**1:100 000 GEOLOGICAL MAP SERIES**

**EXPLANATORY NOTES**

**MOYLE 4969**

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CONTENTS

Abstract

Introduction
Location, access and climate
Geomorphology
Previous investigations

Stratigraphy
Regional geologic setting
Early Proterozoic
  Hermit Creek Metamorphics
  Finnis River Group
  Burrell Creek Formation
  Berinka Volcanics
  Henschke Breccia
  Chilling Sandstone
  Intrusive igneous rocks
  Wangi Basics
  Granitoids
  Murra-Kamangee Granodiorite
  Peppimenarti Granite
Middle Proterozoic
  Fitzmaurice Group
  Moyle River Formation
  Goobacri Formation
  Laliang Formation
  Auvergne Group
  Ti-Tree Granophyre
  Murrenja Dolerite
Palaeozoic
  Permian
  Mesozoic
  Cretaceous
  Cainozoic
  Quaternary

Metamorphism

Structure

Geophysics
Magnetics
Radiometrics
Gravity

Geologic history

Economic geology

Acknowledgements

References

Appendix — New stratigraphic unit

FIGURES
1 Locality map iv
2 Geomorphic units of MOYLE 2
3 Regional tectonic setting of MOYLE 4
4 Regional geologic setting of MOYLE 5
5 Solid geology of MOYLE 6
6 Relationship between units of the Finnis River Group 11
7 Magnetic contours of MOYLE 21
8 Total count radioelement contours of MOYLE 22
9 Bouguer anomaly contours of MOYLE 23

PLATES
1 Relict flow banding in rhyolite, Berinka Volcanics 12
2 Polygonal shrinkage cracks, Berinka Volcanics 13
3 Xenolith of Wangi Basics in Murra-Kamangee Granodiorite 14
4 Basal conglomerate in Moyle River Formation at the unconformity with the Murra-Kamangee Granodiorite 15
5 Stromatolitic dolomite, Moyle River Formation 16

TABLES
1 Stratigraphy of MOYLE 7-9

MAP
1:100 000 Geological Map of Moyle (4969) in pocket
Figure 1  Locality map.
ABSTRACT

The Moyle 1:100 000 sheet area was mapped by the Northern Territory Geological Survey (NTGS) during 1983 using 1:25 000 colour aerial photographs. A supplementary airborne magnetic and radiometric survey was carried out in 1984.

The most prominent topographic feature in MOYLE* is the Wingate Plateau, which occupies almost half of the sheet area and extends beyond the sheet boundaries to the east and south. The plateau is a remnant of a once very extensive Tertiary land surface and its actively dissecting margins produce scenic rugged escarpments and spring-fed waterfalls, the most notable of which is Henschke Falls.

The NE part of MOYLE is formed of Early Proterozoic low grade Hermit Creek Metamorphics which are equivalent to the high grade metamorphics to the NE in DALY RIVER. The Finniss River Group, also of Early Proterozoic age, is inferred to unconformably overlie the Hermit Creek Metamorphics although the exact nature of their relationship is complicated by faulting. In MOYLE, the Finniss River Group is dominated by the extremely thick, monotonous quartzarenites of the Chilling Sandstone and the Berinka Volcanics at the base of the Burrell Creek Formation. To the west, the Henschke Breccia is interpreted as a fault talus stratigraphically equivalent to and forming the westernmost outcrops of the Finniss River Group.

The Hermit Creek Metamorphics and the Finniss River Group were intruded successively by Early Proterozoic basic rocks (Wangi Basics) and by younger Early Proterozoic late-orogenic granitoids (the Murrah-Kamangee Granodiorite and Peppimenarti Granite), although no contacts exist. Shallow-marine or fluvial sediments of the unmetamorphosed Middle Proterozoic Fitzmaurice Group accumulated in a steadily subsiding fault-bounded trough. Later faulting produced open and, in places, truncated folds. Younger Middle Proterozoic intrusives of both basic (Murrenja Dolerite) and acid (Ti-Tree Granophyre) composition intrude the Middle Proterozoic sedimentary sequence; the Ti-Tree Granophyre also forms sills in the Finniss River Group to the east.

Permian arenites unconformably overlie Middle Proterozoic rocks and represent the eastern margin of the Bonaparte Basin. A thin Cretaceous sequence is preserved on the Wingate Plateau and is exposed in shallow drainage and in escarpments on outlying remnants of the penepalned land surface.

INTRODUCTION

Location, access and climate

MOYLE is centred about 210 km SSW of Darwin and covers the area bounded by latitudes 14° 00' and 14° 30'S and longitudes 130° 00' and 130° 30'E (Figure 1).

Most of the sheet area lies within the Daly River Aboriginal Reserve. The remainder forms the westernmost part of the Elizabeth Downs (PL820) and Fish River (CL(P)98) grazing leases. Cattle grazing is the principal land use of the area.

The road from the Daly River crossing to Port Keats provides the main access to the northern and western portions of the sheet area. This road is unsealed but has an all-weather formed surface, as does the road to Peppimenarti which diverges from the Port Keats road east of Richards Hill. Several tracks, which are largely maintained for use during cattle mustering, also provide access in the western area. During the wet season, there is restricted vehicle access into MOYLE from the north as the causeway at the Daly River crossing in DALY RIVER is often deeply submerged. The low-lying areas are inundated during the wet season and remain swampland for several months afterwards, thus restricting vehicle access until well into the dry season. The rugged foothills and steep escarpments which mark the edge of the Wingate Plateau deny vehicle access to the central and SE parts of the sheet area. An airstrip at Peppimenarti provides year-round access.

The climate is monsoonal (Gentilli, 1971) with most of the annual rainfall of about 1400 mm falling between November and March. Temperatures range between an annual average maximum of about 34°C and an annual average minimum of about 20°C.

Geomorphology

The geomorphology of MOYLE had here been divided into four divisions: Laterised mesa surface. Uplands, escarpments and dissected hills, Eluvial lowlands, and Floodplains (Figure 2).

Laterised mesa surface

The Laterised mesa surface has developed on a thin sheet of flat-lying Cretaceous sedimentary rocks. The surface was once very extensive but is now reduced to isolated plateaux and outlying remnant mesas. This penepalned land surface, referred to by Hays (1968) as the ‘Tennant Creek Surface’, formed in the Late Cretaceous or Early Tertiary. Associated with its development was widespread laterisation of both rock and unconsolidated material. In MOYLE, this surface forms the Wingate Plateau which dominates the southern half of the sheet area. The plateau has a maximum elevation of 319 m in the east and slopes gently west and SW towards the actively dissecting margins.

A thicker soil profile, indicated by the growth of a taller and denser open eucalypt forest than occurs in other parts of MOYLE, has developed on the plateau surface. Elsewhere on the plateau drainage is poor, with many low-lying areas remaining permanently swampland. Sometimes associated with these areas are plant communities of the monsoon forests (Christian and Stewart, 1953).

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

+ In this report the Proterozoic is subdivided as follows: Early Proterozoic (2500 Ma to 1700 Ma), Middle Proterozoic (1700 Ma to 1000 Ma), and Late Proterozoic (1000 Ma to 570 Ma)
Uplands, escarpments and dissected hills
The uplands are formed on the Wingate Plateau where Proterozoic rocks have been recently exhumed from below the Cretaceous laterised surface and have not yet been markedly dissected. The escarpments and dissected hills generally lie below 160 m above sea level and form the ground between the laterised mesa surface and the lowlands. Most of the escarpments mark the margin of the plateau surface and generally consist of a small scarp topping a steep, talus-strewn slope. Some escarpments occur along ridges formed by faults that trend through the dissected hills. The dissected hills are formed on Early Proterozoic igneous, sedimentary and metamorphic rocks in the eastern part of the sheet area, and on Middle Proterozoic sedimentary rocks in the western part. In all these terrains the soils are patchy and dominantly skeletal, supporting sparse open woodland characterised by eucalypt species and hardy grasses.

Eluvial lowlands
The eluvial lowlands are scattered throughout the northern half and western portions of the sheet area, and generally lie between the 20 m and 60 m contours. They are formed over granitic, metasedimentary, and sedimentary rocks. Sandy soils have developed over the granites and sedimentary rocks; over other rocks, soils are typically composed of silt to fine sand. The lowlands are characterised by low hills and gently undulating plains, which support open to medium density woodlands and perennial grasses.

Floodplains
In MOYLE, floodplains form an extensive geomorphic unit in the NE and NW of the sheet area. The plains developed in the NE at the headwaters of Hermit Creek lie approximately between the 20 and 30 m contours. During the wet season the plains are inundated, during the latter part of the dry season however, they dry out leaving a chain of billabongs which form a haven for bird and other animal life. The extensive floodplain in the NW of the sheet area represents the eastern extremity of the Moyle River floodplain, which continues westwards into KEATS. In contrast to the floodplains to the NE, this plain lies below the 10 m contour, is permanently swampy, and is vegetated by swamp grasses and stands of melaleuca (paperbarks).

Previous investigations
In the late 1940s D.M. Traves, a geologist of the Bureau of Mineral Resources (BMR) at that time attached to the Land Research Unit of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), carried out the first major geologic reconnaissance of the Ord-Victoria River region which included MOYLE. This resulted in the publication of a bulletin and accompanying geological maps, which depicted the geology at a scale of 16 miles to one inch (1:1 013 760) (Traves, 1955). Walpole and others (1968) published a 1:500 000 scale geological map of the Katherine-Darwin region which included MOYLE. Further geologic reconnaissance through 1:250 000-
scale mapping of the Victoria River region was carried out by BMR geologists in the mid to late 1960s. The results of this program are reported in a number of BMR publications (Morgan and others, 1970; Sweet and others, 1974; Sweet, 1977) including the Port Keats 1:250 000 geological map, (which covers MOYLE) and accompanying explanatory notes (Morgan, 1972). MOYLE was covered by a regional reconnaissance helicopter gravity survey of NW Australia flown by the BMR in 1967 (Whitworth, 1970).

Company exploration commenced in MOYLE in the 1960s with base-metals and uranium as prime targets (Walker, 1968; 1969 a and b; Cameron, 1972 a and b). Later exploration focused on the coal-bearing potential of the Permian sequence, which proved to be limited (Williams, 1973). In the late 1970s and early 1980s exploration again concentrated on base metals and uranium and, in addition, platinum group metals and chromite (Dewar, 1978; Mobil Energy Minerals Australia, 1980; Richardson, 1983). In the early 1980s kimberlite and diamond exploration was carried out without success (Garlick, 1981 a and b). For a full bibliography relating to this exploration period see ECONOMIC GEOLOGY.

**STRATIGRAPHY**

The stratigraphy of MOYLE is summarised in Table 1. Details given in this report are based principally upon petrographic descriptions of thin sections by the Australian Mineral Development Laboratory (AMDEL) (in Edgoose and others, 1984a).

**REGIONAL GEOLOGIC SETTING**

MOYLE lies in the SW part of the Pine Creek Geosyncline, and includes the SW extremities of the Litchfield Province (Figure 3). To the south the sheet area includes the NE margin of the Victoria Basin, and to the west a large thickness of sediments of the Fitzmaurice Mobile Zone. Early Permian rocks forming the western margin of the Bonaparte Basin lie in the NW corner of the sheet area.

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

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

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

**EARLY PROTEROZOIC**

**Hermit Creek Metamorphics (Ph)**

The approximately 250 km² of subcropping Hermit Creek Metamorphics in the NE corner of MOYLE forms the most SW exposures of this extensive but poorly outcropping unit. Cover sequences to the south belong to the Middle Proterozoic Fitzmaurice Mobile Zone. The relationship with rocks of the Pine Creek Geosyncline is complicated by faulting (Figure 5).

The major exposures of the Hermit Creek Metamorphics are found in the vicinity of major faults - the Henschke Fault, Tom Turners Fault in the north, and south of Murra-Kamangee Hill. In contrast to the exposures of the metamorphics to the north where pelitic, psammitic and basic intrusive rocks have been polymetamorphosed up to granulate facies (Dundas and others, 1987a), the exposures in MOYLE constitute a subgreenschist to greenschist metamorphic facies sequence of pelitic and psammitic metasediments. The absence of the basic intrusive rocks in this low grade terrane suggests that their intrusion may have been related to high grade metamorphic conditions. This contrast in grade from NE to SW led earlier workers to include a part of the low grade sequence in MOYLE in the Finniss River Group of the Pine Creek Geosyncline (Morgan, 1972). NTGS mapping has demonstrated that the decrease in grade can be traced across the region, and suggests that there is an unconformable relationship between this low grade sequence and rocks of the Pine Creek Geosyncline (see Henschke Breccia).

Early workers assigned the Hermit Creek Metamorphics an Archaean age on the basis of the structural and metamorphic differences with the adjacent Early Proterozoic rocks of the Pine Creek Geosyncline (Walpole and others, 1968; Morgan, 1972). Sweet (1977) recognised the Hermit Creek Metamorphics as having undergone an amphibolite facies metamorphism followed by a greenschist facies retrogression; this latter event he correlated with the 1870-1780 Ma Top End Orogeny in the Pine Creek Geosyncline. NTGS work supports Sweet’s interpretation. More recently, Hammond and others (1984) proposed a two-fold subdivision of the metamorphics into essentially retrogressed and non-retrogressed sequences. NTGS field and petrologic work finds that such a subdivision is untenable as the retrogression and prograde metamorphism across the sequence is essentially non-uniform in nature (Pietsch and Edgoose, 1988).

The age of the Hermit Creek Metamorphics is poorly defined. Rb/Sr whole rock and mica age determinations from WINGATE MOUNTAINS gave results of 1770±27 Ma and 1803±27 Ma (Edgoose and others, 1984b). These dates have been isotopically re-equilibrated as indicated by the U/Pb age of 1852±3 Ma (Page and others, 1984) for the Murra-Kamangee Granodiorite which intrudes the Hermit Creek Metamorphics. Using the Rb/Sr isochron and Sm/Nd model age method, the Fog Bay Metamorphics, in the northern part of the Litchfield Province have been dated at 2002±42 Ma and 2280±40 Ma respectively (Hickey, 1985). The Fog Bay Metamorphics are here
correlated with the Hermit Creek Metamorphics and both suites represent an early cycle of sedimentation and metamorphism in the Litchfield Province prior to the development of the Pine Creek Geosyncline in its western area at least. The Sm/Nd model age for the Fog Bay Metamorphics also shows that material forming the rocks in this earlier cycle was derived from the mantle during the Early Proterozoic and not in the Archaean, as many earlier workers believed (Walpole and others, 1968; Sweet and others, 1974).

Correlations between the Hermit Creek Metamorphics and the Tickalara Metamorphics of the Halls Creek Mobile Zone have been made by several workers (Sweet, 1977; Dundas and others, 1987a). These correlations were based on similarities in lithology, metamorphic and tectonic history, age, and the structural continuity between the two areas. More recent geochronology in the Halls Creek Mobile Zone shows that the metamorphic event affecting the Tickalara Metamorphics and the Top End Orogeny were
Figure 4  Regional geologic setting of MOYLE.
<table>
<thead>
<tr>
<th>UNIT, MAP SYMBOL, Lithology, Thickness</th>
<th>FIELD RELATIONSHIP</th>
<th>DISTRIBUTION</th>
<th>DEPOSITIONAL ENVIRONMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAINozoic</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Quaternary</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Alluvium (Qa) 3 m</td>
<td>River and creek channel deposits</td>
<td>Drainage areas</td>
<td>Fluvial</td>
</tr>
<tr>
<td>Sand, silt, clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colluvium (Qc) 3 m</td>
<td>Deposits of broad drainage areas, shallow depressions</td>
<td>Drainage areas</td>
<td>Sheet wash</td>
</tr>
<tr>
<td>Sand, silt, clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floodplain Alluvium (Qaf) 30 m</td>
<td>Deposits of extensive low-lying swampy areas</td>
<td>NW of MOYLE</td>
<td>Seasonal flooding</td>
</tr>
<tr>
<td>Black to brown humic soil and clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tertiary/Quaternary</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil (Czs) 30 m</td>
<td>Skeletal soils over all rock types, largely lateritic over Cretaceous sediments</td>
<td>Widespread</td>
<td>Residual</td>
</tr>
<tr>
<td>Unconsolidated sand, gravel, clayey and silty sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laterite (Czl)</td>
<td>Occurs as small, scattered boulders within lateritic soils</td>
<td>Wingate Plateau</td>
<td>Insitu</td>
</tr>
<tr>
<td>Insitu and reworked nodular, concretionary, pisolithic and mottled laterite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talus and Scree (Czt) 2 m</td>
<td>Developed on slopes below escarpments and fault ridges</td>
<td>Margins of Wingate Plateau</td>
<td>Transported</td>
</tr>
<tr>
<td>loose boulders and rock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobble gravel (Cat) 20 m</td>
<td>High-level river terrace gravel</td>
<td>SW of MOYLE</td>
<td>Fluvial</td>
</tr>
<tr>
<td>loose cobbles, pebbles and boulders, rounded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mesozoic</strong></td>
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</tr>
<tr>
<td><strong>Cretaceous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undivided Cretaceous (K) 70 m</td>
<td>Unconformably overlies Bh, Egmk, Ezm, Ezi, Ezg, Efc, P</td>
<td>Central, southern and SE part of MOYLE</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td>70 m, Lateritised quartzarenite, friable, fine to very coarse, feldspathic, micaceous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Unconformity</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Palaeozoic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Permian</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port Keats Group (P)</td>
<td>Unconformably overlies Ezm, unconformably overlain by K</td>
<td>NW corner of MOYLE</td>
<td>Fluvial to shallow-marine</td>
</tr>
<tr>
<td>At least 152 m.</td>
<td></td>
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</tr>
<tr>
<td>Subarkose, white, friable; saccharoidal arenite ± mica ± feldspar</td>
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<td></td>
</tr>
<tr>
<td><em>Unconformity</em></td>
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</tr>
<tr>
<td><strong>Proterozoic</strong></td>
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</tr>
<tr>
<td><strong>Middle Proterozoic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mureenja Dolerite (Pdm)</td>
<td>Intrudes Egp, Ezn</td>
<td>Central west of MOYLE near Moyle River</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Altered gabbro, dolerite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ti-Tree Granophyre (Egi)</td>
<td>Intrudes Pfh, Pfc, Ebw, Ezm</td>
<td>NE and SW parts of MOYLE</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Granophyre, contaminated, chloritised, sencitised, saussuritised, argillised; felsite; micro-adamellite, porphyritic, altered</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIT, MAP SYMBOL, LITHOLOGY, THICKNESS</td>
<td>FIELD RELATIONSHIP</td>
<td>DISTRIBUTION</td>
<td>DEPOSITIONAL ENVIRONMENT</td>
</tr>
<tr>
<td>--------------------------------------</td>
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</tr>
<tr>
<td><strong>FITZMAURICE GROUP</strong></td>
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</tr>
<tr>
<td>Lahngang Formation (Pzl)</td>
<td>Conformable on Pzg</td>
<td>SW part of MOYLE</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>At least 1050 m. Quartzarenite, medium to coarse-grained, feldspathic in places</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goobaieri Formation (Pzg)</td>
<td>Conformable on Pzg</td>
<td>SW part of MOYLE</td>
<td>Shallow and deeper marine</td>
</tr>
<tr>
<td>250 m. Siltstone; interbedded fine-grained quartzarenite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moyle River Formation (Ezm)</td>
<td>Unconformably overlies Ph, Egmk. Intruded by Edm</td>
<td>Western part of MOYLE</td>
<td>Shallow-marine</td>
</tr>
<tr>
<td>At least 5000 m. Quartzarenite, fine to medium-grained, poorly sorted, thickly bedded to massive, abundant cross bedding; basal conglomerate; stromatolitic dolomite; dolomite; siltstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ezv</td>
<td>Interlayered with Ezm</td>
<td>Central west of MOYLE</td>
<td>Volcanic</td>
</tr>
<tr>
<td>Contaminated and altered silicified volcanic rock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AUVERGNE GROUP (Pa)</strong></td>
<td>Unconformably overlain by K</td>
<td>South of MOYLE</td>
<td>Dominantly shallow-marine</td>
</tr>
<tr>
<td>At least 40 m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undivided sedimentary rocks-quartzarenite, flaggy, ripple marked, laminated</td>
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<tr>
<td><strong>EARLY PROTEROZOIC</strong></td>
<td></td>
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<tr>
<td>Peppimenarti Granite (Ego)</td>
<td>Intruded by Edm</td>
<td>Central west of MOYLE</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Biotite leucogranite; adamellite; porphyritic microgranite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murra-Kamangee Granodiorite (Egmk)</td>
<td>Intrudes Ph, Pbw</td>
<td>NE quadrant of MOYLE</td>
<td>Plutonic</td>
</tr>
<tr>
<td>Biotite granodiorite, sometimes garnetiferous, may be weakly to moderately foliated, contains numerous xenoliths; porphyritic biotite adamellite; porphyritic biotite microdiorite 1852±33 Ma U/Pb</td>
<td></td>
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</tr>
<tr>
<td>Wangi Basics (Ebb)</td>
<td>Intrudes Efb</td>
<td>NE part of MOYLE</td>
<td>Plutonic and hypabyssal</td>
</tr>
<tr>
<td>Altered and metamorphosed basic igneous rocks: gabbro; felsic gabbro: dolerite; minor anorthosite; troctolite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field</td>
<td>Relationship and Location</td>
<td>Depositional Environment</td>
<td></td>
</tr>
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<tr>
<td><strong>Finiss River Group</strong></td>
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<tr>
<td>Pfcv, 20 m</td>
<td>Interlayered with Pfc</td>
<td>NE part of MOYLE</td>
<td>Volcanic</td>
</tr>
<tr>
<td>Altered rhyodacite,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rhyolite, banded tuff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chilling Sandstone (Pfc)</td>
<td>Conformably overlies and interlayered with Pfb.</td>
<td>NE and central parts of</td>
<td>Shallow marine to fluval</td>
</tr>
<tr>
<td>6500 m</td>
<td>Intruded by Egi, Pbb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartzarenite, sometimes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>siliceous, micaceous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cross bedded, ripple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>marked</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Burrell Creek Formation</strong></td>
<td>Interfingers with Pfc.</td>
<td>NE part of MOYLE</td>
<td>Deeper to shallow</td>
</tr>
<tr>
<td>(Pfb)</td>
<td>Intruded by Egi, Pbb</td>
<td></td>
<td>marine-coarse turbidite</td>
</tr>
<tr>
<td>Phyllite; (micaceous,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>feldspathic) immature</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>quartzarenite; (siliceous,</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>micaceous) submature</td>
<td></td>
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<tr>
<td>quartzarenite; (siliceous)</td>
<td></td>
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<td></td>
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<tr>
<td>gritty quartzarenite or</td>
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<tr>
<td>quartz grit, (siliceous)</td>
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<td></td>
</tr>
<tr>
<td>quartz conglomerate; clasts</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>of phyllite and quartz-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arenite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Henschke Breccia (Efh)</strong></td>
<td>Unconformably overlain by Pzm. Unconformable with or</td>
<td>Central part of MOYLE</td>
<td>Fault talus</td>
</tr>
<tr>
<td>1500 m</td>
<td>faulted against Eh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massive breccia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>conglomerate, passing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>upwards into well bedded</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>pebbly arenite with a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>phyllite band about 120 m</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>thick</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Berinka Volcanics (Efbv)</strong></td>
<td>Interlayered near base of Efb</td>
<td>NE part of MOYLE</td>
<td>Volcanic</td>
</tr>
<tr>
<td>Altered and metamorphosed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lithic crystal tuff;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rhyodacite; micro-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>spheralitic rhyodacite;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>andesite; agglomerate;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minor interlayered mudstone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hermit Creek Metamorphics</strong></td>
<td>Intruded by Egmk, Pbb</td>
<td>NE to central part of MOYLE</td>
<td>Flysch?</td>
</tr>
<tr>
<td>(Eh)</td>
<td>Faulted against Egmk, Pbb, Efh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelitic and semi-pelitic</td>
<td>Unconformably overlain by</td>
<td></td>
<td></td>
</tr>
<tr>
<td>schist and gneiss; phyllite; quartz-mica schist; sillimanite- andalusite-muscovite schist; andalusite-cordierite hornfels; (minor) quartzite</td>
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roughly synchronous (Page and Hancock, 1988), and therefore postdate the formation of the Hermit Creek Metamorphics.

Phyllite, schist, micaceous meta-arenite, and minor hornfels are the major rock types forming the Hermit Creek Metamorphics in MOYLE. The predominant rock-forming minerals are quartz, muscovite (often in the form of sericite), biotite, andalusite, minor chlorite, limonite, and rare potassic feldspar. Sericite, chlorite and limonite are the major secondary replacement minerals, with sericite replacing muscovite, andalusite and feldspar, and chlorite and limonite forming after biotite and other ferromagnesians. Many of the schists and phyllites show alternating more quartzose and more micaceous layers which probably reflect original sedimentary stratification. Cordierite and andalusite occur in pelitic beds near Murra-Kamanggee Hill and at a few scattered localities to the north. The dominant regional axial plane foliation of the sequence is defined by the alignment of micas. In the Murra-Kamanggee Hill area, cordierite and andalusite porphyroblasts cross-cut the regional foliation. The porphyritic aluminosilicate minerals, described above, hornfels, and spotted phyllites with spots between 0.3 and 1 mm across, have been observed at several exposures near the Murra-Kamanggee Granodiorite. These are all contact effects of the intrusion of the granodiorite.

The Hermit Creek Metamorphics form a monotonous sequence of interbedded pelite and subordinately psammite which has been interpreted as flysch. Locally preserved small-scale cross-laminations and graded bedding, well preserved in the least metamorphosed rocks in the south, are indicative of flysch deposits.

FINNIS RIVER GROUP

The Finniss River Group is the uppermost unit of the Early Proterozoic Pine Creek Geosyncline, and the outcrops in MOYLE form the westernmost exposures of the sedimentary sequence of the geosyncline. In MOYLE, the Finniss River Group comprises the Burrell Creek Formation, an extensive unit throughout the western part of the geosyncline; in this area it includes the Berinka Volcanics at its base. Overlying and interfingered with the Burrell Creek Formation is the Chilling Sandstone which also contains some volcanic interbeds. The locally developed Henschke Breccia in the central part of the sheet area is interpreted as an equivalent of the basal part of the Burrell Creek Formation. The relationships between the units which constitute the Finniss River Group in this area are shown in Figure 6. The group underlies or is inferred to underlie most of the central, eastern and SE portion of the sheet area.

Burrell Creek Formation (Efb)

The Burrell Creek Formation in MOYLE differs quite markedly from the 'typical' sequence of interbedded greywacke and phyllite found further to the east (eg PINE CREEK). In MOYLE, the formation is dominantly by quartz-rich sediments with a small proportion of argillaceous interbeds. Along the eastern edge of the sheet area, the formation forms a sequence of SE-dipping beds conformably overlying the Berinka Volcanics and overlain by the Chilling Sandstone. The Burrell Creek Formation is intruded by sills of the Wangi Basics and Ti-Tree Granophyre, which in places slightly tectonically interfere. The Burrell Creek Formation in the sheet area is distinguished from the Chilling Sandstone by its having a higher proportion of argillaceous material in the quartzarenites, and the presence of individual argillaceous bands. The contact between the two formations is conformable and gradational upwards into the clean, platform sequence of the Chilling Sandstone.

The quartzarenites are massive to well bedded, flaggy in places, and consist of poorly sorted quartz grains in a matrix of fine-grained quartz and hematitic clay. The argillaceous units are typically mudstone and siltstone in which fine-grained phyllosilicates are intergrown with extremely fine-grained quartz. The phyllosilicates form a web-like, parallel orientation which impart a weak foliation to the rocks, thus they are classified as mudstones and siltstones rather than phyllites. It is only in these argillaceous lithologies that any evidence for low grade metamorphism is seen.

Henschke Breccia (Efh)

The Henschke Breccia is unique to MOYLE and represents the basal part of the Finniss River Group in its most westerly outcrop. In the central part of the sheet area and to the west and east of Henschke Falls, the breccia is unconformable and in places faulted against the Hermit Creek Metamorphics. The age and stratigraphic position of the Henschke Breccia has been variably interpreted. Morgan (1972) and Sweet and others (1974), described the breccia as faulted against and younger than the rocks to the north which they considered belonged to the Nolfenius Formation (Finniss River Group). These northern rocks are here interpreted as Hermit Creek Metamorphics. Needham and Stuart-Smith (1984) suggest that the breccia is younger than rocks of the Finniss River Group and correlate it with the El Sherana Group in the central part of the Pine Creek Geosyncline.

The breccia is poorly sorted and was rapidly deposited from a local provenance of metasedimentary rocks. Clast lithologies are consistent with derivation from the adjacent Hermit Creek Metamorphics. Foliation orientation and the grade of metamorphism of the breccia are consistent with those of the Finniss River Group immediately to the east. Undeformed and unmetamorphosed rocks of the Middle Proterozoic Moyle River Formation unconformably overlie the breccia. Along its northern contact, consistently south-dipping sedimentary breccias and minor phyllite of the Henschke Breccia form a poorly exposed, partly faulted contact with chevron folded pelites and psammites of the Hermit Creek Metamorphics. On the basis of gross structural disconformity and contrasting lithologies, this contact has been interpreted as a major unconformity.

Lithologies included within the Henschke Breccia are breccia, well-bedded quartzarenite, gritty quartzarenite, and phyllite. The breccia is massive to weakly bedded, poorly sorted and polymict. It includes pebbles of both foliated (nuyletitic) and non-foliated vein quartz, cleaved arenite, metapelite, potash feldspar and occasional tourmaline. The matrix is composed of fine-grained quartz and sericite cemented in finely divided hematite. The quartzarenite is clean, often gravelly or gritty, and displays abundant cross bedding
and graded bedding. It is identical both compositionally and sedimentologically to the Chilling Sandstone found further to the east. A thick lens of phylite, similar in composition and degree of metamorphism to those of the Burrell Creek Formation, occurs in the middle of the sequence. The phylite consists of quartz, sericite and limonite. Colour laminations define bedding, which is at an angle of about 30° to the well developed cleavage. Foliation is defined by the preferred orientation of platy minerals in the sericitic matrix; the quartzarenites and pebbly quartzarenites have not developed a penetrative fabric.

The inferred depositional environment of the breccia is one in which periodic rapid accumulation of unsorted material (breccia) was interspersed with periods of steady sediment supply allowing moderate sorting and the development of sedimentary structures (quartzarenites) and rarer periods of quiet sedimentation (phyllite). These features are consistent with those of a talus being deposited along an intermittently active fault zone.

**Berinka Volcanics (PtLv)**
The Berinka Volcanics crop out in a broad valley between ridges of quartzite of the Burrell Creek Formation and Chilling Sandstone in the east central part of MOYLE. To the north the Berinka Volcanics are separated from the Chilling Sandstone by a major vertical fault, to the south they lie conformably below Burrell Creek Formation sediments.

There is some disagreement about the stratigraphic position of the volcanics. Previous workers (e.g. Morgan and others, 1970; Pontifex and Mendum, 1972; Sweet, 1974) included the extrusives in the ‘Noltenius Formation’ (Burrell Creek Formation). Recent workers have correlated the Berinka Volcanics (and the Chilling Sandstone) with the El Sherana Group of the central Pine Creek Geosyncline (Needham and Stuart-Smith, 1984). However, NTGS mapping confirms that the Berinka Volcanics form a member at or near the base of the Burrell Creek Formation. This is based on the conformable contacts in MOYLE, and, locally, the presence of acid volcanic clasts in conglomerates of overlying Burrell Creek Formation in WINGATE MOUNTAINS.

The Berinka Volcanics are considered to be comagmatic with the acid to intermediate Warr’s Volcanic Member of the Burrell Creek Formation and the Mulluk Mulluk Volcanics in DALY RIVER (Dundas and others, 1987a). Chemically and mineralogically, the three suites are similar and, although to some extent their depositional environments differ, they appear to reflect a single period of volcanism. This volcanism was initiated at the onset of the Finniss River Group sedimentation along the western margin of the Pine Creek Geosyncline.
Exposure of the volcanics in MOYLE is poor, and most outcrops are deeply weathered. Shear zones trending through the volcanics have in many instances destroyed the igneous fabric of the rocks, a sequence of acid and intermediate volcanics, tufts and agglomerate. To the east in WINGATE MOUNTAINS they also include some thin interbeds of argillaceous sedimentary rocks. The volcanics consist of spherulitic rhyolite, rhyodacite, and lithic crystal tufts, but minor andesite and rare agglomerate also occur. The tufts are dominantly composed of quartz, chlorite, feldspar, sericite and opaque minerals. Most of the quartz or siliceous fragments can be identified as relict pyroclasts, and often appear to be aggregated in groups which may reflect a crude pyroclastic layering or sorting due to reworking. Some quartz is phenocrystic although very few show good crystal outlines. In some specimens, a cherty quartz mosaic probably reflects devitrification of glass fragments. Most of the feldspar has been replaced by sericite. Some shows phenocrystic form, and the alteration makes specific identification difficult. Some of the feldspars form discrete mineral grains, while others form composites typical of a pyroclastic origin. The groundmass is fine quartz, chlorite and feldspar forming a turbid mesh. Some coarser chlorite clusters probably represent glass alteration products or altered lithic fragments. There is indication in some samples that the original groundmass may have been ignimbritic, eg minute veinlets of sericite form patterns reminiscent of perlitic cracking textures. The rhyolites and rhyodacites are heavily altered. They are generally porphyritic or microporphyritic in quartz and feldspar. The predominant feldspar is altered plagioclase; where identification is possible it is oligoclase. The groundmass is a microgranular mesh of quartz, plagioclase, chlorite and opaques. Some slightly coarser patches of chlorite are probably replacing ferromagnesian minerals. Most specimens contain 3-7% of lithic contaminants of quartzo-feldspathic and mafic composition.

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

The rare agglomerate is a very distinctive rock, consisting of dark green fragments of acid or intermediate volcanic rocks with a somewhat trachytic texture. The fragments are set in a dark pink aphanitic matrix of relict equant and tabular feldspar surrounded by clear, well-crystallised quartz. Minor chlorite and epidote within the fragments probably pseudomorph original microphenocrysts.

Flow banding is occasionally observed in the least altered exposures (Plate 1). In one locality, quartz veins infill polygonal fractures within a rhyolite forming a distinctive feature in outcrop (Plate 2). These polygonal fractures are interpreted as shrinkage cracks formed during rapid subaerial cooling.

The extremely variable nature of the groundmass and texture and the size and sorting of the pyroclastic fragments in the tufts indicates, in many instances, that they were deposited under shallow fluvial to subaerial conditions, with some epiclastic reworking. The predominance of quartzarenites in the Burrell Creek Formation overlying the volcanics indicates that deposition following the extrusion of the Berinka Volcanics was occurring in a shallowing environment transitional to the platform sediments of the Chilling Sandstone.

Chilling Sandstone (Pfe)
The Chilling Sandstone is the most extensive formation of the Finniss River Group in MOYLE. It is exposed on the eastern and southern edges of the sheet area, where it has been exhumed from Cretaceous cover rocks. On the eastern edge of the sheet area, the sandstone forms three separate exposures - its most northerly outcrop is a fault-bounded wedge that extends eastward into WINGATE MOUNTAINS, and the southerly outcrops conformably overlie the Burrell Creek Formation. These eastern exposures form a
consistently moderately to steeply SE-dipping sequence. On the southern edge of the sheet area, the sandstone is faulted on the west against the younger Fitzmaurice Group, and here the sandstone forms a steeply ESE-dipping sequence.

The Chilling Sandstone consists of a monotonous sequence of massive, well-bedded, medium-grained, mature quartzarenite, quartzite and lesser gravelly quartzarenite. Very rare, thin lenses of argillaceous rocks occur toward the base of the sequence. Cross-bedding, graded bedding in gravelly quartzarenites, and occasional ripple marks are the only sedimentary features observed in the formation. The sequence is typical of a shallow marine or fluvial sediment deposited on a relatively stable shelf, or continental platform. Deposition matched the rate of basin subsidence and resulted in the accumulation of a large thickness of monotonously uniform sediments. In WINGATE MOUNTAINS where the greatest section is preserved, the thickness is calculated to be about 7000 m.

The fault-bounded wedge that occurs on the eastern edge of MOYLE contains several interbeds of acid volcanics and associated high-level intrusives (Efcv). To the east in WINGATE MOUNTAINS, a 400 m thick acid volcanic unit occurs near the top of the sequence. These igneous rocks are highly weathered and altered and consist of spherulitic volcanics and fine-grained acid intrusives. Banded, tuffaceous sediments occur within the extrusive units in the region south of Murra-Kamangee Hill. The relationship between these extrusive rocks and the Berinka Volcanics is not clear, however limited petrological work indicates that the Berinka Volcanics have a distinctly greater ferromagnesian content which appears to indicate a uniquely different original composition. The slightly cross-cutting high-level intrusives have chilled margins bordering the quartzarenites and contain blocks of quartzarenite near the margins.

Plate 2 Polygonal shrinkage cracks, Berinka Volcanics.

INTRUSIVE IGNEOUS ROCKS

Wangi Basics (Pbb)
The Wangi Basics crop out in the NE corner of MOYLE. The largest body is part of a stock which covers about 28 km² extending into WINGATE MOUNTAINS, two smaller bodies occur to the SW, and several narrow sills intrude the Burrell Creek Formation.

Stocks of the Wangi Basics crop out well as rises and ridges of black to dark grey boulders in a distinctive red-brown clayey soil. The sills are quite small and form boulder outcrops in valley floors. The Wangi Basics are very hard, fine- to coarse-grained, grey to dark grey intrusive rocks. Rock types identified in thin section include altered gabbro, altered dolerite and meta-dolerite and meta-microgabbro. In all samples plagioclase has altered to sericite and in places is argillised. Pyroxene has been altered to amphibole (hornblende) and chlorite, and the ferromagnesian minerals to chlorite and amphibole (tremolite-actinolite). Minor amounts of quartz is present in a few samples. Secondary minerals include biotite, chlorite, calcite and epidote. The degree of alteration varies with some rocks showing unaltered pyroxene, plagioclase and relics of iron oxide crystals. All samples show some effects of hydrothermal alteration and low to medium grade greenschist facies metamorphism.

The Wangi Basics had not been differentiated from the metabasic rocks of the Hermit Creek Metamorphics by BMR in their maps or reports. Work by Mobil resulted in the inclusion of some outcrops of the Wangi Basics in the Hermit Creek Metamorphics (Poynter, 1981). The basics were regarded as extrusive metabasites with pillow lava structures, interlayered with the metasedimentary rocks of the Hermit Creek Metamorphics. NTGS work has shown that the rocks become coarse-grained towards the centre of outcrop, with fine-grained margins, indicating they are intrusive. In thin section, the rocks display a relit text of stumpy interlocking prisms, which is more typically that of an intrusive. The reported occurrence of pillow structures could not be substantiated.

GRANITOIDS

Two granitoid bodies have been distinguished in MOYLE; the Murra-Kamangee Granodiorite, which lies in the northern half of the sheet area, and the herein defined Peppimenarti Granite, which occurs in a small area in the NW of MOYLE. Both granitoids were previously mapped as 'Litchfield Complex' (Morgan, 1972).

Geochronologic studies using the U/Pb method, on zircon and xenotime from Murra-Kamangee Granodiorite taken from the Murra-Kamangee Hill area, indicated crystallisation occurred at 1852±53 Ma (Page and others, 1984). Geochemical studies and field relationships with other rock units indicate that the Peppimenarti Granite crystallised during the same 1840-1850 Ma intrusive event as the Murra-Kamangee Granodiorite and the other granitoids of the Litchfield Province. This intrusive event occurred during the closing stages of the 1870-1850 Ma Nimbuwah Event of the Top End Orogeny in the Pine Creek Geosyncline.
Murra-Kamangee Granodiorite (Pgmk)
The Murra-Kamangee Granodiorite extends over approximately 260 km² in the northern portion of MOYLE and continues northwards into GREENWOOD, NE into DALY RIVER, and eastwards into WINGATE MOUNTAINS. The granodiorite is well exposed with large tors sometimes forming hills rising up to 30 m above the surrounding plains. The Murra-Kamangee Granodiorite has intruded the Wangi Basics and Hermit Creek Metamorphics, is faulted against the Chilling Sandstone and Henschke Breccia, and is unconformably overlain by the Middle Proterozoic Moyle River Formation.

The most common rock types are weakly foliated, xenolithic, medium- to coarse-grained biotite tonalite, granodiorite and minor adamellite. These rocks are composed mainly of quartz, plagioclase and biotite in a typical xenomorphic mosaic. Minor minerals include muscovite, sericite and chlorite; accessory minerals are garnet, apatite, zircon, tourmaline and opaques. The quartz constitutes 20-30% of the rock, is commonly strained, and displays sutured intergranular boundaries. Typically, plagioclase is of andesine composition and generally shows some alteration to sericite or clay. Biotite is the dominant mica forming up to 10% of the rock; it commonly displays alteration to chlorite. Biotite clots up to 1 cm in diameter are ubiquitous and probably represent altered garnets. In thin section, partly retrograde garnets are surrounded by chlorite and poikiloblastically enclose fine biotite, plagioclase and apatite. Although a xenocrystic origin of the garnet is likely, their even distribution throughout the granodiorite and the relative paucity of garnet in the Hermit Creek Metamorphics makes the metamorphics unlikely as the source for the garnet. The garnets together with other aluminosilicate minerals reported in Dundas and others (1987a) appear to be phases derived from the partial melting of the source rock at depth. Tourmaline is generally found in accessory amounts only; however, it may form up to 3% of the rock. The tourmaline appears to have been the last component to crystallise and was possibly introduced during a final pegmatitic phase. This may have also been a water-rich stage which contributed to the alteration of the plagioclase and biotite. In places the granodiorite has been partially recrystallised which has imparted a metamorphic layering or gneissosity, defined by granoblastic aggregates of quartz and plagioclase xenoblasts alternating with mica-rich layers.

The granodiorites and adamellites are generally medium-grained and composed dominantly of quartz, plagioclase, orthoclase and biotite, with minor muscovite, sericite and tourmaline, and accessory zircon, apatite and opaques. These rocks may be porphyritic with subhedral orthoclase poikilocrysts distributed throughout a medium-grained xenomorphic mosaic of quartz and plagioclase. One sample which is compositionally a granite is unusual in that it contains primary andalusite and biotite. The Murra-Kamangee Granodiorite contains numerous country rock xenoliths. The most common xenoliths are garnet-biotite-feldspar-quartz metasediments possibly derived from the Hermit Creek Metamorphics. Other xenoliths include vein quartz, and metabasic igneous rocks. Cognate xenoliths are less common and consist of garnetiferous tonalitic gneiss with diffuse margins.

The intrusive nature of the contact between the Murra-Kamangee Granodiorite and the Wangi Basics is evidenced by veins and pods of granodiorite within the basics, and xenoliths of basics within the granodiorite (Plate 3). In the Murra-Kamangee Hill area, veins and pods of granodiorite occur within the metasedimentary rocks of the Hermit Creek Metamorphics and rafts of metasedimentary rocks occur within the granodiorite. The granodiorite has contact metamorphosed the metasedimentary rocks, illustrated by the development of post-foliation coarse porphyroblasts of cordierite and andalusite which show a marked increase in relative abundance and size towards the contact with the granodiorite. The Murra-Kamangee Granodiorite is separated from the Chilling Sandstone by a low-angle thrust fault. This fault cannot be measured directly but is indicated by the regular planar contact between the two units, brecciation of the sandstone immediately above the contact, and the development of a secondary and locally dominant, mylonitic fabric in the granodiorite immediately below the contact. The contact between the Murra-Kamangee Granodiorite and the Moyle River Formation is clearly unconformable; its irregular nature reflects the undulating palaeotopography developed prior to the deposition of the Moyle River Formation.

Peppimenarti Granite (PgP)\*
The Peppimenarti Granite is of limited extent and crops out within the vicinity of the Peppimenarti settlement in the NW of MOYLE. It includes fine aplitic to coarse-grained pegmatitic phases and ranges compositionally from adamellite to granite.

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\* New unit
The adamellite is coarse to pegmatitic, has an equigranular texture, and is composed of plagioclase, potassium feldspar, quartz and biotite, with secondary chlorite, muscovite, epidote, and accessory sphene and opaques. The granite is fine- to medium-grained and is composed of quartz, potassium feldspar, and plagioclase in an interlocking granular mosaic. There has been considerable alteration of the feldspars with the development of secondary chlorite and epidote and traces of sericite and carbonate. Some of the chlorite may have replaced biotite.

The Peppimenarti Granite is unconformably overlain by the Moyle River Formation immediately SW of Peppimenarti. The field relationship between the granitoid and the Murrenja Dolerite, found immediately to the north of Peppimenarti, is unclear. However, elsewhere the Murrenja Dolerite clearly intrudes the Moyle River Formation (Fahey and Edgoose, 1986), and so by inference the dolerite postdates the Peppimenarti Granite.

Although physically separate from the Murra-Kamangee Granodiorite, the Peppimenarti Granite has in the past been included as an apophysis of the larger granitoid mass. Recent work by NTGS has however shown the Peppimenarti Granite to be geochemically similar to the Wagait Granite further to the north (De Ross, 1987). It could be postulated that these two granitoids are connected beneath the younger cover rocks which comprise the Docherty Hills in GREENWOOD.

MIDDLE PROTEROZOIC

FITZMAURICE GROUP

The rocks of the Fitzmaurice Group in MOYLE mark the northern limit of the Fitzmaurice Mobile Zone, a fault-bounded trough in which a thick sequence of quartz-rich sediments accumulated during the Middle Proterozoic. Outliers of these rocks are preserved at a few localities to the north along Tom Turners Fault. To the south, the Fitzmaurice Mobile Zone forms a younger continuation of the Early Proterozoic Halls Creek Mobile Zone in Western Australia.

In MOYLE, the Fitzmaurice Group rests unconformably on Early Proterozoic basement consisting of the Hermit Creek Metamorphics, granitoids and the Henschke Breccia. An irregular, unconformable contact between the sediments of the group and the older Murra-Kamangee Granodiorite is exposed in the northern escarpment of the Wingate Plateau. This demonstrates the undulating palaeotopography developed on Early Proterozoic rocks prior to deposition during the Middle Proterozoic.

An accurate determination of the thickness of the group is made difficult by the numerous faults which transect its outcrop, however an estimated minimum thickness is in the order of 6000 m. Sweet and others (1974) estimated the thickness of the sequence north of Tom Turners Crossing to be about 10 000 m.

The formations comprising the group in MOYLE are the basal Moyle River Formation, the Goobaieri Formation and the Lalangang Formation. The uppermost formation, the Legune Formation, is absent in MOYLE.

Moyle River Formation (Pzm)

The Moyle River Formation forms the northern escarpment of the Wingate Plateau, and crops out extensively along the western side of the sheet area and to the west of younger formations in the group. In the north it forms a large syncline whose eastern limb is partially truncated by Tom Turners Fault and is juxtaposed against the Hermit Creek Metamorphics.

The unconformity with the underlying Murra-Kamangee Granodiorite is well exposed on the northern escarpment of the plateau, where a basal conglomerate about one metre thick and consisting largely of quartzite and reef quartz clasts rests on weathered granite (Plate 4). The dominant rock type is white to pale grey, fine- to medium-grained quartzarenite which varies from medium- to thick-bedded in outcrop. The quartzarenites range from moderately well sorted, rounded to subrounded quartz set in a fine matrix, to poorly sorted, subangular quartz grains with very little matrix. Detrital mica and tourmaline occur scattered throughout the rock. The originally argillaceous matrix is now commonly converted to very fine sericite. Rare interbeds of micaceous siltstone are composed of very fine, angular quartz and wispy muscovite scattered throughout an argillaceous matrix. Very weak, commonly iron-stained compositional banding of quartz-rich and quartz-poor layers is sometimes evident.

The rocks are deformed where they occur near major faults. A weak to moderate foliation is evident in rocks with a sericitic matrix, most of the quartz shows evidence of strain, and some quartz overgrowths or recrystallisation may be apparent. Where deformation is more severe, crenulation and kinking can be observed in finer beds.

Plate 4 Basal conglomerate in Moyle River Formation at the unconformity with the Murra-Kamangee Granodiorite.
Goobaieri Formation (Bzg)
The Goobaieri Formation crops out in a north-trending linear belt in the SW of the sheet area where it conformably overlies the Moyle River Formation, and is also preserved along a faulted contact with the Moyle River Formation in the SW corner of MOYLE. In both exposures the Goobaieri Formation is conformably overlain by the Lalngang Formation.

The Goobaieri Formation consists of a sequence of interbedded fine sandstone and siltstone, with a coarser sandstone unit near the top of the sequence at the northern end of the main exposure. The siltstone is dark grey and composed of poorly sorted, fine grained angular quartz in a sericitic and argillaceous matrix. Some plagioclase also occurs along with accessory tourmaline and sphene.

Lalngang Formation (Pzl)
The full extent of the Lalngang Formation is obscured by Cretaceous rocks forming the Wingate Plateau. The formation is well exposed along the contact with the conformably underlying Goobaieri Formation, and is faulted against the Chilling Sandstone on the southern edge of the sheet area. To the west of this fault, the formation is intruded by the Middle Proterozoic Ti-Tree Granophyre.

The Lalngang Formation consists of fine- to coarse-grained quartz arenite and feldspathic quartzarenite. The quartzarenites are typically composed of tightly packed, subangular, poorly sorted quartz with some grain overgrowths. Detrital mica and tourmaline may be present.

Some of the quartzarenites contain layers or lenses of gravel-sized quartz. Elsewhere in the Fitzmaurice Mobile Zone, beds of siltstone and pebble conglomerate are described within this formation (Sweet and others, 1974). Cross bedding and ripple marks are the dominant sedimentary structures and are more typical of the Lalngang Formation than the other formations of the Fitzmaurice Group.

Minor drag folding has occurred near faults, otherwise the sequence is flat lying or dips shallowly to moderately to the east or SE.

Auvergne Group (Pa)
Undivided Auvergne Group sedimentary rocks lie in the SW of the sheet area. They are exposed where drainage has dissected the Wingate Plateau, stripping off the Cretaceous cover. The outcrops consist of flat-lying white, friable medium- to coarse-grained quartzarenite. Bedding varies from flaggy to medium. Sedimentary structures include laminations and ripple marks.

Ti-Tree Granophyre (Egi)
The Ti-Tree Granophyre forms several sills intruding rocks of the Finnis River Group south of Murria-Kamangee Hill. The sills form sporadic exposures in recessive valleys between ridges of resistant quartz-rich sediments. A large stock intrudes the Lalngang Formation in the south of the sheet area but the granophyre is poorly exposed, and most outcrops are highly weathered and rubble. Its contact relationship with enclosing rocks is obscured by poor outcrop and superficial cover.
Lithologies include deuterically altered and contaminated granophyre, porphyritic granophyre and porphyritic micro-adamellite. The groundmass consists of micrographic intergrowths of quartz with turbid, argillaceous feldspars, and may be interspersed with minor xenomorphic granular quartz or polygonal veins of quartz and feldspar. Some feldspar phenocrysts up to 4 mm are sparsely distributed in the groundmass. The high degree of alteration makes the composition of the feldspars difficult to determine, but it appears that both potassium feldspar and plagioclase are present. Relics of ferromagnesian phenocrysts, replaced by a fine mesh of chlorite and in some places epidote, show evidence of having originally been stumpy prismatic amphiboles. Calcite is a common alteration product of ferromagnesian minerals. Some samples contain rare clusters and isolated flakes of biotite.

U/Pb isotopic dating of samples of Ti-Tree Granophyre failed to produce any firm results. A possible crystallisation age of 1805±4 Ma was obtained, however it is likely that contamination of the very small zircon concentrate separated from the rock occurred (Edgoose and others, 1984a).

Murrenja Dolerite (Edm)
The Murrenja Dolerite crops out as two large stocks about 12 km apart in the western part of MOYLE. The two very small exposures just south of the Moyle River are probably part of the larger stock which is exposed north of the river. In outcrop, the Murrenja Dolerite is fine- to medium-grained and massive. It forms low hills and rubby rises of very hard, black to dark grey boulders in a red-brown clayey soil.

In thin section, the dolerite has essentially a granitoid texture and is composed of medium-grained plagioclase (labradorite) and pyroxene (dominantly augite, sometimes diopside, occasionally hypersthene). Minor minerals include amphibole, biotite, iron oxide, sulphides, and leucocene. All samples show the effects of hydrothermal alteration. Plagioclase has irregular areas of clay-sericite alteration, and the pyroxenes show alteration along grain margins and within cleavages to a fine, granular, densely turbid, saussuritic epidote.

A petroleum exploration well, Moyle No. 1, drilled by Australian Aquitaine Petroleum Pty Ltd (Aquitaine) to the west in KEATS passed from Early Permian sedimentary rocks into gabbroic ‘basement’ at 517.6 m (Australian Aquitaine Petroleum Pty Ltd, 1966). Petrological description of this gabbro shows it to be compositionally similar to the Murrenja Dolerite. K/Ar age determinations of the gabbro from Moyle No. 1 gave ages of 1393 and 1537 Ma. In MOYLE and in ANSON to the north the Murrenja Dolerite intrudes the Middle Proterozoic Moyle River Formation. This field relationship, and the correlation with the gabbro in Moyle No. 1, indicate that the Murrenja Dolerite is probably of Middle Proterozoic age. Similar Middle Proterozoic dolerites occur in the Alligator Rivers region of the Pine Creek Geosyncline (Nedham and Stuart-Smith, 1984).

PALAEOZOIC

PERMIAN (P)
The only exposures of Permian rocks in MOYLE are isolated outcrops in the NW corner of the sheet area. The extent of Permian rocks is much reduced from that shown on previous maps (Morgan, 1972). Lithologically, stratigraphically and palaeontologically, the rocks at Flood Hill (GR FK228447), previously mapped as Permian, are more consistent with the Cretaceous sequence of the region. In addition, these rocks lie at a much higher topographic level than the Permian sequence generally on the western margin of the Bonaparte Basin. On this basis the entire sequence at Flood Hill has been mapped as Cretaceous.

Previous mapping also showed extensive areas of Permian around Richards Hill in the central part of the sheet area. NTGS mapping showed that the exposure in this area consists of beds about 20 m thick of unconsolidated, rounded and polished quartzite cobbles and boulders lying at approximately 80 m above mean sea level. Exposures similar in type and thickness occur to the north of Richards Hill at about the same topographic level, on low hills immediately to the west of Tom Turners Fault. NTGS mapping has indicated that these boulder deposits probably represent high-level river terraces of Cainozoic age (see Cainozoic-Cat). Similar deposits are banked up on the western side of Chalaney Creek Fault in the west-central part of the sheet area, and also occur west of the fault further to the south.

The main source of information about the Permian rocks in MOYLE comes from eight diamond-drillholes drilled by Utah in 1972 (Williams, 1973). These holes are located on a NW-trending gridline which continues into KEATS where a further three holes were drilled. The sequences intersected consist of alternating horizons of quartzarenite, subarkose and mudstone, with minor conglomerate bands occurring towards the bottom of some holes. Some of the mudstone horizons were carbonaceous in part. On the basis of this drilling, and Aquitaine’s subdivisions of the Early Permian based on information from oil wells drilled in KEATS, Utah distinguished the older Kulshill Formation from the overlying basal sandstone unit of the Sugarloaf Formation. This subdivision has been followed in GREENWOOD to the north where the Kulshill Formation and the basal sandstone unit of the Sugarloaf Formation have been distinguished (Dundas and others, 1987b). As the Permian rocks on the eastern side of the Bonaparte Basin gently dip west (basinwards), the Permian rocks in MOYLE probably correlate with the aforementioned formations.

MESOZOIC

CRETACEOUS (K)
Cretaceous rocks form an extensive unit in MOYLE, although they largely subcrop beneath superficial deposits. Cretaceous rocks form the flat surface of the Wingate Plateau, but are only exposed in minor scarps at and south of Murra-Kamangee Hill and in the SE corner of the sheet area. Elsewhere at the dissected edge of the plateau underlying rocks are exposed as the Cretaceous rocks have receded from the plateau edge. Some Cretaceous is exposed around the shallow drainage on the plateau surface. Outliers, which were at one time probably part of the plateau, are found at Flood Hill, Richards Hill, and blanketing the Chalaney Creek Fault in the southern part of the sheet area.

Friable, clayey, commonly ferringous and mottled arenite is the dominant rock type. The only sedimentary features observed are cross bedding sets which may be up to one metre thick. A basal
conglomerate is ubiquitous and consists of cobbles and
smaller particles of locally-derived material in a deeply
limonitic matrix of coarse arenitic composition. This
basal conglomerate averages 0.3 m in thickness. Thin
beds and lenses of claystone and porcellanite occur
wards the top of the sequence in some areas. The
thickness of the Cretaceous sequence varies from only a
few metres preserved on the Wingate Plateau to 40 to
50 m preserved at Flood Hill.

The Cretaceous sediments unconformably overlie
the Hermit Creek Metamorphics, Finniss River Group,
Fitzmaurice Group, Auvergne Group, and the Murra-
Kamangee Granodiorite. The sequence was referred to
as the 'Mullaman Beds' (Skwarko, 1966; Morgan and
others, 1970) until Hughes (1978) totally revised the
Cretaceous stratigraphy for the northern part of the
Northern Territory. The rocks in MOYLE probably
correlate with Hughes' Late Jurassic to Middle
Cretaceous sequence.

CAINOZOIC

Cainozoic deposits mask approximately 70% of the
bedrock in MOYLE. They form the surface of the
Wingate Plateau in addition to blanketing the flood-
plains and large parts of the lowland area. These
deposits have been subdivided into the following units:
C2s, C2l, Cat, Czt, Qa, Qaf and Qcl.

Eluvial soils (C2s) are the most extensive Cainozoic
sediments. They have developed over large areas in the
lowland and on the Wingate Plateau. On the plateau,
the soils have a coarse fraction consisting of laterite
pisolites which are occasionally cemented to form
laterite outcrops. The soils on the lowlands consist of
sandy and gravelly deposits developed over both
granite and sedimentary rocks while over metamorphic
rocks, the clay fraction is greater and the soils are
dominantly orange-red clayey sands and loams. Deeper
red loamy soils and accompanying denser vegetation
have formed over the basic intrusives. On the uplands,
immature skeletal soils are the predominant type,
although even these have not developed to a great
extent as most unconsolidated material is washed to
lower levels during the heavy rains of the wet season.

Laterite (C2l) does not occur in mappable outcrops in
MOYLE. As described in the previous section, the
soils of the Wingate Plateau have a distinct lateritic
component, and contain small outcrops of cemented,
pisolitic laterite.

High-level river terraces (Cat) form extensive boulder
deposits around and to the north of Richards Hill (GR
257337), and on the western flank and to the west of the
Chalanyi Creek Fault. Previous workers mapped these
deposits as Permian, interpreting them to be rounded,
polished glacial erratics. In the absence of striated
boulders and glacial pavements, it is more likely that
they represent abandoned river terraces. The deposits
consist of unconsolidated rounded boulders and cobbles
of quartzite and quartzarenite derived from the
Moyle River Formation. They are generally about 20
m thick and occur on perched soil on Moyle River Formation
at between 60 and 80 m above sea level.

Talus and scree (Czt) deposits mantle the slopes of fault
ridges and the slopes below the escarpment of the
Wingate Plateau. The scree on fault ridges usually
consists of vein quartz and fault breccia. On the slopes
of the plateau it consists of the rock type that forms the
escarpment in that area.

QUATERNARY

Alluvium (Qa) is distributed over wide areas in
MOYLE. It has formed around the creeks and rivers
which drain the Wingate Plateau and the dissected
country north of Richards Hill. The overbank alluvial
deposits are largely deposited by flooding during the
wet season and consist of sand, silt and clay while the
drainage channels commonly contain coarser deposits
of material up to cobble size.

Colluvium (Qcl) is the dominant Quaternary deposit on
the Wingate Plateau where deposition occurs in broad
drainage areas containing only poorly defined
channels. Lowlying swampy areas where material is de-
posited by sheetwash from the surrounding slightly
more elevated areas are characteristic of this unit.
Many of these low areas are permanently wet. The
deposits consist of fine silt and clay.

Floodplain deposits (Qaf) are concentrated on the
western margin of the sheet area. Black humic soils
which shrink and crack during the dry season character-
ise this unit. The plains formed of these deposits are
inundated during the wet season. They represent the
areas that were submerged during the last Pleistocene
sea level rise.

METAMORPHISM

The Hermit Creek Metamorphics in MOYLE form a
low grade (greenschist facies) sequence that is stratigra-
phically the equivalent of the high grade metamorphics
to the NE and north in DALY RIVER and GREEN-
WOOD. The decrease in grade can be traced from NE
to SW across the region. The Hermit Creek Metamor-
phics have undergone two regional metamorphic ep-
isodes under low pressure and moderate temperature
conditions. The first metamorphism is characterised by
the parallel growth of phyllosilicate minerals defining a
foliation (S1) and accompanied by some recrystallisa-
tion of quartz. The second metamorphism has resulted
in the development of crenulations and micro-crenu-
lation on S1, and the retrogression of the higher grade
rocks (upper-middle greenschist) to low greenschist
facies.

Common retrogressive metamorphic replacement
minerals are sericite after muscovite and sometimes
andalusite, and limonite after biotite or a similar
ferromagnesian phyllosilicate. The first metamorphic
event recognised in the Hermit Creek Metamorphics is
inferred to have preceded the deposition of the Finniss
River Group. The second, retrogressive event is
considered to be the result of overprinting by the
subgreenschist to greenschist facies metamorphism
associated with the Nimbowan Event (1870-1850 Ma)
of the Top End Orogeny of the Pine Creek Geosyn-
cline. The effects of the Top End Orogeny are only
weakly developed in the Finniss River Group in
MOYLE, largely because of the quartz-rich nature of the
sedimentary rocks. In the more pelitic units,
metamorphism is manifest by the parallel growth of
micas, and some recrystallisation and grain growth of
quartz. In the Wangi Basics, subgreenschist to green-
chist facies metamorphism is evidenced by the replacement of pyroxenes by amphiboles and varying degrees of recrystallisation.

The low grade rocks of the Hermit Creek Metamorphics in MOYLE are contact metamorphosed by the Murra-Kamangee Granodiorite, although in the higher grade terranes the intrusion appears to have produced local partial melting. Large porphyroblasts of cordierite and andalusite, up to 20 mm, cross-cut the S1 foliation in the metapelites, and the metapsammites are extensively hornfelsed. The relative timing of the contact metamorphism and second, retrogressive event in the metamorphics is not clear because of the absence of an S2 fabric in these rocks. It is likely that the two were roughly contemporaneous, given that the Murra-Kamangee Granodiorite was emplaced during the peak of the Top End Orogeny.

Patchy but widespread retrogressive effects occur in most of the Early Proterozoic units in MOYLE. The contact metamorphic minerals in the low grade Hermit Creek Metamorphics have been replaced by sercite and the feldspars and mafic minerals in the granites, basic intrusives and the volcanic rocks are pervasively altered. This is the youngest event recorded in the rocks of the Litchfield Province and is believed to be largely hydrothermal in nature. It is indicated by the 1770-1800 Ma Rb/Sr isotopic ages obtained from the granites and the Hermit Creek Metamorphics (Page and others, 1984; Edgoose and others, 1984b).

STRUCTURE
The dominant structural features of MOYLE are the extensive, regional transcurrent faults which cross the sheet area. These faults are northerly continuations of major faults which define the Middle Proterozoic Fitzmaurice Mobile Zone and the Early Proterozoic Halls Creek Mobile Zone.

Folding
The Hermit Creek Metamorphics have undergone two periods of deformation. In the vicinity of Henschke Falls, the first folding episode (F1) has produced chevron-like folds with a well developed axial plane foliation (S1). S1 is defined by the parallel growth of low greenschist facies mineral assemblages. F1 folds in this region have a NE plunge and are overturned to the SE. Elsewhere, S1 dominantly trends NE, but folds and fold axes have not been observed.

South of Murra-Kamangee Hill, porphyroblasts of cordierite and andalusite, contact effects of the intrusion of the Murra-Kamangee Granodiorite, cross-cut the S1 foliation in the metamorphics. It is possible that the intrusion of this granitoid was contemporaneous with the second period of deformation (D2) in the Hermit Creek Metamorphics. However, this second event cannot be recognised in this area. Regionally, S2 is evident as down-dip microcnoturations on the S1 fabric. No F2 folds have been recognised.

In the Pine Creek Geosyncline, the Top End Orogeny produced upright, tight to isoclinal, compressional folding in the Finniss River Group. In MOYLE, no F2 fold axes have been observed. The rocks of the Finniss River Group dip steeply and consistently to the south and SE, with the main area of outcrop on the eastern edge of the sheet area forming part of the western limb of the Chilling Syncline (WINGATE MOUNTAINS). The contrasting structural styles of the tightly folded sequence in the east and the uniformly dipping sequence in the west can be attributed to the differing lithology and depositional environment of the rocks that form the westernmost outcrops of the Finniss River Group. In the more easterly exposures, the flyschoid, basin-fill sediments have been tightly folded, whilst in MOYLE and the western part of WINGATE MOUNTAINS, dominantly quartz-rich sediments and volcanic rocks have been deposited directly on a rigid craton which acted as a resistant block during the deformed period. Although there is some overprinting by later faulting, the quartz-rich sediments have fractured and brecciated rather than being plastically deformed with a corresponding development of a penetrative S1 fabric. Pelitic interbeds and lenses have developed a foliation, which closely parallels bedding (S0). Bedding dips between 35 and 60° SE, with the steeper dips usually associated with younger faulting which slightly crosses the strike.

The Berinka Volcanics have a well developed foliation which trends approximately east and thus slightly cross-cuts the bedding of the enclosing sedimentary units. The variable intensity of this foliation suggests that it is related to zones of high strain trending through the volcanics. This foliation appears to post-date the regional foliation developed during the Top End Orogeny. Both bedding and the strongly developed penetrative foliation in the Henschke Brecia are identical in orientation to those formed in the conglomeratic and pelitic units of the exposures of the Burrell Creek Formation to the east. No fold axes were located within the breccia.

Folding in the Middle Proterozoic Fitzmaurice Group is closely related to faulting. The large syncline in the Moyle River Formation in the northern part of MOYLE has most of its eastern limb truncated by Tom Turners Fault. The Chalanyi Creek Fault disrupts a similar structure to the west. Away from the influence of the major and minor faults, bedding in the Fitzmaurice Group dips gently to moderately to the SE.

Faulting
Several major faults transect the sheet area - the Giants Reef Fault, Tom Turners Fault, Chalanyi Creek Fault, and Henschke Fault. The Giants Reef Fault which approximately marks the SW margin of the Pine Creek Geosyncline, and Tom Turners Fault, coincide in position with ancestral faults along which rifting controlled the development of and sedimentation on the western margin of the geosyncline. This period of tectonism is evidenced by the abundant clasts of stressed vein quartz and low grade metamorphic rocks in the Henschke Brecia which accumulated as a talus along an active fault scarp. The presence of volcanic rocks, and coarse turbidites deposited from a rejuvenated western source area also indicate that deposition of the Finniss River Group, in its western outcrops at least, was partly fault-controlled.

The Giants Reef Fault forms part of a zone of sub-parallel faults and splay on the eastern edge and on the southern margin of the sheet area. To the NE in WINGATE MOUNTAINS and DALY RIVER, the fault is a major dextral strike-slip structure with a horizontal displacement of about 10 km and negligible
vertical offset. Near the eastern margin of MOYLE, it displaces the Finniss River Group, and in the south it brings rocks of the Fitzmaurice Mobile Zone against those of the Pine Creek Geosyncline. Landsat imagery reveals that the fault zone is continuous under Cretaceous cover on the Wingate Plateau, and may connect further south with the Victoria River Fault, although mapping in that region defines the Victoria River Fault as a sinistral structure (Sweet, 1977).

On the eastern edge of the sheet area, map scale drag folds and crumpling of bedding are evident in the Burrell Creek Formation along faults that form the Giants Reef Fault zone. These folds were formed during the last major phase of tecbonism which commenced after the deposition of the Fitzmaurice Group.

In the central eastern part of the sheet area, rocks of the Pine Creek Geosyncline are inferred to be thrust to the NNW over the Hermit Creek Metamorphics and Murra-Kamangee Granodiorite. The fault roughly parallels the trend of the Giants Reef Fault and is indicated by shearing in the underlying granite, brecciation, recrystallisation (but not hornfelsing) in the overlying quartzite, and the planar nature of the contact over several kilometres. The fault plane dips at about 35° SE, parallel to bedding in the overlying quartzite. The magnitude of the displacement on this fault cannot be determined — the absence of the Burrell Creek Formation can be explained by its interfingering relationship with the Chilling Sandstone in the eastern part of this area.

Tom Turners Fault marks the eastern limit of the Fitzmaurice Mobile Zone in the northern part of MOYLE. It shows considerable vertical displacement (where it can be estimated it is approximately 2000 m) downthrowing rocks of the Moyle River Formation against Hermit Creek Metamorphics. The fault probably also has a major dextral component. In the SW the subparallel Chalanyi Creek Fault shows dextral slip, but the vertical offset cannot be determined. The NE trending Henschke Fault juxtaposes Hermit Creek Metamorphics against the Murra-Kamangee Granodiorite. No sense of movement can be gauged for this fault however since the Murra-Kamangee Granodiorite is inferred to underlie the entire area at shallow depth it suggests that vertical displacements may not be very large.

GEOPHYSICS (By T.L.R. Findhammer)

Magnetics
An Airborne magnetic survey over MOYLE was flown in 1984 by Aerodata Holdings Ltd for the NTGS. The results of this survey are available as located, corrected data on magnetic tape, as stacked profiles at 1:100 000 scale, and contoured total magnetic intensity, with the IGRF removed, also at 1:100 000 scale. The stacked profiles have a base value of 47550 nT.

The dominant feature in MOYLE is the magnetic lineament (Figure 7), that closely follows the Giants Reef Fault, and is thought to be caused by Early Proterozoic dolerite dykes of the Wangi Basics (Rodwell, 1980). This lineament, located some 1.5 to 2.5 km east of the surface expression of the fault, has a peak of 250 nT above background located close to the southern edge of the map sheet area. About 6 km to the north of the peak, an east-west dextral fault appears to have displaced the magnetic trend some 600 m.

In MOYLE, the southern two thirds of the lineament trends at 030° and the amplitude steadily decreases in this NE direction. To the NE, the lineament mirrors a change in the trend of the Giants Reef Fault to 050° and at the same time shows interruptions to the linear pattern of the contours, with a clear drop in amplitude. The expression of the magnetic lineament becomes increasingly less distinct towards the NE, and the amplitude continues to diminish. Since the width of the magnetic expression does not increase as the amplitude is reduced, the explanation is not a deepening of the source, but a reduction in the amount of magnetic minerals present. It is quite likely that the original source of the magnetic material was located close to the southern boundary of MOYLE. The stacked profiles over this part of the anomaly show clearly a complex series of superimposed anomalies, undoubtedly due to multiple sources. These reduce in number and intensity further to the NE. The main source of the anomaly is interpreted to be a depth of several hundreds of metres, and dipping to the SE. The magnetic material does not reach the surface, explaining the apparent offset between the magnetic lineament and the Giant Reef Fault. The fault zone has a rather shallow dip to the SE (20-30°) and is fairly wide, as indicated by the multiple magnetic sources existing within it.

Several circular magnetic features can be observed in the central and central-eastern part of MOYLE. One of them (GR FK538302) has a small negative to the NE and has been interpreted as a reversely magnetised volcanic plug (Woyzbun, in Walker, 1969b). The other anomalies, albeit normally magnetised, are in all likelihood also caused by similar volcanic plugs. Depth estimates indicate values of between 700 and 1000 m to the top of the magnetic source material.

The Wangi Basics in the NE corner of MOYLE also display a strong relative magnetic negative on the northern side. This is also interpreted as a reversely magnetised formation consisting of gabbro and hypersthene gabbro (Walker, 1969b; Rodwell, 1980). Although traces of ilmenite have been observed, these appear to be insufficient to explain the strong magnetisation. In the western and NW part of MOYLE, a few isolated outcrops of Murrenja Dolerite have been mapped. The area has very little exposed rock and extensive marshes and floodplains. The magnetic pattern shows that the dolerite is subhorizontal, and together with the sediments of the Moyle River Formation, occurs quite widely throughout the area.

In the north of MOYLE, a prominent quartz vein marks the position of a fault. This fault coincides in position and shape with a curvilinear magnetic high. The anomaly may be due to dolerites intruding along the fault plane, similar to the Giants Reef Fault to the south. The surrounding rock has been mapped as Caimozzo soils over Hermit Creek Metamorphics which are generally nonmagnetic. However, in other areas, the Hermit Creek Metamorphics do, on occasion, contain anomalous magnetic horizons associated with graphitic, ferruginous schists (Poynter, 1981). Occurrences of these schists in the vicinity of the fault could also be the cause of the magnetic high.
Figure 7  Magnetic contours of MOYLE.

Radiometrics
The radiometric data on MOYLE was acquired in 1984 and processed in 1985 by Aerodata Holdings Ltd. The results of this airborne survey are available as located, corrected data on magnetic tape, as stacked profiles for thorium and potassium, and as contoured total radioclement data, all at 1:100 000 scale. The contoured data is in ppm equivalent uranium or units of radioclement concentration (μR), the stacked profiles in ppm equivalent thorium and percent potassium. Most of MOYLE is characterised by an almost complete lack of radiometric response, with values of less than 6 μR (Figure 8). The wetlands in the west, NW and north have even lower values. The drainage channels of the Moyle River and its tributaries are also clearly marked by very low values. Most of the higher values of 6 to 12 μR are associated with Cretaceous rocks on the Wingate Plateau in the central and SW regions of the map sheet area, or with isolated outcrops. Occasional high values occur, eg. over a small granite in the north (GR FK450430), and in association with escarpments where they are probably due to an accumulation of erosion products.

Radiometric anomalies near Murra-Kamangec Hill were investigated by Esso. Drilling failed to discover mineralisation or anomalous radioactivity at depth, in spite of some encouraging results on the surface (Cameron, 1972a and b).

From the total count contour map, there appears to be no relationship between the distributions of the radioactive material and the lithologies in the region.

Gravity
The gravity information on MOYLE is very limited and consists entirely of BMR data. A total number of 51 stations are available; 22 of those stations are from a helicopter survey on a grid of approximately 11 km. The other 29 are from a road survey in the NW part of the map sheet area. The contours, as presented in Figure 9, are from the gravity map in Ferguson and Goleby (1980).

A ridge of high gravity values extends from Bathurst Island in the north, through FOG BAY, ANSON and GREENWOOD into MOYLE. This ridge, defined as the Litchfield Gravity High (Tucker and others, 1980), runs almost due north-south for most of its length, curves to the SE in GREENWOOD, and then to the SW in MOYLE, where it parallels the extension of Tom Turners Fault. The relative values start to diminish in GREENWOOD, and are further reduced in MOYLE.

The significance and possible cause of the ridge have been discussed in the explanatory notes for the above-mentioned map sheet areas, and are commented on by Tucker and others (1980). The interpretation favoured by BMR is a rift-like structure, filled to a depth of 10-15 km with metasediments of a density of 3.0 t/m³, surrounded by a granitic basement with a density of 2.67 t/m³. In MOYLE, the depth of the graben would be much less in view of the reduced amplitude of the anomaly.

An alternative interpretation is given in the FOG BAY explanatory notes (Simons in Hickey, 1985),
where mafic and ultramafic rocks underlie sheets of granitic material. The ultramafic rocks of the Wangi Basics and the occurrence of the Murrenja Dolerite could well support this model.

The regular gradient which is typical of much of the western side of the Litchfield Gravity High is interrupted by a small relative low. The Permian sediments in the western part of MOYLE are known to be relatively unconsolidated and are expected to have a low density. This factor, combined with the occurrence of the Peppimenarti Granite in this area, could explain the Bouguer anomaly contours in the western part of the sheet area. A geologically more attractive solution is a series of step faults in the western flank of a graben that is already considerably shallower than in the sheet areas further north.

The Wangi Basics in the NE corner of the map sheet area not only stand out magnetically, but also coincide with a gravity high. This high appears to branch off from the Litchfield Gravity High and thus might provide a further argument for the source being mafic and ultramafic rocks. A high gravity value on this SE branch coincides with the NE end of the magnetic anomaly which coincides with the fault mapped in that area. This supports the interpretation of a fault with basic material intruded along the fault plane.

The strong gradient in the SE corner of MOYLE closely corresponds to the Giants Reef Fault, including the change in direction in the central east.

**GEOLOGIC HISTORY**

The earliest geologic event recorded in MOYLE is deposition of argillaceous and semi-arenaceous sediments which were later metamorphosed to phyllite, schist and gneiss of the Hermit Creek Metamorphics. Deformation, together with faulting and uplift, preceded and influenced the development of the western margin of the Pine Creek Geosyncline.

Radiometric dating of a tuff horizon in the South Alligator Group (Needham and others, 1985), which underlies the Finniss River Group further east in the geosyncline, shows that deposition of the sediments and extrusion of submarine acid volcanic rocks of the Finniss River Group commenced after about 1880 Ma. Deposition had ceased by about 1870 Ma, when the Top End Orogeny commenced.

In MOYLE, the Finniss River Group sedimentation was initiated, and probably largely controlled, by subsidence associated with faulting along the basin margin. The Henschke Breccia, interpreted as a talus deposit which unconformably overlies and is in places faulted against the basement Hermit Creek Metamorphics, along with the presence of acid volcanics (Berinka Volcanics), provide evidence of growth faults along the western basin margin. These faults, in combination with the absence of the older sequences of the geosyncline, suggest that a more westerly margin developed later in the history of the geosyncline.
Figure 9 Bouger anomaly contours of MOYLE.

Arenaceous sediments of the Burrell Creek Formation were deposited in a predominantly shallow-marine environment. A lateral facies change to a deep-water flysch facies, regionally more typical of the Burrell Creek Formation, is recorded to the east in WINGATE MOUNTAINS (Edgoose and others, 1989). This indicates that, in MOYLE, the Burrell Creek Formation was deposited on the continental margin bordering a deep marine basin (Pine Creek Geosyncline). The sediments of the Burrell Creek Formation pass vertically and laterally into the quartzarenites of the Chilling Sandstone platform sequence, which extended over the continental margin and back-lapped onto the flyschoid sediments in WINGATE MOUNTAINS.

Between 1880 Ma and 1850 Ma the Hermit Creek Metamorphics and the Finniss River Group were intruded by stocks and sills of the Wangi Basins. This was followed by low grade (subgreenstone facies) regional metamorphism, folding and faulting coincident with the 1870 Ma to 1850 Ma Nimbawah Event, during the latter phases of which the granitoids (the Murra-Kamangee Granodiorite, and the Peppimenarti Granite) were emplaced. This tectonic event produced the S2 fabric in the Hermit Creek Metamorphics and folded the Finniss River Group into a broad syncline, the axis of which lies to the SE in WINGATE MOUNTAINS (Edgoose and others, 1989). Erosion exposed the Murra-Kamangee Granodiorite during the Middle Proterozoic, prior to deposition of the Fitzmaurice Group in a fault-bounded trough. Subsidence within this sedimentary basin continued during deposition and as the rate of subsidence largely equalled the rate of sediment supply, a thick, monotonous sequence accumulated. The basin extended north from MOYLE to FOG BAY, and south to the Western Australian border. In contrast, the deposition of the Auvergne Group took place on the relatively stable Sturt Block. After diagenesis, a period of generally NE-SW directed compressional stress led to folding, north- to NE-trending wrench and minor thrust faulting, and localised shearing. During and just after this compressional event, sills and stocks of Ti-Tree Granopyre and Murrenja Dolerite were emplaced.

A long period of erosion followed until the Early Permian, when marine sediments of the Bonaparte Basin extended eastwards into MOYLE. Late Proterozoic movement along Tom Turners Fault probably played an important role in the development of the Palaeozoic Bonaparte Basin. The ensuing period of erosion continued until the Early Cretaceous marine transgression. During the Early Tertiary, epeirogenic uplift was followed by penplanation; the resultant widespread erosion surface, named the 'Tennant Creek Surface' by Hays (1968), is now preserved in the north and south-central areas of MOYLE as the Wingate Plateau.

A rise in sea-level during the Late Pleistocene drowned the lower reaches of the Moyle River. During the Holocene a subsequent small drop in sea-level exposed the estuarine sediments (Christian and Stewart, 1953) over which fresh water black clays have been deposited.
ECONOMIC GEOLOGY

There is no recorded mineral production for MOYLE. As companies were not required to submit details of their activities prior to 1970, incomplete records are available for exploration programs. United Uranium NL (Larsen, 1964) and CRAE (Patterson, 1967) had Authorities to Prospect (APs) which included part of MOYLE but neither did detailed work. In response to the favourable uranium market of the late 1950s and 1960s and the discovery of uranium at Rum Jungle, Planet Mining, later in joint venture with Esso Australia, undertook detailed studies over anomalies identified in an early radiometric survey of the Muldiya Creek-Moyle River area (BMR, 1956 in Walker, 1968; Walker 1969a and b; Cameron 1972a and b). In the course of their activities which included a geophysical survey, they investigated several other targets, primarily for uranium. Utah conducted a drilling program in the NW corner of the sheet area to establish the presence of coal in the Permian rocks of the Bonaparte Basin (Williams, 1973). Coal streaks were intersected in a few of these holes including one seam 0.6 m thick. Utah concluded that the lithologies present indicated there was little potential for thick coal seams, but noted a possibility of commercial quantities of a ‘...pure white very fine clay...’ at depth. In the late 1970s and 1980s Suttons, the then owners of Elizabeth Downs and Fish River pastoral leases, took out Exploration Licences (EL’s) over large areas of their leases. They conducted exploration programs for a range of commodities (Binns, 1978; Dewar, 1978; Thomas, 1979; Robertson Research (Australia) Pty Ltd, 1980; Mobil Energy Minerals Australia Inc, 1980; Hill, 1981; Poynter, 1981; Manning, 1982; Bravo, 1982; Richardson and Bravo, 1983; Richardson, 1983; O’Connor, 1983). Methods employed in the extensive exploration program included detailed photogeologic interpretation, airborne magnetic and radiometric surveys, geologic reconnaissance, stream sediment geochemical surveys and drilling. Mobil Energy Minerals Australia Inc. became joint venturers with Suttons in several EL’s. At the end of the exploration program it was concluded that there was a low potential for economic deposits in the area. AOG Minerals Pty Ltd searched for uranium with a program of airborne geophysics, drilling, mapping and sampling with negative results (Berkman, 1978a and b; Berkman, 1980; Boyd, 1979).

Water

MOYLE has plentiful supplies of surface water suitable for stock. Numerous springs flow throughout the dry season, especially in SW of the sheet area where they originate on the Wingate Plateau and flow northwards and westwards where they feed the Moyle River and some of the smaller permanent creeks.

Henschke Falls are spring-fed, permanent, and are a major supply of water for Tom Turners Creek. An abundance of permanent waterholes dot the extensive plain in the northern half of MOYLE. The Peppimenarti Settlement uses numerous bores to supply the community with water for domestic purposes (Power, 1983).

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REFERENCES


24


**APPENDIX**

**NEW STRATIGRAPHIC UNIT**

Peppimenarti Granite (C.J. Edgoose)

Derivation of name: Name derived from Peppimenarti Aboriginal Settlement, Daly River Aboriginal Reserve. Peppimenarti is situated within the outcrop area, and translates as “Big Rock”.

Distribution: The granitoid crops out over about 3 km² on the north and south side of Tom Turners Creek, in an area bounded by the AMG co-ordinates 154375, 177375, 154365, 177363.

Type area: As above.

Lithology: Ranges in composition from adamellite to granite; also includes aplite and pegmatic phases. The adamellite is a coarse grained, equigranular rock consisting of plagioclase, K-feldspar, quartz and biotite. The granite is fine to medium grained and consists of quartz, K-feldspar and plagioclase in an interlocking granular mosaic. The granitoid is pervasively altered, with sericite and chlorite forming the dominant secondary mineral phases.

Relationships: Overlain unconformably by quartzarenites of the Middle Proterozoic Moyle River Formation. Intruded by the Middle (Late) Proterozoic Murrenja Dolerite, although this relationship is interpreted from other evidence as it is not clearly demonstrated in the field.

Age and correlation: The Peppimenarti Granite is separated from the Early Proterozoic Murra-Kamagge Granodiorite to the east and the Wagait Granite to the north by younger sedimentary sequences. It has the same field relationships with other units as the two above mentioned granitoids. Geochemically, the Peppimenarti Granite is similar to the Wagait Granite. Therefore all three granitoids are believed to have crystallised during the same intrusive event. U-Pb dating of both the Wagait and Murra-Kamagge Granitoids puts this event at 1840-1850 Ma (Page and others, 1984).

Synonymy: Previously undivided from the “Litchfield Complex”, a blanket term for all the granitoids of the Litchfield Province (Morgan, 1972).