS**

**Bathurst Island Formation**

*Darwin Member (Kld)*

Flat-lying Cretaceous sediments cover most of DARWIN. Skwarko (1966) previously mapped these rocks as Mullaman Beds. Hughes (1978) later reclassified them as the Darwin Member, now considered to be the basal member of the Bathurst Island Formation of Early Cretaceous age.

The sediments were deposited on an undulating surface over steeply dipping metamorphic rocks assigned to the Early Proterozoic (Plate 3). The unconformity is well-exposed in cliff sections on the south-west part of Shoal Bay Peninsula and on the southern fringes of Cox Peninsula. As measured between Doctors Gully and Lee Point, and assuming no faulting or relief on the unconformity, the regional dip of the rocks is 0.1 degrees to the north. This trend is consistent with the regional basement surface dips which result in a thickening of Cretaceous sediments to the north and west of DARWIN. The thickness of

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*Figure 8 Measured sections in the Darwin Member of the Bathurst Island Formation in DARWIN.*
Plate 3  Unconformity between the Darwin Member and the Burrell Creek Formation near Frances Bay connector road.
Note thrust faulting.

Plate 4  Unconformity between the Darwin Member and the Burrell Creek Formation at Bullocky Point.
A = Radiolarian claystone (Darwin Member).
B = Ferruginous (glauconitic) sandstone (Darwin Member).
C = Basal conglomerate (Darwin Member).
D = Burrell Creek Formation Siltstone.

cover varies from less than two metres in the south to 40 metres at Lee Point, where the depth of weathering is 25 metres. All units within the Darwin Member are exposed in cliff sections. Elsewhere, soil and ferricrete form a covering veneer apart from some areas where more silicified units are exposed.

A basal unit of polymict conglomerate ranging in thickness from less than 0.5 m to 4 m is almost invariably present. The composition of this unit reflects the underlying strata. It consists of granule- to cobble-size, angular to rounded quartz and angular lithic fragments which are locally derived, in a matrix of sand, silt and clay. On Shoal Bay Peninsula and eastern Cox Peninsula, the conglomerate is generally not more than 1.5 m thick, but on northern Cox Peninsula unsorted gravels up to 4 m thick were deposited. In places there is very little difference between these and the highly weathered, underlying Early Proterozoic metamorphic source rocks.

Isolated outcrops of dark red-brown, poorly sorted, well-rounded, ferruginous quartz sandstone and conglomeratic quartz sandstone occur. The sandstone has a distinctive matrix consisting of limonite and scattered quartz grains. Van den Broek (1974) identified the unit as the Upper Jurassic Petrel Formation, but its relationship with underlying rocks has not been satisfactorily defined. Tentatively it is considered to be a lower unit of the Darwin Member.

Glaucicotic sandstone, with a maximum thickness of 2 m, overlies the basal conglomerate (Plate 4). It is composed of 40 to 90 percent glauconite grains, 10 to 40 percent rounded quartz grains, generally less than 5 percent detrital muscovite, and minor feldspar fragments in a silt and clay matrix. This unit weathers to a very ferruginous, fine to medium-grained, porous siliceous sandstone. Silica and iron oxide after glauconite form cellular walls which weld the quartz grains
together. This unit is absent on the western side of Cox Peninsula.

Claystone and minor silty claystone are the dominant units of the Darwin Member and form the major portions of cliff exposures on the Shoal Bay Peninsula and eastern Cox Peninsula. In BMR DDH1 at Lee Point, unweathered grey claystone of this unit, containing white calcareous speckles, was intersected (Kemezys, 1968). A maximum thickness of 33 m for the unit has been recorded at this location. Deep lateritic weathering has changed the primary montmorillonitic clays to kaolin with the dissolution and redeposition of iron oxide and silica. Exposures of the unit are invariably colourful and mottled, due to selective leaching and redepositing of iron oxides. Silicification in places produces a moderately hard variety which is referred to locally as porcellanite. The claystone is radiolarian-rich and beds less than 20 cm thick with abundant belemnite casts are common.

The generally massive beds in the Dripstone Caves area contain irregular to subangular phosphorite nodules. Some of the nodules have an oolitic or pelletal texture, and are similar both in colour and composition to the enveloping rock. The nodules are confined to several beds less than 30 cm thick which are interbedded with bioturbated beds up to 40 cm thick containing a disorderly array of worm burrows (Plate 5). The worm burrows are infilled with clay and are visibly different from the enclosing rock due to a slight colour variation. The nodule beds and bioturbated beds are confined to a 2 m-thick zone which lies within 20 m of the unconformity. At Lee Point, a 0.6 m intersection of unweathered nodule and bioturbated beds containing accessory glauconite was made 13.0 m above the unconformity in BMR DDH1 (Kemezys, 1968).

Phosphorite nodules varying in diameter from less than 1 cm to 12 cm occur in detrital laterite at Lee Point and in situ laterite at Rapid Creek. Below the high water mark at Rapid Creek, the nodules are generally completely intact while elsewhere above the high water mark they are reduced to soft clay-like material or completely leached. The disintegration is probably caused by the leaching effects of acid groundwater.

Bioturbated beds are best developed in the claystone on eastern Cox Peninsula in a stratigraphic position 5 to 6 m above the unconformity. Here the beds are several metres thick and contain abundant subvertical burrows up to 60 cm in length and 1.5 cm in diameter. Minor nodules also occur, but the phosphate content has not been confirmed.

In the cliff sections at Charles Point, a gradational westerly change in composition occurs from claystone to predominantly sandstone. Claystone becomes more gritty until sandy claystone and clayey sandstone containing sandstone lenses and beds are the main rock types. Trough cross-bedding is present in the lenses. On the northern side of Cox Peninsula sandstone and sandy claystone which vary markedly in grain size and maturity crop out in wave-cut platforms and cliff sections. Pure claystone as described in the Darwin area is generally absent.

The sandy claystone contains up to 50 percent quartz grains in a kaolin matrix. The quartz grains are subrounded to rounded, very fine to very coarse-grained and poorly to moderately sorted. The grain size
of the sandstone varies from fine to coarse. Grains are subrounded to rounded and generally moderately to poorly sorted, in a kaolinitic matrix which constitutes up to 50 percent of the rock. Where thin interbeds of silt and clay occur, the sandstone is laminated. Rocks with less matrix are generally moderately sorted and in places cross-bedded. Coarser units of both rock types contain minor amounts of claystone fragments. Lateritisation has caused brown, red and buff motting of the sandstone and claystone and the formation of a well developed surficial capping of ferricrete.

Toward the east, as noted in drill holes NTGS DRP DDH 3 and DDH 4, sandstone and silty claystone overlie the claystone unit. In the Lee Point and Leanyer areas on Shoal Bay Peninsula, localised conglomeratic sandy claystone and clayey sandstone crop out above the claystone unit. Figure 8 outlines the lithologies at various locations across DARWIN.

Ammonites and a variety of other marine fossils collected from the Darwin Member at Charles Point were assigned a Lower Cretaceous age by Etheridge (1895), and deemed equivalent in age to the European Upper Albian stage by Whitehouse (1928) as reported by Skwaroko (1962).

Berger (in Hughes, 1978) examined preserved microplankton, spores and pollen from BMR DDH 1 and BMR DDH 2 on DARWIN and suggested an Aptian age for the sediments. In offshore exploration wells, including Petrel No 1, Flat Top No 1, and Newby No 1, foraminifera from the interval occupied by the Darwin Member have been dated as Aptian.

CAINozoic

TERTIARY-QUATERNARY

Cainozoic sediments form a veneer over most of the area masking outcrop of older units. They have been divided into the following units: Tertiary to Quaternary soil and laterite, and Quaternary continental and marine sediments. The schematic relationship of the units is shown in Figure 9.

Soil (Czs)

No attempt has been made to subdivide the soil types. The Conservation Commission of the Northern Territory has mapped these in detail. Broadly there are two categories of soils, namely those which are directly and indirectly related to laterite and lithosol, plansol and sandy to gravelly earth overlying Early Proterozoic lutite and arenite. The laterite-related soils occur most commonly over Cretaceous sediments, and consist of red, brown and yellow lateritic podsol soil and lateritic red earth.

Laterite (Czl)

Exposure during Upper Cretaceous to Middle Tertiary time subjected the land surface to intense chemical weathering leading to lateritisation. The standard trizonal laterite profile (Whitehouse, 1940) is commonly observed in the area, and best developed over Cretaceous sediments. It consists of an upper ferruginous (pisolithic) zone grading into a mottled zone and a pallid zone (Plate 6). Exposure, weathering and erosion of this profile in DARWIN has given rise to two products: ‘weathering laterite’ and porcelainite.

‘Weathering laterite’ occurs where the mottled zone has been exposed and then hardened by re-introduction of iron oxide and silica. Porcelainite forms where the pallid zone has been exposed, and intense silification has taken place.

Laterite types recognised are consistent with four of the types described by Williams (1969): Detrital laterite has formed mainly from any reworked material cemented in a ferruginous matrix. It generally forms as benches in low-lying areas fringing drainage depressions and marine flats, in the dissected plains

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**Figure 9** Schematic diagram showing the relationship of Cainozoic units in DARWIN.
 Structures and fabric of the parent rock from which it was derived are obliterated. It occurs as the ferricrete capping at the top of the trizonal profile. It is exposed as pavements, some of which are more resistant and upstanding, on cliff edges, and at breaks in slope. In DARWIN it is up to 4 m in thickness, and has formed over clayey sandstone and sandy claystone where the porous and clayey nature of the rocks allows ready movement of iron oxides and provides a good deposition medium.

*Mottled-zone laterite* represents the middle portion of the standard laterite profile, consisting of red-brown and white, ferruginised, leached and highly weathered claystone, siltstone and clayey sandstone; in places a honeycomb structure occurs. The zone grades upwards into ferruginous pisolithic laterite and merges downward into the pallid zone of essentially white non-ferruginous kaolinitic rock.

*Concretionary laterite* is a laterite of directly pedogenic origin which is actively forming as ferruginous mottling in poorly drained colluvium and as in-situ ironstone nodules in soils. This type of laterite is most commonly forming in low-lying sandy fringe areas of drainage depressions.

The coastal cliffs on Shoal Bay Peninsula and eastern Cox Peninsula generally display the pallid zone which has been subjected to silicification and staining by secondary iron oxides. The cliffs are capped in places by a thin mottled zone, of variable thickness and a thin layer of partly-detrital ferricrete.

**Quaternary**

*Mare in deposits*

*Coastal alluvium (Qca)* Intertidal, marine alluvium consists of poorly-sorted quartz sand, shell, limonite and lithic fragments plus limonite deposited in the swash zone; mud, clay and silt occur on the tidal flats. In the Buffalo-Meckitts Creek area, the flats extend up to 5 km inland. Mangrove swamps are common and consist of black, shelly, marine mud. Sand and clay pans occur in areas less frequently inundated by tidal flows.

*Beach rock (Qcb)* Beach rock consists of tabular broken slabs of conglomerate consisting of quartz sand, together with shell fragments, limonite, lithic fragments and coral, bonded by a carbonate cement (Plate 7). It
occurs at the top of beaches and in places beneath sand ridges. In the banks of Rapid Creek, a 2.5 m section is exposed. This consists of coarse-grained sandstone at the base, grading upward to conglomeratic beach rock (Plate 8). This is overlain by an 'irregular honeycomb-textured' rock consisting of medium-size quartz grains and minor shell and limonite fragments bonded by a calcareous cement. The irregular voids probably formed by leaching out of the original shells. 

Cheniers (Qcr) Coastal sand ridges are common in areas facing the open sea. The ridges are generally parallel and within 2 km of the present coast. Hickey (1981) described these strandlines of sandy shell ridges perched on intertidal mudflats as cheniers. The ridges at Cameron Beach constitute the best-developed chenier plain in the area. Radiocarbon ages ranged from 2350±120 b.p., for the back ridges to 670±110 b.p., for front ridges. This indicates a rapid progradation of the chenier plain seaward since about 2350 years b.p.

Non-marine deposits

Black-soil plains (Qaf) The upper reaches of the saline mudflats grade into estuarine and paludal black soil plains. These are inundated during wet seasons when some intermixing of salt and fresh water occurs to produce a brackish water environment. Stands of paperbark are supported in perennially wet areas which consist of a surface layer of organic-rich clayey silt overlying heavy clay. The seasonally exposed flats consist of brown to dark grey, organic-rich, heavy clay which develops polygonal-shaped shrinkage cracks during dry seasons.

Colluvium (Qcl) The undulating nature of the topography has resulted in the formation of broad drainage areas which often contain no defined drainage channel. Occasionally lagoons form as focal points for internal drainage. Sediment, consisting of sand, silt and clay, has been deposited in these areas by unconcentrated sheetwash, and as such has been mapped as colluvium. The lagoons are rich in humic material and are sources of topsoil.

Colluvium has also developed on slopes of less than 2 degrees, generally marginal to estuarine and littoral areas, as a fringe of water-wonnowed sand and silt concentrated toward the base of the slope by sheetwash. 

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

Talus and scree (Qs) Unconsolidated clay, quartz, sand and rock fragments have been deposited on several slopes below cliffs on the western fringe of Woods Inlet. This material is derived from lateritised Lower Cretaceous claystone and sandstone.

METAMORPHISM

All the Early Proterozoic sedimentary rocks in DARWIN have been regionally metamorphosed to lower greenschist facies. Lutitic rocks have a well-developed slaty cleavage and commonly contain fine-grained sericite. A subtle increase in metamorphic grade to the west is reflected in the increased grain-size of sericite, which, at Fort Hill, imparts a fine schistosity to the rocks.

Anarenic and rudaceous rocks are commonly veined by quartz and in places have recrystallised to quartzites. A visible but minor effect of metamorphism on granular sandstones and conglomerates in the Burrell Creek Formation is flattening of quartz granules and pebbles in some beds into an elliptical shape with the long axes of the particles parallel to the strike of the foliation.

The metamorphic grade within Unit Ba increases to the west from greenschist to amphibolite facies. This increase is indicated by the presence of lenticular aggregates of fibrous sillimanite and minor garnet in the schist.

In NTGS DRP DDH 2 on the eastern side of Cox Peninsula, considerable alteration of feldspar, and the development of muscovite, probably at the expense of biotite suggest that an episode of retrograde metamorphism has been superimposed on an earlier prograde event. Metasomatic recrystallisation, evidenced by later introduction of quartz in conditions of moderate stress, probably took place at the same time. This event is probably related to an episode of strong shearing, fracturing of quartz and feldspar, and the introduction of a second generation of feldspar as observed in NTGS DRP DDH 3. A final phase of this episode was the introduction of significant amounts of microcline and quartz.

STRUCTURE

The Early Proterozoic metasediments have undergone one major deformation during the 1800-m.y. event. This has produced tight folds with limbs dipping steeply.
at more than 50 degrees. The strike of bedding throughout the area is north to north-west.

Well-developed vertical to near-vertical slaty cleavage invariably trends within the range north to west-north-west and diverges from the bedding in most outcrops. In many outcrops, cleavage dominates and obscures bedding planes. As the metamorphic grade increases westwards, the cleavage changes to a penetrative foliation in the Cox Peninsula area.

Major faults in the area are mainly interpreted from geophysical and stratigraphic information, but the sense of relative movement cannot be deduced. A zone of strong quartz veining and silification observed in poorly outcropping Early Proterozoic schists on the western side of Cox Peninsula is considered to be evidence of faulting. This zone is inferred as a northerly extension of Tom Turners Fault. The position of the inferred fault also coincides with abrupt changes in both the regional magnetic pattern and metamorphic rock types.

The contact between the Burrell Creek Formation and the South Alligator Group in DARWIN is also inferred to be faulted. Principal evidence is the abrupt changes in lithologies observed in outcrop and drill holes across the northerly extension of a meridionally trending fault zone in BYNOE.

The Cretaceous sediments have generally undergone minor warping. Dips rarely exceed 5 degrees, except in areas where doline development in underlying carbonate has caused localised depressions. Minor thrust-faults with throws of less than 2 metres occur generally in the lower beds (Plates 3 and 9). Where the unconformity is exposed the faults are seen to parallel jointing in the underlying formations and probably represent minor disruptions during diagenesis. Joint sets are well developed on wave-cut platforms, but no quartz infilling has been observed.

GEOPHYSICS: by B. Simons

GRAVITY
The Bouger anomaly contour map of DARWIN, as shown in Figure 10, is taken from 'Bouger Anomaly

Contours of the Pine Creek Geosyncline, Northern Territory, 1979, 1:500 000', compiled by the Bureau of

Mineral Resources.

The generally positive value of the contours over the Pine Creek Geosyncline has been interpreted by
tucker and others (1980) as representing higher-density metasediments over a basement of average density.

However, a gravity low is situated over Cox Peninsula in BYNOE. Further south, this low extends in a trough
towards the well-developed low associated with the Two Sisters Granite, Middle Proterozoic granitoids
typically have a density of 2.67 t/m³ within the Pine Creek Geosyncline and modelling of the low across

Cox Peninsula by kovi (1980) supports the idea of a lower-density subcropping granitoid, possibly linked to

the Two Sisters Granite at depth. This would be in agreement with the interpretation of the results of the

magnetic and radiometric surveys. The Bouger anomaly contour pattern suggests that the northern extent of the subcropping granitoid occurs at Woods

Inlet on Cox Peninsula. However, the second derivative map of the Bouger anomaly contours (Tucker and

others, 1980) indicates that the granitoid may extend further north at depth.

The strong gravity gradient on the western edge of DARWIN, with Bouger anomaly values increasing to
the west, is probably associated with Tom Turners Fault. This would be in keeping with the interpretation
that denser Unit Eb material was faulted against the less dense Unit Ea. Alternatively, the high-density
metasedimentary pile increases in thickness to the west of Tom Turners Fault.

The Litchfield Gravity High lies to the west of DARWIN and extends from Bathurst Island in the
north to GREENWOOD in the south. This high contributes to the large gravity gradient on the west of

DARWIN, and is also presumed to occur in the north. When considered with the lesser increase to the east,
this Bouger anomaly contour pattern suggests that to the north the Shoal Bay Peninsula metasediments curve
westward and eventually extend down onto Cox Peninsula. Assuming that Unit Ea is an equivalent of
the Burrell Creek Formation, then Unit Eb is possibly a
lateral equivalent of the South Alligator Group. This explanation in no way takes into account the effects of Tom Turners Fault and assumes that Unit Eb is older than Unit Ea.

The station spacing used to produce the map shown in Figure 10 (5 km average) is insufficient to provide information for detailed interpretation. As such, the gravitational response of the magnetic lineaments cannot be determined. However, broadly speaking, the Bouguer anomaly contours do tend to parallel the dykes, with the possibility that the dykes have a strong gravitational response. However, the dykes tend to follow the major regional structural trends. Therefore, the Bouguer anomaly contours may simply be indicative of these north-north-easterly and north-northwesterly trends.

MAGNETICS
A contour map of the Total Magnetic Intensity (TMI) of DARWIN is shown in Figure 11. This map has been produced from data obtained in 1981 from north-south flight lines flown 500 m apart, and 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.

The magnetic features of DARWIN are typical of the Pine Creek Geosyncline, with broad areas of weak magnetic response separating linear and curvilinear zones of strong response and dipole anomalies.

The western edge of Cox Peninsula is marked by a change in magnetic response coinciding with the inferred position of Tom Turners Fault, which corresponds to the contact between metamorphic Units Ea and Eb. The strong magnetic response coincides with the outcropping Unit Eb. This response extends south into BYNOE and FOG BAY. Work on similar magnetic responses in the Welltree area in REYNOLDS RIVER (BHP, 1976), suggests that they correspond with graphitic schists. Petrographic studies carried out on these schists indicates that the magnetic mineral within these rocks is principally magnetite (Tucker and others, 1980).

The magnetic contours west of Tom Turners Fault are characterised by isolated areas of strong magnetic response. This pattern could result from isolated magnetic units within the metamorphic sequence. Alternatively, the magnetic response could result from non-magnetic granitoid material intruding the metasediments, forming non-magnetic ‘pods’ within the magnetic metasediments.

For the most part, Cox Peninsula reflects a magnetic pattern typical of a sedimentary basin, with broad, evenly spaced responses and few closures. This suggests uniformly non-magnetic sediments overlaying a basement of uniform magnetic susceptibility. South of Cox Peninsula in BYNOE, the magnetic response shows an increase in the number of closures. This suggests that the area is largely underlain by a
near-surface granitoid. This suggestion is in agreement with modelling of the gravity over the area by Kevi (1980), and with the occurrence of pegmatites on Cox Peninsula.

A notable feature of the magnetic pattern for the remainder of DARWIN is the presence of strongly developed linear features. These appear as two sub-parallel sets with one set trending at 290° and the other at 330°. The sub-parallel features trending 290° are approximately 12 km apart and are of negative sign. Those trending 330° are approximately 15 km apart and are of positive magnetic sign.

Drilling of the linear features in DARWIN (RN 5858 and Quarantine Island), KOOLPINYAH, NOONAMAH and MARY RIVER has shown that they represent thin dolerite dykes.

Modelling indicates that the dykes are near-vertical with a width of approximately 20 m. The depth to the top of the magnetic response is 10-30 m and probably represents the depth of weathering. The positive response of the dykes is a result of induced magnetism, whereas the negative dykes are the result of a remnant field in an opposite direction to the Earth’s present magnetic field.

A detailed ground magnetic survey over a dyke near Beatrice Hill in NOONAMAH (Newton, 1980) indicates that the linear magnetic features are not the long, continuous closures suggested by the airborne magnetics, but rather a series of shorter negative anomalies aligned along a strip of country approximately 60 m wide. This could be due to a series of small scale, cross-cutting faults off-setting the dyke.

Dating of dykes with negative magnetism around Mount Bundey and Marrakai Creek (Newton, 1980) using K/Ar methods, has provided ages ranging from 112 m.y. to 450 m.y. and a value of 450±40 m.y. using Rb/Sr. The degree of weathering of the dykes makes the K/Ar dates suspect and the 450 m.y. value is likely to represent a minimum age for the emplacement of the dykes. Field evidence on the age of the dykes suggests that at least some may have been emplaced after deposition of the Kombolgie Formation and before deposition of the Tolmer Group (Tucker and others, 1980). However, the Marrakai Creek and Mount Bundey radiometric dates are considerably younger and are similar to the age of the Daly River Group. A date of 1370 m.y. on a sample of dolerite from an east-west, negative anomaly near Jabiru, also postdates the Tolmer Group (Tucker and others, 1980).

The ‘positive’ and ‘negative’ dykes in DARWIN intersect at 131°00’ E, 12°23’ S, and clearly show that the ‘negative’ set (trending 290°) is younger than the ‘positive’ set. The lack of displacement of the ‘positive’ dyke also indicates that there was no associated lateral movement.

Linear magnetic features are truncated at 130°47’ E, 12°24’ S and 130°47’ E, 12°27’ S in DARWIN and 130°47’ E, 12°34’ S in BYNOE by a subtle lineament trending north-south. This feature is interpreted as a north-south fault. As the postulated fault underlies
Darwin Harbour, no supporting field evidence has been found.
Shoal Bay Peninsula has a magnetic response which differs from that found west of a north-south line at 130° 50' E. The magnetic response over the Peninsula exhibits a greater number of closures, some of which are isolated 'bull's-eye' and dipole anomalies. No direct correlation between the magnetic pattern and surface geology can be made. However, it is suggested that the increased magnetic response may be due to magnetite-bearing carbonates within the South Alligator Group.

The different magnetic patterns of Shoal Bay Peninsula and Cox Peninsula suggest that the Burrell Creek Formation and the undifferentiated schists of Unit Ea differ petrophysically. However, there is geological evidence to suggest that Unit Ea is, at least in part, a metamorphic equivalent of the Burrell Creek Formation.

RADIOMETRICS
An airborne radiometric survey was carried out for the NTGS in conjunction with the magnetic survey, using a 50-L 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 multi-plots, and as digital records on magnetic tape.

The total-count contours for DARWIN are shown in Figure 12. A consistently low total count is provided over DARWIN. The radiometric response tends to reflect the nature and thickness of the soil, and is normally related to geomorphological features, such as saline coastal flats, swamps and creeks.

The Cretaceous rocks of the Pine Creek Geosyncline generally coincide with low-count zones, according to Tucker and others (1980). This also appears to be the case in DARWIN, where the areas of higher total count are confined to metasediments assigned to the Early Proterozoic, cropping out around the edges of Frances Bay.

No correlation appears to exist between the total-count response and the magnetic features. The long, linear magnetic features cannot be detected in the total-count contours. This is in keeping with the observation that these dykes are deeply weathered, providing a masking effect on the radiometric response.

It has been noted by Tucker and others (1980) that some of the Middle Proterozoic granitoids within the Pine Creek Geosyncline show a strong radiometric response (e.g., Mount Goyder Syenite on MARY RIVER). The high count north of Bynoe Harbour on Cox Peninsula, therefore, probably results from a granite of Carpentarian age. If so, then the radiometric data support the magnetic and gravity interpretation that Cox Peninsula is to a large extent underlain by a granitoid. The high radiometric count of the granitoids within the Pine Creek Geosyncline may be related to high potassium content and not necessarily to thorium or uranium contents.
GEOLOGICAL HISTORY

According to Stuart-Smith and others (1980b), the Pine Creek Geosyncline developed during Early Proterozoic time by incipient rifting and subsidence of the Archaean basement. Shallow-marine and continental sediments were deposited at the margins, while in the centre a thicker sequence of fine clastic and chemical sediments and volcanics accumulated. Uplift of the basement resulted in partial erosion of these sediments. An influx of clastic material into the basin followed this event resulting in the development of the basal Crater Formation and Mundogic Sandstone units of the Mount Partridge Group. In Rum Jungle Special Sheet area to the south-east, Coomalie Dolomite was deposited in a shallow-marine to supratidal environment (Crick, 1976). Fine-grained chemically deposited dolomitic sediments, also classified as Coomalie Dolomite, occur in KOOLPINYAH. The sltstones and shale of Whites Formation represent a transitional and variable group of sediments between the Coomalie Dolomite and the Wildman Siltstone. This formation lenses out to the north-east in KOOLPINYAH.

The Acacia Gap Quartzite Member is considered to be deposited in a shallow-water environment within the western and south-western areas of the Mount Partridge Group.

The Wildman Siltstone, which is the oldest Early Proterozoic rock unit cropping out in DARWIN, is interpreted by Stuart-Smith and others (1980b) as a shallow-marine deposit, possibly a subtidal facies transitional with the continental deposits of the underlying Mundogic Sandstone. Lithologies in DARWIN support this model. Lack of both outcrop and sedimentary structures precludes any definite statement about the depositional environment.

Uplift, folding and subsequent erosion took place prior to the deposition of the South Alligator Group. This Group is dominated by chemical and organic sediments which accompanied a shallow marine transgression across much of the basin. Continual subsidence allowed the deposition of a thick sequence of lutitic and arenaceous sediments of the Finniss River Group, generally conformable with the South Alligator Group.

In DARWIN the Finniss River Group is represented by lutite, arenite, and rudite of the Burrell Creek Formation. The sedimentary features are characteristic of turbidity-current deposition. Based on an integrated facies model for turbidites and associated coarse clastic rocks by Walker (1981), the sediments of the Burrell Creek Formation in DARWIN are believed to have formed by deposition in a submarine-fan environment where turbidity-current deposition was dominant. The rudaceous units represent inner-fan channels and channelled portions of suprafan lobes, where, by definition, debris flow and normal to inverse graded conglomerates are common. The finer units represent the more distal classical turbidites.

At the close of sedimentation of the Finniss River Group, sills of tholeitic basalt (Zamu Dolerite) were introduced. This event was followed by deformation, metamorphism and partial anatexis of the Early Proterozoic sediments. Igneous activity, which involved the intrusion of granitic plutons in the Geosyncline, marked the completion of the orogenic event.

The schists underlying Cox Peninsula were probably formed during the main Pine Creek Orogeny. However, elucidation of the history of these rocks is difficult. Petrographic evidence suggests that the original schists were exposed to a second episode of metamorphism which caused the strong shearing, fracturing of quartz and feldspar, alteration of mica to clay and the introduction of a second generation of feldspar. The third and final episode of alteration is marked by the metasomatic introduction of large quantities of microcline and quartz.

Extensive pegmatite veining noted in drill cores and in outcrop at the Tuble Head-Mica Beach area supports the concept that a granitic source was responsible for the late phases of metamorphism and metasomatism. A gravity low beneath Cox Peninsula may also be interpreted as confirmation of an intrusive body at depth.

Intrusion of dolerite dykes coincident with regional magnetic lineaments took place subsequent to deformation.

Following the Pine Creek Orogeny, a long period of terrestrial erosion and weathering took place. In DARWIN, Mesozoic marine sedimentation began in the Early Cretaceous period with the encroachment of a shallow sea in Aptian time. The inundation was from the north-west, flooding the Shoal Bay Peninsula area and extending to central Cox Peninsula. During this transgression shallow water glauconite sands developed over a reworked regolith. Radiolarian clay and silt was deposited in a moderately shallow sea with fluctuating levels, as indicated by horizons of worm burrows, glauconitic mud and phosphorite concretions. On the western side of Cox Peninsula, sandstone and sandy claystone represent paralic conditions. Toward the end of Aptian time the sea progressed to the north-west and, in doing so, deposited poorly-sorted sandstone and sandy claystone, which occur as scattered remnant outcrops overlying sandstone on Shoal Bay Peninsula. Since Albian time, the land surface in DARWIN has remained exposed.

ECONOMIC GEOLOGY

Construction materials

Quartz sand

The main sand occurrences are found in and adjacent to broad drainage areas as superficial deposits of a colluvial nature. The deposits are thin extensive sheets, generally 0.5 m to 1.5 m thick, with little or no humic topsoil. At the base, the sand usually passes abruptly into ferricrete and sandy clay and clayey sand, and in places limonitic gravelly sand.

The deposits contain moderately-sorted, subrounded to rounded quartz grains with an average grain-size of 0.2 mm to 0.3 mm. Some grains have a frosted surface and partial iron-oxide staining gives an overall pink or light brown colour. Due to the nature of their deposition, the deposits have a clay content of less than 10 percent.

Much of the sand in DARWIN comes from the sandy units within the Bathurst Island Formation. Deep weathering and lateritisation during the Cainozoic Era has produced lateritic podzolic soils and red earths. Subsequent action by surface water has winnowed clay and some iron oxide from the soil, concentrating the sand into colluvial deposits. Very little transport of sediment has been involved in the formation of these deposits.
A second source of sand is from the Early Proterozoic carbonates. Silification of the pre-Cretaceous surface has replaced the carbonate by saccharoidal quartzite. Deposits of sand resulted from weathering of the carbonate beds and concentration in low-lying areas before and during Cretaceous sedimentation. Deposits of this type are common near Marlowes Lagoon.

**Lateritic gravel**

Lateritic gravel consists of red and yellow earths and related soils containing a gravel fraction of pisolithic ferro-manganiferous nodules. In DARWIN the gravel is readily obtainable from the flat-lying Cretaceous Plateau areas, where deep lateritic weathering has produced a trizonal profile. Gravel suitable for pavement construction is essentially derived from the lower ferruginous zone and the mottled zone of the laterite profile. This mixture gives a product with sufficient gravel content and plasticity to allow good compactive properties.

**Aggregate**

The Acacia Gap Quartzite is the only suitable rock in the area for use as aggregate. This is currently being mined and crushed in quarries located near Milners Creek. Annual production from July 1981 to June 1982 was 344 888 tonnes. Future supplies of aggregate are assured, as extensive outcrops of quartzite occur in areas adjacent to DARWIN.

**Building stone**

Some early buildings in Darwin were successfully constructed using Cretaceous claystone as a building medium. Massive silicified claystone was quarried from the Larракейя area for this purpose. This rock type commonly occurs in the Darwin area, and according to McQueen (1957), tests of its physical properties suggest that it is suitable for use as a building stone.

**Groundwater**

Groundwater is a major source of water in areas not connected to the City supply. The Cretaceous sediments are sufficiently permeable to allow downward movement of surface water. Early Proterozoic siltstone and shale are relatively impermeable and transmit only small amounts of groundwater. Sandstone and quartzite are slightly more permeable and dolomite usually acts as a good aquifer. The best aquifers occur within and at the base of the Cretaceous sediments. Honeycomb structures formed in the mottled zone of lateritised Cretaceous sediments are highly permeable, and the basal conglomerate generally acts as an excellent aquifer. But, in some areas, particularly those underlain by shale and siltstone of the Burrell Creek Formation, the basal conglomerate contains a large amount of fines and yields small amounts of water. Where the underlying rocks are carbonates, the conglomerate is well-developed, coarse and very permeable.

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