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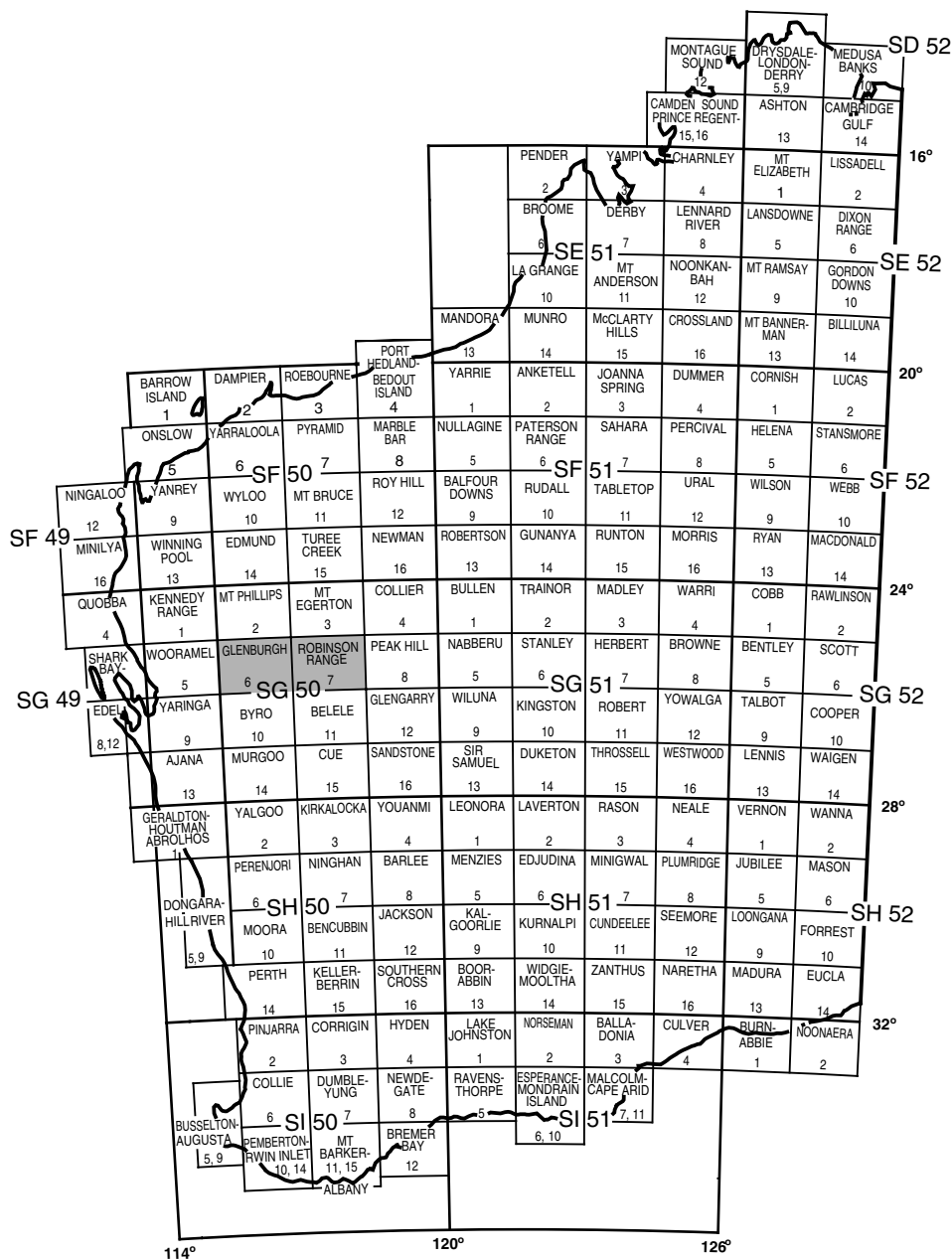
# **GEOLOGY OF THE ERRABIDY AND LANDOR 1:100 000 SHEETS**

**by S. Sheppard and S. A. Occhipinti**

**1:100 000 GEOLOGICAL SERIES**



**GEOLOGICAL SURVEY OF WESTERN AUSTRALIA  
DEPARTMENT OF MINERALS AND ENERGY**



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**GEOLOGICAL SURVEY OF WESTERN AUSTRALIA**

# **GEOLOGY OF THE ERRABIDY AND LANDOR 1:100 000 SHEETS**

by  
**S. Sheppard and S. A. Occhipinti**

**Perth 2000**

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**Cover photograph:**

**View north over the Errabiddy Shear Zone, from the Petter Calc-silicate of the Camel Hills Metamorphics.**

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# Geology of the Errabiddy and Landor 1:100 000 sheets

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## Abstract

The ERRABIDDY and LANDOR 1:100 000 sheets straddle the eastern end of the Errabiddy Shear Zone, which marks the boundary between the northwestern edge of the Archaean Yilgarn Craton and the southern margin of the Palaeoproterozoic Gascoyne Complex.

The Narryer Terrane forms the northwestern part of the Yilgarn Craton, and is mainly composed of early to late Archaean granitic gneisses intruded by late Archaean granite sheets and plutons. Numerous layers of amphibolite, metamorphosed ultramafic rock, calc-silicate gneiss, quartzite, and metamorphosed banded iron-formation are tectonically interleaved with the granitic gneisses.

On ERRABIDDY and LANDOR, the Gascoyne Complex comprises the Glenburgh Terrane, the Camel Hills Metamorphics, and granites of the Moorarie Supersuite. In this region the Glenburgh Terrane consists of meta-igneous rocks of the Dalgaringa Supersuite, comprising 2005–1985 Ma foliated and gneissic granites intruded by c. 1975 Ma tonalite and granodiorite of the Nardoo Granite. The foliated to gneissic granites were deformed and metamorphosed at medium to high grade during the Glenburgh Orogeny before intrusion of the Nardoo Granite. High-grade metasedimentary rocks of the Camel Hills Metamorphics are confined to the Errabiddy Shear Zone. These metamorphic rocks are subdivided into the Petter Calc-silicate, which consists of calc-silicate schist and gneiss, and the Quartpot Pelite, which consists of pelitic schist and gneiss, and migmatitic pelitic gneiss. Protoliths to the Petter Calc-silicate were derived from the Archaean Yilgarn Craton, whereas the protoliths to the Quartpot Pelite were derived from a now unexposed Palaeoproterozoic terrain. The Dalgaringa Supersuite and Camel Hills Metamorphics were both deformed and metamorphosed at medium grade during the latter stage of the Glenburgh Orogeny.

The northeastern part of the Narryer Terrane was pervasively deformed and metamorphosed, and intruded by granite sheets and dykes between 1820 and 1800 Ma during the Capricorn Orogeny, and is referred to as the Yarlarweelor gneiss complex. During the same period, the Glenburgh Terrane and Camel Hills Metamorphics on LANDOR were intruded by batholithic masses of granite belonging to the Moorarie Supersuite. Also during the Capricorn Orogeny, the Gascoyne Complex was deformed and metamorphosed at low to medium grade. Palaeoproterozoic siliciclastic sedimentary rocks of the Mount James Formation developed on top of, and are in faulted contact with, rocks of the Gascoyne Complex. The formation was probably deposited during the waning stages of the Capricorn Orogeny.

Sedimentary rocks of the latest Palaeoproterozoic to Mesoproterozoic Bangemall Supergroup rest unconformably on, or are in faulted contact with, the Gascoyne Complex. Sills of dolerite and gabbro intruded the Bangemall Supergroup at c. 1020 Ma. The Bangemall Supergroup was deformed into upright folds with easterly to southeasterly trending axes during the c. 1000 Ma Edmundian Orogeny. During this time, east-southeasterly trending faults that may have initially formed during the Palaeoproterozoic were reactivated and filled with quartz veins.

**KEYWORDS:** Yilgarn Craton, Narryer Terrane, Gascoyne Complex, Glenburgh Terrane, Yarlarweelor gneiss complex, Camel Hills Metamorphics, Glenburgh Orogeny, Capricorn Orogeny, Palaeoproterozoic, granite, deformation, regional geology

## Introduction

### Location, access, and previous work

The ERRABIDDY\* and LANDOR 1:100 000 sheets lie within the Gascoyne region of Western Australia. ERRABIDDY (SG 50-7, 2347) and LANDOR (SG 50-6, 2247) cover the northwestern portion of the ROBINSON RANGE 1:250 000

sheet and the northeastern part of the GLENBURGH 1:250 000 sheet respectively.

Beef cattle and sheep grazing are the only commercial activities on ERRABIDDY and LANDOR. Errabiddy Homestead is located in the southwest corner of ERRABIDDY, and Landor Homestead is located in the northeast corner of LANDOR. There are no sealed roads, but several well-maintained, unsealed roads service the sheet areas. Errabiddy and Landor homesteads are linked by the Landor–Meekatharra Road, which also provides access to Meekatharra, about 200 km southeast of ERRABIDDY. Meekatharra can also be reached from LANDOR via the Landor – Mount Clere Road. From LANDOR, access to Mount Augustus 80 km to the north is provided by the

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\* Capitalized names refer to standard 1:100 000 map sheets. Where 1:100 000 and 1:250 000 sheets have the same name, the 1:100 000 sheet is implied, unless otherwise indicated.

Landor – Mount Augustus Road, and access to Gascoyne Junction and Carnarvon to the west is provided by the Landor – Dalgety Downs Road. A network of station tracks provides year-round access to most parts of the two sheet areas.

Geological investigations prior to 1980 on ERRABIDDY are covered in the Explanatory Notes for the first edition ROBINSON RANGE 1:250 000 sheet (Elias and Williams, 1980). Geological investigations prior to 1983 on LANDOR are covered in the Explanatory Notes for the second edition GLENBURGH 1:250 000 sheet (Williams et al., 1983b). More recent work is referred to when appropriate in the following notes.

Remapping of ERRABIDDY and LANDOR was carried out in 1997 and mainly concentrated on the Archaean rocks of the Narryer Terrane (Yilgarn Craton), Archaean and Palaeoproterozoic igneous rocks of the Yarlalweelor gneiss complex, and Palaeoproterozoic rocks of the Gascoyne Complex. Some remapping of Mesoproterozoic sedimentary rocks of the Bangemall Supergroup on the northern part of ERRABIDDY was also carried out. ERRABIDDY and LANDOR straddle the eastern end of the Errabiddy Shear Zone, which marks the boundary between the Archaean Narryer Terrane, the Archaean to Palaeoproterozoic Yarlalweelor gneiss complex, and the Palaeoproterozoic Gascoyne Complex.

## Physiography, vegetation, and climate

ERRABIDDY and LANDOR contain five main physiographic units (Fig. 1). These comprise the Gascoyne River and its tributaries; floodplains and low-gradient sheetwash plains; upland areas in the western and southern parts of LANDOR and along the southern and eastern edges of ERRABIDDY; dissected strike ridges in the northeastern corner of ERRABIDDY; and small areas of an old, dissected land surface present in the southwestern corner of LANDOR and along the eastern edge of ERRABIDDY.

The Gascoyne River system consists of sandy watercourses and braided streams and is surrounded by broad alluvial floodplains and low-gradient sheetwash areas. The upland areas consist of broad rises and low, rugged hills of metamorphic rock and granite dissected by dendritic, incised creeks. In the southern parts of the sheet areas, these uplands form a drainage divide between the Gascoyne River to the north, and the Murchison River to the south. Areas of ferruginous duricrust and weathered quartzofeldspathic rock are present in the southeast corner of ERRABIDDY and on the western and central east parts of LANDOR. These areas are remnants of an extensive Tertiary land surface, which is better preserved further to the west (Elias and Williams, 1980). In the northeast corner of ERRABIDDY, resistant sedimentary rocks, such as quartz sandstone and chert, form prominent strike ridges, whereas shale and siltstone underlie the intervening valleys.

The floodplains and sheetwash areas are mainly occupied by open mulga woodland. The woodland consists of an open tree layer with a sparse, low shrub

layer and a ground cover of grasses and ephemeral herbs (Beard, 1981). A large part of the woodland shows a banded, mosaic vegetation pattern on aerial photographs ('tiger bush'; Wakelin-King, 1999). It consists of low vegetated dunes alternating with sparsely vegetated inter-ridge areas. Large bare areas are also present in some parts of the sheetwash and on low-gradient colluvial deposits. On low, rocky hill slopes, rock fuchsia bush, terpetine bush, and green cassia are abundant. The main river channels are lined by ghost gums and various acacias, while many of the smaller creeks are fringed by creekline miniritchie. The poor stony soils of the uplands are dominated by acacia and mulga scrub.

ERRABIDDY and LANDOR have a semi-arid climate with hot summers and mild winters. January is the hottest month with an average daily maximum temperature of about 39°C, and an average daily minimum temperature of 25°C. July is the coolest month with an average daily maximum temperature of 21°C, and an average daily minimum temperature of 8°C. The mean annual rainfall recorded at Errabiddy Homestead is about 200 mm\*. Almost all of this rain falls between January and July. Rainfall between January and April is provided by rain-bearing depressions from the northwest, and by more localized thunderstorms. In late autumn and winter, rain is produced by the interaction of tropical cloud bands from the north-northwest with strong cold fronts approaching from the southwest. All the creeks on ERRABIDDY and LANDOR are ephemeral, and the Gascoyne River flows only after heavy rain.

## Regional geological setting

ERRABIDDY and LANDOR lie within the Capricorn Orogen (Fig. 2), which formed during the collision and suturing of the Archaean Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990). This orogen includes medium- to high-grade metamorphic rocks and granites of the Gascoyne Complex, a number of Palaeoproterozoic sedimentary basins (such as the Bryah and Padbury Basins), and the deformed margins of the Pilbara and Yilgarn Cratons. On MARQUIS and MOORARIE immediately east and southeast of ERRABIDDY, granite intrusion and medium- to high-grade metamorphism associated with this collision have been dated at 1820–1800 Ma by Occhipinti et al. (1998). The main tectonic elements on ERRABIDDY and LANDOR are the Archaean Narryer Terrane (Yilgarn Craton), the Yarlalweelor gneiss complex, the Palaeoproterozoic Gascoyne Complex, and the Mesoproterozoic Edmund Basin (formerly Bangemall Basin, see **Bangemall Supergroup**; Figs 2 and 3; Tables 1 and 2).

The Narryer Terrane (Myers, 1990c) represents one of the largest fragments of early Archaean (>3300 Ma) crust on earth. The terrane comprises several groups of gneiss, derived from early to late Archaean granites, and interleaved metasedimentary and mafic igneous rocks (Williams and Myers, 1987; Nutman et al., 1991). The Narryer Terrane was repeatedly deformed and

\* Climate data from Commonwealth Bureau of Meteorology website, 2000.

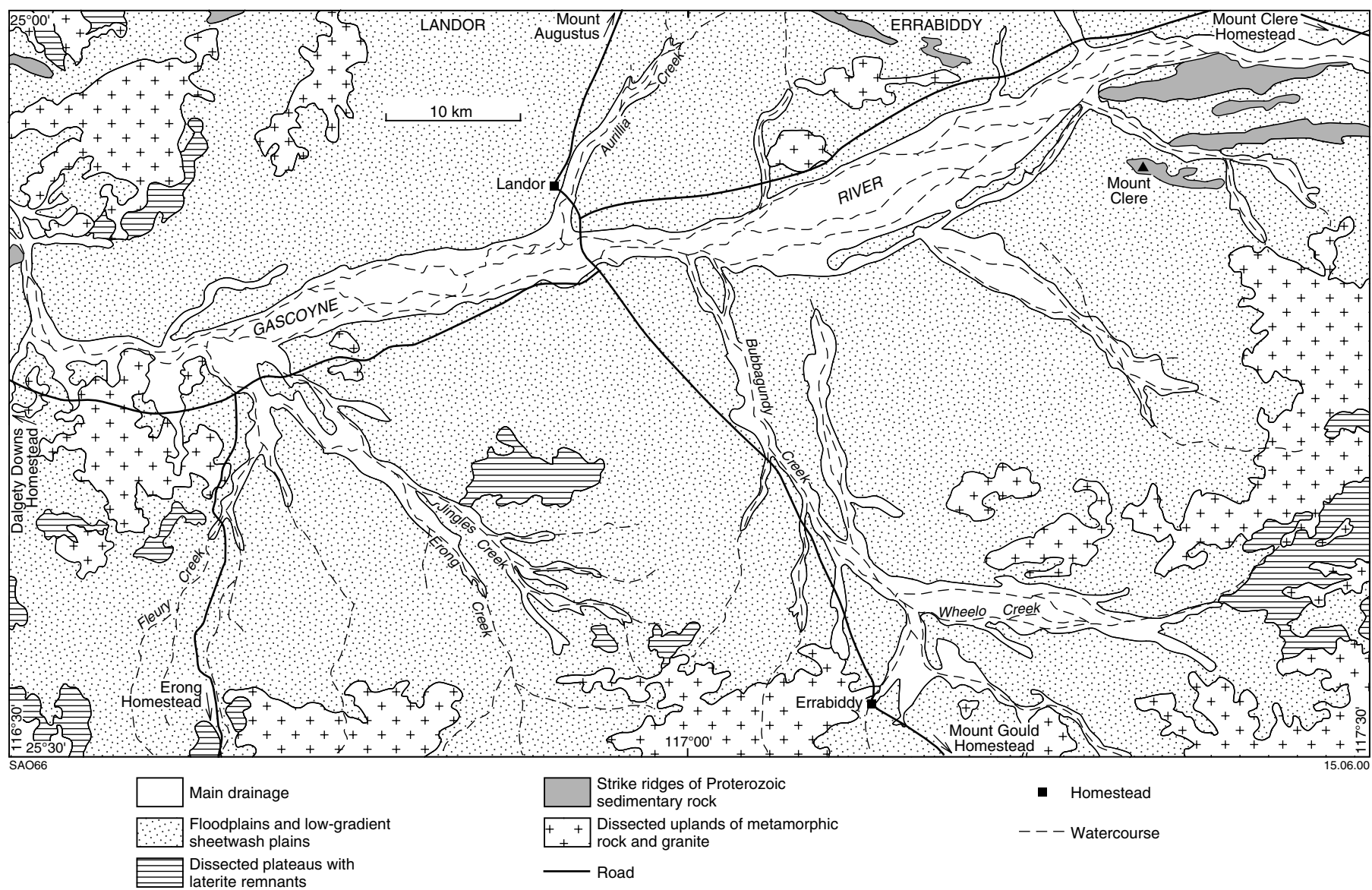
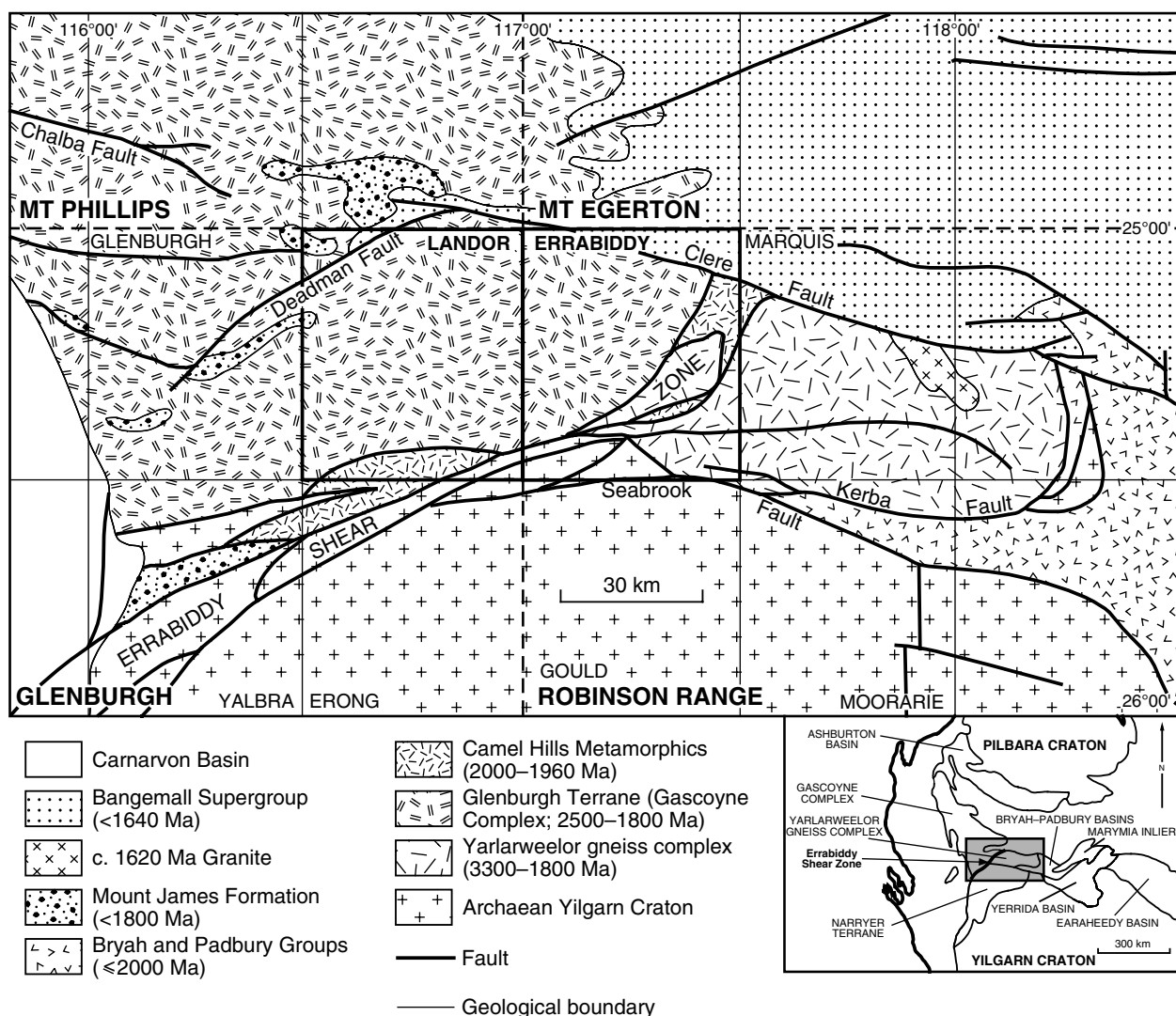


Figure 1. Physiographic and drainage sketch map of Errabiddy and Lander



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Figure 2. Simplified map showing the relationship of ERRABIDDY and LANDOR to major tectonic units in the region

metamorphosed, and extensively intruded by granites\* in the late Archaean (Myers, 1990b). The Yarlalweelor gneiss complex (Occhipinti and Myers, 1999; Sheppard and Swager, 1999) includes part of the Narryer Terrane that was deformed and metamorphosed, and intruded by voluminous granite sheets and dykes during the Palaeoproterozoic. The Yarlalweelor gneiss complex is separated from the Narryer Terrane by the Seabrook Fault. Elias and Williams (1980) and Williams (1986) referred to the 'Yarlalweelor gneiss belt', which encompassed a much larger area extending as far south as the Bullbadger Shear Zone on GOULD. The 'gneiss belt' included Archaean gneisses that were unaffected by Palaeoproterozoic deformation, other than in discrete shear zones, as well as undeformed and little-deformed, late Archaean granites.

\* In these notes the term 'granite' is used to refer to any quartz-bearing plutonic rock. Specific granite types are referred to using recommended IUGS terminology (Streckeisen, 1976); e.g. monzogranite, syenogranite, etc.

The Narryer Terrane and Yarlalweelor gneiss complex are separated from the Gascoyne Complex to the north and northwest by the Errabiddy Shear Zone (Fig. 2; Williams et al., 1983b). The Gascoyne Complex mainly consists of medium- to high-grade, Palaeoproterozoic meta-igneous and metasedimentary rocks extensively intruded by granite (Williams, 1986; Myers, 1990a). Metasedimentary rocks on ERRABIDDY and LANDOR are mainly confined to the Errabiddy Shear Zone. Both the Narryer Terrane and Yarlalweelor gneiss complex are in faulted contact with the Palaeoproterozoic Padbury and Bryah Basins (Fig. 2; Myers, 1990b; Occhipinti et al., 1996). Low-grade metasedimentary and meta-igneous rocks of these basins were tectonically interleaved with the Yarlalweelor gneiss complex during the Capricorn Orogeny.

Palaeoproterozoic rocks of the Mount James Formation are in faulted contact with rocks of the Gascoyne Complex. Mesoproterozoic sedimentary rocks of the Bangemall Supergroup are unconformable on, or are in



**Table 1. Summary of the structural, metamorphic, and magmatic history of Archaean rocks on the ROBINSON RANGE and GLENBURGH 1: 250 000 sheets**

Age (Ma)	Narryer Terrane	Reworked Narryer Terrane (Yarlarweelor gneiss complex)
3730–2920	Narryer Terrane: Intrusion of granite protoliths to the leucocratic and mesocratic granitic gneisses ( <i>Angl</i> , <i>Angm</i> )	
2750–2640	Intrusion of granite sheets into gneisses. Deformation ( $D_2 - D_3$ ) and high-grade metamorphism; development of gneissic layering	
2630–2600	Intrusion of biotite monzogranite sheets, plugs, and plutons into the Narryer Terrane (Yilgarn Craton)	
1960	Intrusion of biotite monzogranite of the Bertibubba suite into northwestern part of the Narryer Terrane (Yilgarn Craton)	
1820–1800	Intrusion of voluminous biotite granite into part of the Narryer Terrane. Deformation and metamorphism during the Capricorn Orogeny ( $D_{1n}$ , $D_{2n}$ ). Formation of Yarlarweelor gneiss complex ( <i>Ængl</i> , <i>Ængm</i> )	

faulted contact with, the Yarlarweelor gneiss complex, Gascoyne Complex, and Mount James Formation.

## Archaean geology

### Yilgarn Craton

Myers (1988) introduced the term Narryer Gneiss Complex for the ‘early Archaean rocks ( $\geq 3300$  Ma) . . . consisting of high-grade gneisses mainly derived from granite and minor sedimentary rocks and basic intrusions . . .’ forming the northwestern part of the Archaean Yilgarn Craton. Myers (1990c) subsequently introduced the term Narryer Terrane for the late Archaean fragment of continental crust characterized by early Archaean rocks of the Narryer Gneiss Complex, and intruded by numerous late Archaean granites during accretion with the Murchison Terrane (Myers, 1993).

Gneisses of the Narryer Terrane belong to several groups (Williams and Myers, 1987; Myers, 1990b) or associations (Nutman et al., 1991, 1993). Extensive U–Pb (zircon) sensitive high-resolution ion microprobe (SHRIMP) geochronological work in the southern and central parts of the Narryer Terrane (summarized in Nutman et al., 1993), indicates that the granite protoliths to the gneisses ranged in age from 3730 to 3300 Ma and 3000 to 2920 Ma. The early gneisses were intruded by widespread sheets of granite at 2750–2620 Ma, broadly coincident with a major episode of deformation and metamorphism (Kinny et al., 1990; Myers, 1990b). These later intrusions now range from strongly banded and pegmatite-veined granitic gneiss to little-deformed, discordant sheets with igneous textures (Myers, 1990b).

Myers (1990b) attributed the 2750–2620 Ma granite magmatism and deformation to collision of the Narryer Terrane with the Murchison Terrane to the east, and thrusting and stacking of the Narryer Terrane onto the Murchison Terrane. Nutman et al. (1993) interpreted the 3730–3300 Ma gneisses in terms of an allochthon that was

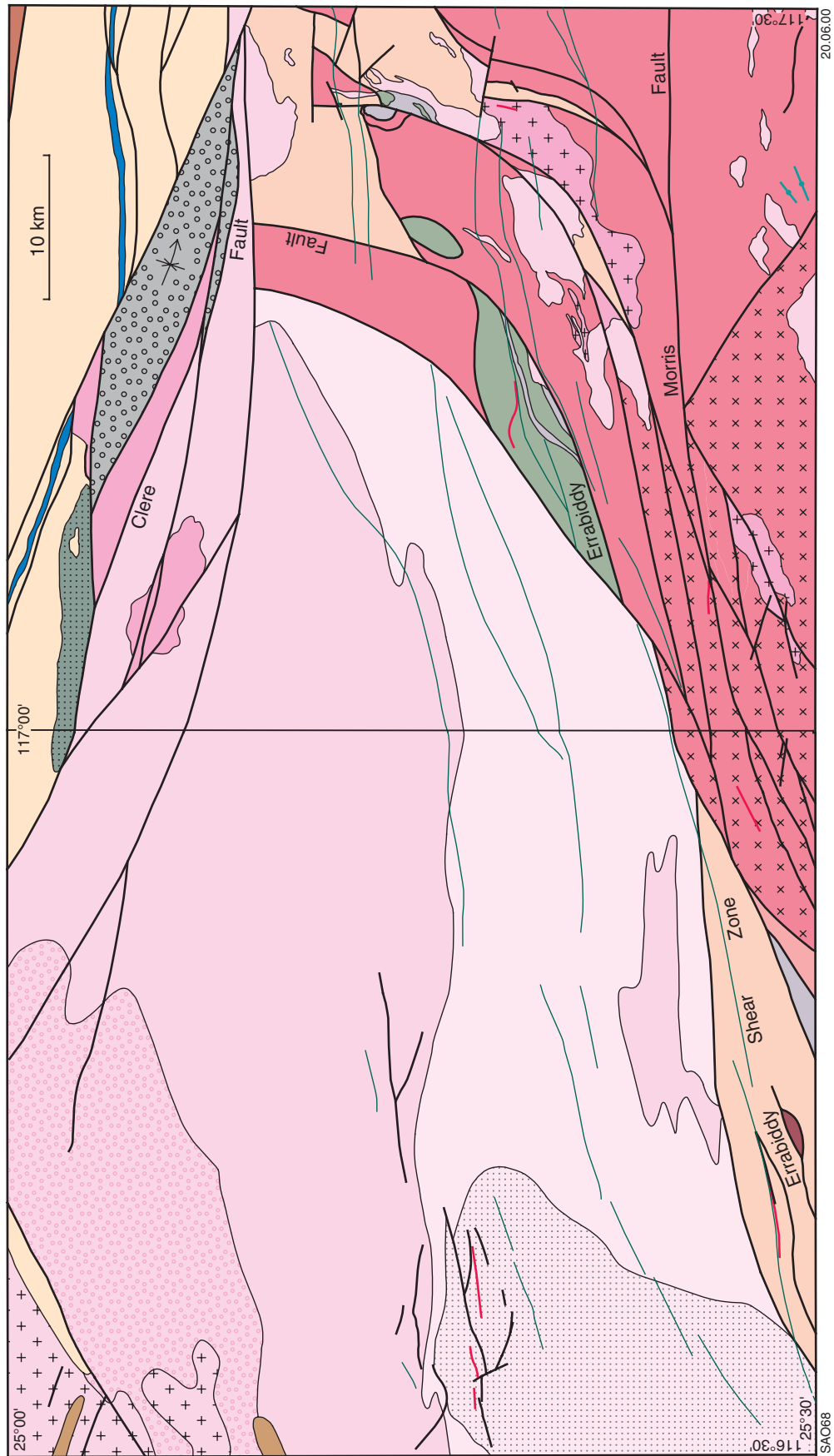
thrust over the 3000–2920 Ma gneisses, with subsequent partial melting of the younger gneisses to produce the late Archaean granites. The Yarlarweelor gneiss complex (Figs 2 and 3; Sheppard and Swager, 1999) in the eastern and southeastern parts of ERRABIDDY includes part of the Narryer Terrane that was strongly overprinted by Palaeoproterozoic deformation, metamorphism (Williams, 1986), and voluminous granite intrusion (Occhipinti et al., 1998). A southeasterly trending fault zone, the Seabrook Fault (Figs 2 and 3), marks the contact between the Yarlarweelor gneiss complex and Archaean Narryer Terrane to the west.

### Leucocratic granitic gneiss (*Angl*, *Ængl*)

Banded leucocratic granitic gneiss is the major component of the Narryer Terrane and Yarlarweelor gneiss complex on ERRABIDDY and LANDOR. It forms low, rocky hills and is dissected by a close-spaced network of dendritic creeks. The gneisses are commonly weathered, but exposure is commonly good. Fresh rock is locally present west of Errabiddy Homestead.

Leucocratic granitic gneiss is subdivided into two rock units; Archaean gneiss (*Angl*) and reworked gneiss (*Ængl*; Table 1). Archaean gneiss consists of middle to late Archaean granitic protoliths with Archaean structures and fabrics preserved. Reworked gneiss outcrops in the Yarlarweelor gneiss complex on the eastern part of ERRABIDDY, and is a composite of Archaean and Palaeoproterozoic components. The reworked leucocratic granitic gneiss is characterized by the presence of abundant sheets and veins of coarse-grained biotite granite and pegmatite (*BgMp*). Both varieties of gneiss consist of several interlayered rock types that have been repeatedly deformed and metamorphosed.

Nutman et al. (1991) reported a SHRIMP U–Pb zircon age of  $3298 \pm 6$  Ma for a sample of banded, even-textured, reworked granitic gneiss on MOORARIE. In addition, a sample of leucocratic gneiss from a low-strain zone of reworked gneiss on MOORARIE gave a crystallization age of  $3292 \pm 4$  Ma for the granite precursor (Nelson, 1998;



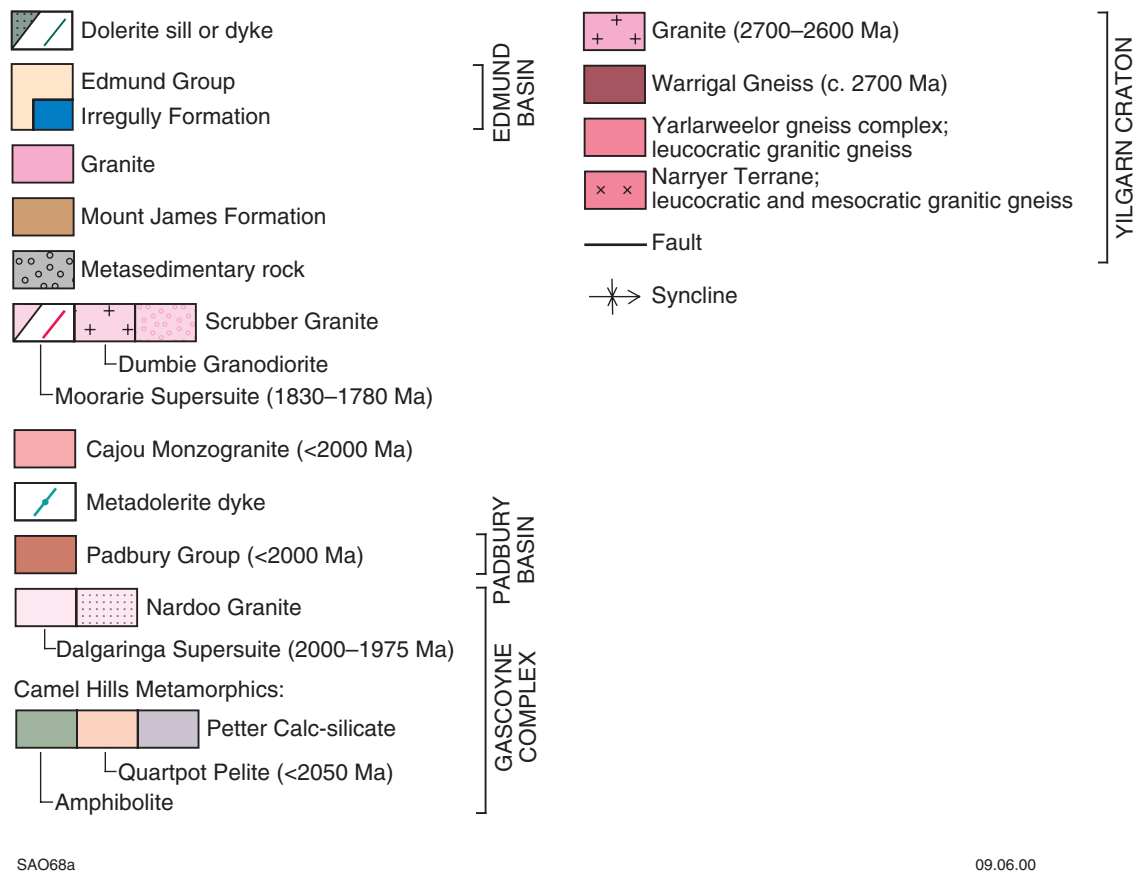


Figure 3. Simplified geological map of ERRABIDDY and LANDOR

Table 2. Summary of the Proterozoic geological history of ERRABIDY and LANDOR

Orogeny	Age (Ma)	Domain		
		Glenburgh Terrane	Errabiddy Shear Zone	Yarlarweelor gneiss complex
<b>GLENBURGH</b>				
?	2000–?1960		Deposition of precursor sedimentary rocks to Camel Hills Metamorphics onto ?northern Yilgarn Craton, ?southern Gascoyne Complex	
D <sub>1g</sub> , M <sub>1g</sub>	<c. 2000	Foliation (S <sub>1g</sub> ) in folded pegmatite, banded fine-grained tonalite, granodiorite or monzogranite. Medium- to high-grade metamorphism		
M <sub>1g</sub>	c. 1989	Local folding of c. 2000 Ma granite and intrusion of pegmatite, quartz diorite, and monzogranite. High-grade metamorphism up to granulite facies		
	c. 1975	Intrusion of veins, sheets, and dykes of the Nardoo Granite		
D <sub>2g</sub> , M <sub>2g</sub>	c. 1960		High-grade metamorphism; deformation and local migmatization of Camel Hills Metamorphics	Intrusion of granites of the Bertibubba suite
	c. 1960	Deformation of Nardoo Granite (S <sub>2g</sub> )		
	c. 1960		Intrusion of veins of biotite trondhjemite into Quartpot Pelite of the Camel Hills Metamorphics; local recumbent to subhorizontal tight folding of calc-silicate rocks of Camel Hills Metamorphics	
<b>CAPRICORN</b>				
D <sub>1n</sub> , M <sub>1n</sub>	1830–1810	~~~~~ Intrusion of sheets, veins, and dykes of leucocratic granite. Upright folding (F <sub>1n</sub> , S <sub>1n</sub> ), dextral shearing ~~~~~		
	c. 1810	Intrusion of Dumbie Granodiorite		
D <sub>2n</sub> , M <sub>2n</sub>	c. 1795	Intrusion of Scrubber Granite		Intrusion of granite dykes
Local extension	1795–?	Deposition of Mount James Formation sediments in possible pull-apart structures		
<b>post-CAPRICORN</b>	?>1640	Coplanar deformation with D <sub>1n</sub> <sup>(a)</sup> possible into tight asymmetric folds ~~~~~		
		Deformation of Mount James Formation		
Extension leading to rifting and intracratonic sag	?< 1640	Deposition of Bangemall Supergroup		Deposition of Bangemall Supergroup
<b>EDMUNDIAN</b>				
	c. 1020	~~~~~ Intrusion of voluminous dolerite sills into Bangemall Supergroup ~~~~~		
D <sub>1e</sub>	post c.1020	~~~~~ Deformation of Bangemall Supergroup (F <sub>1e</sub> , S <sub>1e</sub> ), easterly structures coplanar with D <sub>1n</sub> structures. Subgreenschist facies metamorphism		
D <sub>2e</sub>	?post c.1020	~~~~~ Deformation of the Bangemall Supergroup, folds (S <sub>2e</sub> , F <sub>2e</sub> ) and faults, northerly trends ~~~~~		
	c. 750	~~~~~ Intrusion of dolerite dykes ~~~~~		

NOTE: (a) Alternatively the Mount James Formation may have been deformed during the Edmundian Orogeny



Occhipinti and Myers, 1999). This sample is representative of a rock type that forms much of the leucocratic gneiss unit, including that on ERRABIDDY and LANDOR.

Reworked leucocratic granitic gneiss (*Angl*) of the Yarlalweelor gneiss complex contains late Archaean granite plugs, dykes, and veins that were strongly deformed, metamorphosed, and intruded by felsic granites during the Palaeoproterozoic. In areas of low Palaeoproterozoic strain, the late Archaean granites are locally preserved. For example, in the northwestern corner of MOORARIE, a folded dyke of foliated, fine-grained biotite monzogranite cuts the gneissic layering in the leucocratic granitic gneiss, and has been dated at  $2656 \pm 4$  Ma (GSWA 142848; Nelson, 1999). On ERRABIDDY east of Erminea Waterhole and around Bullaroo Hill, deformed sheet-like intrusions of foliated, medium- to coarse-grained porphyritic biotite monzogranite (*Agpr*) dated at  $2594 \pm 4$  Ma (GSWA 142903; Nelson, 1999) are preserved within the leucocratic granitic gneiss. East of Bullaroo Hill, folded leucocratic granitic gneiss is commonly cut by a well-foliated, fine-grained porphyritic biotite monzogranite that is probably late Archaean in age.

#### Archaean leucocratic granitic gneiss (*Angl*)

Archaean, banded leucocratic granitic gneiss (*Angl*) mainly outcrops in the southwestern corner of ERRABIDDY, west of Errabiddy Homestead, and in the adjacent southeastern corner of LANDOR. It is contained in a series of fault slices within the Errabiddy Shear Zone.

Archaean leucocratic gneiss is a composite of several different quartz-rich rock types ranging from tonalite to syenogranite, with monzogranite and granodiorite compositions the most abundant. The unit also includes minor amounts of mesocratic granitic gneiss (*Angm*). There are no sharp boundaries between the leucocratic and mesocratic granitic gneiss units, and they are tectonically interleaved on both a mesoscopic and megascopic scale. Leucocratic granitic gneiss is also tectonically interleaved with metamorphosed ultramafic rock (*Aus*), amphibolite (*Aba*), metamorphosed banded iron-formation (*Aci*), and quartzite gneiss (*Asq*). Lower strain domains of the leucocratic granitic gneiss (*Angl*) consist of foliated, coarse-grained biotite granite through to gneissic granite with a flaser fabric. The coarse-grained leucocratic biotite granite contains inclusions of amphibolite and banded granitic gneiss.

The leucocratic granitic gneiss is intruded by a range of late Archaean and Palaeoproterozoic granites, in the form of plugs, sheets, veins, and dykes. The intrusive rocks include mesocratic, strongly porphyritic biotite monzogranite (*Agp*); augen gneiss and coarse-grained porphyritic biotite monzogranite (*Agpr*); medium-grained, even-textured biotite monzogranite (*Age*); and coarse-grained biotite granite and pegmatite (*Egmp*).

The two main rock types making up the Archaean leucocratic gneiss are medium-grained leucocratic gneiss with thin, discontinuous layers of biotite (Fig. 4), and fine- to medium-grained, strongly banded granitic gneiss. Both rock types contain up to 10% biotite with accessory



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**Figure 4.** Folded, pegmatite-banded leucocratic granitic gneiss on ERRABIDDY (at MGA 006842). The shallowly plunging fold on the left of the figure is rotated into the steeply plunging fold at the right of the figure. Note pen for scale

allanite, zircon, and apatite, and trace magnetite. Abundant secondary epidote and sericite, recrystallization of quartz, and fine-grained granophyric textures reflect a later, lower grade metamorphic event.

### **Reworked leucocratic granitic gneiss (*Ængl*)**

Reworked leucocratic granitic gneiss (*Ængl*) is confined to the Yarlalweelor gneiss complex. It outcrops over a large area on the eastern part of ERRABIDY, and also outcrops extensively to the east and southeast on MARQUIS (Sheppard and Swager, 1999) and MOORARIE (Occhipinti and Myers, 1999). Reworked leucocratic granitic gneiss contains abundant sheets and veins of Palaeoproterozoic coarse-grained granite and pegmatite (*EgMp*). The coarse-grained granite and pegmatite sheets were intruded during deformation and medium- to high-grade metamorphism at c. 1812 Ma (Occhipinti et al., 1998; Sheppard and Swager, 1999; see **Capricorn Orogeny**). The gneiss is also intruded by a plug east of Wheelo Bore and numerous dykes of Palaeoproterozoic even-textured muscovite–biotite granite (*EgMv*) south and east of Wheelo Bore dated at  $1802 \pm 9$  Ma (see **Leucocratic muscovite–biotite granite**).

The leucocratic granitic gneiss (*Ængl*) displays a variety of textures reflecting different strain states, all overprinted by lower grade metamorphic events. Lower strain domains of the gneiss indicate that the precursors were mainly medium- to coarse-grained monzogranite and granodiorite.

### **Mesocratic granitic gneiss (*Angm*, *Ængm*)**

Mesocratic granitic gneiss (*Angm*, *Ængm*) is a minor component of the Narryer Terrane on ERRABIDY and LANDOR. The mesocratic gneiss forms low, rounded hills with extensive outcrop. The gneiss is commonly weathered, but fresh exposures are locally present.

Mesocratic granitic gneiss is subdivided into two rock units; Archaean gneiss (*Angm*) and reworked gneiss (*Ængm*). Archaean mesocratic gneiss consists of Archaean granitic protoliths with Archaean structures and fabrics preserved. Reworked gneiss outcrops in the Yarlalweelor gneiss complex, and is a composite of Archaean and Palaeoproterozoic components (Table 1). Both types of mesocratic granitic gneiss contain minor to subordinate amounts of finely interleaved, leucocratic granitic gneiss.

A sample of reworked mesocratic granitic gneiss (*Ængm*) from the Yarlalweelor gneiss complex on MARQUIS has components with early, middle, and late Archaean ages (GSA 142853; Nelson, 1998). The youngest late Archaean component in this sample ( $2637 \pm 3$  Ma) is the same age as some of the late Archaean granites that intrude Archaean mesocratic gneiss (*Angm*) to the west of Errabiddy Homestead. For example, a sample from a plug of mesocratic porphyritic biotite granite (*Agp*) that intrudes Archaean mesocratic gneiss 6 km to the west-southwest of Beedarry Well (at

MGA 083810\*), has been dated at  $2630 \pm 4$  Ma (GSA 142906; Nelson, 1998). Therefore, reworked mesocratic granitic gneiss includes late Archaean granites that were deformed and metamorphosed during the Capricorn Orogeny, and are now contained within the gneissic layering.

### **Archaean mesocratic granitic gneiss (*Angm*)**

Archaean mesocratic granitic gneiss (*Angm*) is common in the Errabiddy Shear Zone west of Errabiddy Homestead. It is tectonically interleaved with Archaean leucocratic granitic gneiss (*Ængl*), amphibolite (*Aba*), calc-silicate gneiss (*Asl*), metamorphosed banded iron-formation (*Aci*), quartzite (*Asq*), and metamorphosed ultramafic rock (*Aus*). Plugs, dykes, and veins of late Archaean monzogranite (*Agp*, *Agpr*, *Age*) intrude across the Archaean gneissic layering and Archaean structures in the mesocratic granitic gneiss. However, locally the gneiss includes deformed late Archaean granite intrusions (*Agp*, *Age*).

The mesocratic granitic gneiss is a fine- to medium-grained, strongly banded, biotite-rich rock with thin layers of pegmatite and quartzofeldspathic material. The mesocratic granitic gneiss is commonly porphyritic. It contains up to 30% round and oval phenocrysts and porphyroclasts of microcline. In strongly deformed zones the porphyroclasts are attenuated into thin, discontinuous quartzofeldspathic layers. The porphyritic gneiss locally grades into veins and sheets of mesocratic porphyritic biotite monzogranite (*Agp*). In lower strain domains the precursor rocks consist of mafic granodiorite and tonalite. The rocks are biotite-bearing, with accessory allanite, zircon, apatite, and iron oxides. Allanite (now hydrated) commonly forms prominent prismatic crystals, and locally forms porphyroclasts.

### **Reworked mesocratic granitic gneiss (*Ængm*)**

Reworked mesocratic granitic gneiss (*Ængm*) of the Yarlalweelor gneiss complex is restricted to a small exposure about 5 km southwest of Vince Bore (at MGA 325032) on ERRABIDY. Like the reworked leucocratic gneiss (*Ængl*), the reworked mesocratic granitic gneiss is a composite of Archaean and Palaeoproterozoic components. The reworked mesocratic granitic gneiss is characterized by the presence of abundant sheets and veins of coarse-grained biotite granite and pegmatite (*EgMp*).

### **Amphibolite (*Aba*)**

Lenses and strips of fine- and medium-grained amphibolite (*Aba*) are extensively interleaved with the granitic gneisses on ERRABIDY and LANDOR. Most of the amphibolites are about 1–3 m thick and up to 40–50 m long, although some exceed 100 m in length. In strongly

\* Localities are specified by the Map Grid of Australia (MGA) standard six-figure reference system whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on this sheet, to within 100 m. All references to MGA use the Geocentric Datum of Australia 1994 (GDA94). MGA coordinates of localities mentioned in the text are listed in the Appendix.



deformed granitic gneiss, the amphibolites locally form boudinaged pods less than 10 m long.

Contacts between the amphibolites and granitic gneisses are typically tectonic and parallel to the compositional layering in the gneisses. However, in the reworked leucocratic granitic gneiss (*Angl*), amphibolites are locally discordant, occurring at a low angle to the banding in the gneisses, indicating that these amphibolites were originally mafic dykes. These amphibolites commonly show evidence for only one generation of folding, whereas amphibolite layers aligned parallel to the gneissic layering may display complex, refolded fold patterns. The amphibolites, therefore, probably represent two (or more) generations of mafic magmatism. As the mesocratic granitic gneisses (*Angm*, *Angm*) include late Archaean components ( $\geq 2630$  Ma), those amphibolites that truncate the gneissic layering must be either latest Archaean or Palaeoproterozoic in age.

The amphibolites are intruded by coarse-grained granite and pegmatite (*PgMp*) in the reworked and Archaean granitic gneisses, and by various late Archaean granites (*Age*, *Agp*, *Agpr*) in the Archaean granitic gneisses. In the reworked gneisses, the amphibolites are tectonically interleaved with late Archaean granites, which are now contained within the gneissic layering.

Most of the amphibolites are even textured with a weak compositional banding. Layers of metamorphosed gabbro and leucogabbro are widespread, but much less abundant than aphyric amphibolites. Both types of amphibolite have a polygonal texture and are composed of green hornblende and plagioclase (andesine), with minor quartz and titanite, and accessory apatite. Locally, clinopyroxene may constitute up to 20% of the rock. In some samples, clinopyroxene forms cores to hornblende. These minerals are variably overprinted by fine-grained minerals that grew during low-grade metamorphism related to the Capricorn Orogeny (see **Capricorn Orogeny**).

### Metamorphosed ultramafic rock (*Au*, *Aus*)

Lenses of metamorphosed ultramafic rock are interleaved with the leucocratic and mesocratic granitic gneisses west of Errabiddy Homestead on ERRABIDDY. Most are contained within an east-northeasterly trending belt about 6 km long and less than a kilometre wide, which extends onto LANDOR. Individual lenses are up to 50 m wide and a kilometre long. The lenses outcrop as narrow, blocky ridges up to about 30 m high. Most of the rocks are medium grained and massive, although where cut by narrow shear zones, the rocks are fine grained and strongly foliated. Contacts with the enclosing gneisses are probably tectonic. Veins of muscovite pegmatite (*PgMp*) and medium- to coarse-grained, weakly porphyritic biotite granite (*Age*) intrude some of the lenses.

The lenses mainly consist of serpentine–talc–magnetite–calcite(–tremolite–titanite) rock. These rocks weather to a dark-brown colour, but are dark green on fresh surfaces. Domains of decussate talc crystals up to

5 mm long, with fine-grained serpentine inclusions, are contained within a matrix of serpentine and talc. Fine-grained magnetite and calcite typically line grain boundaries of the coarser grained talc. The rocks show pervasive and fracture-related alteration to fine-grained talc–chlorite rock. About 2.8 km south-southeast of K13 Well (at MGA 076833), a lens of ultramafic rock consists of tremolite–chlorite–magnetite–ilmenite schist. Many tremolite crystals contain cores of pale-green to bluish-green ?pargasite.

### Calc-silicate gneiss (*Asl*)

Calc-silicate gneiss (*Asl*) forms narrow layers interleaved with the granitic gneisses in the Yarlalweelor gneiss complex and Narryer Terrane. It is a minor component on ERRABIDDY and LANDOR and forms discontinuous lenses or layers less than about 3 m wide and up to a few hundred metres long. The calc-silicate rocks are pale green on a fresh surface, but typically weather to reddish-brown. The calc-silicate gneiss is mainly composed of plagioclase–quartz–diopside–tremolite(–microcline) and diopside–tremolite–titanite assemblages. The rock typically has alternations of quartz-rich layers and tremolite- and clinopyroxene-rich layers up to several centimetres thick. Calc-silicate gneiss ranges from fine to coarse grained, with radiating bundles of pale-green tremolite–actinolite or clinopyroxene within the compositional layering.

### Quartzite gneiss (*Asq*)

Quartzite gneiss forms large, resistant ridges southwest of K13 Well and about 9 km south-southeast of Pines Bore (at MGA 503138) on the eastern edge of ERRABIDDY. The quartzite is tectonically interleaved with leucocratic granitic gneiss (*Angl*, *Angl*). Outcrops of the unit south-southeast of Pines Bore include some metamorphosed quartz arenite. Quartzite is white or very pale green, and contains less than 10% combined diopside, tremolite–actinolite, microcline, and accessory tourmaline.

### Metamorphosed banded iron-formation (*AcI*)

Metamorphosed banded iron-formation is a widespread rock type throughout the granitic gneisses (*Angl*, *Angl*, *Angm*, *Angm*), forming layers or lenses up to a few metres thick. These layers are particularly abundant in the Errabiddy Shear Zone west of Errabiddy Homestead, and in a belt that extends from Orient Bore in the southeastern corner of ERRABIDDY, eastwards on to MARQUIS. The layers are commonly intruded and disrupted by late Archaean granites and coarse-grained biotite granite and pegmatite (*PgMp*). In contrast with the metamorphosed iron formation on MARQUIS and MOORARIE, grunerite is abundant in iron formation layers in the Archaean granitic gneisses west of Errabiddy Homestead. The most common assemblage is fine-grained grunerite–quartz–magnetite (–hematite).

## Late Archaean granite and gneiss

### Even-textured biotite granite (*Age*)

Dykes, veins, and sheets of pale-grey, medium-grained, even-textured biotite granite are abundant in Archaean gneisses of the Narryer Terrane on ERRABIDDY and LANDOR. They intrude Archaean leucocratic and mesocratic granitic gneisses (*Angl*, *Angm*), mesocratic porphyritic biotite monzogranite (*Agp*), and foliated strongly porphyritic granite (*Agpr*). Even-textured biotite granite is probably present within the reworked granitic gneisses (*Angl*, *Angm*) of the Yarlalweelor gneiss complex, but is unrecognizable as a result of Palaeoproterozoic deformation.

Medium-grained, even-textured biotite granite forms thick sheets or lenticular plugs up to about 600 m wide west and southwest of Errabiddy Homestead. These sheets are locally intruded by east-northeasterly trending dykes of coarse-grained biotite pegmatite, and biotite–muscovite granite and pegmatite (*PgMp*). Elsewhere, the granite forms planar veins and thin dykes up to about 1 m wide, which typically trend 070–080°, parallel or subparallel to the layering in the gneisses. However, some biotite granite dykes intrude the granitic gneisses at a high angle to layering. A biotite granite dyke, which intruded mesocratic granitic gneiss (*Angm*) and mesocratic porphyritic biotite monzogranite (*Agp*) about 1 km north-northwest of Bilja Well (GSWA 142907, at MGA 043813), was dated at  $2608 \pm 3$  Ma (Nelson, 1998).

Medium-grained, even-textured biotite granite also forms an elliptical pluton, about 3 km wide and 5 km long, south-southwest of Cockarra Well (centred at MGA 276802) across the boundary between ERRABIDDY and GOULD to the south. On GOULD, the granite contains inclusions of leucocratic granitic gneiss (*Angl*; Occhipinti et al., in prep.). Veins and sheets of coarse-grained granite and pegmatite (*PgMp*) intrude the pluton.

Medium-grained, even-textured biotite granite is mostly massive or weakly foliated. However, locally it is strongly foliated where overprinted by narrow, east-northeasterly trending shear zones. The granite includes a rare, weakly porphyritic variety with up to 5% tabular phenocrysts of microcline commonly about 5 mm long. Most of the granite is monzogranite. Biotite (~10%) is the sole mafic mineral. Accessory minerals consist of ilmenite, magnetite, apatite, zircon, monazite, and allanite. A low-grade metamorphic overprint is evident from replacement of igneous plagioclase by albite, sericite, and clinozoisite, and titanite rims on ilmenite crystals. In addition, most of the quartz has been recrystallized to fine-grained polygonal aggregates.

### Warrigal Gneiss (*Anwa*)

The Warrigal Gneiss (*Anwa*) forms fault-bounded inliers within Palaeoproterozoic rocks of the Camel Hills Metamorphics on LANDOR. On ERONG, granitic protoliths to the gneiss have been dated at 2700–2740 Ma (Nelson, 2000). The Warrigal gneiss may have formed the basement to the sedimentary protoliths to the Camel Hills Metamorphics, or may have been tectonically interleaved, and later folded with them.

On LANDOR the Warrigal Gneiss consists of leucocratic and mesocratic, well-foliated to gneissic granite that is locally pegmatite banded. The leucocratic component is biotite-bearing monzogranite. It is even textured and medium grained, with a foliation defined by sparse biotite. The mesocratic component is also biotite-bearing monzogranite, and is pale grey, fine to medium grained and even textured, and locally porphyritic. Feldspar phenocrysts are up to 1 cm in diameter and commonly rounded. Both the mesocratic and leucocratic components are cut by amphibolite, probably representing late Archaean to early Palaeoproterozoic dykes. All of the components of the gneiss are cut by sheets and veins of coarse-grained granite to pegmatite (*PgMp*).

### Mesocratic porphyritic biotite monzogranite (*Agp*)

Mesocratic porphyritic biotite monzogranite is only recognized in the Narryer Terrane in the southwestern corner of ERRABIDDY and in the southeastern corner of LANDOR. In these areas, individual east- to east-northeasterly trending shear zones, within the Errabiddy Shear Zone, may preserve a transition from mesocratic porphyritic biotite monzogranite to porphyritic mesocratic granitic gneiss. Mesocratic granitic gneiss (*Angm*) in the Errabiddy Shear Zone is commonly porphyritic, and some of it may be strongly deformed mesocratic porphyritic biotite monzogranite. In the Yarlalweelor gneiss complex on ERRABIDDY, the mesocratic porphyritic biotite monzogranite is gneissic and cannot be separated from older components of the reworked mesocratic granitic gneiss (*Angm*).

Mesocratic porphyritic biotite monzogranite forms several small plugs, the largest of which, located 6 km east-southeast of Billycan Bore on LANDOR (at MGA 986812), is about 1 km<sup>2</sup> in area. The plugs contain up to 50% inclusions of banded leucocratic and mesocratic granitic gneiss (*Angl*, *Angm*) and amphibolite (*Aba*; Fig. 5). Veins of mesocratic porphyritic biotite monzogranite are also widespread in the granitic gneisses west of Errabiddy Homestead. Nelson (1998) dated a sample from the plug east of Bilja Well (GSWA 142906) at  $2630 \pm 4$  Ma. This date is within error of the youngest zircon population ( $2637 \pm 3$  Ma) in a sample of reworked mesocratic granitic gneiss (*Angm*; GSWA 142853) from MARQUIS (Sheppard and Swager, 1999). Mesocratic porphyritic biotite monzogranite is intruded by veins and dykes of medium-grained, even-textured biotite granite (*Age*).

Mesocratic porphyritic biotite monzogranite consists of round phenocrysts of microcline, up to 5 cm in diameter, and smaller tabular plagioclase phenocrysts set in a dark-grey, fine- to medium-grained groundmass. The groundmass is composed of variably recrystallized quartz, andesine, microcline, and biotite, with accessory apatite, zircon, and allanite. Small crystals of partly hydrated allanite are ubiquitous. Andesine is partly replaced by sericite and clinozoisite. Magnetite is pseudomorphed by epidote. Microcline crystals commonly display deformation lamellae and ribbon and chequerboard microperthite textures.





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**Figure 5. Plug of mesocratic porphyritic granite (Agp) with numerous xenoliths of mesocratic granitic gneiss (Angm) and amphibolite (Aba) on ERRABIDDY (at MGA 081808)**

### **Augen gneiss and porphyritic granite (Agpr)**

Augen gneiss and porphyritic granite form a series of sheets that intrude leucocratic granitic gneiss (*Agnl*, *Ængl*) on ERRABIDDY. The largest sheet, which is centred on Bullaroo Hill, is over 15 km long and almost 5 km wide. The sole rock type is a foliated to gneissic, strongly porphyritic biotite monzogranite with round phenocrysts of K-feldspar, mainly 2–5 cm in diameter. Augen gneiss and porphyritic granite outcrop as low ridges covered in tors and boulders, or as extensive pavements.

A sample of strongly foliated, coarse porphyritic granite about 1 km east of Bullaroo Hill (at MGA 388961) was sampled for SHRIMP U–Pb zircon dating. All the zircon crystals analysed have high U contents, and many grains have probably lost radiogenic Pb (Nelson, 1999). Seven weighted mean analyses define an age of  $2594 \pm 4$  Ma, which is interpreted by Nelson (1999) as providing the minimum age of crystallization of the monzogranite. Two zircons defining an age of  $2605 \pm 2$  Ma, and another zircon with an age of  $2616 \pm 4$  Ma, may date crystallization of the melt or represent xenocrysts. Augen gneiss and porphyritic granite, to the west-southwest of Errabiddy Homestead, is intruded by veins or dykes of medium-grained, even-textured biotite granite (*Age*), a sample of which is dated at  $2608 \pm 3$  Ma. Augen gneiss and porphyritic granite outcropping northwest of Dewar Bore is extensively intruded by sheets and veins of coarse-grained granite and pegmatite (*EgMp*).

Least-deformed parts of the augen gneiss and porphyritic granite have about 30–40% round phenocrysts

of microcline in a medium-grained (2–3 mm) groundmass. Most of the samples are strongly deformed. Microcline porphyroclasts commonly have deformation lamellae and ribbon micropertite textures. The groundmass consists of extensively recrystallized quartz, microcline, and plagioclase, with seams of biotite, sericite, and epidote. Igneous plagioclase is variably replaced by fine-grained sericite, epidote, and albite–oligoclase.

### **Even-textured biotite granodiorite (Agg)**

Several sheet-like intrusions of even-textured, biotite-rich granodiorite (*Agg*) intrude the granitic gneisses (*Angl*, *Angm*) in the southeastern corner of LANDOR. The largest of the intrusions extends onto ERRABIDDY. The intrusions are up to 2 km long and up to 400 m wide, and were emplaced subparallel to the trend of the layering in the gneisses. Where east-northeasterly trending shear zones cut the granodiorite, it resembles mesocratic granitic gneiss. The granodiorite is intruded by dykes and veins of pale-grey, medium-grained, even-textured biotite granite (*Age*). Even-textured biotite granodiorite forms low rises covered in boulders and tors.

The most abundant rock type is grey, medium-grained, even-textured or weakly porphyritic granodiorite. Locally the rock is a tonalite or mesocratic monzogranite. Angular and lenticular inclusions of fine-grained mafic rock up to 20 cm long, and clots of fine-grained biotite less than 5 mm in diameter, are widespread in all rock types. In most samples, quartz is extensively recrystallized to fine-grained aggregates. Plagioclase is largely replaced by

albite–oligoclase and fine-grained epidote and sericite. Microperthite crystals display deformation lamellae and ribbon-like zones of fine-grained recrystallized K-feldspar. Accessory minerals are apatite, zircon, allanite, and either magnetite or ilmenite, or both.

## Deformation and metamorphism

Nutman et al. (1991) suggested that rocks of the Narryer Terrane were metamorphosed to high grade and intruded by granite and pegmatite at c. 3300 Ma and c. 3050 Ma. However, no structures of this age are preserved. Deformation and further metamorphism occurred in the late Archaean, between about 2750 and 2620 Ma. These late Archaean deformation and metamorphic events are constrained by SHRIMP U–Pb ages on deformed and undeformed granites, and by metamorphic rims on igneous zircons and metamorphic zircons in melt patches (Myers, 1990b; Nutman et al., 1991). Williams and Myers (1987) and Occhipinti and Myers (1999) recognized three major phases of late Archaean deformation in the Narryer Terrane. The first deformation,  $D_1$ , produced a gneissic layering ( $S_1$ ). This layering is folded about subhorizontal, upright  $F_2$  folds that have easterly trending axial surfaces. The  $F_2$  folds were then refolded about upright, north- to north-northeasterly trending  $F_3$  folds that plunge moderately to steeply to the north. Granulite facies metamorphism ( $M_2$ ) accompanied  $D_2$ , and amphibolite facies metamorphism ( $M_3$ ) was associated with  $D_3$  (Williams and Myers, 1987).

Archaean structures in the southeastern corner of LANDOR and southwestern part of ERRABIDY are preserved in domains that are cut by faults and mylonite zones of the Proterozoic Errabiddy Shear Zone. However, they are not preserved in the Yarlalweelor gneiss complex, in the eastern part of ERRABIDY, which is the part of the Narryer Terrane that was extensively reworked during the Capricorn Orogeny. The Yarlalweelor gneiss complex is separated from the rest of the Narryer Terrane by an east-southeasterly trending fault zone up to about 5 km wide, near Cockarra Well.

### Deformation

On ERRABIDY and LANDOR, the earliest recognizable Archaean structure is a well-developed gneissic layering ( $S_1$ ), which typically strikes between north-northwest and north-northeast and dips steeply to the west or east.

In the Yarlalweelor gneiss complex on ERRABIDY, Archaean  $F_2$  folds are preserved in zones in which strain was low to moderate during the Capricorn Orogeny, and in the hinges of some Palaeoproterozoic folds. Archaean structures are similarly preserved in the Yarlalweelor gneiss complex on MOORARIE (Occhipinti and Myers, 1999) and MARQUIS (Sheppard and Swager, 1999). The folds are small scale, recumbent or gently inclined, and tight to isoclinal. In some tight Palaeoproterozoic fold hinges, ‘arrowhead-shaped’ fold interference structures (type 2 of Ramsay, 1967) are developed (see **Capricorn Orogeny**).

The Archaean granitic gneisses and tectonically interleaved amphibolite layers are folded about vertical to

steeply dipping, Archaean, mesoscopic tight to isoclinal folds on southwestern ERRABIDY and southeastern LANDOR. The plunge of the folds ranges from shallow to subvertical to the north-northeast. The orientation of the folds is similar to that of  $F_3$  folds in Archaean gneisses on the southwestern part of ROBINSON RANGE (1:250 000) (Occhipinti et al., in prep.), on MOORARIE (Occhipinti and Myers, 1999), and in the Mount Narryer region (Williams and Myers, 1987). Sheets of augen gneiss and foliated porphyritic granite (*Agpr*) in the southwestern corner of ERRABIDY contain a steeply dipping foliation that also strikes north-northwest to north-northeast. These sheets intruded into, and also contain inclusions of, banded granitic gneiss, indicating that they post-dated formation of the gneissic layering ( $S_1$ ), but were intruded before or during the deformation that produced the Archaean  $F_3$  folds. Plugs of mesocratic porphyritic biotite monzogranite (*Agp*) and dykes of medium-grained, even-textured biotite granite (*Age*) dated respectively at  $2630 \pm 4$  and  $2608 \pm 3$  Ma, succeeded this folding event.

### Metamorphism

Williams and Myers (1987) suggested that gneisses of the Narryer Terrane were metamorphosed at granulite facies during  $D_2$  and at amphibolite facies during  $D_3$ . In the Jillawarra Bore area on ROBINSON RANGE, about 23 km east-southeast of Errabiddy Homestead, granitic gneisses contain melt patches that formed during high-grade metamorphism (Occhipinti et al., in prep.). Nelson (1998) dated these melt patches at  $2643 \pm 4$  Ma. The melt patches disrupt the gneissic layering, but it is not known whether they formed at the same time as  $D_2$  or  $D_3$ .

The Archaean granitic gneisses and granites on ERRABIDY consist of quartzofeldspathic assemblages, which are poor indicators of metamorphic grade (Elias and Williams, 1980). Nevertheless, the presence in some samples of polygonal or amoeboid granoblastic textures and antiperthite, is indicative of high-grade metamorphism. In areas of low Palaeoproterozoic strain, interleaved amphibolite layers typically contain assemblages of green hornblende and plagioclase (andesine), diagnostic of the amphibolite facies. Clinopyroxene cores to hornblende in some samples may be either a relict from a higher grade metamorphic assemblage, or from the igneous protolith. Locally the amphibolites contain the assemblage brown hornblende, plagioclase, clinopyroxene, and ilmenite, indicating that the rocks were metamorphosed to upper amphibolite or granulite facies. Calc-silicate gneiss contains assemblages typical of aluminous marl metamorphosed at amphibolite facies conditions, that is, plagioclase, quartz, diopside, and tremolite with minor microcline in quartz-rich rocks, and diopside, tremolite, and titanite with minor plagioclase in quartz-poor rocks (Bucher and Frey, 1994).

Evidence for medium- to high-grade metamorphism is lacking in plugs of mesocratic porphyritic biotite granite (*Agp*) dated at  $2630 \pm 4$  Ma, which intrude the granitic gneisses and amphibolite. The upper amphibolite facies metamorphism on ERRABIDY may correlate with the high-grade metamorphism at  $2643 \pm 4$  Ma that produced the melt patches in the Jillawarra Bore area.



The leucocratic biotite granite shows polygonal or amoeboid granoblastic textures, which along with the presence of antiperthite in some samples, are indicative of high-grade metamorphism. A lower grade metamorphic event caused the recrystallization of quartz and biotite, replacement of plagioclase by albite, sericite, and clinozoisite, and titanite rims on ilmenite crystals.

## Proterozoic geology

Proterozoic geology on LANDOR and ERRABIDDY includes components of the Palaeoproterozoic Gascoyne Complex and Mount James Formation, and the latest Palaeoproterozoic to Mesoproterozoic Bangemall Supergroup. The Gascoyne Complex consists of variably metamorphosed granitic, sedimentary, and mafic and ultramafic igneous rocks. The Gascoyne Complex has several components, and on ERRABIDDY and LANDOR these include the Glenburgh Terrane, Camel Hills Metamorphics, and granites of the Moorarie Supersuite. The Palaeoproterozoic Mount James Formation dominantly consists of siliciclastic sedimentary rocks that were deposited on top of the Gascoyne Complex and on the northern margin of the Yilgarn Craton (Fig. 2). The latest Palaeoproterozoic to Mesoproterozoic Bangemall Supergroup comprises siliciclastic and carbonate sedimentary rocks deposited within the Capricorn Orogen unconformably on the Gascoyne Complex, Bryah and Padbury Basins, and northern Yilgarn Craton.

## Gascoyne Complex

Granites and metamorphic rocks of the Gascoyne Complex are part of the Capricorn Orogen, a major tectonic zone formed during collision firstly between the Archaean Yilgarn Craton and Glenburgh Terrane (Occhipinti et al., 1999b), and secondly between the combined Yilgarn Craton and Glenburgh Terrane and the Pilbara Craton in the Palaeoproterozoic (Tyler and Thorne, 1990). Much of ERRABIDDY and LANDOR is underlain by the southern margin of the Gascoyne Complex, which includes the Glenburgh Terrane and Camel Hills Metamorphics (Fig. 2). Williams (1986) suggested that the southern part of the Gascoyne Complex consisted mainly of reworked Archaean gneisses of the Yilgarn Craton. Myers (1990a) interpreted the southern part of the Gascoyne Complex as para-autochthonous Yilgarn Craton interleaved with Proterozoic rocks (his Zone B). He suggested that the Errabiddy Shear Zone (Fig. 2) marks the boundary between para-autochthonous Yilgarn Craton to the north, and unreworked Yilgarn Craton to the south. However, this interpretation is contradicted by the failure of reconnaissance SHRIMP U–Pb dating to identify Archaean crust in the southern margin of the Gascoyne Complex (Nutman and Kinny, 1994).

Remapping of LANDOR, ERRABIDDY, and GLENBURGH (Occhipinti and Sheppard, in prep.), combined with SHRIMP U–Pb zircon geochronology (Nelson, 1998;

1999), indicate that the southern margin of the Gascoyne Complex comprises mainly meta-igneous and metasedimentary rocks between 2000 and 1975 Ma in age. However, some c. 2540 Ma foliated to gneissic granites on northern GLENBURGH immediately west of LANDOR (Nelson, 2000; Occhipinti and Sheppard, in prep.) appear to be tectonically juxtaposed against Palaeoproterozoic rocks that form much of the southern margin of the Gascoyne Complex. These latest Archaean foliated to gneissic granites are younger than any known rocks from the northwestern part of the Yilgarn Craton, which are all older than c. 2610 Ma. Their relationship to the Archaean Yilgarn and Pilbara Cratons is unknown.

The rocks in the southern part of the Gascoyne Complex are divided into two main units, the Glenburgh Terrane and Camel Hills Metamorphics. The Glenburgh Terrane consists of latest Archaean granitic gneisses interleaved with supracrustal rocks, 2000–1975 Ma granitic gneiss and granite of the Dalgaringa Supersuite, and metasedimentary rocks. Supracrustal rocks include mafic meta-igneous (*Pba*) and some metasedimentary rocks (*Plm*) that are present as discontinuous lenses within granite or granitic gneiss, and are commonly too small to show on the map. The Glenburgh Terrane on the southern part of LANDOR is dominated by rocks of the Dalgaringa Supersuite. The composition of the Glenburgh Terrane on ERRABIDDY is largely unknown because it is almost entirely covered by alluvium and colluvium. Outcrop of the Palaeoproterozoic medium- to high-grade metasedimentary rocks of the Camel Hills Metamorphics is confined to the Errabiddy Shear Zone. The Dalgaringa Supersuite and Camel Hills Metamorphics were deformed and metamorphosed during the 2000–1960 Ma Glenburgh Orogeny (Occhipinti et al., 1999a; Sheppard et al., 1999; see **Glenburgh Orogeny**). Later during the Capricorn Orogeny at 1830–1780 Ma, the rocks were deformed and metamorphosed at low to medium grade, and intruded by granite and pegmatite dykes and plugs of the Moorarie Supersuite.

## Supracrustal rocks (*Pba*, *Pu*, *Plm*)

Supracrustal rocks of the Glenburgh Terrane (Gascoyne Complex) outcrop as small pods and strips within granite and granitic gneiss of the Dalgaringa and Moorarie Supersuites. The supracrustal rocks consist of metasedimentary and mafic meta-igneous rocks. Mafic meta-igneous rocks consist of amphibolite and schist (*Pba*), which are commonly too small to show on the map. The amphibolite mainly consists of hornblende, plagioclase, quartz, epidote, and titanite, with minor actinolite or tremolite. Metasedimentary rocks (*Plm*) mainly outcrop in the northern part of LANDOR within the Scrubber Granite of the Moorarie Supersuite. Here they are composed of muscovite–quartz schist that is variably ferruginized and weathered. Within the Dumbie Granodiorite (Moorarie Supersuite) on northwestern LANDOR, biotite schist, of probable sedimentary origin, forms abundant xenoliths (along with amphibolite and tonalite). Ultramafic schist (*Pu*) containing tremolite, talc, and chlorite is present as isolated pods on eastern central ERRABIDDY.

### Camel Hills Metamorphics

Medium- to high-grade metasedimentary rocks of the Camel Hills Metamorphics outcrop in the Errabiddy Shear Zone (Fig. 2). The Camel Hills Metamorphics were deformed and metamorphosed during both the 2000–1960 Ma Glenburgh Orogeny and 1830–1780 Ma Capricorn Orogeny. These metasedimentary rocks were previously included within the Morrissey Metamorphic Suite (Williams et al., 1983b; Williams, 1986), the name given for a suite of metamorphosed and deformed Proterozoic sedimentary rocks thought to outcrop throughout the Gascoyne Complex (Williams et al., 1983a). The suite was considered to be equivalent, in part, to sedimentary rocks of the Wyloo Group to the north, and sedimentary rocks of the Yerrida and Bryah Groups (Pirajno et al., 1998) to the east. However, there is no certainty that all the metasedimentary rocks throughout the Gascoyne Complex were deposited in the same sedimentary basin or are the same age. The Camel Hills Metamorphics on ERRABIDDY and LANDOR are separated from the Morrissey Metamorphics, as defined on the MOUNT PHILLIPS 1:250 000 sheet (Williams et al., 1983a), by large areas of granitic gneiss, supracrustal metasedimentary and mafic meta-igneous rocks, and large fault structures.

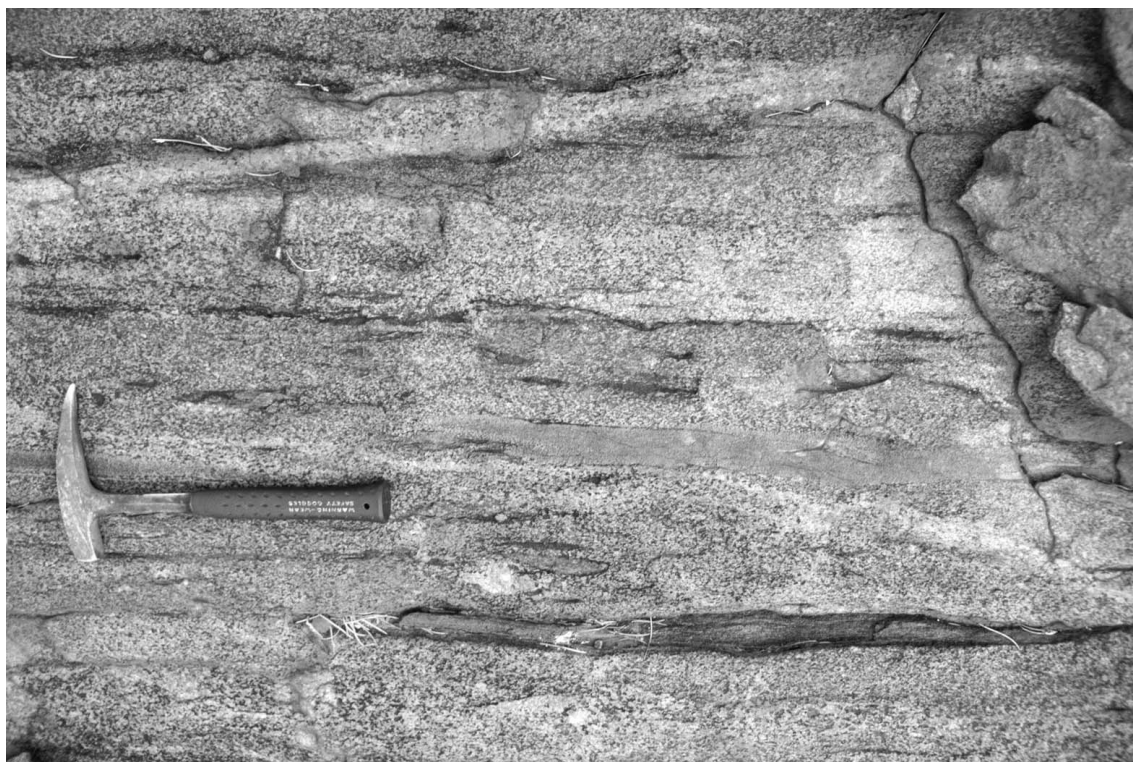
The Camel Hills Metamorphics is subdivided into the Quartpot Pelite (*PmCqn*) and Petter Calc-silicate (*PmCp*, *PmCpq*). The petrography and metamorphic history of the

Camel Hills Metamorphics is described under the **Glenburgh Orogeny** and **Capricorn Orogeny** sections below.

### Quartpot Pelite (*PmCqn*)

The Quartpot Pelite (*PmCqn*) outcrops extensively within the Errabiddy Shear Zone on the eastern part of ERRABIDDY and the southern edge of LANDOR. This unit consists of pelitic schist or gneiss and migmatitic pelitic gneiss (Fig. 6), with minor amounts of interlayered quartzite, calc-silicate schist and gneiss, and amphibolite.

SHRIMP U–Pb zircon data were obtained from two samples of migmatitic pelitic gneiss; GSWA 142905 (Nelson, 1998) located about 11 km south of Pines Bore (at MGA 480106) on ERRABIDDY, and GSWA 142910 (Nelson, 1999) located about 4 km south of Pannikan Bore (at MGA 780843) on LANDOR. Both samples were of the diatexite that locally constitutes up to half of the volume of the outcropping rock. Pitted zircon grains, between 2025 and 2550 Ma in age, interpreted to be of detrital origin, dominate in both samples, with a small population in GSWA 142910 of older zircons (>2600 Ma). The youngest zircon population in GSWA 142905 consists of two zircons at  $1951 \pm 13$  Ma, and the youngest population in GSWA 142910 is of two zircons at  $1966 \pm 5$  Ma. These analyses were obtained from rims and cores of pitted grains with very low Th/U ratios.



SAO 73  
a)

15.06.00

**Figure 6.** Migmatitic pelitic gneisses of the Quartpot Pelite: a) Schollen migmatite showing diatexite melt with inclusions of dark biotite-rich restite, and lumps of unmelted psammite on ERRABIDDY (at MGA 473101); b) Stromatic migmatite with locally derived minimum melt vein cutting stromatic layering on ERRABIDDY (at MGA 469053); c) Nebulitic migmatite with dark fragments of biotite-rich restite. Note the lack of well-developed layering in the rocks (on ERRABIDDY at MGA 463102)





SAO 75

15.06.00

b)



SAO 74

15.06.00

c)

Nelson (1998, 1999) suggested that the rims, which constitute the youngest zircon population in each sample, formed before incorporation of the zircons into the sedimentary precursor to the migmatitic gneiss. This interpretation is based on the pitted nature of the zircon surfaces. The youngest populations would therefore provide a maximum depositional age of the sedimentary protolith. This interpretation requires zircon dissolution and no zircon crystallization from the extensive melt phase. Alternatively, the rims may have grown during the high-grade metamorphism that produced partial melting of these rocks. The low Th/U ratios of the rims and their pitted surfaces are similar to observations in other melt-related zircon overgrowths (Fraser et al., 1997; Tyler et al., 1999). This would then constrain the age of high-grade metamorphism to c. 1960 Ma, and indicate a maximum depositional age for the sedimentary precursor of c. 2025 Ma. Regardless of which interpretation is correct, the data indicate that none of the zircons in GSWA 142905, and only a minority of the zircons in GSWA 142910 could have come from the 3700–2600 Ma Yilgarn Craton (Nelson, 1998, 1999).

The Quartpot Pelite is in faulted contact with leucocratic granitic gneiss (*Angl*, *Ængl*) and augen gneiss and porphyritic granite (*Agpr*) of the Narryer Terrane. The relationship of the Quartpot Pelite with rocks of the Glenburgh Terrane is unknown, but contacts are likely to be faulted. Veins and sheets of coarse-grained trondhjemite intrude pelitic gneiss on LANDOR. One sheet, located about 4 km west-southwest of Quartpot Bore (MGA 813848), has been dated at  $1970 \pm 15$  Ma (GSWA 142909; Nelson, 1999), within error of the youngest, possibly metamorphic zircon ages obtained from the Quartpot Pelite. Medium-grained, even-textured biotite granite (*BgMe*) and strongly porphyritic, foliated granite (*BgMpr*) intruded migmatitic gneiss at the northern end of the belt. The migmatites were also extensively intruded by veins, sheets, and dykes of coarse-grained biotite–muscovite granite and pegmatite (*BgMp*).

#### *Petter Calc-silicate (EmCp, EmCpq)*

The Petter Calc-silicate is composed of calc-silicate schist or gneiss (*EmCp*) and interlayered quartzite (*EmCpq*), and minor pelitic schist or migmatitic pelitic gneiss and amphibolite. On ERRABIDY and LANDOR, the Petter Calc-silicate is mainly restricted to fault-bounded slices. On ERRABIDY, calc-silicate gneiss is also interlayered with fine-grained amphibolite (*EmC(a)*) east of Black Adder Well (at MGA 221992) and interlayered with subordinate quartzite and minor amphibolite east of Vince Bore (at MGA 432099). Calc-silicate gneiss typically forms low rubbly and bouldery strike ridges with a dark-brown pattern on aerial photographs.

A quartz-rich, calc-silicate gneiss on LANDOR, located about 6 km west-southwest of Packsaddle Bore (at MGA 810803), was sampled for SHRIMP U–Pb zircon geochronology (GSWA 142908; Nelson, 1999). Most of the zircons (22 of 26) have ages between 2600 and 2700 Ma. Of the remaining zircons, three have ages greater than 3000 Ma, and one was dated at  $1944 \pm 5$  Ma. The youngest zircon is rounded and pitted, and Nelson (1999) interpreted the date on this grain as providing the

maximum depositional age of the precursor to the gneiss. However, this age is apparently younger than that of the  $1970 \pm 15$  Ma trondhjemite sheet west-southwest of Quartpot Bore that cuts gneissic layering in pelitic gneiss of the Quartpot Pelite (see **Quartpot Pelite**), which has the same structural and metamorphic history as the Petter Calc-silicate. The depositional age based on SHRIMP U–Pb zircon geochronology for this sample remains uncertain. Nevertheless, the detrital ages in the calc-silicate gneiss imply that the Petter Calc-silicate was sourced from the Yilgarn Craton. It thus had a different provenance to the Quartpot Pelite.

Calc-silicate rocks are pale green on a fresh surface, but typically weather to a reddish-brown exterior. The calc-silicate gneiss is compositionally layered, with alternations of tremolite- and clinopyroxene-rich layers and quartz-rich layers, up to several centimetres thick. The calc-silicate rocks range from fine grained to coarse grained with radiating bundles of pale-green tremolite–actinolite or clinopyroxene within the compositional layering.

Quartzite (*EmCpq*) outcrops as a series of low, rugged strike ridges interlayered with calc-silicate gneiss and amphibolite (*EmC(a)*) east of Vince Bore (at MGA 433096). The quartzite is white or pale grey, foliated, and has a mortar texture.

#### *Unassigned units (EmC(a), EmC(i))*

A thick package of fine-grained amphibolite (*EmC(a)*) is present east of Black Adder Well, where it is interlayered with subordinate fine- and coarse-grained calc-silicate gneiss. The amphibolite is structureless apart from one amygdaloidal layer about 50 cm thick (at MGA 207996). At the northeastern end of the exposure (at MGA 230006), fine-grained, weakly foliated amphibolite is net-veined by massive, medium-grained, even-textured biotite granite. Numerous veins and dykes of muscovite–biotite granite and pegmatite (*BgMp*) intruded along the foliation of the amphibolite. The amphibolite forms low, rounded hills covered in rubble.

The age of the amphibolites is unknown. They have been assigned a Palaeoproterozoic age here, because unlike Archaean amphibolites from the Narryer Terrane, they lack refolded folds. In addition, the amphibolites east of Black Adder Well are not associated with any granitic gneiss.

Metamorphosed banded iron-formation (*EmC(i)*) forms a layer about 1 km long and 2 m thick, about 2 km west-northwest of Wheelo Bore (at MGA 237992).

#### *Dalgaringa Supersuite (EgD)*

The Dalgaringa Supersuite consists of massive, foliated, and gneissic granites dated at 2005–1975 Ma (Sheppard et al., 1999). The supersuite comprises two episodes of magmatism separated by a deformation and high-grade regional metamorphic event. The two episodes consist of 2005–1985 Ma foliated to gneissic tonalite, granodiorite, and monzogranite, and c. 1975 Ma tonalite and granodiorite plutons. The foliated to gneissic granites were



previously shown as 'migmatite' on the second edition GLENBURGH 1:250 000 sheet (Williams et al., 1983b). The rocks were regarded as Archaean gneiss and granite that were partially melted during the Proterozoic (Williams, 1986). The c. 1975 Ma plutons roughly correspond to the 'early-stage gneissic granites' of Williams (1986).

Foliated and gneissic 2005–1985 Ma granites outcrop over a wide area on the southern part of GLENBURGH, west of LANDOR. These granites are present as inclusions in the Nardoo Granite in the southwest corner of LANDOR. The Nardoo Granite on LANDOR belongs to the group of c. 1975 Ma plutons.

#### *Nardoo Granite (PgDna, PgDnam)*

The Nardoo Granite (*PgDna*) is a newly defined unit named after Nardoo Bore on the adjacent GLENBURGH sheet (Occhipinti and Sheppard, in prep.). It consists of foliated, or locally gneissic, medium-grained biotite tonalite and granodiorite. The Nardoo Granite forms an elliptical, east-northeasterly trending intrusion at least 45 km long and up to 20 km wide, the bulk of which is exposed on GLENBURGH. It is equivalent to the gneissic biotite–hornblende granodiorite of the Dalgety Gneiss Dome of Williams (1986).

On LANDOR, the Nardoo Granite is mainly exposed south of the Landor – Dalgety Downs Road in the west of the sheet area. It is also exposed in the southwestern corner of LANDOR, and probably underlies much of the southwestern part of the sheet area. Isolated outcrops of fresh granodiorite west of Dispute Bore (at MGA 961008),

on the eastern part of LANDOR, are interpreted to be part of the Nardoo Granite. If this interpretation is correct, the Nardoo Granite may be more than 75 km long and underlie an area greater than 1000 km<sup>2</sup>. The Nardoo Granite forms a gently undulating land surface with boulders and tors, and some whalebacks amongst locally derived sandy colluvial and sheetwash deposits. In the southwestern corner of LANDOR, fresh granite is exposed beneath an old, dissected land surface marked by ferruginous duricrust, saprolite, and weathered rock.

The Nardoo Granite consists of two intrusive phases: medium-grained, mesocratic even-textured or porphyritic biotite tonalite (*PgDna*; Fig. 7); and lighter coloured medium-grained, weakly porphyritic biotite tonalite and granodiorite (*PgDnam*). Contacts between the two are commonly sharp, but locally gradational. In low-strain zones, irregular veins and dykes of tonalite and granodiorite consistently intrude the mesocratic tonalite, nevertheless, SHRIMP U–Pb zircon dating on GLENBURGH indicates that the two phases have indistinguishable ages. A sample of the mesocratic tonalite (GSWA 142932) gave a date of  $1977 \pm 4$  Ma, whereas a sample of granodiorite (GSWA 142928) was dated at  $1974 \pm 4$  Ma (Nelson, 1999).

On GLENBURGH, the Nardoo Granite intruded foliated and gneissic granite dated at 2005–1985 Ma (Sheppard et al., 1999; Occhipinti and Sheppard, in prep.) and interlayered amphibolite and calc-silicate gneiss. Inclusions of fine-grained tonalite and amphibolite are widespread in the Nardoo Granite. The contact between the Nardoo Granite and Camel Hills Metamorphics is not

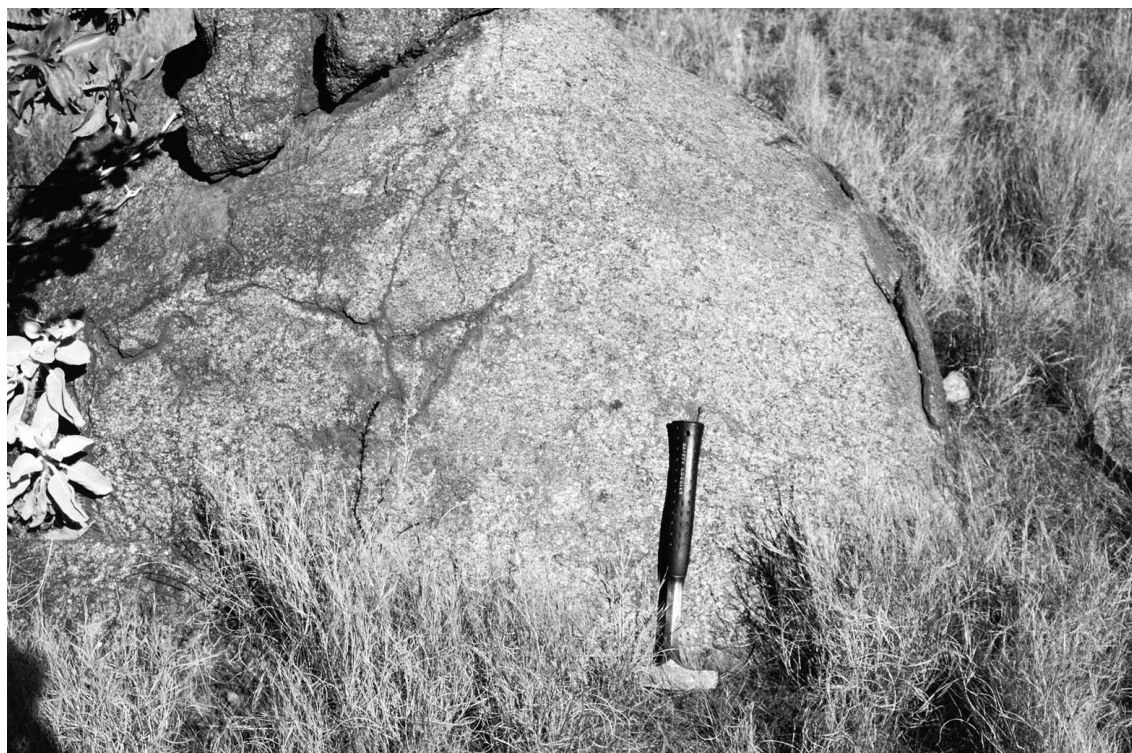


Figure 7. Massive, weakly porphyritic tonalite of the Nardoo Granite on LANDOR (at MGA 560019)

exposed, but is probably faulted. Williams (1986) interpreted the Nardoo Granite as a para-autochthonous diapir formed by partial melting of the enclosing foliated and gneissic granites. However, recent mapping and SHRIMP U–Pb zircon dating on GLENBURGH (Sheppard et al., 1999) indicates that the rocks intruded by the Nardoo Granite were deformed and metamorphosed at high grade before intrusion of the Nardoo Granite. The leucosome veins in ‘migmatites’ noted by Williams (1986) are externally derived veins and sheets of pegmatite into foliated granites. One of these pegmatite sheets on GLENBURGH has been dated at  $1994 \pm 2$  Ma (GSWA 142930; Nelson, 1999); this age is 10–20 million years older than that of the Nardoo Granite.

The mesocratic tonalite contains less than 5% tabular feldspar phenocrysts up to 1 cm long in a medium-grained groundmass. In places, the tonalite contains rust-brown coloured prismatic crystals of altered allanite. On weathered surfaces the tonalite is commonly dark grey and contains small pits after mafic clots. Numerous clots, 0.5–1.0 cm in diameter, composed of fine-grained biotite and chlorite are scattered throughout the rock. Elliptical and lenticular inclusions of fine-grained tonalite up to 1 m long are common in the mesocratic tonalite. Angular slab-like inclusions of fine-grained tonalite up to several metres long are locally present in the southwest corner of the sheet area. The more leucocratic tonalite and granodiorite typically contains 5–10% tabular feldspar phenocrysts up to 1 cm long in a medium-grained groundmass. Relative to the mesocratic tonalite, the granodiorite has a slightly more felsic appearance, a paler weathering surface, and contains far fewer mafic clots or inclusions of fine-grained tonalite.

Most samples of the mesocratic tonalite are variably foliated and recrystallized. Tonalite is composed of andesine, subordinate quartz, and biotite, with accessory apatite, zircon, and allanite. Quartz forms fine-grained aggregates with a polygonal texture. Most of the biotite has recrystallized to fine crystals. Coarser biotite crystals of probable igneous origin contain numerous inclusions of acicular rutile. Samples of the granodiorite on LANDOR are commonly less recrystallized than the mesocratic tonalite. The granodiorite ranges from a biotite granodiorite to a felsic tonalite. It consists of plagioclase, quartz, biotite, up to about 8% microperthite, rare hornblende, and accessory apatite and zircon.

### **Metadolerite dykes (Edm)**

Metadolerite dykes (Edm) outcrop on the southeastern part of ERRABIDDY. These dykes intruded subparallel to the fold axial surfaces of  $D_{1n}$  folds that developed during the Capricorn Orogeny. The metadolerite dykes are only 1–3 m wide, and range in length from a few metres to 1 km. They are cut by coarse-grained biotite granite to pegmatite veins and sheets, one of which has been dated on MARQUIS at c. 1812 Ma (Sheppard and Swager, 1999). Metadolerite dykes with similar mineralogy, texture, and field relationships have also been mapped on northern GOULD (Muhling, 1986, 1990), where they intruded into Palaeoproterozoic shear zones. The metadolerite dykes may also have equivalents on MARQUIS and LANDOR. On these sheet areas, the dykes consist of amphibolite that cut

Archaean gneissic layering, but have some igneous textures preserved.

The metadolerite dykes on southeastern ERRABIDDY and northern GOULD are different from other Palaeoproterozoic and Archaean amphibolites (Eba, Aba) in that they commonly contain corona textures (Fig. 8), and do not contain a well-developed gneissic banding or schistosity.

On ERRABIDDY, the metadolerite dykes contain orthopyroxene, clinopyroxene, hornblende, garnet, K-feldspar, plagioclase, quartz, minor biotite, and accessory opaque minerals. The garnet and hornblende form coronas around orthopyroxene or clinopyroxene. Garnet also forms coronas directly around the pyroxenes. The orthopyroxene and clinopyroxene are the original igneous minerals, whereas the hornblende and garnet are metamorphic. Muhling (1986, 1990) suggested that on northern GOULD, dolerite dykes intruded into an ambient amphibolite or granulite facies environment and subsequently underwent slow cooling, thus developing corona textures.

### **Cajou Monzogranite (Pgci)**

The Cajou Monzogranite (Pgci) comprises even-textured and porphyritic, medium-grained biotite monzogranite and forms part of the c. 1960 Ma Bertibubba suite, which also includes the Yamagee Granite (Sheppard and Swager, 1999). The Cajou Monzogranite does not outcrop on LANDOR or ERRABIDDY; however, south of LANDOR on ERONG abundant outcrop of this granite is present where it intrudes Archaean granite of the Yilgarn Craton. On ERONG the Cajou Monzogranite has been dated by SHRIMP U–Pb zircon as  $1961 \pm 3$  Ma, which is within error of the  $1958 \pm 4$  Ma age of the Yamagee Granite (Nelson, 2000).

### **Moorarie Supersuite**

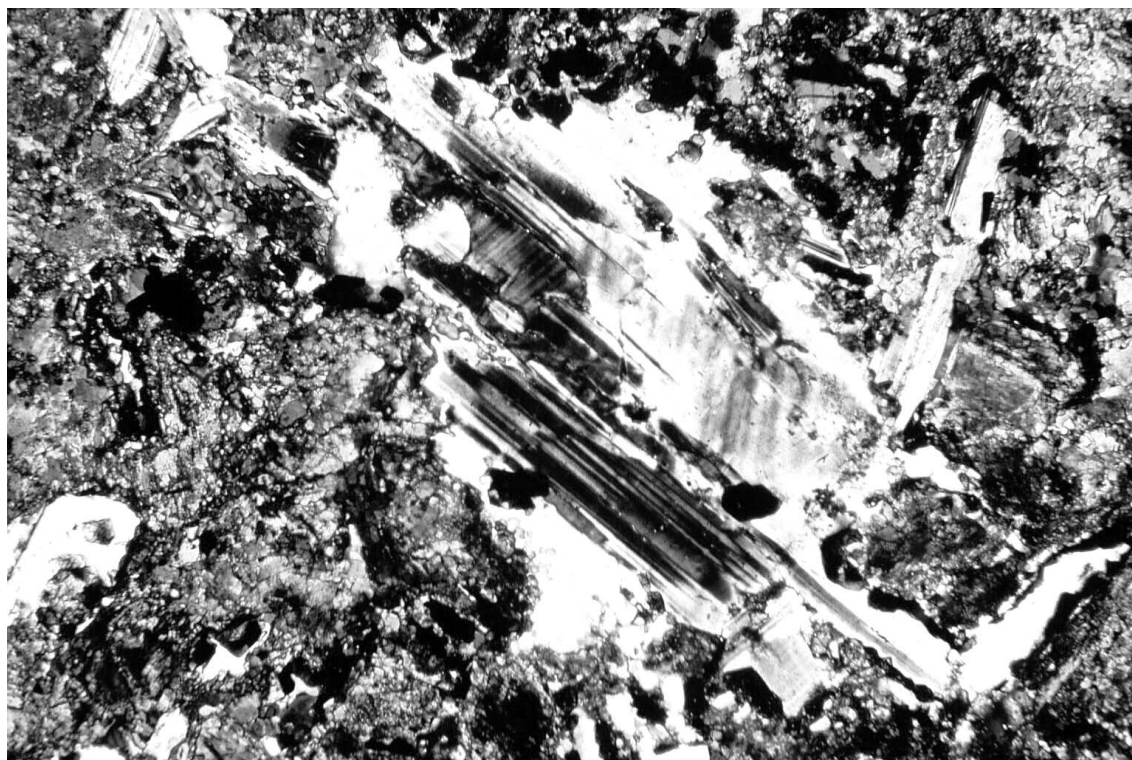
The Moorarie Supersuite comprises granite and pegmatite dated between 1830 and 1780 Ma. These granites and pegmatites intrude the Glenburgh Terrane, Camel Hills Metamorphics, and reworked Archaean gneisses of the Yarlalweelor gneiss complex. The granites and pegmatites were emplaced during and after deformation and regional metamorphism associated with the Capricorn Orogeny (Occhipinti et al., 1998).

Intrusions of the Moorarie Supersuite outcrop over a wide area on ERRABIDDY and LANDOR. Where they intrude the Yarlalweelor gneiss complex and Camel Hills Metamorphics, the intrusions commonly form veins, sheets, dykes, plugs, and stocks. Most of the intrusions are leucocratic and pegmatites are abundant. In the Glenburgh Terrane on LANDOR, granites of the Moorarie Supersuite also form large plutons, some of which are dominated by mesocratic granodiorite.

### **Medium-grained biotite–muscovite granite (Pgme)**

Southwest of Pines Bore on ERRABIDDY (at MGA 421157), a pluton of medium-grained biotite–muscovite granite





**Figure 8.** Photomicrograph (taken in crossed polars) of the corona texture of garnet and green hornblende around plagioclase in a metadolerite dyke (*Edm*) on ERRABIDDY (at MGA 406795). GSWA 144370. Field of view is 3 mm across

intrudes migmatitic pelitic gneiss (*BmCqn*), together with minor dark-grey, massive tonalite, and fine-grained biotite granite with disseminated clots of biotite. The pluton is about 10 km long and 5 km wide, and strikes in an easterly direction. The granite is pale grey and varies from even textured to weakly porphyritic (up to 5% tabular or rounded phenocrysts of microcline). Inclusions are rare. The granite is commonly massive or weakly foliated, except where cut by narrow, east-southeasterly trending shear zones and quartz-filled faults. Dykes of medium-grained, even-textured to weakly porphyritic biotite granite also intrude the surrounding pelitic gneiss.

The pluton and dykes consist of fine- to medium-grained biotite–muscovite monzogranite, locally with accessory garnet. Other accessory minerals are ilmenite, apatite, allanite, and zircon, mostly hosted in, or located adjacent to, biotite. Microcline phenocrysts contain small euhedral inclusions of plagioclase and biotite, and rounded inclusions of quartz. All samples are metamorphosed at a low grade, mainly under static conditions. This is evident from partial recrystallization of quartz, biotite, and muscovite to finer grained aggregates, from ribbon microperthite textures in microcline, and from the alteration of plagioclase to albite, sericite, and minor clinozoisite.

#### **Coarse-grained leucocratic granite dykes (*BgMl*)**

Dykes of coarse-grained leucocratic biotite granite (*BgMl*) intrude the Nardoo Granite in the area southeast of

Brockman Well (at MGA 601029) in the western part of LANDOR. The dykes are up to 10 m wide. The larger dykes may be traced along strike for up to 3 km. The dykes contain elliptical microcline–microperthite phenocrysts up to 1 cm long, which commonly have small inclusions of subhedral plagioclase and biotite. The rocks are commonly moderately recrystallized. Fine-grained granophyric intergrowths of quartz and microcline are common. Plagioclase (oligoclase) is partly replaced by albite, sericite, and epidote.

#### **Coarse-grained granite and pegmatite (*BgMp*)**

Sheets, dykes, and veins of coarse-grained granite and pegmatite (*BgMp*) are widespread in the Narryer Terrane and the Camel Hills Metamorphics on ERRABIDDY and LANDOR. Coarse-grained granite and pegmatite are much more abundant in the Yarlalweelor gneiss complex (*Angl*, *Angm*) than in the Narryer Terrane (*Angl*, *Angm*). In addition, medium- to coarse-grained biotite–muscovite granite and pegmatite form an elongate, northeasterly trending pluton about 15 km long and 5 km wide north of Dewar Bore. Dykes of coarse-grained granite and pegmatite also intruded the Nardoo Granite on LANDOR.

In the Camel Hills Metamorphics and Yarlalweelor gneiss complex, the sheets and some veins are concordant or slightly discordant to the gneissic layering. Dykes and many veins are strongly discordant to the gneissic layering. The granite and pegmatite are folded and deformed by  $D_{1n}$  structures, but they also cut  $D_{1n}$  folds —

therefore, they were intruded during  $D_{in}$  (see **Capricorn Orogeny**). In the area east of Vince Bore and south of Pines Bore on eastern ERRABIDY, pegmatite commonly forms east-southeasterly or southeasterly trending dykes. A sample from a large sheet on MARQUIS gave a SHRIMP U–Pb zircon date of  $1813 \pm 8$  Ma (GSWA 142849; Nelson, 1998). On ERRABIDY, coarse-grained granite and pegmatite north of Dewar Bore is intruded by a plug and associated veins of massive, fine- to medium-grained, leucocratic muscovite–biotite granite (*PgMv*) dated at  $1802 \pm 9$  Ma. This field relationship is consistent with the coarse-grained granite and pegmatite on ERRABIDY and LANDOR being the same age as those on MARQUIS.

The pluton north of Dewar Bore (centred at MGA 340975) is composed of sheets of weakly to strongly foliated, medium- to coarse-grained muscovite–biotite granite and pegmatite. The pluton contains up to 20% angular and lenticular inclusions of leucocratic granitic gneiss (*Engl*) and amphibolite (*Aba*) from less than a metre, up to a few hundred metres long. Along the southern margin of the pluton, numerous granite and pegmatite veins, dykes, and sheets intruded foliated, strongly porphyritic granite (*Agpr*).

On the southeastern part of ERRABIDY, sheets of coarse-grained biotite monzogranite to granodiorite, up to 1.5 km thick, intrude reworked leucocratic granitic gneiss (*Engl*). This part of ERRABIDY is close to the tectonic boundary between the Yilgarn Craton and Yarlalweelor gneiss complex, and the abundance of the coarse-grained granite sheets in this zone may represent magmatic ‘stitching’ of this faulted contact.

The mineralogy of the sheets and veins is variable, and may be partly dependent on the country rocks. The pegmatites commonly contain biotite, with or without muscovite, where they intrude granitic gneiss. In contrast, where they intrude migmatitic pelitic gneiss, the bulk of the pegmatites contain muscovite with or without tourmaline and biotite. Many of the pegmatite veins and sheets are hypersolvus — they contain plagioclase crystals with microcline intergrowths. All coarse-grained granite and pegmatite samples are moderately to strongly recrystallized. On ERRABIDY, both the pluton north of Dewar Bore and the granites that intruded the migmatitic pelitic gneiss consist of biotite–muscovite tonalite and trondjemite. Unaltered plagioclase crystals are andesine, but most crystals show some alteration to fine-grained sericite and minor clinozoisite.

### **Strongly porphyritic, foliated granite (*PgMpr*)**

Strongly porphyritic, foliated granite (*PgMpr*) forms several sheets that intrude migmatitic pelitic gneiss east of Vince Bore (at MGA 451082) on ERRABIDY. The granite is typically moderately to strongly foliated, and locally it is an augen gneiss. Although strongly porphyritic, foliated granite has an identical appearance to Archaean augen gneiss and porphyritic granite (*Agpr*), the Archaean unit is intruded by late Archaean granite (*Age*), whereas the strongly porphyritic, foliated granite intruded migmatitic pelitic gneiss (*PmCqn*) of the Camel Hills Metamorphics. The Palaeoproterozoic, strongly

porphyritic, foliated granite commonly contains abundant biotite-rich inclusions and mafic schlieren, features absent from the Archaean unit.

The granite consists of about 30–40% round phenocrysts or porphyroclasts of microcline in a medium-grained (2–3 mm) groundmass. The porphyroclasts typically display deformation lamellae and chequerboard microperthite textures. Small inclusions of round quartz and subhedral plagioclase are preserved in many phenocrysts. The groundmass consists of extensively recrystallized quartz, microcline, plagioclase, and biotite, with accessory zircon, apatite, and monazite. Igneous plagioclase is typically altered to fine-grained sericite, epidote, and ?albite–oligoclase.

Foliated, strongly porphyritic biotite monzogranite also forms a series of exposures between the Gascoyne River and the Landor – Dalgety Downs Road in the western half of LANDOR. The monzogranite contains tabular phenocrysts of microcline up to 3 cm long in a grey, medium-grained groundmass. The monzogranite is veined by medium-grained, even-textured leucocratic biotite granite (*PgMe*). Thin sections show the monzogranite to have a metamorphic overprint; quartz and biotite are largely recrystallized, granophyric intergrowths of microcline and quartz are abundant, and plagioclase is strongly altered to sericite, epidote, and ?albite.

### **Dumbie Granodiorite (*PgMdu*)**

The Dumbie Granodiorite (*PgMdu*) is named after Dumbie Well on GLENBURGH to the west, where this unit outcrops extensively. Foliated, strongly porphyritic biotite granodiorite and biotite tonalite on northwestern LANDOR are correlated with the Dumbie Granodiorite on GLENBURGH (Occhipinti and Sheppard, in prep.). On GLENBURGH and PINK HILLS, porphyritic biotite granodiorite of the Dumbie Granodiorite that can be traced south onto LANDOR, has been dated respectively at  $1811 \pm 6$  Ma (GSWA 159995; Nelson, 2000) and  $1810 \pm 9$  Ma (GSWA 159987; Nelson, 2000).

On LANDOR, the Dumbie Granodiorite contains tabular or rounded phenocrysts of microcline up to 3 cm long in a grey, medium-grained groundmass of plagioclase, quartz, and biotite. Biotite is commonly recrystallized and aligned in the foliation, and is locally overprinted by chlorite or sericite, and epidote. Accessory minerals include zircon, apatite, allanite, and titanite. Fine-grained epidote, chlorite, sericite, and titanite grew during a later greenschist facies metamorphic event.

Inclusions of amphibolite, fine-grained granodiorite, and biotite schist are common in the Dumbie Granodiorite on LANDOR. These inclusions commonly contain a folded foliation, whereas the porphyritic biotite monzogranite commonly only contains one foliation that is subparallel to the axial surfaces of folds contained within the inclusions. The granite is veined by medium-grained, even-textured leucocratic biotite monzogranite of the Scrubber Granite (*PgMsc*) and younger leucocratic biotite granite veins that cut both the Scrubber Granite and Dumbie Granodiorite.



### Scrubber Granite (*EgMsc*)

A pluton of fine- to medium-grained, even-textured biotite(–tourmaline) monzogranite, which locally contains abundant ovoid clusters of tourmaline and biotite, outcrops northeast and northwest of Biddenew Well in the northwestern corner of LANDOR. It outcrops as tors and whalebacks over an extensive area approximately 20 km long and 14 km wide. The composite granite pluton is made up of sheets that are commonly only a few metres thick, which trend roughly east. This granite is herein called the Scrubber Granite (*EgMsc*), after Scrubber Bore on LANDOR. Much of the Scrubber Granite on LANDOR was previously mapped by Williams et al. (1983b) as Palaeoproterozoic migmatite.

North of the Mount Gascoyne Creek, on north-western LANDOR, dykes and veins of the Scrubber Granite intrude porphyritic biotite granodiorite of the Dumbie Granodiorite (*EgMdu*; see **Dumbie Granodiorite**). Further to the west and north on GLENBURGH, a SHRIMP U–Pb zircon date on the Scrubber Granite yielded two age populations at  $1796 \pm 6$  Ma and  $2290 \pm 11$  Ma (GSWA 159996; Nelson, 2000). The younger population is interpreted to be the igneous crystallization age, whereas the older population is interpreted to be xenocrystic zircons.

The Scrubber Granite is commonly massive, but is locally weakly foliated. It is composed of quartz, K-feldspar, plagioclase, biotite, tourmaline, and fine-

grained muscovite, with accessory zircon and apatite, and sparse opaque minerals. In some instances the granite does not contain any biotite, but instead contains abundant muscovite. Ovoid clusters are composed of tourmaline and quartz, each making up about 45% of the cluster (Fig. 9), with minor amounts of plagioclase and K-feldspar. The tourmaline replaces both feldspar and biotite, apparently pseudomorphing these minerals where the ovoid clusters are best developed. In places, smaller tourmaline crystals are scattered through the groundmass of the Scrubber Granite; the timing of their crystallization relative to the igneous minerals in the groundmass is uncertain. Sericite commonly dusts plagioclase and K-feldspar, and less commonly partially replaces biotite. Quartz is commonly present as small subgrains or larger grains with undulose extinction.

### Leucocratic muscovite–biotite granite (*EgMv*)

A small plug (~2 km<sup>2</sup>) of leucocratic muscovite–biotite granite intrudes leucocratic granitic gneiss (*Engl*) about 4 km east of Wheelo Bore (at MGA 306974). Veins and dykes of fine-grained leucocratic muscovite–biotite granite also intrude the granitic gneiss, strongly foliated porphyritic granite (*Agpr*), and coarse-grained muscovite–biotite granite and pegmatite (*EgMp*) up to 3 km away from the plug. The plug and veins and dykes of leucocratic muscovite–biotite granite are massive or weakly foliated. Several dykes of muscovite pegmatite



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Figure 9. Photomicrograph of the Scrubber Granite taken in plane-polarized light. Field of view is 3 mm. GSWA 144728 on LANDOR (at MGA 751334). Left part of the slide shows the tourmaline–quartz(–feldspar) orbicular structure, right part of the slide shows the groundmass, which comprises quartz–feldspar(–sericite). The feldspar has a ‘dusty’ appearance, and the quartz is clear

intrude the plug. A sample of the granite from the plug gave a SHRIMP U–Pb zircon age of  $1802 \pm 9$  Ma (GSWA 142900; Nelson, 1998).

Leucocratic muscovite–biotite granite is composed of quartz, plagioclase, and microcline, and up to about 10% combined muscovite and biotite. Some samples contain traces of garnet. The accessory minerals are zircon and apatite. The proportion of plagioclase to microcline indicates that the rocks are mainly granodiorite with minor monzogranite. All samples show a static or weak dynamic metamorphic overprint: quartz is recrystallized to fine-grained polygonal aggregates, plagioclase is largely replaced by fine-grained sericite, clinozoisite, and albite, and myrmekitic textures are developed.

### **Fine- to medium-grained, even-textured biotite granite (*Pge*)**

A pluton of fine- to medium-grained, even-textured biotite monzogranite outcrops in the northwestern corner of ERRABIDDY. This granite is in sheared contact with dolerite and gabbro that intrude the Bangemall Supergroup, and unassigned siltstone of the Bangemall Supergroup. The granite is commonly massive, but contains a cleavage in proximity to fault zones where it is also cut by quartz veins that strike  $070^\circ$  to  $130^\circ$ .

The granite contains 15–20% microcline, 20% plagioclase, 30–40% quartz, and about 5% biotite. Accessory minerals include ilmenite, apatite, zircon, and titanite. The biotite is very pleochroic from green to greenish brown. Microcline and plagioclase form subhedral grains. Ribbon-like micropertite texture is locally developed in the microcline. Anhedral quartz is abundant and locally graphic intergrowths between feldspar and quartz are well developed. The only metamorphic recrystallization evident in the rock is that of minor sericite replacing biotite.

### **Mount James Formation (*Pjt*)**

The Mount James Formation (*Pjt*) consists of deformed and metamorphosed siliciclastic rocks that form isolated, commonly fault-bounded, elongate outcrops in the Glenburgh Terrane of the Gascoyne Complex. The Formation unconformably overlies rocks of the Gascoyne Complex and is unconformably overlain by the latest Palaeoproterozoic to Mesoproterozoic Bangemall Supergroup. The age of the Mount James Formation is poorly constrained. Hunter (1990) suggested that it was deposited after late-stage granite emplacement in the Gascoyne Complex, which was poorly constrained by reconnaissance Rb–Sr work to between 2.0 and 1.6 Ga (Libby et al., 1986). More recent work in the southern part of the Gascoyne Complex (Drew, 1999; Nelson, 1999; Occhipinti and Sheppard, in prep.) has found that the youngest rocks underlying the Mount James Formation have an age of c. 1796 Ma.

Hunter (1990) suggested that the Mount James Formation may be correlated with parts of the Padbury Group (Padbury Basin), Mount Minnie Group, and

Capricorn Formation of the Ashburton Basin on the basis of lithological and structural relationships. However, recent mapping has shown that the Mount James Formation cannot be correlated with the Padbury Group, as the Padbury Group is more complexly deformed (Occhipinti et al., 1996). A further difference is that the Mount James Formation outcrops in elongate, discontinuous fault zones that may have controlled initial sedimentation (Hunter, 1990), whereas individual formations of the Padbury Group are not fault bounded.

Hunter (1990) suggested that the Mount James Formation consists of a basal conglomerate overlain by quartzitic, arkosic, and conglomeratic sandstone, locally onlapping the basement. However, mapping on LANDOR and, more recently to the west on GLENBURGH (Occhipinti et al., 1999a; Occhipinti and Sheppard, in prep.) has found that the Mount James Formation succession cannot always be correlated between different fault-bounded lenses. The Mount James Formation outcrops in the northwestern part of LANDOR and mainly consists of quartzite interbedded with metasiltstone (phyllite, slate). Locally, particularly in the area 3.5 km west-northwest of Daly Well, conglomeratic layers within the quartzite contain flattened quartz pebbles, which are elongate subparallel to a strong downdip mineral lineation. The Mount James Formation is tightly folded, but on LANDOR it is difficult to map out individual folds due to poor outcrop. Further to the west on GLENBURGH, tight east-southeasterly trending, slightly inclined folds in the quartzite are present. The Mount James Formation has been metamorphosed at sub- to low-greenschist facies conditions.

### **Unassigned metasedimentary rocks (*Psq*, *Pst*)**

Some outcrops of siliciclastic metasedimentary rock on ERRABIDDY have not been assigned to any formation. These include isolated outcrops of quartzite (*Psq*), locally with fuchsite lenses, which outcrop 7 km east of Milly Mia Bore and 2 km northwest of Mumbarra Pool, and metaquartz sandstone interbedded with siltstone (*Pst*). The metaquartz sandstone locally contains ripple marks and cross-beds and is folded into a tight, east-southeasterly trending synform. The middle of the syncline is poorly exposed, as this part is dominated by metasiltstone (or slate), compared with more-competent metaquartz sandstone that makes up narrow ridges in outcrop (*Pst*). North-northwesterly to north-northeasterly trending faults with small displacements (up to 1 m) cut the folded metaquartz sandstone and siltstone. Locally, particularly in the areas 500 and 1500 m east-southeast of Mount Clere on ERRABIDDY (respectively at MGA 333235 and MGA 355234), silicified fault breccia cuts the quartz sandstone (see **Edmundian Orogeny**).

The age of these metasedimentary rocks is uncertain. They may be equivalent to the Mount James Formation to the west, and are likely to have been deposited late in the Capricorn Orogeny.

## Padbury Group (*Pp*)

The Padbury Group includes metamorphosed siliciclastic and chemical sedimentary rocks that were deposited in the Padbury Basin at <c. 2000 Ma. These rocks form some of the basement to the younger Bangemall Supergroup (Swager and Myers, 1999). Therefore, even though rocks of the Padbury Group do not outcrop on ERRABIDDY or LANDOR, the group has been included in the cross section and simplified bedrock geology on ERRABIDDY.

## Palaeoproterozoic structure

On ERRABIDDY and LANDOR, the regional geology can be separated into three structural domains: the Glenburgh Terrane, Errabiddy Shear Zone, and Yarlaweelor gneiss complex (Table 2). The Glenburgh Terrane and Yarlaweelor gneiss complex are separated by the Errabiddy Shear Zone.

Evidence for two main orogenic events is observed in all three domains. The Glenburgh Orogeny is the older of the two events and its age is constrained on GLENBURGH to 2000–1960 Ma (Sheppard et al., 1999). Occhipinti et al. (1999b) suggested that the orogeny reflects southeastward-directed accretion of the southern part of the Gascoyne Complex (a late Archaean to Palaeoproterozoic micro-continent) onto the passive northwestern margin of the Yilgarn Craton forming the Errabiddy Shear Zone. The Capricorn Orogeny took place between 1830 and 1780 Ma (Occhipinti et al., 1999b) as a result of oblique north-south collision of the Archaean Pilbara and Yilgarn Cratons. Table 2 summarizes the deformation and metamorphic history on ERRABIDDY and LANDOR.

### Glenburgh Orogeny

In the Glenburgh Terrane, two main regional metamorphic and deformation events between c. 2000 and c. 1960 Ma are collectively referred to as the Glenburgh Orogeny (Occhipinti et al., 1999b; Sheppard et al., 1999).

### Deformation and metamorphism ( $D_{1g}$ , $M_{1g}$ )

The oldest fabric in the Glenburgh Terrane is a gneissic layering ( $S_{1g}$ ) in regionally extensive, c. 2000 Ma pegmatite-banded tonalite, granodiorite, and monzogranitic gneiss on GLENBURGH (Occhipinti and Sheppard, in prep.). This fabric was locally folded into tight to isoclinal folds, and intruded by c. 1990 Ma quartzdiorite, monzogranite, or pegmatite. The quartz diorite, monzogranite and pegmatite were metamorphosed to high grade (granulite or amphibolite facies,  $M_{1g}$ ) coincident with the folding. Locally, a foliation subparallel to the fold axial surface of the folds is developed. The metamorphic grades of  $S_{1g}$  and the locally developed axial-planar fabric are indistinguishable, and both possibly formed during the same metamorphic event ( $M_{1g}$ ). The  $M_{1g}$  metamorphic event may have peaked during intrusion of sheets of c. 1990 Ma quartz diorite (Nelson, 1998; Occhipinti and Sheppard, in prep.).

On LANDOR, the evidence for early deformation and metamorphism ( $D_{1g}$ ,  $M_{1g}$ ) is restricted to a gneissic layer-

ing or foliation ( $S_{1g}$ ) in folded inclusions of gneissic tonalite within the c. 1975 Ma Nardoo Granite. This folded fabric developed at medium to high grade metamorphic ( $M_{1g}$ ) conditions.

### Deformation and metamorphism ( $D_{2g}$ , $M_{2g}$ )

Inclusions of gneissic tonalite, granodiorite, and monzogranite in the c. 1975 Ma Nardoo Granite are commonly folded about an axial surface parallel to a penetrative foliation ( $S_{2g}$ ) in the Nardoo Granite. On GLENBURGH, this foliation is cut by a dyke of biotite monzogranite, which has been dated at  $1945 \pm 14$  Ma (GSWA 142929; Nelson, 1999). Therefore,  $D_{2g}$  is constrained to between c. 1975 and c. 1945 Ma. In the migmatitic pelitic gneiss of the Camel Hills Metamorphics, widespread high-grade metamorphism and partial melting are dated at c. 1960 Ma. This metamorphism and deformation is correlated with the penetrative  $S_{2g}$  foliation in the Nardoo Granite.

In the Nardoo Granite,  $D_{2g}$  produced a penetrative foliation defined by alignment of biotite or, in places, a gneissic layering (Fig. 10). Pegmatite segregations or veins that contain clots of biotite are commonly developed in conjunction with the gneissic layering. In strongly foliated or gneissic rocks, quartz defines a grain flattening fabric. Assemblages formed during  $M_{2g}$  consist of biotite, oligoclase-andesine, and epidote.

The earliest structure recognized in the Camel Hills Metamorphics is a gneissic banding ( $S_{2g}$ ), along with coeval leucosomes and diatexite melts in the migmatites of the Quartpot Pelite. The first fold structures ( $F_{2g}$ ) in the Camel Hills Metamorphics are preserved in calc-silicate gneiss northeast of Vince Bore (at MGA 434105) on ERRABIDDY. The folds are recumbent or gently inclined, and tight to isoclinal. They are refolded about upright  $F_{1n}$  folds (see **Capricorn Orogeny**).

The migmatites ( $PmCqn$ ) consist mainly of medium-grained, schollen (raft) and stromatic migmatites (nomenclature after Mehnert, 1968; Ashworth, 1985). The schollen migmatites consist of lumps and fragments of refractory psammite and biotite-rich restitic material set in a heterogeneous diatexite melt in situ (Fig. 6a). Veins and dykes of a more-homogeneous, externally derived diatexite melt also intrude the schollen migmatites, typically at a low angle to the gneissic layering. The stromatic migmatites have well-developed leucosomes parallel to the lithological layering (Fig. 6b). In places, the stromatic migmatites grade into nebulitic migmatites as the layering in the rocks becomes increasingly disrupted (Fig. 6c). The migmatites, in particular those with schollen structures, reflect large degrees of partial melting in situ.

The local and discordant diatexite melts from the schollen migmatites are medium-grained, anhedral granular rocks composed of quartz, plagioclase (andesine), biotite, garnet, sillimanite, and K-feldspar, with accessory opaque minerals, zircon, apatite, and monazite. The diatexites have the composition of a granodiorite. Restite fragments in the diatexite melt, and palaeosomes from the stromatic migmatites are composed of biotite-garnet-sericite mats after possible sillimanite, plagioclase





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**Figure 10. Foliated to gneissic Nardoo Granite with pegmatite segregations or veins parallel to  $S_{2g}$  on LANDOR (at MGA 439962)**

(oligoclase–andesine), quartz, and minor K-feldspar, and accessory opaque minerals, zircon, and apatite. Lumps of refractory psammite in the diatexite melt have amoeboid granoblastic textures and are composed of quartz, plagioclase (andesine), K-feldspar, biotite, minor garnet, and accessory iron-oxides and zircon.

At the northern end of the Quartpot Pelite outcrop on ERRABIDDY, pelitic gneiss and pelitic schist ( $EmCqn$ ) predominate. These rocks locally contain small amounts of a leucosome, but otherwise show no evidence of melting. High-grade pelitic rocks on ERRABIDDY consist of muscovite–biotite(–garnet) gneiss and schist. These rocks are composed of quartz, muscovite, and biotite, with minor plagioclase and garnet, and accessory opaque minerals, apatite, zircon, and ?monazite. Garnet is partly altered along rims and fractures to fine-grained biotite, muscovite, and quartz. Plagioclase is weakly altered to fine-grained sericite.

Calc-silicate gneiss may be divided into two main types based on mineral assemblages; tremolite rich or epidote rich. The tremolite-rich rocks have a decussate texture, and are dominated by bladed tremolite and granular epidote or clinozoisite, with subordinate clinopyroxene, quartz, and albite. Titanite, biotite, and apatite are accessory minerals. The rocks originally consisted of polygonal-textured clinopyroxene and subordinate plagioclase, which are now preserved as small domains or inclusions in tremolite. Epidote-rich rocks are composed of variable proportions of epidote, plagioclase, hornblende, quartz, and grossular garnet, with accessory

ilmenite, titanite, apatite, chlorite, and opaque minerals. Early high-grade assemblages consist of grossular garnet, plagioclase, quartz, and ilmenite with an amoeboid granoblastic texture. Metamorphic assemblages in the tremolite- and epidote-rich rocks indicate metamorphism in the amphibolite facies (Bucher and Frey, 1994).

The amphibolites ( $EmC(a)$ ) are polygonal-textured rocks composed of green hornblende and plagioclase (andesine), with minor quartz and ilmenite. Apatite is an accessory mineral and some samples contain traces of zircon. The occurrence of green hornblende and andesine is indicative of amphibolite facies metamorphism. The quartzite ( $EmCpq$ ) is composed of quartz with minor amounts of grossular garnet and magnetite.

### Capricorn Orogeny

Archaean granitic gneisses in the northeastern part of the Narryer Terrane (Yilgarn Craton) were extensively reworked and intruded by granite and pegmatite during the Capricorn Orogeny (Occhipinti et al., 1998). This zone of reworking was recognized by Williams (1986) and others, and referred to as the Yarlalweelor ‘gneiss belt’. These workers considered the gneiss belt to extend westward onto the GLENBURGH 1:250 000 sheet, and south to the Bullbadger Shear Zone on the southern part of GOULD. However, Palaeoproterozoic intrusions are absent from much of the belt and deformation is restricted to discrete shear zones. Pervasive Palaeoproterozoic reworking of the Archaean granitic gneisses and intrusion

of granite and pegmatite is restricted to the northeastern corner of the Narryer Terrane (Fig. 2), and this area is referred to as the Yarlarweelor gneiss complex (Sheppard and Swager, 1999).

In the Narryer Terrane on ERRABIDDY and LANDOR, Palaeoproterozoic deformation and metamorphism was largely restricted to narrow shear zones. This domain preserves many of the intrusive relationships of the late Archaean granites and some of the Archaean deformation history.

Palaeoproterozoic deformation, metamorphism, and granite intrusion of the Capricorn Orogeny also affected the Camel Hills Metamorphics and Glenburgh Terrane. The main Palaeoproterozoic structure on ERRABIDDY and LANDOR is the Errabiddy Shear Zone. It is about 5–6 km wide and consists of numerous narrow, anastomosing, east and east-northeasterly trending shear zones. This shear zone initially developed during the Glenburgh Orogeny, but was modified during the Capricorn Orogeny.

Two deformation and regional metamorphic events  $D_{1n}$ ,  $M_{1n}$  and  $D_{2n}$ ,  $M_{2n}$  are attributed to the Capricorn Orogeny (Table 2). The  $D_{1n}$  and  $D_{2n}$  structures have been referred to as  $D_{2n}$  and  $D_{3n}$  structures by Occhipinti and Myers (1999) and Sheppard and Swager (1999) respectively. These authors regarded an earlier flat fabric in rocks of the Bryah Group as belonging to the Capricorn Orogeny. However, it is now considered likely that this early fabric formed during the Glenburgh Orogeny.

### Deformation and metamorphism ( $D_{1n}$ , $M_{1n}$ )

Archaean granitic gneisses of the Yarlarweelor gneiss complex and metasedimentary rocks of the Camel Hills Metamorphics are folded about upright  $F_{1n}$  folds. These folds are the most common structures in the Yarlarweelor gneiss complex and the Camel Hills Metamorphics. The  $F_{1n}$  structures fold the migmatitic pelitic gneisses, including the leucosomes and diatexite melts of the Quartpot Pelite (Fig. 11).

The  $F_{1n}$  folds range from close in areas of moderate  $D_{1n}$  strain, to isoclinal in zones of high  $D_{1n}$  strain. Pelitic schist and gneiss at the northern end of the outcrop of Quartpot Pelite on ERRABIDDY commonly contain a steeply dipping crenulation cleavage. The axis of the crenulation plunges parallel to the  $F_{1n}$  folds. The plunge of  $F_{1n}$  folds ranges from shallow to steep. The limbs of  $F_{1n}$  folds are commonly marked by a strong foliation, or in some places, by a gneissic banding. For example, sheets of coarse-grained granite and pegmatite (*PgMp*) may be essentially undeformed in  $F_{1n}$  fold hinges, but become gneissic granite in the limbs where they may be boudinaged. Thicker layers of calc-silicate gneiss and amphibolite in the northeast part of ERRABIDDY commonly define fold hinges with amplitudes of up to 200 m.

The  $F_{1n}$  folds within the Errabiddy Shear Zone show a change in trend from easterly on LANDOR, to northerly on the eastern edge of ERRABIDDY. In the area 8–10 km east-northeast of Vince Bore on ERRABIDDY, north-



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**Figure 11.** Migmatitic  $S_{2g}$  fabric in the Quartpot Pelite folded about a shallowly plunging, easterly trending  $F_{1n}$  fold. The fold is cut by a leucocratic pegmatite vein at the right of the figure on LANDOR (at MGA 778837)



northeasterly trending  $F_{1n}$  folds plunge shallowly to moderately to the north or south. This contrasts with the upright, easterly trending  $F_{1n}$  folds on south central LANDOR that plunge shallowly to the east or west.

In the southwestern corner of ERRABIDY and the southeastern corner of LANDOR in the Errabiddy Shear Zone, east-northeasterly trending shear zones with associated tight to isoclinal, mesoscopic upright folds cut the Narryer Terrane (Fig. 4). These folds are correlated with pervasive  $F_{1n}$  folds in the Yarlalweelor gneiss complex and Camel Hills Metamorphics (discussed above).

In the Errabiddy Shear Zone on southwest ERRABIDY and southeast LANDOR,  $F_{1n}$  folds plunge moderately or steeply to the northeast, or shallowly or moderately to the southwest. Individual folds may show changes in the angle of plunge of up to  $50^\circ$ , including plunge reversals. Northeasterly plunging folds commonly have a 'Z' sense of asymmetry consistent with a dextral sense of shear (i.e. north block to the east-northeast). Locally, an intersection lineation plunges parallel to the  $F_{1n}$  folds. Porphyroclasts show reversals in sense of shear around some  $F_{1n}$  fold axes indicating that an early lineation has been folded. Small-scale, type 2 refolded fold structures (Ramsay, 1967) produced by interference between Archaean  $F_2$  and  $F_{1n}$  are widespread.

Shear zones that form part of the Errabiddy Shear Zone (Fig. 12) typically display a strong stretching

lineation with a variable plunge. The lineation commonly plunges shallowly or moderately to the northeast or southwest, but locally it plunges very steeply to the north or south. On steeply northerly dipping surfaces, asymmetric porphyroclast tails typically indicate reverse movement (i.e. north block over south), commonly with a component of dextral strike-slip movement. Surfaces that dip steeply to the south record both dominantly normal (north block up) and reverse movement (south block up). The large variations in plunge of  $F_{1n}$  fold axes and lineations suggests that early formed structures were being rotated into a new orientation. On ERONG, to the southwest, an early formed, shallowly plunging lineation is overprinted by a steeply dipping lineation (Passchier, C. W., 1997, pers. comm.). The early lineation may be related to dextral strike-slip movement and amphibolite facies metamorphism, possibly during  $D_{1n}$ .

The age of the  $D_{1n}$  event is tightly constrained by U–Pb SHRIMP dating on MARQUIS and MOORARIE (Occhipinti and Myers, 1999; Sheppard and Swager, 1999). Pegmatite and coarse-grained granite sheets and veins truncate  $D_{1n}$  structures at a low angle, whereas others are folded around  $F_{1n}$  folds, and in places, become deformed into pegmatitic and granitic gneiss. These relationships suggest that  $D_{1n}$  was synchronous with granite and pegmatite intrusion, dated at  $1813 \pm 8$  Ma. A maximum age for the deformation is provided by a date of  $1811 \pm 9$  Ma for a dyke of medium-grained, weakly porphyritic biotite monzogranite on MARQUIS



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**Figure 12.** Foliated, Archaean mesocratic porphyritic granite (*Agp*) cut by a narrow shear zone developed during  $D_{1n}$  of the Capricorn Orogeny. Within the shear zone, the granite is transformed into a gneiss, similar in appearance to Archaean and reworked mesocratic granitic gneiss (*Angm*, *Ængm*; on LANDOR at MGA 995800)



(Sheppard and Swager, 1999). This is one of a number of dykes that are consistently folded about  $F_{1n}$  and intruded by coarse-grained granite and pegmatite (*PgMp*). A minimum age of the  $D_{1n}$  event is provided by a U–Pb SHRIMP zircon date of  $1808 \pm 6$  Ma for the Kerba Granite on MOORARIE, which is discordant to  $D_{1n}$  structures (Occhipinti and Myers, 1999). A plug of fine- to medium-grained muscovite–biotite granite on ERRABIDDY, dated at  $1802 \pm 9$  Ma (see **Leucocratic muscovite–biotite granite**), is also discordant to  $D_{1n}$  structures.

On MARQUIS, Sheppard and Swager (1999) documented amphibolite or upper amphibolite facies assemblages associated with  $D_{1n}$  (their  $D_{2n}$ ). The presence of ductile fabrics in coarse-grained granite and pegmatite (*PgMp*) on  $F_{1n}$  fold limbs on ERRABIDDY is consistent with medium- to high-grade metamorphism during  $D_{1n}$ . Many of the steeply dipping shear zones that make up the Errabiddy Shear Zone are marked by ductile fabrics. Archaean granites cut by these shear zones are commonly transformed into gneisses (Fig. 12). Amphibolite layers in areas pervasively deformed during  $D_{1n}$  consist of green hornblende and plagioclase (andesine), or green hornblende, andesine, and clinopyroxene, both with quartz and ilmenite. The assemblages are typical of regional metamorphism at amphibolite or upper amphibolite facies (Bucher and Frey, 1994).

In the Yarlarweelor gneiss complex on southern ERRABIDDY, in the area 2 km southwest of Wilton Bore, Palaeoproterozoic metadolerite dykes (*Pdm*) trend parallel to  $F_{1n}$  folds. Although the dykes are not deformed by the  $F_{1n}$  folds, corona textures and mineral assemblages in the dykes suggest emplacement into ambient upper amphibolite or granulite facies conditions (Muhling, 1986, 1990). Therefore, the metadolerite dykes probably intruded late during  $D_{1n}$ ,  $M_{1n}$ . The metadolerite dykes are intruded by veins and dykes of coarse granite and pegmatite (*PgMp*) coeval with  $D_{1n}$ .

### Deformation and metamorphism ( $D_{2n}$ , $M_{2n}$ )

Numerous subvertical,  $D_{2n}$  brittle–ductile shear zones and faults, which mainly trend east or east-southeast ( $80$ – $110^\circ$ ), cut the  $D_{1n}$  structures in the Errabiddy Shear Zone, Yarlarweelor gneiss complex, and migmatitic pelitic gneiss. These structures correlate with conjugate ductile  $D_{2n}$  shear zones and faults in two orientations:  $080$ – $110^\circ$  and  $140$ – $170^\circ$  observed to the east on MOORARIE and MARQUIS (Occhipinti and Myers, 1999; Sheppard and Swager, 1999). The largest of these faults is the Morris Fault (Fig. 3), which is a splay off the Errabiddy Shear Zone.

The  $D_{2n}$  structures range from shear zones a few metres wide, up to zones about one hundred metres wide marked by upright, open to close folds and a foliation of variable intensity. Fold plunges range from shallow to nearly vertical and dip towards the southeast. In strongly sheared granitic gneisses and interlayered amphibolite and metamorphosed ultramafic rock,  $D_{2n}$  structures may consist of a crenulation cleavage. The axis of the crenulation typically plunges steeply to the southeast. Many of the shear zones contain mylonitic quartz veins, indicating that some quartz veins formed prior to

deformation. Most of the faults and shears are marked by a dextral offset ranging from a centimetre up to a few hundred metres. In places, shallowly plunging, east-northeasterly trending  $F_{1n}$  folds were rotated into steeply plunging, east-southeasterly trending folds, probably during  $D_{2n}$  (Fig. 4).

In the Errabiddy Shear Zone on ERRABIDDY, a number of faults and narrow shear zones strike between  $140^\circ$  and  $160^\circ$ . They overprint the  $D_{2n}$  foliation that strikes east to east-southeast and may be accompanied by small-scale, upright, open to tight folds. These structures may be related to a younger deformation event, or by analogy with MARQUIS (Sheppard and Swager, 1999), they may be the conjugate structures to those that strike  $080$ – $110^\circ$ .

Occhipinti and Myers (1999) and Sheppard and Swager (1999) noted that the sigmoidal shapes of some of the faults that strike between  $140^\circ$  and  $170^\circ$ , and the dextral sense of shear on many of the faults that strike between  $080^\circ$  and  $110^\circ$ , are consistent with dextral movement on the Morris Fault. They suggested that dextral movement on the Morris Fault at c. 1800 Ma may have been a result of oblique north–south compression. However, Pirajno et al. (2000) suggested that late dextral shear movement in the Yarlarweelor gneiss complex may be due to extension.

The age of  $D_{2n}$  is well constrained on MARQUIS and MOORARIE (Occhipinti and Myers, 1999; Sheppard and Swager, 1999). Coarse-grained granite and pegmatite sheets dated at  $1813 \pm 8$  Ma and the Kerba Granite dated at  $1808 \pm 6$  Ma are cut by  $D_{2n}$  faults, and thus provide a maximum age for the deformation. Dykes of medium-grained granite (*PgMe*) are widely emplaced into  $D_{2n}$  faults and display a range of textures from massive to foliated, implying that they were intruded coeval with  $D_{2n}$ . One of these dykes on MARQUIS has been dated at  $1797 \pm 4$  Ma.

On ERRABIDDY, many of the  $D_{2n}$  faults and fractures are associated with veins of epidote, in conjunction with epidote and sericite alteration in the wall rocks. Gneisses of the Narryer Terrane and Yarlarweelor gneiss complex, metasedimentary rocks of the Camel Hills Metamorphics, and Palaeoproterozoic granites are all variably overprinted by low- to medium-grade metamorphic assemblages. Much of this overprint may be related to  $M_{2n}$ .

In the granitic gneisses and granites of the Narryer Terrane and Yarlarweelor gneiss complex, the  $M_{2n}$  overprint consists of recrystallized quartz and biotite, alteration of plagioclase to albite, sericite, and clinozoisite, and retrogression of microcline to albite and sericite. Ilmenite crystals are commonly rimmed by titanite. Similar mineralogical and textural changes are noted in late Archaean granites and Palaeoproterozoic granites of the Dalgaringa and Moorarie Supersuites.

Medium- and high-grade assemblages ( $M_{2g}$ ,  $M_{1n}$ ) in the pelitic rocks of the Quartpot Pelite are variably overprinted by a lower grade metamorphic event. Plagioclase is moderately to extensively replaced by fine-grained sericite, epidote, and albite, and garnet is partly altered to fine-grained biotite and muscovite. Sillimanite is entirely replaced by fine-grained mats of sericite.

K-feldspar is partly replaced by sericite, quartz, and albite. Accompanying these mineralogical changes are recrystallization of quartz and biotite, and the development of granophyric and myrmekitic textures.

In both the Archaean and Palaeoproterozoic amphibolites, mineral growth during  $M_{2n}$  consists of titanite replacement of ilmenite and partial replacement of andesine by epidote, untwinned plagioclase, and calcite. In addition, hornblende is commonly partly replaced by finer grained actinolite. In the Archaean and Palaeoproterozoic calc-silicate gneisses, epidote, green hornblende, albite, and titanite partly or largely replace high-grade assemblages.

The time of deposition and deformation of the Mount James Formation is uncertain. Occhipinti et al. (1999a) suggested that the Mount James Formation may have been deposited during the waning stages of the Capricorn Orogeny. The formation commonly outcrops as elongate, fault-bounded lenses of tightly folded rock (Occhipinti and Sheppard, in prep.). The trend of the fold axial surface is subparallel to the trend of faults that bound the outcrops of Mount James Formation. Bedding is commonly steeply dipping and folded into asymmetric folds that may have developed during the Capricorn or Edmundian Orogenies. In the area 3.5 km west-northwest of Daly Well on LANDOR, the southern limb of an asymmetric east-southeasterly trending syncline is exposed. This limb contains steeply dipping, slightly overturned strata with a well-developed cleavage at a low angle to bedding, which indicates vergence to the south-southwest.

## **Latest Palaeoproterozoic to Mesoproterozoic geology**

### **Bangemall Supergroup**

The Bangemall Supergroup consists of the Edmund and Collier Groups (Martin et al., 1999b). This supergroup was previously known as the Bangemall Group, and the Edmund and Collier Groups were considered subgroups of the Bangemall Group (Muhling and Brakel, 1985; Cooper et al., 1998). Martin et al. (1999b) found evidence for a major unconformity between the older Edmund Subgroup and the overlying Collier Subgroup on the EDMUND, TUREE CREEK, and MOUNT EGERTON 1:250 000 sheets. Accordingly, these subgroups were raised to group status, and the Bangemall Group to supergroup status. The Edmund and Collier Groups were deposited respectively in the Edmund and Collier Basins (Martin et al., 1999a).

The Bangemall Supergroup consists mainly of fine-grained siliciclastic and carbonate sedimentary rocks. These rocks unconformably overlie granitic and supra-crustal rocks of the Archaean Yilgarn Craton, granitic and metamorphic rocks of the latest Archaean to Palaeoproterozoic Gascoyne Complex, and Palaeoproterozoic metasedimentary and meta-igneous rocks of the Bryah and Padbury Groups. In the east, the Bangemall Supergroup is overlain by the Neoproterozoic–Palaeozoic Officer Basin (Williams, 1990).

The age of the Bangemall Supergroup is poorly constrained. It unconformably overlies the c. 1800 Ma granites of the Gascoyne Complex, and is older than the Neoproterozoic–Palaeozoic Officer Basin. Martin et al. (1999b) suggested that the supergroup was deposited between c. 1640 and 1000 Ma. The maximum age of c. 1640 Ma is based on a SHRIMP U–Pb zircon date for the Tangadee Rhyolite near the base of the Bangemall Supergroup (Nelson, 1995). However, this date is controversial as it based on only two zircon analyses. Six zircon analyses from the same sample indicated an age of c. 1800 Ma, and are thought to represent xenocrystic zircons. Nelson (1995) suggested that the c. 1640 Ma age may give a maximum age for the emplacement of the rhyolite as the zircons could also be xenocrystic in origin.

On MARQUIS, the 1619 ± 15 Ma Discretion Granite is in faulted contact with the Bangemall Supergroup (Sheppard and Swager, 1999), and thus the original relationship between them is unknown. No veins or dykes of the Discretion Granite are known to intrude the Bangemall Supergroup. Hence, the Bangemall Supergroup and Discretion Granite were tectonically juxtaposed after their formation, although their faulted boundary could represent a faulted unconformity.

The minimum age of c. 1000 Ma for deposition of the Bangemall Supergroup is supported by a c. 1020 Ma U–Pb SHRIMP baddeleyite age for dolerite sills (Wingate, M., 1999, pers. comm.) that intruded into consolidated siltstone of the Edmund Group.

### **Edmund Group**

The Edmund Group unconformably overlies rocks of the Capricorn Orogen and is unconformably overlain by the Collier Group (Martin et al., 1999b). On the eastern part of EDMUND, Martin et al. (1999b) considered the base of the Edmund Group to be the Irregully Formation. On ERRABIDY, however, the Tringadee Formation appears to conformably underlie the Irregully Formation and is included in the Edmund Group.

#### **Tringadee Formation (*PMEe*)**

On ERRABIDY, the Tringadee Formation (*PMEe*) is considered to be the base of the Bangemall Supergroup and Edmund Group. This formation outcrops just south of the Gascoyne River on northeastern ERRABIDY and typically consists of quartz sandstone interbedded with siltstone. The formation appears to be conformably overlain by the Irregully Formation, but the contact between the two formations is not exposed on ERRABIDY. On ERRABIDY, outcrop of the Tringadee Formation is poor, and the base of the formation is not exposed so the thickness of the unit is unknown.

#### **Irregully Formation (*PMEi*)**

On northeastern ERRABIDY, the Irregully Formation (*PMEi*) forms a shallowly dipping unit that is apparently conformable between the underlying Tringadee Formation, and the overlying Kiangi Creek Formation. On ERRABIDY, the formation is between 200 and 350 m thick

and consists of grey, fine-planar, parallel-laminated dolomitic shale and minor sandstone. Elsewhere in the Edmund Basin the formation consists largely of dolostone (formerly dolomite) interbedded with dolomitic siltstone and quartz sandstone (Copp, 1998). To the east on MILGUN, stromatolites are present within the Irregully Formation, outcropping east of Coolinbar Hill and were reported by Elias and Williams (1980) as possible *Conophyton*.

#### *Kiangi Creek Formation (PMEK)*

The Kiangi Creek Formation (*PMEK*) forms a 200–600 m-thick unit on northern ERRABIDDY, although the thickness of the unit may be greater as the base is not exposed. On northeastern ERRABIDDY, the formation consists largely of white, cross-bedded quartz sandstone locally interbedded with grey to greenish siltstone, particularly at the base of the unit. On northwestern ERRABIDDY the Kiangi Creek Formation includes a 300–400 m-thick unit previously mapped as quartz sandstone of the Jillawarra Formation (Elias and Williams, 1980). This is because the Jillawarra Formation is laterally equivalent to the Kiangi Creek Formation. Recently Martin et al. (1999b) considered that where rocks of the Jillawarra Formation appear to be laterally equivalent to the Kiangi Creek Formation, they should be considered to be part of that formation. Outcrop of the Kiangi Creek Formation in the northeastern part of ERRABIDDY mainly consists of planar, fine-laminated siltstone and planar, parallel-laminated and cross-bedded, medium-grained quartz sandstone. Locally, weathered-out mud casts are present within sandy beds. On ERRABIDDY the Kiangi Creek Formation is commonly shallow to moderately dipping and is apparently conformable on the Irregully Formation.

#### *Discovery Formation (PMEd)*

On ERRABIDDY, the Discovery Formation (*PMEd*; Martin et al., 1999b) consists of planar, parallel-laminated to locally wavy beds of chert and siltstone. The formation was previously mapped by Elias and Williams (1980), Muhling and Brakel (1985), Sheppard and Swager (1999), and Swager and Myers (1999) as the Discovery Chert. The chert is grey and black, and is locally silicified and partly ferruginized to form a massive, structureless rock. Locally, for example, 5.5 km north-northwest of Rustler Bore on ERRABIDDY, the Discovery Formation consists of grey, parallel-laminated chert interbedded with siltstone. Muhling and Brakel (1985) suggested that the Discovery Formation is conformable between the underlying Kiangi Creek or Jillawarra Formations and the overlying Ullawarra Formation. However, contacts between the Discovery Formation and these units are not exposed on ERRABIDDY.

#### *Devil Creek Formation (PMEv)*

The Devil Creek Formation consists of bedded dolomite, interbedded with shale and minor chert. To the east on MARQUIS, abundant outcrop of this formation forms elongate lenses on the northern part of the sheet. However, the Devil Creek Formation is not present on ERRABIDDY or LANDOR although, as it may be present in the sub-surface, it has been included in the map cross section.

#### *Ullawarra Formation (PMEI, PMElf)*

On ERRABIDDY, the Ullawarra Formation (*PMEI*) forms low, rounded to steep-sided hills of sandstone and siltstone. The Nanular Member is the only part of the Ullawarra Formation that outcrops on ERRABIDDY. Elias and Williams (1980) mapped the Nanular Member as an undivided arenite of the Bangemall Group. On MARQUIS to the east, the same unit was called the Nanular Sandstone, following Muhling and Brakel (1985) who selected an area south of the Sawback Range as the type section for the unit. On ERRABIDDY, the unit mostly consists of quartz siltstone, and this along with its apparent lateral equivalence to the Ullawarra Formation, has resulted in it being renamed the Nanular Member of the Ullawarra Formation.

The Nanular Member (*PMElf*) consists of mature quartz siltstone, sandstone, and minor conglomerate, and overlies the Discovery Formation. This contact is not exposed on ERRABIDDY, and thus the precise relationship between the two units is uncertain. On ERRABIDDY, the Nanular Member mainly comprises planar, parallel-laminated siltstone that contains thin- to medium-bedded lenses of fine- to medium-grained, mature quartz sandstone. The lenses of quartz sandstone range in size from 300 by 40 m up to 2 km by 500–600 m, and locally contain thin, discontinuous lenses (up to 3 m long) of conglomerate, less than 60 cm wide with pebble-sized, rip-up mud clasts. The quartz sandstone contains subrounded to rounded quartz grains, with minor opaque minerals and feldspar grains ( $\leq 3\%$ ). Some quartz grains show evidence of transport and sedimentation prior to redeposition in the Nanular Member. A few quartz grains showing straight to slightly curved, subparallel lamellae spaced across the grain are present indicating some of the sedimentary material was derived from an meteorite impact site (King, 1976). Seriate grain boundaries and undulose extinction throughout GSWA 144343 indicate that the rock has been deformed, although a foliation has not developed.

#### *Unassigned units of the Bangemall Supergroup (PME(s), PME(t))*

Some outcrops of siliciclastic sedimentary rocks of the Bangemall Supergroup on LANDOR and ERRABIDDY have not been assigned to any formation. Massive and planar-laminated quartz sandstone interbedded with siltstone (*PME(t)*) outcrops only over about 2 km<sup>2</sup> at the northern edge of LANDOR.

Strongly foliated quartz–sericite–hematite siltstone (*PME(s)*) outcrops on northern ERRABIDDY and LANDOR. On ERRABIDDY, this outcrop largely forms rafts within dolerite (see **Dolerite and gabbro**), and has been very strongly deformed to form a phyllite. On northwestern LANDOR, steeply dipping, planar, parallel-laminated siltstone is strongly foliated locally, particularly around a north-easterly trending fault.

#### *Dolerite and gabbro (Pd)*

Dolerite and gabbro sills that contain screens of meta-siltstone (*PME(s)*) outcrop on northwestern ERRABIDDY. The dolerite is locally very fine grained and in places contains



amygdales, suggesting it may be a high-level intrusion. Discontinuous lenses of gabbro and microgabbro form within the very fine grained dolerite. In thin section, the dolerite largely consists of mats of actinolite, plagioclase, and titanite. The plagioclase is locally replaced by fine-grained sericite.

## Edmundian Orogeny

The Edmundian Orogeny (Halligan and Daniels, 1964) resulted in the deformation of the Bangemall Supergroup, and the formation or reactivation of structures in the underlying basement. The Edmundian Orogeny largely resulted in north–south shortening to form easterly to southeasterly trending, open to tight, upright folds and faults. Myers et al. (1996) suggested that this event resulted from the collision of the North and West Australian Cratons between 1300 and 1100 Ma. However, dolerite sills dated at c. 1020 Ma (Wingate, M., 1999, pers. comm.) that intrude the Edmund Group are also deformed into easterly trending folds. The Bangemall Supergroup and dolerite sills are refolded about a north to northeasterly trend to form dome-and-basin structures. Northwest of ERRABIDY and LANDOR, on the EDMUND 1:250 000 sheet, undeformed dolerite dykes that cut both sets of folding of the Bangemall Supergroup have been dated at c. 750 Ma (Wingate, M., 1999, pers. comm.; Martin et al., 1999a). This date, and the age of the deformed dolerite sills, constrains the Edmundian Orogeny to between 1020 and 750 Ma.

Based on this structural sequence, it is apparent that the Edmundian Orogeny, as defined here, involved two main periods of deformation of the Bangemall Supergroup: the first involved north–south shortening and the second, east-southeast to west-northwest shortening. On ERRABIDY, a tight, east-southeasterly trending synform at Mount Clere is present in deformed quartzite. Other east-southeasterly or easterly trending structures include faults, a slaty cleavage, and locally some dextral, strike-slip shear sense indicators.

## Deformation and metamorphism ( $D_{1e}$ , $M_{1e}$ , $D_{2e}$ )

Boundary faults that separate the Edmund Group from the underlying Yarlswheel gneiss complex and Gascoyne complex on ERRABIDY and LANDOR, and the underlying Bryah and Padbury Groups on MILGUN (Swager and Myers, 1999), may have initially developed as early as the Capricorn Orogeny. These faults may have originally been compressional structures, such as thrust or high-angle reverse faults, which were reactivated as normal faults during formation of the Edmund Basin. Quartz veins that trend parallel to these faults in the northwestern part of ERRABIDY cut a massive to locally foliated biotite monzogranite, and in part, form the boundary between this granite and a Proterozoic dolerite sill that cuts the Edmund Group. On MARQUIS, easterly trending, quartz-filled faults cut the Discretion Granite, which is dated at  $1619 \pm 15$  Ma, and separate this granite from the Edmund Group (Sheppard and Swager, 1999). Locally, porphyroclasts within the Discretion Granite record both sinistral and dextral shear movements within the easterly to east-southeasterly trending shear zones, or just show strong flattening, indicating possible plane strain during  $D_{1e}$ .

Folds that strike subparallel to the faults in the Edmund Group on ERRABIDY include the tight, upright, moderately plunging, east-southeasterly trending fold at Mount Clere. Elsewhere on ERRABIDY and LANDOR, rocks of the Edmund Group are not folded about easterly or east-southeasterly trending fold axial surfaces.

Large-scale, northerly or north-northeasterly trending folds in the Bangemall Supergroup reformat east-southeasterly trending folds to form a dome-and-basin structure. On LANDOR, some northerly trending cleavages may correspond to this second deformation event in the Edmundian Orogeny ( $D_{2e}$ ). In addition, a northerly trending fault breccia that cuts the quartz sandstone interbedded with siltstone (*Bst*) on northern ERRABIDY probably developed during  $D_{2e}$ . This fault breccia contains angular fragments of quartz sandstone in a fine-grained, ferruginous matrix (Fig. 13). Contacts between the fault breccia and quartz sandstone are sharp. The fault breccias fill narrow zones that are up to 15 m wide, which coincided with northerly to northeasterly trending faults. The breccia is made up of angular, ‘jigsaw-fit’ fragments of quartz sandstone in a fine-grained, pink or black ferruginous matrix. The ferruginous matrix consists of black or pink, fine-grained iron oxide that may have replaced fine-grained tourmaline.

## Dolerite dykes (d)

Rare, fine-grained, massive dolerite dykes intruded the Archaean and Palaeoproterozoic rocks on ERRABIDY and LANDOR. Most of the dykes strike either east or east-northeast and range from less than 5 to 20 m wide. The largest dykes can be traced for up to about 5 km. A cleavage or foliation developed along the dyke margins. The dykes are composed of rare plagioclase microphenocrysts in a groundmass of very fine grained, granular epidote, albite, chlorite, and titanite, with some relict ilmenite.

## Quartz veins (q)

Quartz veins of various ages outcrop on both ERRABIDY and LANDOR. Large quartz veins commonly mark major faults, including those that constitute the Errabiddy Shear Zone. Locally, within the Errabiddy Shear Zone, grey quartz veins that have a mylonitic fabric have been veined by younger bucky white quartz. This indicates that the shear zone has been periodically reactivated. Locally the quartz veins contain tourmaline. The timing of formation of quartz veins on ERRABIDY and LANDOR is problematic, but it is apparent that the quartz veins are not folded into  $D_{1n}$  folds, indicating that the earliest quartz veins may have formed during the Capricorn Orogeny.

## Cainozoic geology

The Cainozoic geology on ERRABIDY and LANDOR has been divided into twelve units, including Quaternary deposits. These are broadly similar to those on the



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**Figure 13. Hydraulic breccia cutting a quartz arenite (*PME(t)*) in unassigned sedimentary rock (*Pst*) on ERRABIDDY (at MGA 333235)**

ROBINSON RANGE (Bradley et al., 1997) and GLENBURGH 1:250 000 (Sanders et al., 1998) regolith map sheets. Alluvial deposits (*A*) consist of sand, gravel, clay, and silt in the main river channels and floodplains. Calcrete (*Ak*) forms extensive outcrops along the Gascoyne River and some of its tributaries. Alluvial deposits locally grade into overbank (*A<sub>f</sub>*) and sheetwash (*W*) deposits of sand, silt, and gravel. Isolated chemical lake deposits (*L*) containing sand, silt, and clay are present on northern ERRABIDDY and LANDOR. Vegetated sand dunes (*S*) are present on ERRABIDDY southwest of Square Well and north of Bumburra Well. On northeastern LANDOR, vegetated sand dunes are abundant north of the Gascoyne River. Colluvium (*Cl*) is prominent around the steep and rounded slopes underlain by the Camel Hills Metamorphics, and hills of granite tors, whalebacks, and pavements. In flat areas and on gentle slopes, most colluvium forms a veneer of gravel-sized, angular or rounded fragments within sand or silt either over rock or older, consolidated colluvium (*C2*). In some areas, colluvium is dominated by quartz vein (*Cl<sub>q</sub>*) or ferruginous debris (*Cl<sub>f</sub>*). On southeastern ERRABIDDY, ferruginous colluvium around banded iron-formation rocks dominantly consists of banded iron-formation debris.

Laterite (*R<sub>f</sub>*) mainly comprises ferruginous duricrust and is particularly well developed on southeastern LANDOR, where weathered saprolitic rock (*R<sub>g</sub>*), which probably developed over granitic rock, is also present. Consolidated colluvium (*C2*) is well developed around incised creeks, particularly on northwestern and southern LANDOR.

Consolidated ferruginous rubble, developed over iron-rich rocks, comprises highly ferruginized and weathered rock (including laterite), and transported fragments of laterite duricrust. Silcrete (*R<sub>z</sub>*) is well developed at Erong Springs and over granite on northwestern ERRABIDDY.

## Economic geology

Limited mineral exploration has been conducted in the ERRABIDDY–LANDOR region, and no deposits have been discovered yet. However, to the west on GLENBURGH, mineral occurrences of uranium and copper have been reported (Williams et al., 1983b).

Much of the exploration on ERRABIDDY and LANDOR has been directed towards base metals (Cu, Pb, Zn) in rocks of the Bangemall Supergroup. Various companies have undertaken this exploration over the past 30 years, focusing on stratabound mineralization. Locally elevated values of Cu–Pb–Zn in certain horizons within the Bangemall Supergroup have been reported (Bradley et al., 1997). They suggested that elevated base metal values in regolith on northern ERRABIDDY were sourced from the Discovery Chert (now Discovery Formation), Jillawarra Formation (reassigned to the Kiangi Creek Formation), and small dolerite sills. Sanders et al. (1998) reported elevated copper values in the Bangemall Group about 30 km northwest of Landor Homestead on LANDOR.

Two magnetic anomalies identified in a regional aeromagnetic survey conducted by CRA Exploration in



1979 were thought to be related to pyrrhotite-associated, base metal mineralization. Drilling of the anomalies did not encounter any significant mineralization (Eggo and Ryder-Turner, 1982), and it was concluded that the anomalies were related to minor disseminated pyrite and chalcopyrite in chloritized mafic intrusions.

No gold occurrences have been reported on ERRABIDDY and LANDOR. Sanders et al. (1998) reported anomalous gold values (4–6 ppb) in regolith samples about 30 km northwest and 10 km west-southwest of Landor Homestead.

## References

- ASHWORTH, J. R., 1985, *Migmatites*: Glasgow, Blackie, 302p.
- BEARD, J. S., 1981, The vegetation of Western Australia at the 1:3 000 000 scale: Western Australia Forests Department, Explanatory Notes, 32p.
- BRADLEY, J. J., FAULKNER, J. A., and SANDERS, A. J., 1997, Geochemical mapping of the Robinson Range 1:250 000 sheet: Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, 57p.
- BUCHER, K., and FREY, M., 1994, *Petrogenesis of metamorphic rocks* (6th edition): Berlin, Springer-Verlag, 318p.
- COOPER, R. W., LANGFORD, R. L., and PIRAJNO, F., 1998, Mineral occurrences and exploration potential of the Bangemall Basin: Western Australia Geological Survey, Report 64, 42p.
- COPP, I. A., 1998, The Mesoproterozoic Irregularly Formation, Bangemall Basin: a preliminary interpretation of the type section: Western Australia Geological Survey, Annual Review 1997–98, p. 91–98.
- DREW, B., 1999, The geology of the Mount James Formation in the Coor-de-wandy Hill area, Western Australia: Geology Department, University of Western Australia, Preliminary mapping report, 27p.
- EGGO, A. J., and RYDER-TURNER, A. G., 1982, Final report on exploration completed within Mount Erong MCA 09/3396–3397, 3399–3400, and Dingo Well MCA 09/3387–3395, Glenburgh, SG 50–6, Western Australia: Western Australia Geological Survey, M-series, Item 2066 (unpublished).
- ELIAS, M., and WILLIAMS, S. J., 1980, Robinson Range, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 32p.
- FRASER, G., ELLIS, D. J., and EGGINS, S. M., 1997, Zirconium abundance in granulite-facies minerals, with implications for zircon geochronology in high-grade rocks: *Geology*, v. 25, p. 607–610.
- HALLIGAN, R., and DANIELS, J. L., 1964, The Precambrian geology of the Ashburton Valley region, northwest Division: Western Australia Geological Survey, Annual Report 1963, p. 38–46.
- HUNTER, W. M., 1990, Mount James Formation, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 221–223.
- KING, E. A., 1976, *Space geology an introduction*: New York, J. Wiley and Sons Incorporated, 349p.
- KINNY, P. D., WIJBRANS, J. R., FROUDE, D. O., WILLIAMS, I. S., and COMPSTON, W., 1990, Age constraints on the geological evolution of the Narryer Gneiss Complex, Western Australia: *Australian Journal of Earth Sciences*, v. 37, p. 51–69.
- LIBBY, W. G., de LAETER, J. R., and MYERS, J. S., 1986, Geochronology of the Gascoyne Province: Western Australia Geological Survey, Report 20, 31p.
- MARTIN, D. M., THORNE, A. M., and COPP, I. A., 1999a, Elliot Creek, W.A. Sheet 2250 (Preliminary edition): Western Australia Geological Survey, 1:100 000 Geological Series.
- MARTIN, D. M., THORNE, A. M., and COPP, I. A., 1999b, A provisional revised stratigraphy for the Bangemall Group on the Edmund 1:250 000 sheet: Western Australia Geological Survey, Annual Review 1998–99, p. 51–55.
- MEHNERT, K. R., 1968, *Migmatites and the origin of granitic rocks*: Amsterdam, Elsevier, 405p.
- MUHLING, J. R., 1986, Tectonothermal history of the Mukalo Creek area, southern Gascoyne Province, Western Australia: Crustal evolution of Archaean gneisses reworked during Proterozoic orogenesis: University of Western Australia, PhD thesis (unpublished).
- MUHLING, J. R., 1990, The Narryer Gneiss Complex of the Yilgarn Block, Western Australia — a segment of Archaean lower crust uplifted during Proterozoic orogeny: *Journal of Metamorphic Geology*, v. 8, p. 47–64.
- MUHLING, P. C., and BRAKEL, A. T., 1985, Geology of the Bangemall Group — the evolution of an intracratonic Proterozoic basin: Western Australia Geological Survey, Bulletin 128, 266p.
- MYERS, J. S., 1988, Early Archaean Narryer Gneiss Complex, Yilgarn Craton, Western Australia: *Precambrian Research*, v. 38, p. 297–307.
- MYERS, J. S., 1990a, Gascoyne Complex, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 198–202.
- MYERS, J. S., 1990b, Part 1 — Summary of the Narryer Gneiss Complex, in *Third International Archaean Symposium Excursion Guidebook* edited by S. E. HO, J. E. GLOVER, J. S. MYERS, and J. R. MUHLING: University of Western Australia, Geology Department and University Extension, Publication no. 21, p. 62–71.
- MYERS, J. S., 1990c, Precambrian tectonic evolution of part of Gondwana, southwestern Australia: *Geology*, v. 18, p. 537–540.
- MYERS, J. S., 1993, Precambrian history of the West Australian Craton and adjacent orogens: *Annual Reviews in Earth and Planetary Science*, v. 21, p. 453–485.
- MYERS, J. S., SHAW, R. D., and TYLER, I. M., 1996, Tectonic evolution of Proterozoic Australia: *Tectonics*, v. 15, p. 1431–1446.
- NELSON, D. R., 1995, Compilation of SHRIMP U–Pb zircon geochronology data, 1994: Western Australia Geological Survey, Record 1995/3, 243p.
- NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.
- NELSON, D. R., 1999, Compilation of geochronology data, 1998: Western Australia Geological Survey, Record 1999/2, 222p.
- NELSON, D. R., 2000, Compilation of geochronology data, 1999: Western Australia Geological Survey, Record 2000/2, 251p.
- NUTMAN, A. P., BENNETT, V. C., KINNY, P. D., and PRICE, R., 1993, Large-scale crustal structure of the northwestern Yilgarn Craton, Western Australia: evidence from Nd isotopic data and zircon geochronology: *Tectonics*, v. 12, p. 971–981.
- NUTMAN, A. P., and KINNY, P. D., 1994, SHRIMP zircon geochronology of the southern Gascoyne Province and the northwestern margin of the Yilgarn Craton, W.A.: *Geological Society of Australia, Abstracts* 37, p. 320–321.
- NUTMAN, A. P., KINNY, P. D., COMPSTON, W., and WILLIAMS, I. S., 1991, SHRIMP U–Pb zircon geochronology of the Narryer

- Gneiss Complex, Western Australia: *Precambrian Research*, v. 52, p. 275–300.
- OCCHIPINTI, S. A., and MYERS, J. S., 1999, Geology of the Moorarie 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 20p.
- OCCHIPINTI, S. A., MYERS, J. S., SHEPPARD, S., SWAGER, C. P., and TYLER, I. M., in prep., Robinson Range, W.A. Sheet SG 50-7 (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series.
- OCCHIPINTI, S. A., and SHEPPARD, S., in prep., Glenburgh, W.A. Sheet 2147: Western Australia Geological Survey, 1:100 000 Geological Series.
- OCCHIPINTI, S. A., SHEPPARD, S., NELSON, D. R., MYERS, J. S., and TYLER, I. M., 1998, Syntectonic granite in the southern margin of the Palaeoproterozoic Capricorn Orogen, Western Australia: *Australian Journal of Earth Sciences*, v. 45, p. 509–512.
- OCCHIPINTI, S. A., SHEPPARD, S., and TYLER, I. M., 1999a, The Palaeoproterozoic tectonic evolution of the southern margin of the Capricorn Orogen, Western Australia: Geological Society of Australia, Abstracts 53, p. 173–174.
- OCCHIPINTI, S. A., SHEPPARD, S., TYLER, I. M., and NELSON, D. R., 1999b, Deformation and metamorphism during the c. 2000 Ma Glenburgh Orogeny and c. 1800 Ma Capricorn Orogeny: Geological Society of Australia, Abstracts 56, p. 26–29.
- OCCHIPINTI, S. A., SWAGER, C. P., and PIRAJNO, F., 1996, Structural and stratigraphic relationships of the Padbury Group, Western Australia — implications for tectonic history: Western Australia Geological Survey, Annual Review 1995–96, p. 88–95.
- PIRAJNO, F., OCCHIPINTI, S. A., and SWAGER, C. P., 1998, Geology and tectonic evolution of the Palaeoproterozoic Bryah, Padbury, and Yerrida Basins (formerly Glengarry Basin), Western Australia — implications for the history of the south-central Capricorn Orogen: *Precambrian Research*, v. 90, p. 119–140.
- PIRAJNO, F., OCCHIPINTI, S. A., and SWAGER, C. P., 2000, Geology and mineralization of the Palaeoproterozoic Bryah and Padbury Basins, Western Australia, Western Australia Geological Survey, Report 59, 52p.
- RAMSAY, J. G., 1967, *Folding and fracturing of rocks*: New York, McGraw-Hill, 568p.
- SANDERS, A. J., FAULKNER, J. A., COKER, J., and MORRIS, P. A., 1998, Geochemical mapping of the Glenburgh 1:250 000 sheet: Western Australia Geological Survey, 1:250 000 Regolith Geochemistry Series Explanatory Notes, 33p.
- SHEPPARD, S., OCCHIPINTI, S. A., NELSON, D. R., and TYLER, I. M., 1999, The significance of c. 2.0 Ga crust along the southern margin of the Gascoyne Complex: Western Australia Geological Survey, Annual Review 1998–99, p. 56–61.
- SHEPPARD, S., and SWAGER, C. P., 1999, Geology of the Marquis 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 21p.
- STRECKEISEN, A., 1976, To each plutonic rock its proper name: *Earth Science Reviews*, v. 12, p. 1–33.
- SWAGER, C. P., and MYERS, J. S., 1999, Geology of the Milgun 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 27p.
- TYLER, I. M., PAGE, R. W., and GRIFFIN, T. J., 1999, Depositional age and provenance of the Marboo Formation from SHRIMP U–Pb zircon geochronology: Implications for the early Palaeoproterozoic tectonic evolution of the Kimberley region, Western Australia: *Precambrian Research*, v. 95, p. 225–243.
- TYLER, I. M., and THORNE, A. M., 1990, The northern margin of the Capricorn Orogen, Western Australia — an example of an early Proterozoic collision zone: *Journal of Structural Geology*, v. 12, p. 685–701.
- WAKELIN-KING, G. A., 1999, Banded mosaic ('tiger bush') and sheetflow plains: a regional mapping approach: *Australian Journal of Earth Sciences*, v. 46, p. 53–60.
- WILLIAMS, I. R., 1990, The Bangemall Basin, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 308–329.
- WILLIAMS, I. R., and MYERS, J. S., 1987, Archaean geology of the Mount Narryer region, Western Australia: Western Australia Geological Survey, Report 22, 32p.
- WILLIAMS, S. J., 1986, Geology of the Gascoyne Province, Western Australia, Western Australia Geological Survey, Report 15, 85p.
- WILLIAMS, S. J., WILLIAMS, I. R., CHIN, R. J., MUHLING, P. C., and HOCKING, R. M., 1983a, Mount Phillips, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 29p.
- WILLIAMS, S. J., WILLIAMS, I. R., and HOCKING, R. M., 1983b, Glenburgh, W.A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 25p.

## Appendix

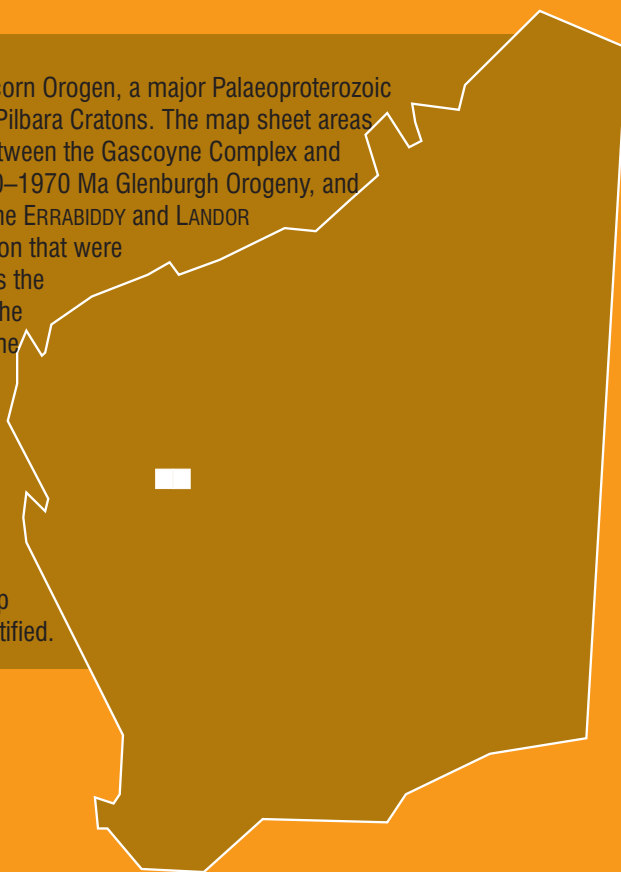
**Gazetteer of localities on ERRABIDDY**

<i>Locality</i>	<i>GDA coordinates</i>	
	<i>Easting</i>	<i>Northing</i>
Beedarry Well	513800	7183400
Bilja Well	504800	7180500
Black Adder Well	515800	7197800
Bumburra Well	525700	7229400
Bullaroo Hill	538500	7195600
Cockarra Well	528700	7184000
Dewar Bore	533400	7194300
Erminea Waterhole	524900	7194900
Errabiddy Homestead	513600	7183700
K13 Well	505900	7185600
Milly Mia Bore	532300	7219800
Mount Clere	533900	7223700
Mumbarra Pool	526400	7226600
Orient Bore	534300	7184300
Pines Bore	545800	7221100
Rustler Bore	519300	7226300
Square Well	540000	7223900
Vince Bore	535300	7207300
Wheelo bore	525800	7198300
Wilton Bore	542800	7181600

**Gazetteer of localities on LANDOR**

<i>Locality</i>	<i>GDA coordinates</i>	
	<i>Easting</i>	<i>Northing</i>
Biddenew Well	461500	7217900
Billycan Bore	492400	7183100
Brockman Well	457800	7205800
Dalgaringa Bore	455300	7192200
Daly Well	455600	7230300
Dispute Bore	499300	7200600
Erong Springs	487700	7182200
Landor Homestead	490400	7220600
Packsaddle Bore	486500	7182400
Pannikan Bore	478700	7188200
Quartpot Bore	485400	7186000
Scrubber Bore	466000	7213200

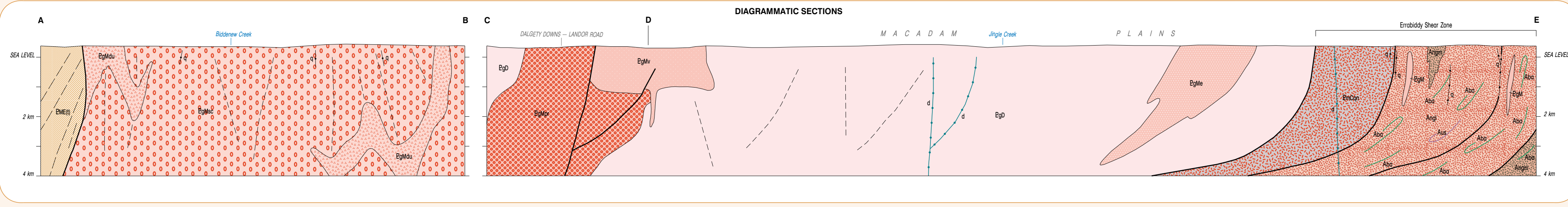
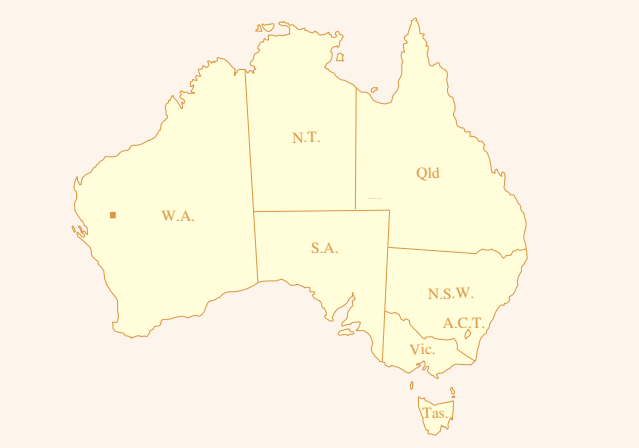
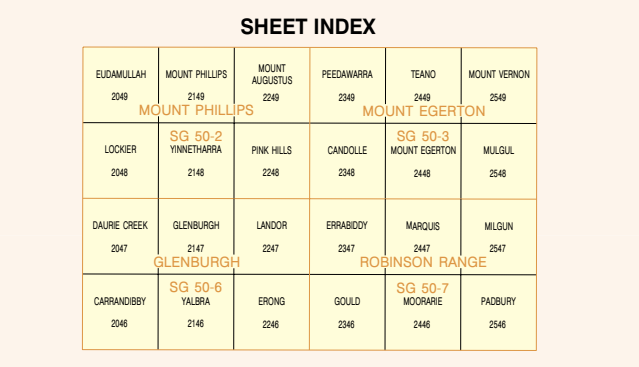
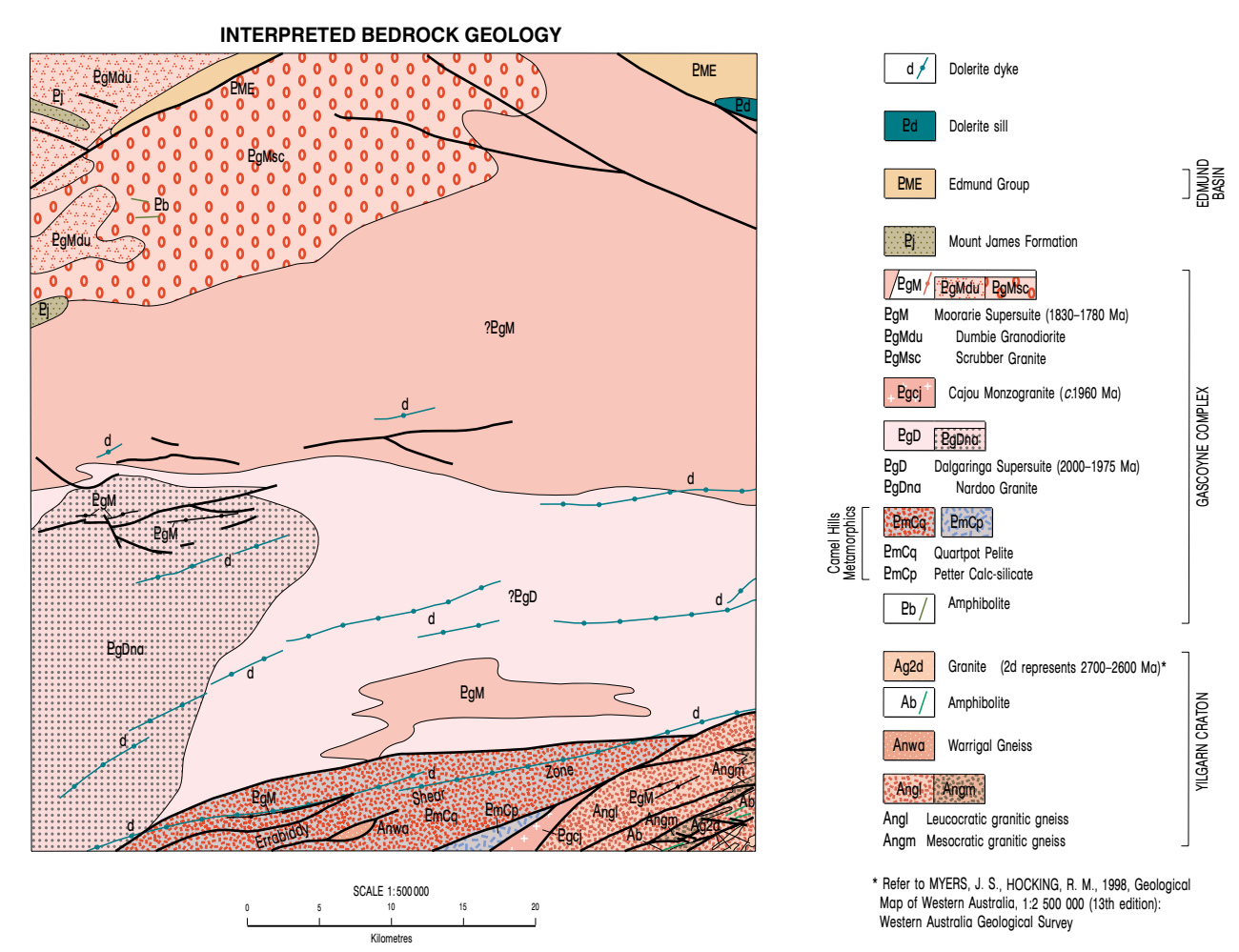
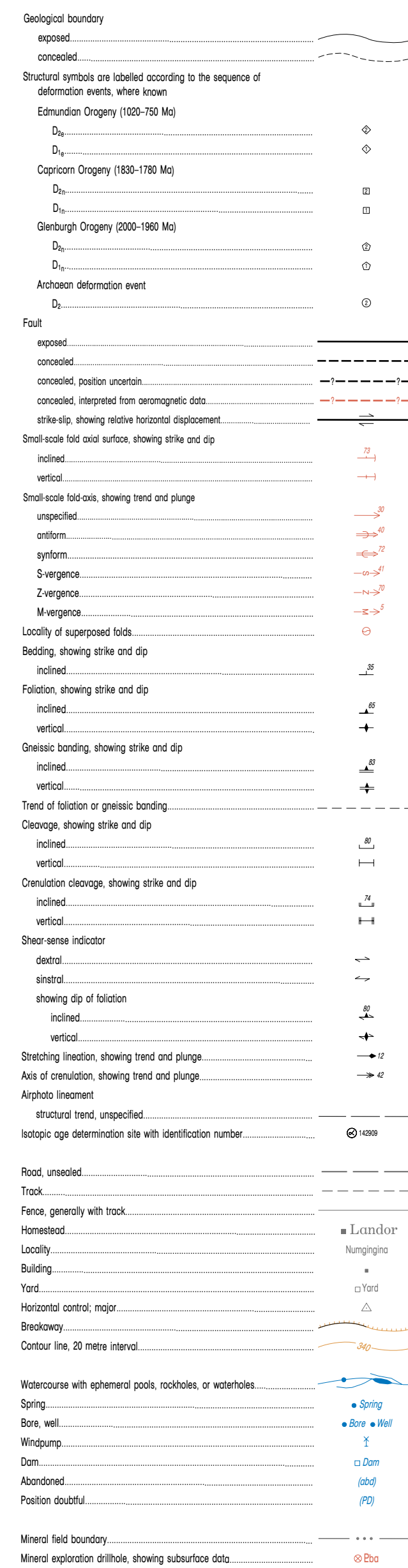
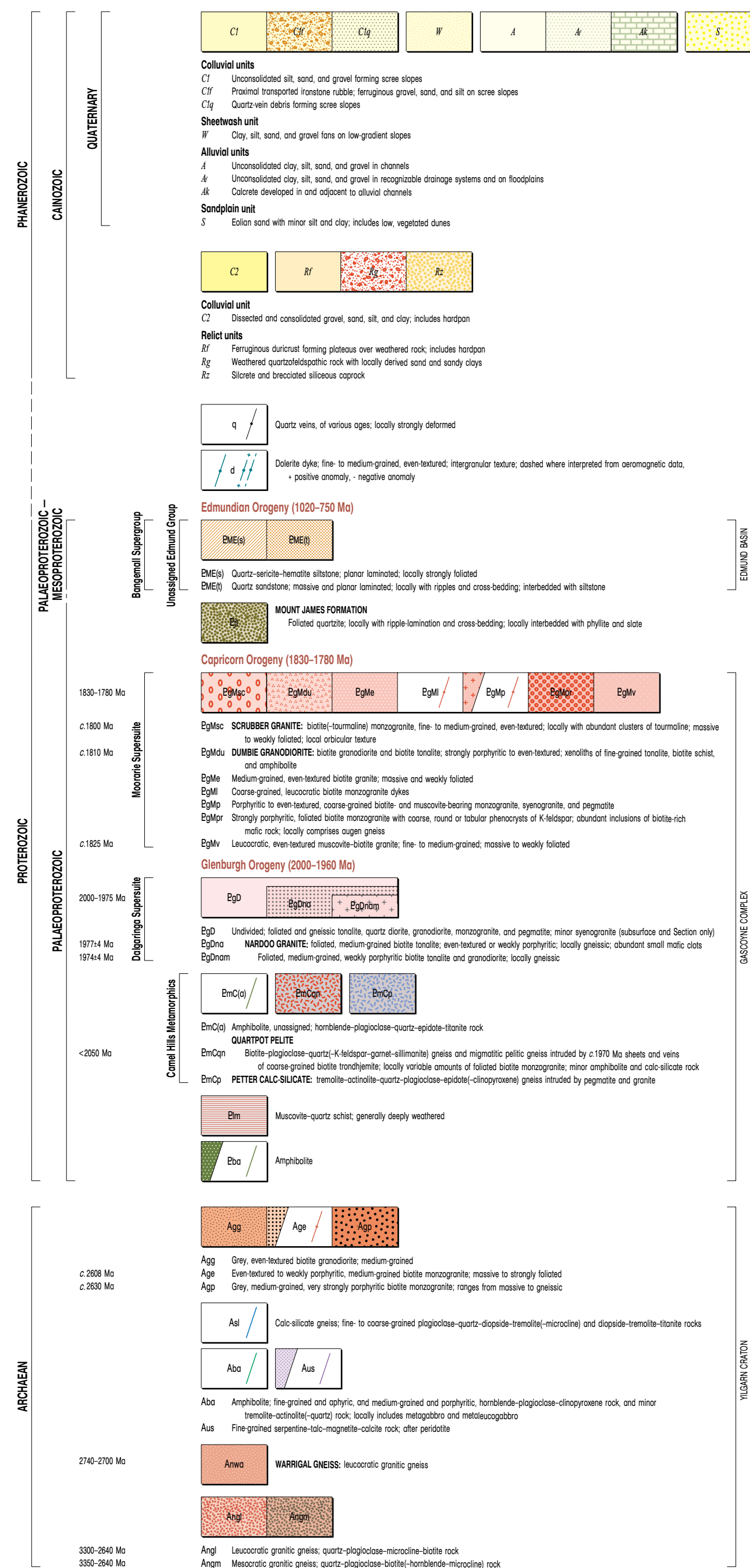
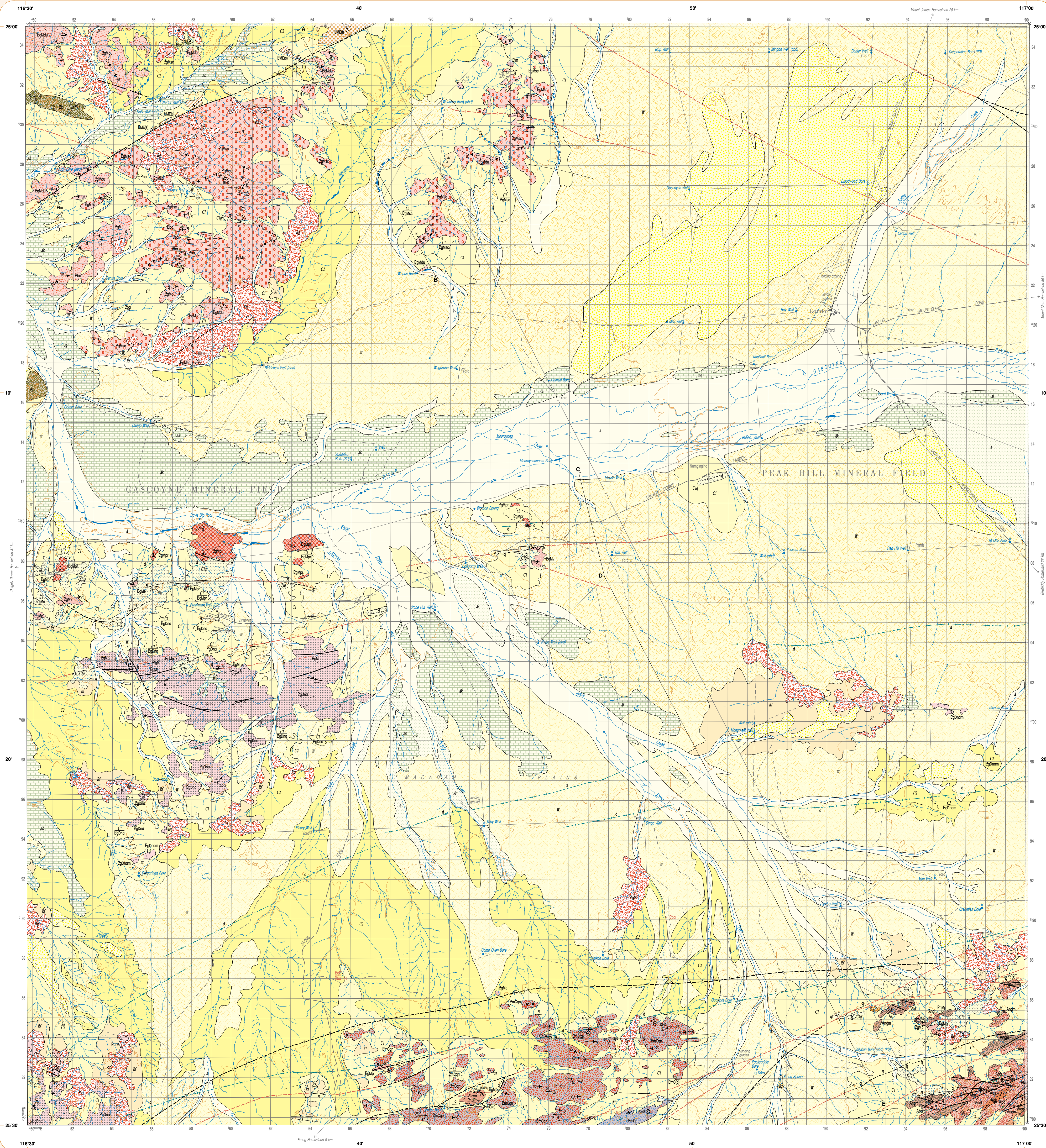
The ERRABIDY and LANDOR 1:100 000 sheets lie within the Capricorn Orogen, a major Palaeoproterozoic orogenic zone that developed between the Archaean Yilgarn and Pilbara Cratons. The map sheet areas straddle the Errabiddy Shear Zone, which marks the boundary between the Gascoyne Complex and Yilgarn Craton. The Errabiddy Shear Zone formed during the 2000–1970 Ma Glenburgh Orogeny, and was reactivated during the 1830–1780 Ma Capricorn Orogeny. The ERRABIDY and LANDOR sheets also cover the boundary between parts of the Yilgarn Craton that were extensively reworked during the Capricorn Orogeny (referred to as the Yarlaweelor gneiss complex), and parts that were not. Towards the end of the Capricorn Orogeny, siliciclastic sedimentary rocks of the Mount James Formation were deposited on the Gascoyne Complex. Sedimentary rocks of the latest Palaeoproterozoic to Mesoproterozoic Bangemall Supergroup rest unconformably on, or are in faulted contact with, the Gascoyne Complex. The Bangemall Supergroup was intruded by sills of dolerite at c. 1020 Ma. During the Neoproterozoic Edmundian Orogeny, the Bangemall Supergroup was deformed and basement structures were reactivated. No mineralization has been recorded on the map sheets, but geochemical anomalies in the regolith have been identified.



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Geochronology by D. R. Nelson 1997-1999  
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Western Australia Geological Survey, 1:100 000 Geological Series

True north, grid north and magnetic north  
are shown diagrammatically for the centre  
of the map. Magnetic north is correct for  
1985 and moves slowly by about 0.1° in  
15 years.

