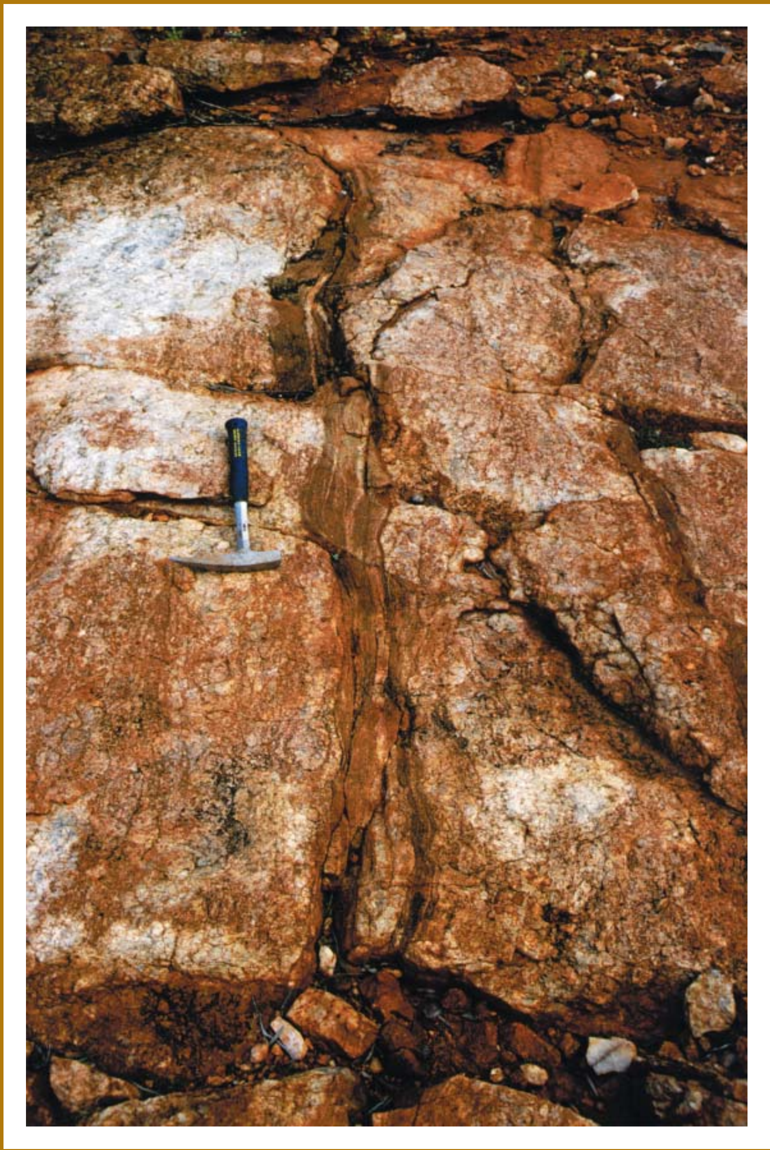
EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE MARQUIS 1:100 000 SHEET

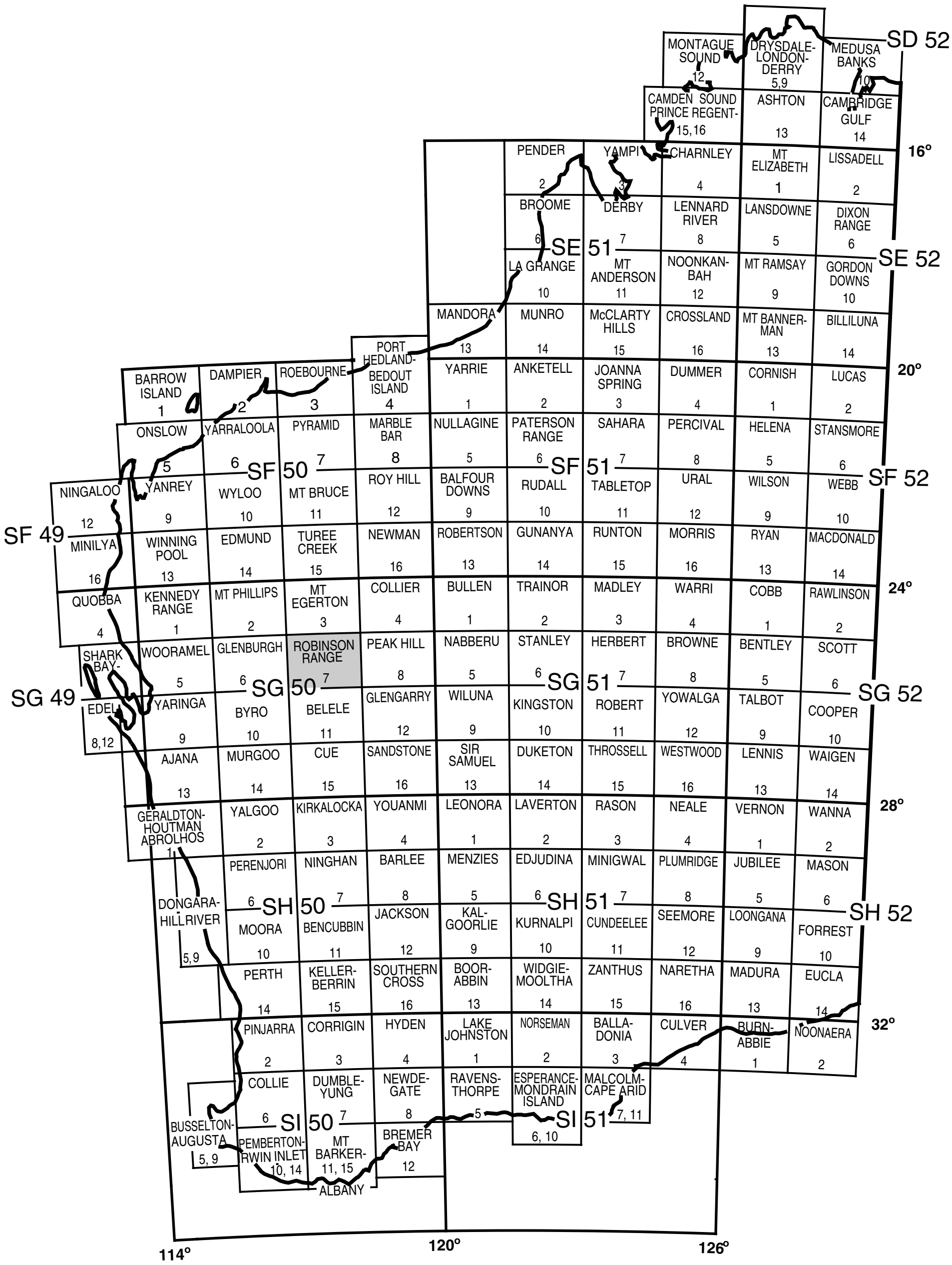
by S. Sheppard and C. P. Swager

1:100 000 GEOLOGICAL SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY



ERRABIDDY 2347	MARQUIS 2447	MILGUN 2547
ROBINSON RANGE SG 50-7		
GOULD 2346	MOORARIE 2446	PADBURY 2546

SS58

02.03.99

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE MARQUIS 1:100 000 SHEET

by
S. Sheppard and C. P. Swager

Perth 1999

MINISTER FOR MINES
The Hon. Norman Moore, MLC

DIRECTOR GENERAL
L. C. Ranford

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
David Blight

Copy editor: **D. P. Reddy**

REFERENCE

The recommended reference for this publication is:
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.

National Library of Australia Card Number and ISBN 0 7309 6643 7

ISSN 1321–229X

The locations of points mentioned in this publication are referenced to the Australian Geodetic Datum 1984 (AGD84)

Cover photograph:
Thick sheet of foliated, coarse-grained pegmatite with screens of mesocratic granitic gneiss, 3 km east-southeast of 13 Mile Well (AMG 970819), in the southeastern corner of the MARQUIS 1:100 000 map sheet.

Contents

Figures

Tables

Geology of the Marquis 1:100 000 sheet

by

S. Sheppard and C. P. Swager

Abstract

The MARQUIS 1:100 000 geological map sheet lies across the boundary between the Yarlarweelor gneiss complex, which forms the northern part of the Narryer Terrane of the Yilgarn Craton, and the Mesoproterozoic Bangemall Basin.

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. The Yarlarweelor gneiss complex consists of Archaean rocks of the Narryer Terrane that were deformed and metamorphosed, and then intruded by granite sheets and dykes, during the Palaeoproterozoic Capricorn Orogeny. On MARQUIS, leucocratic and mesocratic granitic gneisses in the Yarlarweelor gneiss complex have protolith ages between 3300 and 2640 Ma. Numerous layers of amphibolite, metamorphosed ultramafic rock, calc-silicate gneiss, quartzite, quartz–diopside rock, and metamorphosed iron-formation are tectonically interleaved with the granitic gneisses. Widespread refolded fold patterns suggest that most of the interleaved metasedimentary and meta-igneous rocks are late Archaean in age, but some of the amphibolites may be Palaeoproterozoic. At c. 1960 Ma plutons of medium-grained monzogranite (Yamagee Granite) intruded the Yarlarweelor gneiss complex. At c. 1812 Ma the granitic gneisses and interleaved rocks were extensively intruded by sheets and veins of coarse-grained granite and pegmatite and metamorphosed at medium to high grade. At c. 1795 Ma the gneisses were cut by conjugate east-southeasterly and south-southeasterly trending ductile shear zones and faults, and intruded by granite dykes. At c. 1619 Ma plutons of porphyritic granite (Discretion Granite) intruded the Yarlarweelor gneiss complex.

Low-grade metasedimentary rocks of the Palaeoproterozoic Padbury Group are in faulted contact with the Narryer Terrane. Sedimentary rocks of the dominantly Mesoproterozoic Bangemall Group rest unconformably on, or are in faulted contact with, the Narryer Terrane. Sills of dolerite and gabbro intruded the Bangemall Group. The Discretion Granite and leucocratic biotite monzogranite dykes that intruded it are apparently younger than the lower part of the Bangemall Group. However, the nature of the relationship between these granites and the Bangemall Group is uncertain.

The rocks in the western part of the Bangemall Basin are deformed into upright folds with easterly to east-southeasterly trending axes. East-southeasterly trending faults initially formed during the Palaeoproterozoic were reactivated and filled with quartz veins at 1300–1100 Ma. These faults cut the Bangemall Basin, the Yarlarweelor gneiss complex, and the Discretion Granite. Dolerite dykes intruded all the early to late Archaean and Palaeoproterozoic rocks on MARQUIS, and at least some of the Mesoproterozoic east-southeasterly trending faults. Mesoscopic northerly trending folds overprint the east-southeasterly trending folds, and may be related to development of the Blake fold-and-thrust belt at 750–700 Ma.

KEYWORDS: Yilgarn Craton, Narryer Terrane, Capricorn Orogeny, Yarlarweelor gneiss complex, Palaeoproterozoic granite, Bangemall Basin, regional geology.

Introduction

Location, access, and previous work

The MARQUIS* 1:100 000 geological sheet (SG 50-7, 2447) is bounded by latitudes 25°00' and 25°30'S and longitudes 117°30' and 118°00'E. The map sheet lies within the ROBINSON RANGE 1:250 000 sheet area in the Gascoyne region of Western Australia.

Beef-cattle grazing is the only commercial activity on MARQUIS, on the Mount Gould, Yarlarweelor, Milgun, and Mount Clere pastoral leases. The Mount Clere Homestead is located in the northwestern corner of MARQUIS. A network of station tracks provides year-round access. The Mount Clere – Mount Augustus road traverses the mapped area from the southeastern to the northwestern corner. This road provides access to Meekatharra, about 140 km southeast of MARQUIS.

Remapping of MARQUIS was carried out during 1996, concentrating on the Archaean rocks and Palaeoproterozoic igneous rocks of the Narryer Terrane of the Yilgarn Craton. Reconnaissance mapping of Mesoproterozoic sedimentary rocks of the Bangemall Basin was also carried out. Remapping of MARQUIS and MOORARIE, immediately to the south, provided a geological traverse from the granite–greenstones of the northern Murchison terranes, across the northeastern part of the Narryer Terrane (including Palaeoproterozoic and Mesoproterozoic granite intrusions), into the Mesoproterozoic Bangemall Basin (Fig. 1).

Physiography, vegetation, and climate

Elias and Williams (1980) recognized three main physiographic units on MARQUIS. These comprise the plains around the Gascoyne River and its tributaries, an upland area in the southern half of the mapped area, and dissected Proterozoic sedimentary rocks in the north. In these explanatory notes, the physiographic units of Elias and Williams (1980) are subdivided into six units (Fig. 2):
- main drainage channels;
- sheetwash plains;
- colluvial deposits
- rugged uplands of metamorphic and igneous rock;
- strike ridges of sedimentary rock;
- laterite; dissected laterite plateau.

The Gascoyne River system consists of sandy watercourses and braided streams surrounded by broad alluvial floodplains and low-gradient sheetwash areas. The southern part of the mapped area consists of rugged uplands of metamorphic rock and granite dissected by dendritic, incised creeks. These uplands form a drainage divide between the Gascoyne River to the north, and the Murchison River to the south. In the southwestern part of the sheet area there is a small plateau of lateritic material (Fig. 2). This is a remnant of an extensive Tertiary land surface, which is more extensively preserved further to the west (Elias and Williams, 1980). In the north, resistant sedimentary rocks, such as sandstone and chert, form prominent strike ridges, whereas shale and siltstone underlie the intervening valleys. Upland colluvial deposits fringe strike ridges in the north and rugged, dissected uplands in the south.

The sheetwash plains are occupied by open mulga woodland with large bare areas. The woodland consists of an open tree layer with a sparse, low, shrub layer and a ground layer of grasses and ephemeral herbs (Beard, 1981). The main river channels are lined by spectacular ghost gums and miniritchie, with low bushes of red grevillea. The poor, stony soils of the uplands are dominated by acacia and mulga scrub, which is commonly most dense on the flanks of the dissected old land surface.

MARQUIS has an arid climate with hot, dry summers (average daily maximum temperature of 38°C in January) and mild winters (average daily maximum temperature of 19°C in June). Mean annual rainfall for the mapped area is between 190 and 240 mm. Rainfall in the summer months (November–April) is provided by rain-bearing depressions from the northwest, which represent degraded cyclones, and more localized thunderstorms. In the winter months, 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 MARQUIS are ephemeral, and the Gascoyne River flows only after heavy rain.

Regional geological setting

The main tectonic elements on MARQUIS are the Yarlarweelor gneiss complex (Elias and Williams, 1980) and the Mesoproterozoic Bangemall Basin (Figs 1 and 3). The Yarlarweelor gneiss complex consists of Archaean rocks of the Narryer Terrane (forming the northwestern part of the Yilgarn Craton) that were deformed and metamorphosed, and then intruded by granite sheets and dykes during the Palaeoproterozoic (1820–1800 Ma). Elias and Williams (1980) and Williams (1986) referred to the Yarlarweelor 'gneiss belt', which encompassed an 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.

The occurrence of Palaeoproterozoic deformation, metamorphism, and magmatism indicates that MARQUIS lies within the Capricorn Orogen, which formed during the collision and suturing of the Archaean Pilbara and Yilgarn Cratons between c. 2000 and 1800 Ma (Tyler and Thorne, 1990, 1994). The orogen includes Palaeoproterozoic medium- to high-grade metamorphic rocks of the Gascoyne Complex, a number of Palaeoproterozoic sedimentary basins (such as the Bryah and Padbury

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

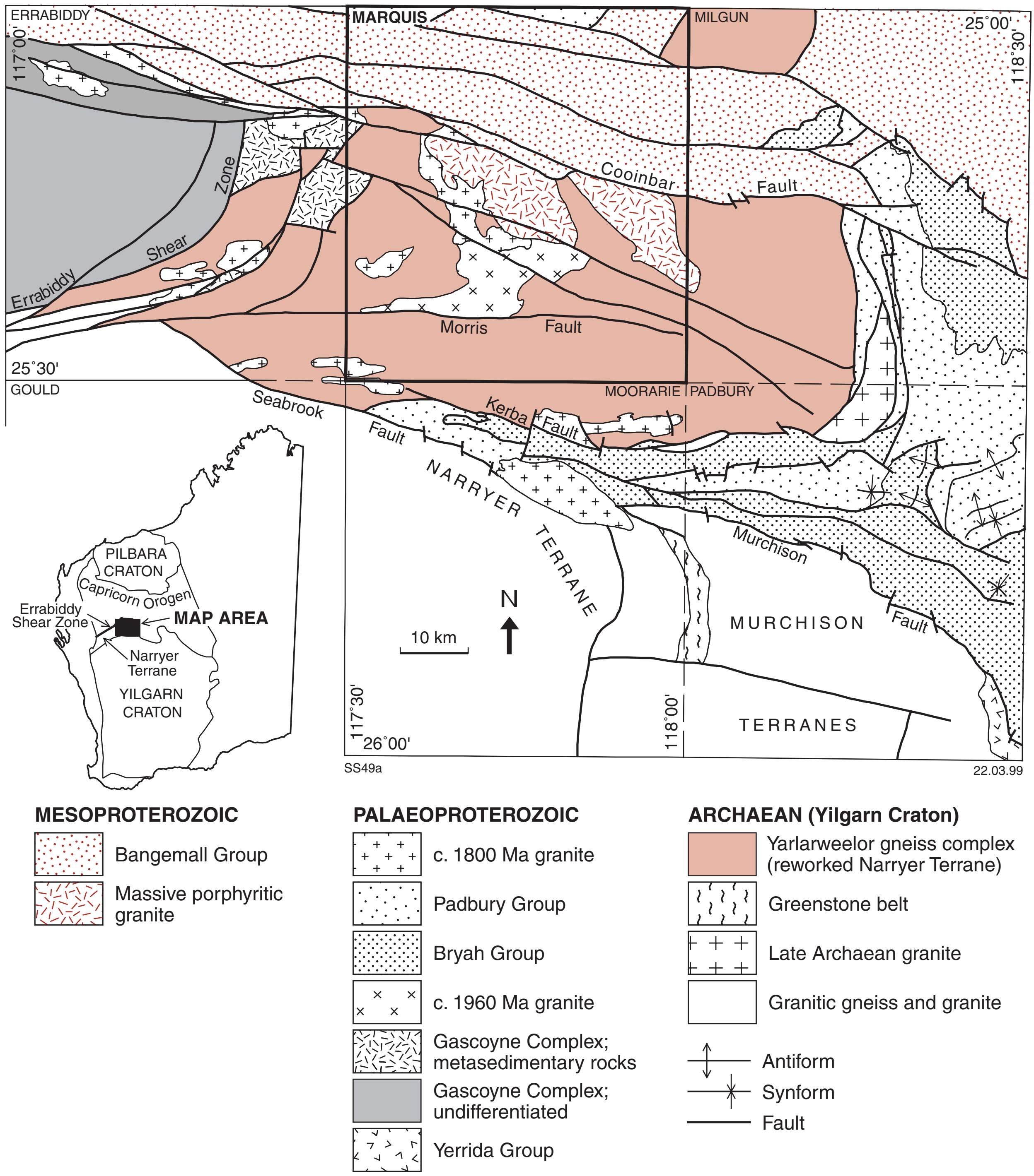


Figure 1. Simplified map showing the geological setting of the Narryer and Murchison terranes and the location of the Marquis 1:100 000 map sheet

Basins), and the deformed margins of the Pilbara and Yilgarn Cratons.

The Narryer Terrane (Myers, 1990a) represents one of the largest intact 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 metamorphosed, and extensively intruded by granites, in the late Archaean (Myers, 1990b). The Errabiddy Shear Zone separates the Narryer Terrane from the Gascoyne Complex to the north and northwest (Williams et al., 1983). The Gascoyne Complex consists of reworked ?allochthonous Archaean rocks and medium- to high-grade Palaeoproterozoic metasedimentary and meta-igneous rocks extensively intruded by granite (Williams, 1986; Myers, 1990c). To the south and east the Narryer Terrane is in faulted contact with the Palaeoproterozoic

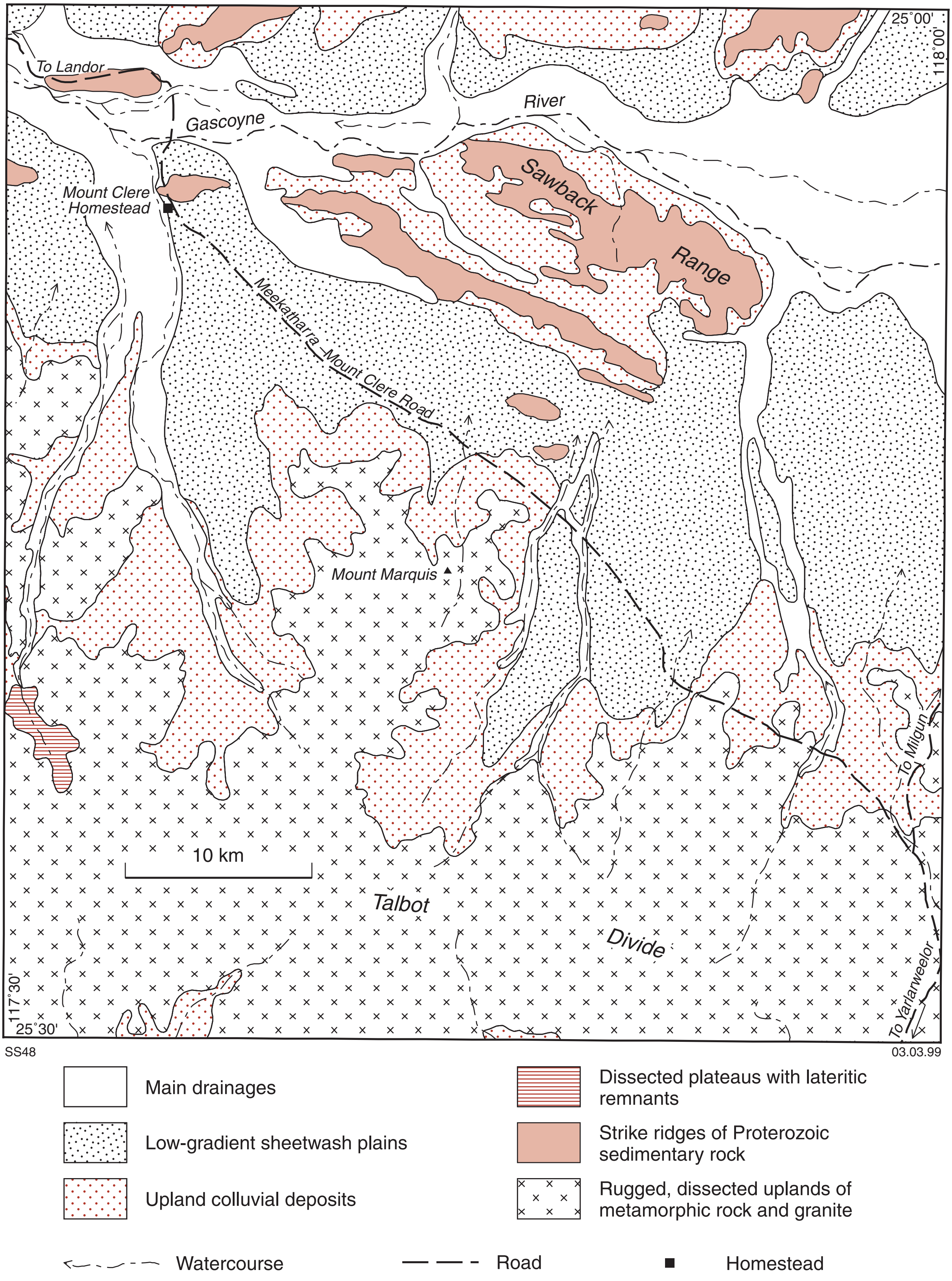


Figure 2. Physiographic and drainage sketch map of MARQUIS

Padbury and Bryah Basins (Fig. 1; Myers, 1990b; Occhipinti et al., 1996). Low-grade metasedimentary rocks of these basins were probably tectonically interleaved with gneisses of the Narryer Terrane during the Capricorn Orogeny between c. 2000 and 1800 Ma.

Archaean geology

Yilgarn Craton

Myers (1988) introduced the term Narryer Gneiss Complex for the '…early Archaean rocks (≥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 (1990a) 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 terranes. The Narryer Terrane is composed of several groups of gneiss (Williams and Myers, 1987; Myers, 1990b) or gneiss associations (Nutman et al., 1991, 1993). Extensive U–Pb Sensitive High-Resolution Ion Microprobe (SHRIMP) geochronological work in the southern and central parts of the Narryer Terrane, summarized by Nutman et al. (1993), indicates that granite protoliths to the gneisses range in age from 3730 to 3300 Ma and 3000 to 2920 Ma. The gneisses were extensively intruded by sheets of granite at 2750–2620 Ma, broadly coincident with a major episode of deformation and metamorphism (Kinny et al., 1990; Myers, 1990b). These intrusive rocks range from strongly banded and pegmatite-veined granitic gneiss to little-deformed discordant sheets with igneous textures (Myers, 1990b).

Myers (1990b) attributed granite magmatism and deformation to collision of the Narryer Terrane with the Murchison terranes to the east, and thrusting and stacking of the Narryer Terrane on the Murchison terranes. Nutman et al. (1993) interpreted the 3730–3300 Ma gneisses as an allochthon thrust over the 3000–2920 Ma gneisses, with subsequent partial melting of the younger gneisses to produce the late Archaean granites. The Narryer Terrane on MARQUIS was also strongly overprinted by Palaeoproterozoic deformation and metamorphism (Williams, 1986), and this part of the Narryer Terrane is referred to here as the Yarlarweelor gneiss complex (Fig. 3). Palaeoproterozoic tectonism was also accompanied by voluminous granite intrusion (Occhipinti et al., 1998b). The contact between the Yarlarweelor gneiss complex and the unreworked Narryer Terrane to the southwest may be marked by the Seabrook Fault (which consists of a broad shear zone) or a series of east-southeasterly trending faults (Fig. 1).

Leucocratic granitic gneiss (*Ængl*)

Banded, leucocratic granitic gneiss (*Ængl*) outcrops over most of the southern half of MARQUIS, and is the most widespread and abundant unit on the map sheet. The gneiss forms an easterly trending belt that swings to trend northerly along the eastern edge of MARQUIS. The gneiss consists of several extensively and intimately interlayered rock types that have been repeatedly deformed and metamorphosed. The unit is a composite of Archaean and Palaeoproterozoic components, and the Archaean fabrics were extensively overprinted during the Palaeoproterozoic. The granitic gneiss is part of a belt of gneisses extending from the Mount Narryer region (Williams and Myers, 1987; Nutman et al., 1991, 1993) to about 200 km southwest of MARQUIS. The granitic gneisses on MARQUIS form a zone of low, rocky hills strongly dissected by a close-spaced network of dendritic creeks. The gneisses are commonly weathered, but exposure is good along the flanks of the hills.

Nutman et al. (1991) reported a SHRIMP U–Pb zircon age of 3298 ± 6 Ma for a sample of banded, even-textured granitic gneiss from near Midnight Bore on MOORARIE, a few kilometres south of the southern edge of the MARQUIS sheet. In conjunction with this remapping, granitic gneiss from a low-strain zone just south of MARQUIS, about 4 km south-southeast of Stevie Bore (AMG 649773* on MOORARIE), was sampled for SHRIMP U–Pb zircon dating. The sample is of a foliated and recrystallized monzogranite with lenticular aggregates of fine-grained biotite, and is characterized by an absence of pegmatitic layers or veins. Most of the zircons define a population at 3292 ± 4 Ma, which is interpreted as the crystallization age of the granite precursor (Nelson, 1998). The sample is representative of a rock type that forms much of the leucocratic granitic gneiss unit, and confirms that early Archaean crust of the Narryer Gneiss Complex (Myers, 1988) is abundant on MARQUIS and MOORARIE.

The leucocratic granitic gneiss is a composite of at least two different rock types, and also includes subordinate amounts of mesocratic granitic gneiss (*Ængm*). The two main rock types are medium-grained leucocratic gneiss with thin, discontinuous layers of biotite (Fig. 4), and fine- to medium-grained, strongly banded granitic gneiss (Fig. 5). Lower strain domains of the gneiss indicate that the precursors were medium- and coarse-grained monzogranite and granodiorite. There are no sharp boundaries between the leucocratic and mesocratic granitic gneiss units, and they are interleaved on both a mesoscopic and megascopic scale. Mapped boundaries define areas of dominance of one gneiss type over the other. Both types of gneiss contain abundant thin pegmatite veins and bands. Much of the pegmatite is probably Palaeoproterozoic in age. The leucocratic granitic gneiss is also tectonically interleaved with amphibolite, calc-silicate gneiss, metamorphosed iron-formation, and quartzite and quartz–diopside rock. The gneiss is extensively intruded by sheets of coarse-grained granite and pegmatite (*ЕgMp*), dykes of medium-grained biotite granite (*ЕgMe*), and by the Yamagee Granite and Discretion Granite.

* Localities are specified by the Australian Map Grid (AMG) 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.

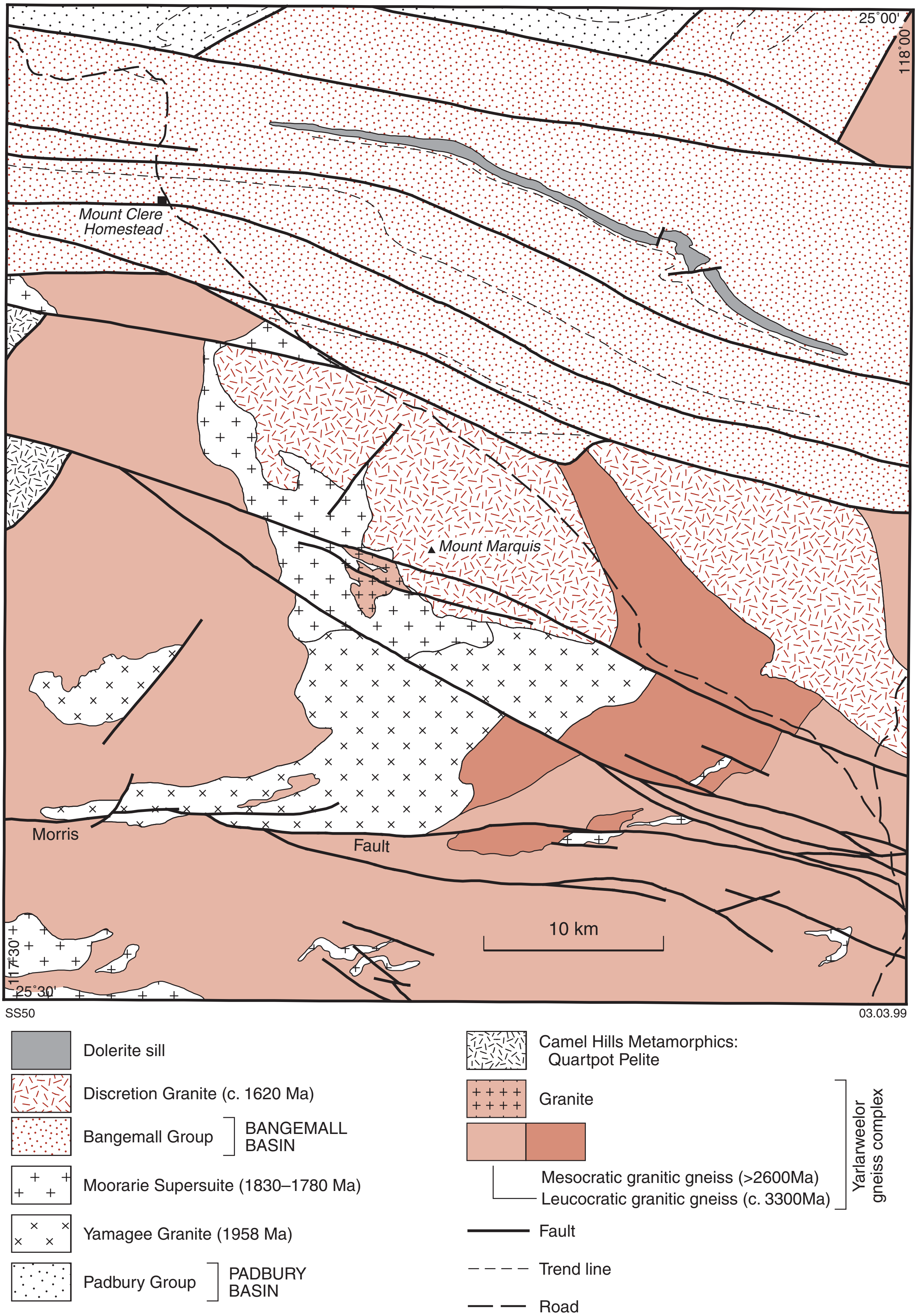
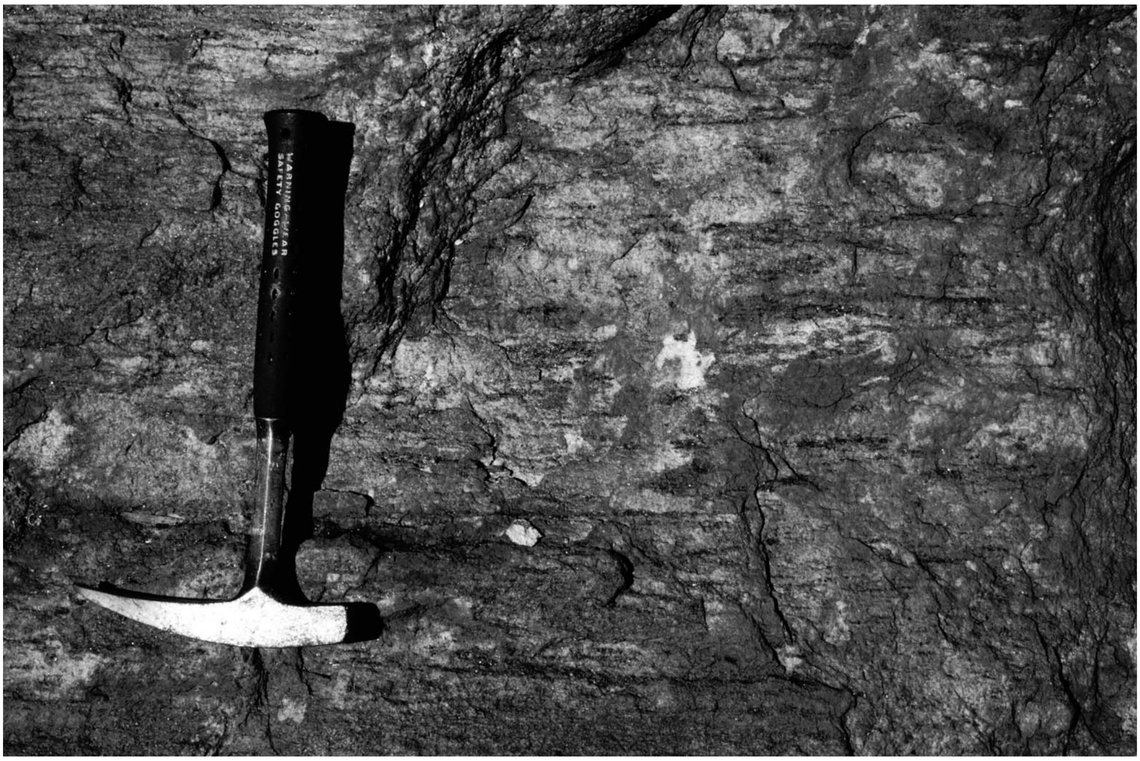


Figure 3. Simplified geological map of MARQUIS



SS54 17.02.99

Figure 4. Medium- to coarse-grained leucocratic granitic gneiss with discontinuous lenticular aggregates of biotite. This is the same rock type dated by Nelson (1998) at 3292 ± 4 Ma. Outcrop about 4 km east of Red Peak Bore (AMG 840815)

SS55 17.02.99

Figure 5. Fine- to medium-grained, strongly layered and pegmatite-banded leucocratic granitic gneiss. Outcrop about 4 km east-southeast of Stevie Bore (AMG 682806).

Leucocratic granitic gneiss is composed of several quartz-rich rock types ranging from tonalite to syenogranite, with monzogranite and granodiorite compositions the most abundant. The rocks display a variety of textures reflecting different strain states and overprinting by lower grade metamorphic events. Most of the rocks consist of various proportions of plagioclase, microcline, quartz, biotite (up to 10%), and accessory allanite, zircon, apatite, and trace magnetite. In some samples amoeboid and polygonal granoblastic textures and antiperthitic plagioclase provide evidence of high-grade metamorphism. Samples from zones of very low strain may display recrystallized igneous textures. Abundant secondary epidote and sericite, recrystallization of quartz, and fine-grained granophyric textures indicate widespread overprinting by lower grade metamorphism.

Mesocratic granitic gneiss (*!ngm*)

Mesocratic granitic gneiss (*Ængm*) is the dominant type of gneiss in the eastern part of MARQUIS, north of the Morris Fault (Fig. 3), and contains minor to subordinate amounts of finely interleaved leucocratic granitic gneiss (*Ængl*). Like the leucocratic granitic gneiss, the mesocratic granitic gneiss is also a composite of Archaean and Palaeoproterozoic components, and Archaean fabrics were largely overprinted during the Palaeoproterozoic. The mesocratic gneiss forms low rounded hills and scattered outcrops amongst colluvium, but the rock is commonly quite fresh.

A sample from about 2 km northeast of Jubilee Bore (AMG 868919) was selected for SHRIMP U–Pb zircon dating. The sample is a strongly banded, grey, biotite-rich gneiss with numerous layer-parallel veins of coarse-grained granite and pegmatite. The results indicate that the sample contains components with ages ranging from early to late Archaean (Nelson, 1998). Two concordant analyses corresponding to an age of 2637 ± 3 Ma provide an estimate of the age of the youngest component in the gneiss, and hence a minimum age for its formation. Most of the analyses from the dated sample do not define discrete groups and many of the zircons are rounded. These features led Nelson (1998) to suggest a large sedimentary component to the gneiss. However, such an interpretation is not supported by the granodioritic to tonalitic compositions and the absence of aluminous minerals in the gneisses.

The bulk of the mesocratic granitic gneiss is composed of a fine- to medium-grained, strongly banded, biotite-rich granitic gneiss with 10–20% layer-parallel veins of pegmatite and coarse-grained granite. The rocks consist of dark-grey, biotite-rich layers about 1–4 cm thick, alternating with paler, more quartzofeldspathic layers up to 2 cm thick. Despite the intensity of deformation, much of the gneiss has a granoblastic texture. The mesocratic granitic gneiss is interleaved with amphibolite, calc-silicate gneiss, metamorphosed iron-formation, and quartzite and quartz–diopside rock. The gneiss is extensively intruded by sheets of coarse-grained granite and pegmatite (*ᵽgMp*), dykes of medium-grained biotite granite (*ᵽgMe*), and by the Yamagee Granite and Discretion Granite.

Lower strain domains indicate that the protolith to much of the gneiss was a tonalite or mafic granodiorite. Samples of mesocratic gneiss consist of plagioclase, quartz, microcline, biotite (up to 15%), and accessory zircon, allanite, and apatite. In high-grade rocks, the plagioclase is oligoclase–andesine, green hornblende may be preserved, and amoeboid or polygonal granoblastic textures dominate. Recrystallized quartz, oligoclase, and widespread secondary epidote and sericite in many samples indicate a lower grade metamorphic overprint. The mesocratic gneiss also includes rare layers of calc-silicate gneiss comprising quartz, plagioclase (labradorite), aegirine-augite and grossular garnet with accessory titanite and allanite.

Calc-silicate gneiss and quartz–diopside rock (*Asl, Aslq*)

Calc-silicate gneiss (*Asl*) forms narrow layers interleaved with the granitic gneisses, and is a minor rock type, only abundant in the southeastern corner of the mapped area. Calc-silicate gneiss forms discontinuous lenses or layers typically less than 3 m wide and up to a few hundred metres long. West and south of Deep Well (AMG 992905) in the southeastern part of the sheet area, a few calc-silicate layers up to about 50 m thick are traceable along strike for up to 1.5 km. The calc-silicate rocks are pale green on a fresh surface, but typically weather to a reddish-brown exterior. Many of the calc-silicate gneiss layers are compositionally banded, with alternations of tremolite- and clinopyroxene-rich bands and quartz-rich bands, up to several centimetres thick. Locally, abundant quartz–diopside rock (*Aslq*) is interlayered with the calc-silicate rocks. Calc-silicate rocks are also interlayered with quartzite (*Asq*). The calc-silicate rocks range from fine to coarse grained, with radiating bundles of pale-green tremolite–actinolite or clinopyroxene within the compositional banding.

Contacts between the calc-silicate gneiss and granitic gneiss are tectonic, but coarse-grained granite and pegmatite (*ᵽgMp*) veins intruded the calc-silicate rocks. The age of the calc-silicate gneiss is unknown, but the presence of a few refolded patterns and the parallelism of the contacts to the banding in the gneiss imply that they were interleaved early in the structural history of the area. By analogy with similar rock types interleaved with early and late Archaean granitic gneisses in the Mount Narryer region (Williams and Myers, 1987), the protoliths to the calc-silicate gneisses are probably late Archaean in age.

The calc-silicate rocks can be divided into two main types based on the abundance or paucity of quartz and plagioclase. Both rock types may be fine or coarse grained. Quartz-poor rocks commonly have decussate textures, and are characterized by assemblages of clinopyroxene, tremolite–actinolite, and titanite, with less than a few percent of plagioclase and quartz. Coarser grained tremolite may be intergrown with clinopyroxene, but some tremolite has enclosed and partly replaced crystals of clinopyroxene. Quartz-rich rocks are composed of clinopyroxene, tremolite–actinolite, quartz, plagioclase, and microcline. The quartz and feldspar contents of the rocks range from about 30% up to nearly 80%. Most of the rocks have decussate or polygonal textures, but rare examples of granoblastic or amoeboid polygonal textures are present in assemblages with abundant clinopyroxene. Both quartz-poor and quartz-rich rocks contain minor to abundant, fine-grained, secondary clinozoisite–epidote, albite, and sericite.

Quartzite and minor quartz–diopside rock (*Asq*)

Quartzite and quartz–diopside rock (*Asq*) is a very minor unit on Marquis, largely restricted to an area south and south-southeast of Lucys Bore (AMG 514159) in the western part of the map sheet. Quartzite and quartz–diopside rocks are white or very pale green, and commonly outcrop as rocky, narrow ridges. Quartzite forms layers up to 20 m thick, whereas layers of quartz–diopside rock are less than about 5 m thick. Contacts between the quartzite and quartz–diopside rock and the enclosing granitic gneisses are tectonic and parallel to the banding in the granitic gneisses. Quartzite contains, at most, a few percent of diopside, tremolite–actinolite, microcline, and accessory tourmaline. Quartz–diopside rocks contain about 80–90% quartz, with clinopyroxene, tremolite–actinolite, plagioclase, and microcline.

Metamorphosed iron-formation (*Aci, Acig*)

Metamorphosed iron-formation is a widespread rock type throughout the granitic gneisses, forming lenses and layers up to a few metres thick. The layers are commonly discontinuous, having been dismembered during deformation and disrupted by intrusion of younger granites. Some layers can be traced along strike for several hundred metres, and thicker layers are about a kilometre or more in length. Many layers are readily identified on the 1:25 000-scale colour aerial photographs because of their dark colour and apron of ironstone rubble. The layers commonly form narrow, blocky ridges. Most of the layers are concentrated in two belts in the southern part of the sheet area: one trending west-southwesterly from Weedarra Bore, and the second trending east-northeasterly from Red Peak Bore.

The metamorphosed iron-formation layers are composed of a fine- to medium-grained, quartz–magnetite(–hematite) rock (*Aci*), which is either weakly banded or granular. Very fine grained crystals of tourmaline are a trace component in most samples. There are a few layers of grunerite-bearing metamorphosed iron-formation (*Acig*). Contacts between metamorphosed iron-formation and the enclosing granitic gneisses are tectonic and parallel to banding in the gneisses. By analogy with the Mount Narryer region (Williams and Myers, 1987), the metamorphosed iron-formation is probably late Archaean in age.

Amphibolite (*Aba, Aban, Abao*)

Lenses and strips of fine- and medium-grained amphibolite (*Aba*) are extensively interleaved with the granitic gneisses on Marquis and Moorarie. A few of the amphibolites display complex refolded fold patterns, but others cut the gneissic layering and show evidence for only one generation of folding. The amphibolites, therefore, probably comprise two (or more) generations of mafic magmatism. Most of the amphibolites are about 1–3 m wide and up to 40–50 m long, although a few may exceed 100 m in length. About 2 km north of Weedarra Bore (AMG 675882), however, individual amphibolite layers up to 10 m thick are traceable for several hundred metres or more along strike. Locally, the amphibolites form boudinaged pods less than 10 m long in strongly deformed granitic gneiss. In most areas the amphibolites comprise less than 5% of the outcrop, but in places they may comprise up to 30–40%. The presence of a large body of layered amphibolite near 13 Mile Well (AMG 945836) reported by Elias and Williams (1980) could not be substantiated.

Contacts between the amphibolites and granitic gneisses are usually tectonic and parallel to the compositional banding in the gneisses. Locally, however, some amphibolites are discordant at a low angle to the banding in the gneisses, indicating that the amphibolites were originally mafic dykes. Along with the granitic gneisses, the amphibolites are intruded by coarse-grained granite and pegmatite (*PgMp*). As the mesocratic granitic gneisses include late Archaean components (≥2630 Ma), those amphibolites that truncate the gneissic layering must be either of latest Archaean or Palaeoproterozoic age.

Most of the amphibolites are fine grained, or fine to medium grained (grain size of <2 mm) and even textured, with a weak compositional banding. Layers of metamorphosed porphyritic microgabbro, gabbro, and leucogabbro (*Abao*) are widespread, but much less abundant than the aphyric amphibolites. In places, thicker layers of plagioclase-phyric amphibolite are associated with metamorphosed leucogabbro. Rarely, layers with centres of plagioclase-phyric amphibolite are seen to have margins of fine-grained, aphyric amphibolite.

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. Clinopyroxene may be absent or comprise up to 20% of the rock. In some samples clinopyroxene forms cores to hornblende, suggesting that it is a relict from a higher grade metamorphic assemblage or the igneous protolith. Amphibolite gneiss (*Aban*), consisting of brown hornblende–plagioclase–clinopyroxene – iron oxides or clinopyroxene–plagioclase – green hornblende – iron oxides, is common near the southern edge of Marquis. These rocks have a polygonal or amoeboid granoblastic texture, and the plagioclase is labradoritic in composition. Medium- to high-grade assemblages are overprinted by very fine grained epidote, actinolite, sericite, and albite. The degree of overprinting by this lower grade assemblage varies from very weak to near-complete, and is also common along fractures.

Metamorphosed ultramafic rock (*Aus, Aur*)

About 6 km southwest (AMG 557047) and 13 km south-southwest (AMG 558976) of Cardingie Bore near the western edge of MARQUIS, several layers of fine-grained, pale-brown, metamorphosed ultramafic rock (*Aus*) are present within the granitic gneisses. Elias and Williams (1980) also noted these layers. The layers are composed of fine-grained serpentine, talc, granular magnetite, and calcite, and were derived from medium- to low-grade metamorphism of ultramafic rocks. Metamorphosed pyroxenite layers (*Aur*), composed of tremolite(–clinopyroxene) – iron oxide with accessory apatite, are rare. These rocks are overprinted to varying degrees by epidote, chlorite, talc, and calcite.

Even-textured, biotite granodiorite (*Agg*)

Even-textured, biotite granodiorite (*Agg*) forms the bulk of a complex, multiphase intrusion centred about 3 km west-southwest of Mount Marquis. The unit forms rounded hills, mainly covered with boulders and small tors, as well as whalebacks and large pavements. The granodiorite cannot be easily distinguished on aerial photographs from the pluton of biotite granite (*ƁgMe)* or the Discretion Granite. Most of the rocks assigned to the biotite granodiorite unit are part of a pluton, which is about 3.5 km long and 2 km wide. Two smaller exposures (<0.1 km^2) of this unit are present about 2 and 3.5 km north of the main pluton.

The northern and southern ends of the biotite granodiorite pluton are defined by faults. However, intrusive relationships with several other units are preserved along the western and eastern margins of the pluton. Biotite granodiorite is intruded by foliated and weakly banded, medium-grained, even-textured monzogranite (*ƁgMe*) about 3 km southwest of Round Yard Bore (AMG 703069 and 704080). At the latter locality, veins of the monzogranite intrude grey, gneissic, biotite granodiorite, and are folded along with the host rock. The granodiorite is also intruded by medium- to coarse-grained, porphyritic monzogranite of the Discretion Granite, 3 km southwest of Round Yard Bore (AMG 704079) and 2 km southwest of Mount Marquis (AMG 721032). Dykes, and a thick sheet of massive or weakly foliated, leucocratic, biotite monzogranite (*Ɓgm*) striking at 110–120°, also intruded the main pluton.

Most of the pluton is composed of grey, even-textured or weakly porphyritic, medium-grained, biotite granodiorite. This consists of a few percent plagioclase phenocrysts in an anhedral granular groundmass of plagioclase (albite), quartz, microcline, and biotite with accessory magnetite, ilmenite, allanite, zircon, and apatite. Some samples contain abundant prismatic allanite crystals, 1–2 mm long. Epidote, titanite, and sericite are abundant secondary minerals. The granodiorite has locally intruded and broken up a dark-grey, weakly porphyritic, fine-grained tonalite. The fine-grained tonalite is composed of a few percent plagioclase phenocrysts in a fine-grained groundmass of plagioclase (andesine), quartz, biotite, sparse microcline, and accessory allanite, zircon, and apatite. Fine-grained secondary epidote and titanite are abundant. The granodiorite and fine-grained tonalite are intruded by locally abundant, irregular veins and dykes of medium-grained, weakly porphyritic biotite monzogranite. Along the western margin of the pluton these veins and dykes of weakly porphyritic monzogranite can be traced back into the even-textured biotite monzogranite (*ƁgMe*).

The granodiorite is mostly weakly to moderately foliated, but it is locally gneissic. Where the rocks are gneissic, they commonly contain abundant mafic schleiren and are intruded by pegmatite veins subparallel to the banding. The veins are deformed along with the host rock. The foliation and gneissic layering are parallel to those in the nearby biotite granite (*ƁgMe*). A sparse network of planar, randomly oriented veins and thin dykes of biotite pegmatite and coarse-grained, porphyritic granite cut most of the pluton. These veins may be equivalent to the folded veins in the gneissic parts of the pluton.

Fine-grained, mafic inclusions are a minor, but widespread component of the biotite granodiorite. In the northern part of the pluton, the inclusions are locally abundant (e.g. AMG 700038). The inclusions are lenticular or subangular, and most are about 2–7 cm long. Many of the inclusions have a slightly coarser grained, 2–3 mm-wide biotite-rich rim. The dark-grey, weakly porphyritic, fine-grained tonalite phase contains up to about 10–30% of the same mafic inclusions.

Deformation and metamorphism

Nutman et al. (1991) suggested that rocks of the Narryer Terrane were subjected to high-grade metamorphism at c. 3300 Ma and c. 3050 Ma, accompanied by granite and pegmatite intrusion. However, no structures of this age are preserved. Rocks of the Narryer Terrane were multiply deformed and metamorphosed in the late Archaean, between about 2750 and 2620 Ma (Myers, 1990b; Nutman et al., 1991). In the Jillawarra Bore area on GOULD, about 20–30 km southwest of MARQUIS, zircons from melt patches that disrupt gneissic layering are related to a high-grade metamorphic event dated at 2643 ± 4 Ma (Nelson, 1998).

The granitic gneisses on MARQUIS have been heterogeneously deformed and metamorphosed. The deformation sequence and accompanying metamorphic and igneous events are summarized in Table 1. On PADBURY to the east, Occhipinti et al. (1998a) suggested that the first Archaean deformation event involved interleaving of granitic gneiss and supracrustal rocks. Only one Archaean deformation event (D_2) and one metamorphic event are recognized on MARQUIS. This is largely due to the very strong overprint by Palaeoproterozoic deformation and metamorphism. Archaean metamorphism may have accompanied D_2 or may be correlated with the 2643 ± 4 Ma granulite metamorphism on GOULD.

Deformation (D_2)

The dominant feature of the gneisses on MARQUIS, and the earliest recognizable structure, is a well-developed

Table 1. Summary of the geological history of the MARQUIS and MOORARIE 1:100 000 sheets

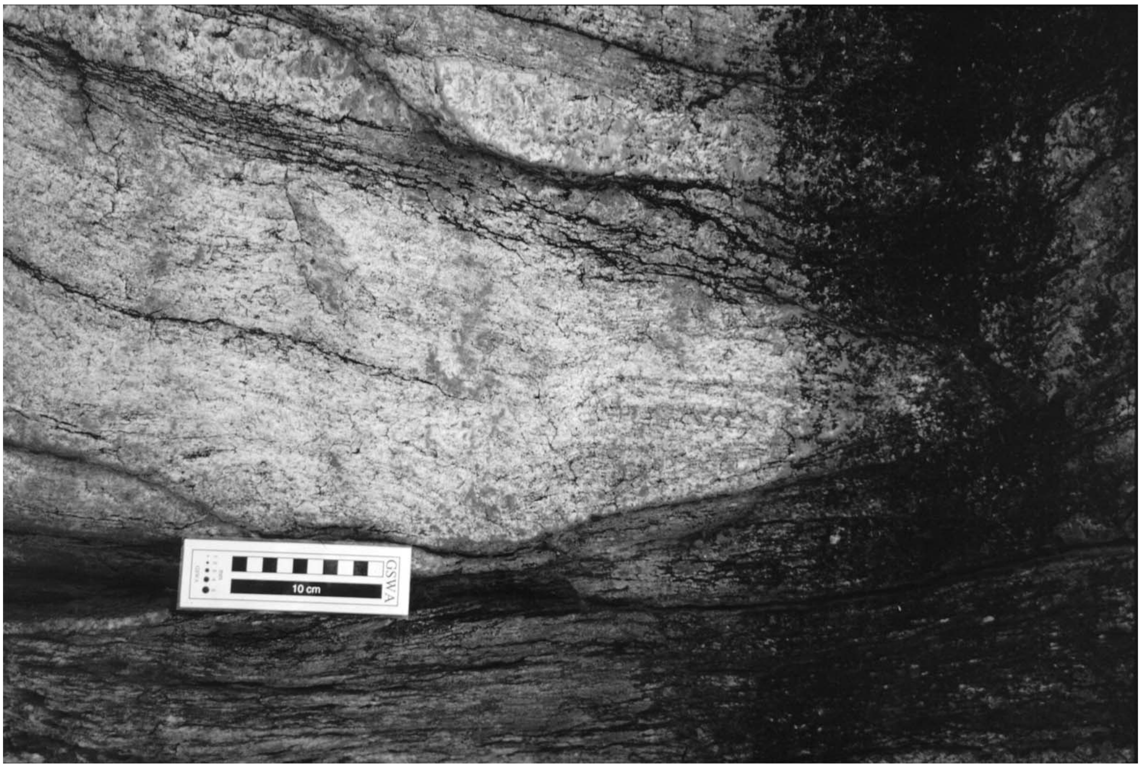
Age (Ma)	*Geological event*
?	Intrusion of easterly trending dolerite dykes into the Yarlarweelor gneiss complex and Bangemall Basin. Northerly trending kinks and open folds (D_{2e})
?	Reactivation of east-southeasterly trending faults (D_{1e}), and associated static low-grade metamorphism (M_{1e}). Intrusion of dykes of leucocratic biotite granite into Yarlarweelor gneiss complex
?	Intrusion of dolerite sills into the Bangemall Basin
1619 ± 15	Intrusion of massive, porphyritic biotite granite of the Discretion Granite into the Yarlarweelor gneiss complex on MARQUIS
c. 1640	Deposition of sedimentary rocks of the Edmund Subgroup (Bangemall Basin)
c. 1800	Intrusion of biotite monzogranite pluton and dykes into the Yarlarweelor gneiss complex. Formation and reactivation of easterly and east-southeasterly trending faults, in particular, the Morris Fault. Deformation (D_{3n}) accompanied by low-grade metamorphism (?M_{3n})
1808 ± 6	Intrusion of Kerba Granite along the contact between the Yarlarweelor gneiss complex and the Bryah Group on MOORARIE
c. 1812	Development of Yarlarweelor gneiss complex: Deformation and medium- to high-grade metamorphism (D_{2n}, M_{2n}) of the northeastern Narryer Terrane. Intrusion of medium- and coarse-grained granite and pegmatite sheets
?1900–1820	Tectonic juxtaposition of the Narryer Terrane and the Bryah and Padbury Basins (D_{1n}, M_{1n}). Development of a layer-parallel foliation in the Palaeoproterozoic rocks
1958 ± 4	Intrusion of Yamagee Granite on MARQUIS late in D_{2n}
c. 2000	Deposition of volcanic and sedimentary rocks in the Bryah and Padbury Basins
2640–2610	Intrusion of biotite monzogranite plugs and plutons into the Narryer Terrane
3400–2640	Narryer Terrane of the Yilgarn Craton — intrusion of granite protoliths to the leucocratic and mesocratic granitic gneisses. Multiple deformation and high-grade metamorphic events

gneissic layering (S_2). The layering is folded about small-scale, recumbent isoclinal folds (F_2). The subhorizontal folds are only preserved in zones within which strain was low to moderate during Proterozoic deformation, and in the hinges of younger folds. Very good examples of mesoscopic recumbent F_2 folds are found in exposures beside a waterhole about 2.5 km west-northwest of Stevie Bore (AMG 614825; Fig. 6). The F_2 folds are associated with a strong stretching lineation, which has a shallow plunge subparallel to that of the fold axes. The gneisses in these areas were commonly recrystallized with a granoblastic texture during high-grade metamorphism syncronous with or younger than the D_2 event.

Metamorphism

The bulk of the Archaean rocks on MARQUIS consist of quartzofeldspathic assemblages, which are poor indicators of metamorphic grade. Furthermore, the Archaean rocks have been strongly deformed and metamorphosed in the Palaeoproterozoic, so that evidence for high-grade metamorphism in the Archaean may not be preserved. For example, sheets of coarse-grained granite and pegmatite (*ĿgMp*), mainly in the southeastern part of the sheet, locally contain textures and assemblages consistent with upper amphibolite – lower granulite facies metamorphism (see **Deformation and metamorphism (D_{2n}/M_{2n})**).

There is an absence of granulite-facies assemblages in the mafic rocks on MARQUIS, in contrast to the area around Jillawarra Bore on GOULD to the southeast (Elias and Williams, 1980; Muhling, 1988). These features suggest that most, or nearly all, of the metamorphic assemblages on MARQUIS were developed in the Palaeoproterozoic. However, the lack of detectable changes in metamorphic grade between areas of low and high D_{2n} (Palaeoproterozoic) strain may indicate that there was simply very little or no difference in metamorphic grade during the Archaean and Palaeoproterozoic. If this is correct, then it is possible that localized development of amoeboid and polygonal granoblastic textures in the gneisses and amphibolites, and assemblages of brown hornblende – plagioclase–clinopyroxene – iron oxide in amphibolite and quartz–plagioclase–clinopyroxene–grossular in a mesocratic gneiss sample, could be relicts of Archaean metamorphism. All samples with these assemblages and textures come from an area between Red Peak Bore, Morris Bore, and Jubilee Bore in the central southern part of MARQUIS.



SS56 17.02.99

Figure 6. Recumbent fold (F_2) in leucocratic granitic gneiss. The folds are refolded about Palaeoproterozoic upright folds (F_{2n}). Outcrop about 2.5 km west-northwest of Stevie Bore (AMG 614825)

Proterozoic geology

Palaeoproterozoic geology

Padbury Group

The Padbury Group (Occhipinti et al., 1996) was deposited in the Padbury Basin, one of three newly defined basins (Pirajno et al., 1996) that were previously included in the former Glengarry Basin of Gee and Grey (1993). The sedimentary and volcanic rocks in these basins were deposited and deformed along the northern margin of the Yilgarn Craton between 2.0 and 1.65 Ga (Gee, 1990), although these ages are not well constrained. The Padbury Group contains mineral assemblages indicative of greenschist-facies metamorphism (Swager and Myers, in prep.). Rocks of the Padbury Group on MOORARIE contain a D_{1n} fabric parallel to bedding, and they are folded about D_{2n} folds (Occhipinti and Myers, in prep.). Therefore, the Padbury Group is older than the Palaeoproterozoic granites intruding the Yarlarweelor gneiss complex (see **Moorarie Supersuite**).

Undivided Padbury Group (ⱣP(q), ⱣP(s))

The Padbury Group comprises a range of clastic and chemical sedimentary rocks (Occhipinti et al., 1996). Undivided sedimentary rocks correlated with the Padbury Group outcrop on the northern edge of MARQUIS. They consist of quartz wacke, siltstone, and shale (*ⱣP(s)*), and quartz arenite with lenses of conglomerate (*ⱣP(q)*) with pebbles of vein quartz, black chert, and foliated wacke. These rocks are metamorphosed, and more deformed than the sedimentary rocks of the Bangemall Basin. They are commonly strongly cleaved, and the shales contain porphyroblasts of muscovite, 2–3 mm in diameter.

Yamagee Granite (*Ᵽgya, Ᵽgyap*)

The Yamagee Granite is a newly defined unit named after the abandoned Yamagee Bore (AMG 685904). Most of the intrusion is exposed as rubbly outcrops along the flanks of creeks incised into an old land surface. The Yamagee Granite forms either a pluton or a very thick sheet-like body. Smaller isolated exposures toward the western edge of MARQUIS probably consist of a series of sheets. The latter are assigned to the Yamagee Granite because they have only one foliation and, unlike low-strain equivalents of the granitic gneisses, they intruded amphibolite lenses that had a pre-existing foliation. A sample of the Yamagee Granite from about 2 km southeast of Nanular Bore (AMG 621907) has a SHRIMP U–Pb zircon date of 1958 ± 4 Ma (Nelson, in prep.)

The Yamagee Granite intruded early to late Archaean granitic gneiss as well as amphibolite and metasedimentary gneisses. About 6 km northwest of Nanular Bore (AMG 565954 and 559976) foliated and diffusely banded, medium-grained, even-textured monzogranite assigned to the Yamagee Granite intruded leucocratic granitic gneiss, thick lenses of amphibolite, and thin lenses of metasedimentary rock.

The Yamagee Granite consists of two phases: variably foliated, medium- to fine-grained, even-textured biotite monzogranite (*Ꝑgya*), which forms the bulk of the intrusion; and a composite sheet-like body of foliated, medium-grained, porphyritic, biotite monzogranite (*Ꝑgyap*). The porphyritic phase contains about 20% rounded phenocrysts of K-feldspar, 1.0–1.5 cm in diameter. There is no sharp contact between the two phases; rather, it is a transition from sheets of dominantly one rock type to sheets dominantly of the other. Contacts between individual sheets are parallel to the foliation in the intrusion, and thus the relative ages of the rock types cannot be established. Leucocratic biotite–garnet monzogranite is a minor component of the even-textured phase.

Samples from the Yamagee Granite range from weakly foliated to locally strongly foliated and moderately well banded. Pegmatite veins and thin dykes are widespread, but only locally abundant. The veins and dykes are commonly parallel to the foliation in the granite. In places the veins and the foliation are folded about mesoscopic upright, isoclinal D_{2n} folds. Weakly deformed samples of the even-textured phase consist of a few percent subhedral microcline phenocrysts in a fine- to medium-grained, granular groundmass of plagioclase, microcline, quartz, and biotite. Magnetite, zircon, and apatite are accessory minerals. Strongly deformed samples have a foliation defined by seams of biotite and a grain-flattening fabric defined by tabular quartz and plagioclase crystals. Both weakly and strongly deformed rocks are overprinted by a low- to medium-grade metamorphism, responsible for sutured quartz boundaries, and replacement of plagioclase and magnetite by fine-grained sericite and epidote.

Moorarie Supersuite

Coarse-grained granite and pegmatite (ꝐgMp)

Sheets and veins of medium- to coarse-grained granite and pegmatite (*ꝐgMp*) extensively and intensively intruded the granitic gneisses on MARQUIS and MOORARIE. This unit includes only those granite and pegmatite bodies that cut the banding in the gneisses, and does not include older pegmatite layers contained within the gneissic fabric. Coarse-grained granite and pegmatite mostly form bodies ranging in width from about a centimetre to several metres, but sheets or lenses up to 200 m thick and 4 km long are also present. Large sheets are particularly abundant in the southwestern corner of the sheet area. One sample from a large sheet about 4.5 km northeast of White Bore (AMG 608863) has been dated by SHRIMP U–Pb in zircon at 1813 ± 8 Ma (Nelson, 1998).

Also included within this unit are dykes of foliated, medium-grained, weakly porphyritic monzogranite. The dykes are widespread through the granitic gneisses, but never abundant. They are intruded by coarse-grained granite and pegmatite. A sample of a foliated granite dyke from about 4 km east-northeast of Jubilee Bore (AMG 884917) has a SHRIMP U–Pb in zircon age of 1811 ± 9 Ma, which is indistinguishable from the date of the sample of the pegmatitic granite sheet discussed above.

The sheets and veins are composed of very coarse to coarse-grained biotite monzogranite and syenogranite, and biotite(–muscovite) pegmatite. Some sheets and dykes show zoning, parallel to their margins, from coarse-grained granite to pegmatite. The granite and pegmatite sheets intruded the leucocratic and mesocratic granitic gneiss, and the interleaved amphibolites and metasedimentary rocks. The sheets and veins range from slightly to grossly discordant to D_2 layering in the gneisses, and to earlier formed, layer-parallel pegmatite veins. The granite and pegmatite are folded and deformed by D_{2n} structures, but they also cut D_{2n} folds — they were therefore intruded broadly synchronous with the D_{2n} event. Where strongly deformed, the sheets are gneissic and may contain layers up to a few centimetres thick of idioblastic almandine garnet crystals. In the southeastern corner of MARQUIS, pegmatite and coarse-grained granite also form dykes trending east-southeast to southeast. Sheets and veins of granite and pegmatite also intruded the Yamagee Granite, but they are much less abundant than in the granitic gneisses.

Most of the coarse-grained granites and some of the pegmatites contain plagioclase and microcline, but many of the pegmatites contain only plagioclase with microcline intergrowths. Biotite is commonly the main mafic mineral, but the mineralogy may be partly dependent on the country rocks. The pegmatite commonly contains tremolite where it has intruded calc-silicate gneiss, and magnetite is common in the pegmatite where iron-formation is locally abundant. The granites and pegmatites display a range of textures consistent with their variable states of deformation. Some preserve coarse-grained igneous textures, but others have medium-grained amoeboid and polygonal granoblastic textures indicative of recrystallization at medium to high metamorphic grade. Igneous and high-grade metamorphic plagioclase is altered to fine-grained sericite, epidote, and albite–oligoclase and quartz is recrystallized to finer grained, sutured crystals.

Biotite granite (ꝐgMe)

Biotite granite forms a large (>60 km^2) crescent-shaped pluton west of Mount Marquis, and dykes that intruded the granite gneisses around the Morris Fault. The pluton is exposed as low, rounded, bouldery hills and consists of foliated, medium-grained, even-textured biotite monzogranite. The pluton intruded grey, medium-grained, even-textured, biotite-rich monzogranite and granodiorite (*Agg*) at several localities southwest of Round Yard Bore (e.g. AMG 703069), and was intruded by the Discretion Granite about 7 km east of Cardingie Bore (AMG 660099) and 3.4 km southwest of Round Yard Bore (AMG 707068). A sample of biotite granite (*ꝐgMe*) from west of Round Yard Bore (AMG 703082) was dated by SHRIMP U–Pb in zircon at 1801 ± 7 Ma (Nelson, 1998). Dykes of medium- to coarse-grained, even-textured to moderately porphyritic biotite granite (*ꝐgMe*) intruded the granitic gneisses for up to 3 km on either side of the Morris Fault. The dyke swarm also includes several large, even-textured biotite monzogranite sheets up to 150 m thick, which intruded the Morris Fault. Towards the eastern edge of MARQUIS the dykes also intruded a series of east-southeasterly trending faults, which are splays off the Morris Fault. One of the dykes from this swarm, about 2 km southwest of Dune Bore (AMG 912877), was dated by SHRIMP U–Pb in zircon at 1797 ± 4 Ma (Nelson, 1998). This date is indistinguishable from that of the pluton west of Mount Marquis.

Most of the dykes strike in one of two orientations: between about 90–120° and 150–160°. About 3 km east-northeast of Weedarra Bore (AMG 710877), dykes trending in each of the orientations intruded the other, indicating that they were contemporaneous. Some of the dykes in the 150–160° orientation have a sigmoidal shape, consistent with emplacement during dextral strike-slip faulting. The veins and dykes are mostly less than 2 m wide, but locally dykes may reach 5 m in width. Most of the dykes consist of medium-grained, even-textured to moderately porphyritic, biotite monzogranite, but with subordinate medium- to coarse-grained, porphyritic monzogranite and associated pegmatite. The coarser monzogranite and pegmatite commonly intruded the medium-grained granite. Pegmatite is abundant about 5 km southwest of Mount Marquis. The dykes range from massive and weakly recrystallized to strongly foliated with mafic schleiren and compositional layering.

The biotite granite dykes intruded the granitic gneisses as well as the interleaved amphibolite and metasedimentary rocks. The dykes also intruded the Yamagee Granite and sheets of coarse-grained, porphyritic biotite granite and pegmatite (*ℙgMp*). The sigmoidal shape of some dykes noted above, together with a range of textures from massive to strongly foliated, implies that the dykes were intruded during movement on the Morris Fault. The large sheets emplaced into the Morris Fault are massive, and they are only overprinted by brittle fracturing and quartz veining. The dykes may represent one swarm emplaced over a long time (synchronous with D_{3n}; see **Deformation and metamorphism**) or several discrete magmatic events.

The majority of the granite dykes are granodiorite and monzogranite in composition, but dykes of trondhjemite are also common. Granodiorite and monzogranite dykes are composed of quartz, plagioclase, microcline, and 5–15% biotite, with accessory zircon, allanite, and apatite. The trondhjemite dykes are leucocratic and composed of plagioclase and quartz with about 5% or less biotite, and accessory zircon, apatite, and allanite. Subhedral granular igneous textures are present in many of the dykes, although this texture is obliterated in foliated dykes. Seams of biotite, epidote, and muscovite define the foliation, which is accompanied by a reduction in grain size of the quartz and feldspars. All of the massive samples are overprinted by a weak to moderate static alteration of plagioclase to sericite and clinozoisite, and replacement of magnetite by epidote.

Capricorn Orogeny

Archaean granitic gneisses belonging to the Narryer Terrane of the Yilgarn Craton were extensively reworked and intruded by granite and pegmatite during the Palaeoproterozoic Capricorn Orogeny (Occhipinti et al., 1998b). This zone of reworking was recognized by Williams (1986) and others, and referred to as the Yarlarweelor 'gneiss belt'. These workers considered the 'gneiss belt' to extend as far south as the Bullbadger Shear Zone on GOULD to the southwest, and westward onto the GLENBURGH 1:250 000 sheet area. Palaeoproterozoic intrusions are absent over much of the belt, however, and deformation is restricted to discrete shear zones. Pervasive Palaeoproterozoic reworking of the Archaean granitic gneisses and intrusion of granite and pegmatite are restricted to areas north and northeast of the Seabrook Fault and east of the Errabiddy Shear Zone (Figs 1 and 3). This area is referred to here as the Yarlarweelor gneiss complex.

The earliest Palaeoproterozoic deformation recognized on MARQUIS correlates with large east–west fold structures in the Bryah Basin on MOORARIE (Occhipinti and Myers, in prep.). These structures fold a layer-parallel foliation in the metavolcanic rocks of the Bryah Basin. That foliation is designated D_{1n}, and the first Palaeoproterozoic structures recognized on MARQUIS are therefore labelled D_{2n}. The layer-parallel foliation may reflect tectonic interleaving of the Archaean gneiss basement with low-grade metasedimentary and metavolcanic rocks of the Palaeoproterozoic Bryah and Padbury Basins, sometime between 1900 and 1812 Ma (Occhipinti and Myers, in prep.). During the D_{2n} event (c. 1812 Ma) granitic gneisses of the Archaean Narryer Terrane and metasedimentary and metavolcanic rocks of the Palaeoproterozoic Padbury and Bryah Groups were deformed together (Occhipinti and Myers, in prep).

Deformation and metamorphism (D_{2n}/M_{2n})

On MARQUIS D_{1n} structures are not recognized, but Palaeoproterozoic rocks of the Trillbar Complex and Padbury Group on MOORARIE contain a pervasive schistosity parallel to the primary layering. This schistosity (S_{1n}) is folded about steeply dipping tight to isoclinal folds that strike easterly, and have vertical plunges (Occhipinti and Myers, in prep.). In places a well-developed crenulation cleavage (S_{2n}) is formed. Faults have developed along the limbs of these large-scale easterly trending folds, and one (the Kerba Fault) forms the contact between the Palaeoproterozoic rocks and the Archaean granitic gneisses. The Kerba Fault trends east-southeasterly and cuts D_{2n} structures in the Archaean gneisses, and hence is regarded as a D_{3n} structure (see **Deformation and metamorphism (D_{3n}/M_{3n})**).

Mesoscopic upright folds (F_{2n}) are the most abundant fold structures in the granitic gneisses, interleaved metasedimentary and mafic igneous rocks, and coarse-grained granite and pegmatite sheets (Fig. 7). Mesoscopic upright folds attributed to D_{2n} are also present in the Yamagee Granite. The folds range from open, in areas of low D_{2n} strain, to isoclinal, in zones of high D_{2n} strain. The limbs are commonly marked by a strong foliation or, in places, a gneissic banding. The gneissic granoblastic texture formed in the Archaean is commonly overprinted by a S_{2n} foliation formed at medium metamorphic grade (M_{2n}). Fold hinges hundreds of metres across are commonly defined by thicker layers of metamorphosed iron-formation and amphibolite. The F_{2n} folds trend

Figure 7. Tight upright folds in strongly layered leucocratic granitic gneiss. Folds plunge shallowly to the southwest. Outcrop about 4 km east-southeast of Stevie Bore (AMG 682806)

westerly or southwesterly, and plunge shallowly or moderately to the east and northeast or to the west and southwest. Small-scale, 'arrowhead'-shaped, refolded fold structures produced by interference between F_2 and F_{2n} are widespread.

Large-scale fold structures are very difficult to identify because of the uniform nature of much of the granitic gneisses, intensity of later shearing, and large amounts of younger granite and pegmatite. Several large-scale fold closures in granitic gneiss around 13 Mile Well in the southeastern corner of MARQUIS (AMG 955853) are outlined (relative to the surrounding gneiss) by the presence of abundant amphibolite layers. The distribution of metamorphosed iron-formation layers near the southern edge of the sheet area (around AMG 780840) is consistent with a large fold closure north of the abandoned Red Peak Bore.

The age of the D_{2n} event is tightly constrained by U–Pb SHRIMP dating. Pegmatite and coarse-grained granite veins and sheets truncate D_{2n} structures at a low angle, whereas others are folded around F_{2n} folds, and in places become deformed into pegmatitic and granitic gneiss. These relationships suggest that D_{2n} was synchronous with granite and pegmatite intrusion at 1813 ± 8 Ma (see **Coarse-grained granite and pegmatite (*ꝒgMp*)**). A maximum age for the deformation is provided by a date of 1811 ± 9 Ma for a dyke of medium-grained, weakly porphyritic biotite monzogranite. This is one of a number of dykes that are consistently folded about F_{2n} and intruded by coarse-grained granite and pegmatite (*ꝒgMp*). These dates are consistent with a minimum age for the D_{2n} event provided by a U–Pb SHRIMP date of 1808 ± 6 Ma for the Kerba Granite on MOORARIE, which is discordant to D_{2n} structures (Occhipinti and Myers, in prep.).

Amphibolite layers cutting D_2 layering in the granitic gneisses and coarse-grained granite and pegmatite sheets emplaced during D_{2n} contain mineral assemblages and textures indicative of medium- to high-grade metamorphism. The indicated grade of regional metamorphism is the same as that determined from Archaean granitic and calc-silicate gneisses, and amphibolite layers folded about F_2. Therefore, most of the observed mineral assemblages are probably related to M_{2n} metamorphism.

Most of the amphibolites are characterized by the assemblages green hornblende and plagioclase (andesine) or green hornblende, plagioclase (andesine), and clinopyroxene, both with minor quartz and titanite. These assemblages are typical of regional metamorphism at middle to upper amphibolite facies (Bucher and Frey, 1994). In some samples clinopyroxene is intergrown with green hornblende, but in others it forms cores to the hornblende, suggesting that the clinopyroxene is a relict from the igneous precursor or an earlier, higher grade metamorphic event. Amphibolite gneisses from the area between Red Peak Bore, Morris Bore, and Jubilee Bore have a polygonal or amoeboid granoblastic texture, and assemblages of brown hornblende, plagioclase (labradorite), clinopyroxene, and iron oxides, or clinopyroxene, plagioclase (labradorite), green hornblende, and iron oxides. The assemblages and textures are consistent with local higher grade metamorphism, at the transition between amphibolite and granulite facies (Bucher and Frey, 1994).

Sheets of coarse-grained granite and pegmatite show a wide range of textures depending on their relationship to D_{2n} folds. Sheets or dykes cutting the folds have weakly recrystallized igneous textures, but those folded about F_{2n} may show gneissic fabrics, with development of almandine garnet and domains of feldspar and quartz with amoeboid and granoblastic polygonal textures. Antiperthite is present in strongly deformed and little-deformed samples, suggesting that it is a feature of the igneous precursor. The textures and growth of garnet imply medium- to high-grade metamorphism.

Calc-silicate gneiss contains assemblages typical of aluminous marl metamorphosed at amphibolite-facies conditions, that is, clinopyroxene, tremolite, and titanite with minor plagioclase and quartz in quartz-poor rocks, and clinopyroxene, tremolite, quartz, plagioclase, and microcline in quartz-rich rocks (Bucher and Frey, 1994). In the granitic gneisses, relict amoeboid and granoblastic textures and the assemblage quartz, microcline, plagioclase, biotite with green hornblende and magnetite represent high-grade metamorphic conditions.

Hornblende–plagioclase–clinopyroxene–orthopyroxene(–garnet) assemblages in amphibolite dykes on GOULD (Elias and Williams, 1980; Muhling, 1988) may be related to this event. Muhling (1988) determined P–T conditions of 9–10 kbar and 730–780°C for these assemblages.

Deformation and metamorphism (D_{3n}/M_{3n})

The D_{2n} structures in the gneisses are cut by numerous conjugate D_{3n} ductile shear zones and faults in two orientations: 080–110° and 140–170°. The largest of these faults is the Morris Fault (Fig. 3), which is a splay off the Errabiddy Fault. The sigmoidal shapes of some of the faults striking 140–170° and the dextral sense of shear on many of the faults striking 080–110° are consistent with dextral movement on the Morris Fault. Some of the 080–110° faults dip steeply to the north, and shear-sense indicators record a component of reverse movement with north-side-up. The displacement on these faults is unknown.

The D_{3n} faults are associated with small-scale, upright, open to tight folds, which may produce complex fold-interference structures where they refold D_{2n} folds. Away from the faults, D_{3n} is evident as a warping or gentle folding on F_{2n} limbs. A large synform in the Yamagee Granite near the centre of the mapped area also probably formed during D_{3n}. This structure folds small-scale D_{2n} folds and is cut by faults reactivated during the Edmundian Orogeny (see **Edmundian Orogeny**). Undivided sedimentary rocks of the Padbury Group north of the mapped area are also cut by D_{3n} faults.

The age of the D_{3n} event is well constrained by field relationships with igneous rocks dated by U–Pb SHRIMP zircon geochronology. Coarse-grained granite and pegmatite sheets dated at 1813 ± 8 Ma and the Kerba Granite dated at 1808 ± 6 Ma are cut by D_{3n} faults, and provide a maximum age for the deformation. Dykes of medium-grained granite (*ṖgMe*) are widely emplaced into D_{3n} faults and display a range of textures from massive to foliated, implying that they were intruded coeval with the D_{3n} event. One of these dykes has been dated at 1797 ± 4 Ma (see **Biotite granite (*ṖgMe*)**). Some of the dykes oriented at 140–170° have sigmoidal shapes consistent with dextral movement on the Morris Fault. Many of the east-southeasterly striking faults cutting the gneisses on MARQUIS record a component of south-directed thrusting, and dextral movement on the Morris Fault at this time may have occurred during oblique north–south compression.

Mesoproterozoic geology

Bangemall Group

The Bangemall Group rests unconformably on, or is in faulted contact with, the Narryer Terrane of the Yilgarn Craton and the Gascoyne Complex. The established stratigraphic framework (Elias and Williams, 1980; Muhling and Brakel, 1985) for the western part of the Bangemall Basin is followed here (Table 2). The rocks in the western part of the basin are deformed into zones of tight, upright folding about east–west axes parallel to basement faults, with intervening zones of broad open folds. The formations on MARQUIS form an apparently conformable sequence that belongs to the Edmund Subgroup (Muhling and Brakel, 1985). A poorly defined SHRIMP U–Pb zircon age of 1638 ± 14 Ma has been reported for the Tangadee rhyolite (Nelson, 1995) in the lower Edmund Subgroup (or 'western facies') of the Bangemall Group (Williams, 1990). This age places the lowest part of the Bangemall Group in the Palaeoproterozoic, but the group is dominantly Mesoproterozoic.

Table 2. Stratigraphy of the Edmund Subgroup of the Bangemall Basin

Formation and code	*Thickness (m)*	*Lithology*
Ullawarra Formation (*ƂMl*)	650	Laminated shale
Nanular Member (*ƂMlf*)	2 200	Quartz sandstone, feldspar sandstone, quartz wacke, siltstone, shale
Devil Creek Formation (*ƂMv*)	<800	Dolomite, shale, chert
Discovery Chert (*ƂMd*)	70	Chert, finely bedded, cream to black; interbedded siltstone
Jillawarra Formation (*ƂMj*)	600	Siltstone, shale, chert
Kiangi Creek Formation (*ƂMk*)	700	Quartz sandstone, quartz wacke, shale, and conglomerate
Irregully Formation (*ƂMi*)	1 300	Dolomitic shale and dolomite; quartz–carbonate sandstone
Tringadee Formation (*ƂMe*)	1 100	Pebbly quartz sandstone and wacke; conglomerate and siltstone

The lower part of the Edmund Subgroup is therefore nominally older than the Discretion Granite, but the original relationship between the granite and the Edmund Subgroup is unknown. On MARQUIS, the southern margin of the Bangemall Basin is marked by a southeasterly trending fault against, in part, the Discretion Granite.

Tringadee Formation (ƂMe)

The Tringadee Formation is the basal unit of the Edmund Subgroup and consists of regularly interbedded quartz sandstone and wacke with lenses of conglomerate and siltstone. Conglomerate pebbles, cobbles, and locally boulders consist of vein quartz, chert, and foliated quartz wacke. On MILGUN to the east, gently dipping Tringadee Formation overlies folded and foliated quartz wacke and siltstone of the Labouchere Formation of the Padbury Group (Swager and Myers, in prep.).

Irregully Formation (ƂMi)

The Irregully Formation comprises layered dolomite, dolomitic shale, shale, quartz–carbonate sandstone, and local, thin, white chert lenses. Small-scale erosional channels and cross-bedding are present. The Irregully Formation conformably overlies the Tringadee Formation about 10 km west of MARQUIS, immediately south of the Gascoyne River (Elias and Williams, 1980).

Kiangi Creek Formation (ƂMk)

The Kiangi Creek Formation is mainly composed of well-sorted, medium-grained, quartz arenite and quartz wacke with lenses of shale. Granule or pebble conglomerate lenses are present near the base of the formation (Elias and Williams, 1980).

Jillawarra Formation (ƂMj)

The Jillawarra Formation consists of finely bedded siltstone and shale, with chert lenses common near the base. The shale and mudstone are greyish-green, black, and brown (Elias and Williams, 1980).

Discovery Chert (ƂMd)

The Discovery Chert conformably overlies the Jillawarra Formation; the contact is gradational and marked by an upward increase in chert. The Discovery Chert consists of finely laminated light- and dark-coloured chert and some interbedded shale. The unit is about 50–80 m thick. The Discovery Chert is the best regional marker bed in the western Bangemall Basin, and was most likely deposited as a silica gel (Muhling and Brakel, 1985).

Devil Creek Formation (ƂMv)

The Devil Creek Formation consists of finely bedded dolomite, dolomitic shale, shale, and minor chert, and has a transitional lower contact with the Discovery Chert.

Ullawarra Formation (ƂMl)

Some low rounded hills about 6 km west of Consolation Bore, which are shown on the first edition ROBINSON RANGE sheet (Elias and Williams, 1980) as Devil Creek Formation, have been reassigned to the Ullawarra Formation (Muhling et al., 1978). The hills are composed of cream and greenish-grey, finely laminated shale that conformably overlies dolomite of the Devil Creek Formation.

Nanular Member (ƂMlf)

South of the Sawback Range the Nanular Member forms a large strike ridge, which is the type section for the unit (Muhling and Brakel, 1985), and several smaller hills to the east and west. These rocks were previously mapped by Elias and Williams (1980) as undivided arenite. The Nanular Member apparently conformably overlies the Devil Creek Formation, and is in part laterally equivalent to the Ullawara Formation, but the lower contact is not exposed on MARQUIS. The Nanular Member is composed of fine- to medium-grained, well-sorted quartz arenite, with beds of more feldspathic arenite and poorly sorted quartz wacke interbedded with siltstone and shale.

Discretion Granite (*Ꝑgdn, Ꝑgdne, Ꝑgdnf*)

The Discretion Granite (*Ꝑgdn*) is a newly defined unit named after the Discretion Bore. A sample of porphyritic, medium-grained monzogranite from about 2 km north of Anderson Well (AMG 925979) was dated by SHRIMP U–Pb in zircon at 1619 ± 15 Ma (Nelson, 1998). The Discretion Granite is well exposed around and northeast of Mount Marquis in the central part of the sheet, where it forms rounded hills covered with tors and boulders, and whalebacks. Smaller exposures are present north of Anderson Well and around Red Rock on the eastern edge of the mapped area. The latter exposure continues for a short distance onto MILGUN. Extensive sandplains separate the three main exposures, but airborne magnetic data indicate that the exposures are all linked below the surface. Therefore, the Discretion Granite probably forms an elongate intrusion over 40 km long and up to 10 km wide trending east-southeasterly. The bulk of the intrusion is composed of medium-grained, porphyritic biotite monzogranite with tabular phenocrysts of K-feldspar. Even-textured to weakly porphyritic monzogranite is common around Red Rock, and fine- to medium-grained, porphyritic biotite monzogranite is present about 5.5 km east of Cardingie Bore (AMG 655086).

Massive, medium-grained, porphyritic monzogranite (*Ꝑgdn*) of the Discretion Granite intruded mesocratic granitic gneiss about 2 km north of Anderson Well (AMG 925977). In addition, several dykes of monzogranite with tabular K-feldspar phenocrysts cut mesocratic granitic gneiss about 300 m northwest of Anderson Well. About 5 km northeast of Cardingie Bore (AMG 643121), weakly porphyritic monzogranite of the Discretion Granite intruded strongly banded, pegmatite-veined, leucocratic granite gneiss. About 3 km west-southwest of Round Yard Bore (AMG 704079), the Discretion Granite intruded grey, pegmatite-veined, gneissic biotite granodiorite (*Agg*). The Discretion Granite also intruded diffusely banded, fine- to medium-grained monzogranite (*ꝐgMe*) about 5 km east of Cardingie Bore (AMG 656098).

The Discretion Granite consists of at least three intrusive phases: porphyritic, medium-grained monzogranite (*Ꝑgdn*), which forms the bulk of the intrusion; even-textured, medium-grained to weakly porphyritic monzogranite (*Ꝑgdne*); and fine-grained, porphyritic monzogranite (*Ꝑgdnf*). The contact between the porphyritic and even-textured, medium-grained monzogranite around Red Rock is sharp and, in part, faulted. In the absence of veins, dykes, or inclusions of one phase in the other, their relative age could not be established. About 6 km east of Cardingie Bore (AMG 660089), dykes of medium-grained porphyritic monzogranite intruded fine-grained porphyritic monzogranite. North and north-northeast of Mount Marquis, however, dykes and sheets of fine-grained porphyritic monzogranite extensively intruded variably foliated medium-grained porphyritic monzogranite. The dykes are intruded roughly parallel to a variably tectonized igneous flow fabric defined by an alignment of tabular K-feldspar phenocrysts. The fabric defines a broad arc open to the southeast. The northwestern corner of the Discretion Granite lacks a flow fabric and contains more inclusions of fine-grained porphyritic monzogranite and biotite-rich rock. Therefore, the medium-grained, porphyritic monzogranite in the northwestern corner of the pluton may form another intrusive phase.

Porphyritic, medium-grained monzogranite consists of 15–30% tabular phenocrysts of microcline in an anhedral or subhedral granular groundmass of microcline, oligoclase, biotite (2–7%), and small amounts of muscovite intergrown with biotite. Microcline phenocrysts commonly contain small inclusions of plagioclase, biotite, and quartz. Accessory mineral assemblages are magnetite, ilmenite, apatite, zircon, and allanite or, in more felsic samples, magnetite, apatite, and zircon. Even-textured, medium-grained monzogranite has the same mineralogy as the porphyritic phase. Fine-grained, porphyritic monzogranite is composed of 10–15% phenocrysts of microcline and subordinate plagioclase in an anhedral granular groundmass of quartz, oligoclase, microcline, biotite, and a little muscovite. Accessory mineral assemblages are the same as those in the coarser grained phases. All samples show some degree of recrystallization and development of secondary minerals, such as weak to moderate sericite alteration of plagioclase, epidote rims on magnetite, and titanite rims on ilmenite. Granophyric textures are present in some samples.

The Discretion Granite contains inclusions of porphyritic, fine-grained monzogranite and a fine-grained, even-textured, biotite-rich rock, in addition to inclusions of country rock close to the margins of the pluton. The monzogranite and biotite-rich inclusions are widespread, but only locally abundant. An exception is the area about 3–4 km west-northwest of Round Yard Bore, north of Mount Marquis, where angular to subangular monzogranite inclusions up to a metre in diameter are abundant. Both inclusion types are commonly round or elliptical. The monzogranite inclusions are typically less than 30 cm in diameter, and the biotite-rich inclusions up to 5 cm in diameter.

Leucocratic biotite monzogranite dykes (*Ꝑgm*)

In the area around Mount Marquis in the central part of the map sheet, dykes and a thick sheet of massive or weakly foliated, pale-grey, leucocratic biotite monzogranite (*Ꝑgm*) intruded the Discretion Granite, the pluton of biotite granite (*ꝐgMe*), and the pluton of biotite granodiorite (*Agg*). The dykes have a similar appearance and orientation to dykes of medium-grained, even-textured to moderately porphyritic biotite monzogranite dated at 1797 ± 4 Ma. However, the leucocratic biotite monzogranite dykes intruded the Discretion Granite, which is dated at 1619 ± 15 Ma, and so they must represent a younger magmatic event than the 1797 Ma dykes. Where the younger dykes intruded the gneisses and older foliated granites, they cannot be distinguished from the older dykes.

The leucocratic biotite monzogranite dykes are associated with a fault zone striking at 110°, south of Mount Marquis. The dykes mainly strike at 110–120°, but dykes oriented at about 150° are also present. The dykes are up to 30 m wide, whereas the thick sheet west of Mount Marquis ranges from less than 100 m up to 250 m wide. The dykes are medium to fine grained and most are weakly porphyritic, containing up to about 5% rounded, grey K-feldspar phenocrysts less than 7 mm in diameter. Many of the dykes contain scattered lenticular and rounded, fine-grained mafic inclusions up to about 10 cm long. In places, the inclusions have narrow biotite-rich rims.

Dolerite and gabbro (*Ƥd*)

Sills of dolerite and gabbro intruded the Jillawarra Formation in the Sawback Range. Elias and Williams (1980) reported that contact metamorphism of the adjacent sedimentary rocks is restricted to spotting and slight baking of siltstone and shale.

Edmundian Orogeny

Rocks of the Mesoproterozoic Bangemall Basin were folded about arcuate easterly to southeasterly trending folds during the Edmundian Orogeny (Halligan and Daniels, 1964). The sedimentary rocks and dolerite sills intruded into the succession are folded onto broad dome-and-basin structures. The age of the folding is poorly constrained, but may be as young as 1000 Ma. Folding post-dates deposition of the Collier Subgroup, the age of which is loosely constrained to 1200–1000 Ma (Williams, 1990).

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

Faults initially formed during the D_{3n} event were later reactivated and filled with quartz veins during the Mesoproterozoic or Neoproterozoic (D_{1e}). These easterly and east-southeasterly trending, quartz-filled faults cut the swarm of medium-grained, biotite granite dykes dated at 1797 ± 4 Ma, and the Discretion Granite (*Ƥgdn*) dated at 1619 ± 15 Ma. One of these faults also cuts out a large-scale F_{3n} synform in the Yamagee Granite about 7 km southwest of Mount Marquis. Narrow shear zones striking east-southeasterly cut the Discretion Granite. Porphyroclast tails in some shear zones record both sinistral and dextral sense of shear or a strong flattening. Others show a consistent sense of shear, indicating sinistral motion and north-block-up. A large-scale fold closure of a weak tectonic fabric in a phase of the Discretion Granite may also be related to the D_{1e} event. Gently to moderately plunging open folds with easterly striking fold axes in the Bangemall Basin may be associated with a number of large, east-southeasterly trending D_{1e} faults that slice up the Bangemall Basin and define its southern margin. These structures cut a locally strong, bedding-parallel cleavage or foliation in the sedimentary rocks. Myers et al. (1996) suggested that the D_{1e} event was related to collision of the North Australian and West Australian Cratons between 1300 and 1100 Ma.

Mesoscopic northerly trending folds (F_{2e}) have overprinted steeply dipping, tight to isoclinal, east-southeasterly trending folds (F_{3n}). Northerly trending kinks fold the pervasive S_{1n} foliation in the Palaeoproterozoic rocks on MOORARIE (Occhipinti and Myers, in prep.), and the fabric in the Archaean gneisses. In addition, northerly trending faults with consistent sinistral offset are widespread in the gneisses. Faults in a similar orientation also cut sedimentary rocks of the Bangemall Basin. The D_{2e} event may be related to reactivation of structures within the Capricorn Orogen in the Blake fold-and-thrust belt to the north at 750–700 Ma (Myers et al., 1996).

Where weakly overprinted by M_{1e}, amphibolites contain rims of fine-grained granular epidote between hornblende and plagioclase, together with sericite and clinozoisite alteration of plagioclase. Adjacent to the Morris Fault, amphibolite layers are moderately or strongly recrystallized to fine-grained actinolite, albite–oligoclase, epidote, and sericite. Tremolite(–clinopyroxene) rocks are retrogressed to actinolite and epidote, or chlorite, talc, and calcite. In the calc-silicate gneisses, both quartz-poor and quartz-rich rocks contain minor to abundant fine-grained clinozoisite–epidote, albite, and sericite alteration of clinopyroxene and plagioclase, with associated fine-grained recrystallization of quartz and microcline. The granitic gneisses, dykes of medium-grained granite, and Discretion Granite all underwent similar mineralogical and textural changes during M_{1e}. High-grade metamorphic or igneous plagioclase is weakly or moderately altered to sericite and clinozoisite, some biotite may be replaced by chlorite, and quartz shows undulose extinction and widespread sutured grain boundaries.

Dolerite dykes (*d*)

Dolerite dykes intruded all the early to late Archaean and Proterozoic rocks of the Narryer Terrane on MARQUIS. The dykes strike roughly easterly, although one dyke south of 13 Mile Well (AMG 937820) strikes northerly. An easterly trending dolerite dyke intruded this dyke. Some of the easterly trending dykes swing around to the east-southeast, perhaps following earlier fault structures. The dykes are marked by a scarcity of mulga trees and abundant rubble of dolerite boulders in a reddish-brown soil. The dolerite dykes range from about 5 to 50 m in thickness, with the largest dykes being at least 10 km long. The age of the dolerite dykes is unknown, but they intruded the 1619 ± 15 Ma Discretion Granite. Large dolerite sills and several generations of dolerite dykes intruded sedimentary rocks of the Bangemall Basin (Muhling et al., 1978), but it is not known with which of these dolerites, if any, the dykes on MARQUIS correlate.

The dolerite dykes are massive, and range from fine grained and aphyric to medium grained (grain size of about 2 mm) and weakly plagioclase-phyric. Most of the larger dykes (i.e. ≥10 m wide) show zoning from fine-grained margins to medium-grained interiors. Two types of dykes may be distinguished chemically: dolerites similar to enriched mid-ocean ridge basalt (E-MORB); and dolerites with affinities to high-TiO_2 continental flood basalts (CFB). Both types of dykes are weakly plagioclase-phyric to even-textured, with a subophitic or intergranular texture. The CFB-like dolerites consist of plagioclase, clinopyroxene, and Fe–Ti oxides, and possibly pigeonite, with traces of quartz and biotite. The E-MORB-like dolerites consist of plagioclase, clinopyroxene, and Fe–Ti oxides, with accessory hornblende, biotite, and quartz. The CFB-like dolerites have higher whole-rock K_2O, P_2O_5, Rb, Zr, and lower Nb than the E-MORB-like dolerites (unpublished data). Where metamorphosed, both types of dykes show extensive replacement of pyroxene by blue-green actinolite, and rims of epidote around magnetite.

The northerly trending dyke south of 13 Mile Well is weakly foliated in places, and contains small phenocrysts of clinopyroxene and plagioclase. Phenocryst and groundmass clinopyroxene is extensively replaced by actinolite, and plagioclase is moderately altered to epidote and albite.

Quartz veins (*q*)

Many of the faults on MARQUIS are filled with quartz veins. Some of the veins consist of laminated, mylonitic quartz, whereas others are composed of massive milky quartz. The veins are likely to be of various ages, ranging from Palaeoproterozoic to Phanerozoic.

Cainozoic deposits

Twelve Cainozoic, including Quaternary, units are recognized on MARQUIS. The distribution of the regolith materials regimes on MARQUIS is broadly consistent with that on the ROBINSON RANGE 1:250 000 regolith-materials map sheet (Bradley et al., 1997), despite the much greater number of units on the regolith map. The Quaternary units (*Qa*, *Qak*, *Qc*, *Qcf*, *Qci*, *Qcq*, *Qs*, and *Qw*) and one Cainozoic unit (*Czc*) form the depositional regime. Two of the Cainozoic units (*Czrf* and *Czrz*) are part of the relict regime, and a unit of weathered quartzofeldspathic rock (*Czeg*) forms the erosional regime.

Consolidated deposits of silt, sand, and gravel (*Czc*) are common in the southern part of the map along the drainage divide formed by the Archaean gneisses. They form part of an old land surface that is dissected by creeks to reveal exposures of granitic gneiss. In the western part of MARQUIS, remnants of a more extensive surface of massive ferruginous duricrust and hardpan (*Czrf*) are present. This forms a residual plateau over deeply weathered rock (*Czeg*). The latter is extensively developed in the southwestern part of the map sheet. Silcrete (*Czrz*) is a subvitreous siliceous rock with small to large, angular to rounded quartz fragments developed over faults on the northern edge of MARQUIS.

Colluvium (*Qc*) comprises unconsolidated and partly consolidated rubble of bedrock, gravel, sand, and silt forming scree slopes surrounding rock outcrops. This unit includes substantial amounts of quartz-vein debris and fine- to medium-grained quartz–feldspar sand surrounding and overlying granite. Ferruginous rubble and colluvium (*Qcf*) is derived from highly weathered rock and ferruginous duricrust, and consists of ferruginous pisolites, and degraded and transported duricrust fragments. This unit is restricted to the Sawback Range area. Proximal transported ironstone rubble (*Qci*) forms scree slopes surrounding or overlying many layers of metamorphosed iron-formation. Quartz vein debris (*Qcq*) forms scree slopes surrounding quartz veins, or sheetwash fans overlying degraded remnants of quartz veins.

Sandplain deposits (*Qs*) comprise low windblown dune ridges of sand and silt that are commonly covered by low bushes. These deposits are commonly very thin, and overlie flat surfaces of ferruginous duricrust and hardpan. Sheetwash of unconsolidated clay, silt, sand, and gravel (*Qw*) forms low-gradient slope deposits and extensive fans. Alluvial deposits (*Qa*) consist of silt, sand, and gravel in the main river channels and overbank deposits on adjacent floodplains. Calcrete sheets (*Qak*) are developed along the Gascoyne River, and consist of white carbonate and opaline silica deposits.

Economic geology

The only recorded mineral production on MARQUIS comes from a variscite deposit, 3.5 km northwest of Sawback Well (AMG 874226) in the northern part of the map sheet (Bradley et al., 1997). Variscite is a green, hydrated aluminium phosphate ($AlPO_4.2H_2O$). About 1.8 t was mined from the deposit, which is located in a brecciated chert near the base of the Jillawarra Formation in the Bangemall Basin. No other prospects or mineral occurrences are known from MARQUIS.

Regolith geochemical mapping has identified two minor anomalous occurrences (AMG 754275 and AMG 769253) in the Sawback Range area east of Mount Clere Homestead. The two samples contain some of the highest Zn, V, and Sc values on the ROBINSON RANGE 1:250 000 map sheet (i.e. >150 ppm Zn, >500 ppm V, and >24 ppm Sc; Bradley et al., 1997). The samples are probably sourced from a dolerite sill or the Discovery Chert.

References

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, Geochemical Series Explanatory Notes, 57p.

BUCHER, K., and FREY, M., 1994. Petrogenesis of metamorphic rocks (6th edition): Berlin, Springer-Verlag, 318p.

ELIAS, M., and WILLIAMS, S. J., 1980, Robinson Range, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 32p.

GEE, R. D., 1990, Nabberu Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 202–210.

GEE, R. D., and GREY, K., 1993, Proterozoic rocks on the Glengarry 1:250 000 sheet — stratigraphy, structure and stromatolite biostratigraphy: Western Australia Geological Survey, Report 41, 30p.

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.

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.

MUHLING, J. R., 1988, The nature of Proterozoic reworking of early Archaean gneisses, Mukalo Creek area, southern Gascoyne Province, Western Australia: Precambrian Research, v. 40/41, p. 341–362.

MUHLING, P. C., BRAKEL, A. T., and DAVIDSON, A. W., 1978, Mount Egerton, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 28p.

MUHLING, P. C., and BRAKEL, A. T., 1985, Geology of the Bangemall Group: 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, Precambrian tectonic evolution of part of Gondwana, southwestern Australia: Geology, v. 18, p. 537–540.

MYERS, J. S., 1990b, Part 1 — Summary of the Narryer Gneiss Complex, *in* Third International Archaean Symposium, Perth, 1990, 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, Gascoyne Complex, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 198–202.

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, 244p.

NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.

NELSON, D. R., in prep., Compilation of SHRIMP U–Pb zircon geochronology data, 1998: Western Australia Geological Survey, Record 1999/2.

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.

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.

OCCHIPINTI, S. A., and MYERS, J. S., in prep., Geology of the Moorarie 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

OCCHIPINTI, S. A., MYERS, J. S., and SWAGER, C. P., 1998a, Geology of the Padbury 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 29p.

OCCHIPINTI, S. A., SHEPPARD, S., NELSON, D. R., MYERS, J. S., and TYLER, I. M., 1998b, 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., 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., BAGAS, L., SWAGER, C. P., OCCHIPINTI, S. A., and ADAMIDES, N. G., 1996, A reappraisal of the stratigraphy of the Glengarry Basin, Western Australia: Western Australia Geological Survey, Annual Review 1995–96, p. 81–87.

SWAGER, C. P., and MYERS, J. S., in prep., Geology of the Milgun 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

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.

TYLER, I. M., and THORNE, A. M., 1994, The role of structural geology in the search for high-grade iron ore bodies in the Hamersley Basin: Geological Society of Australia, Abstracts 37, p. 437.

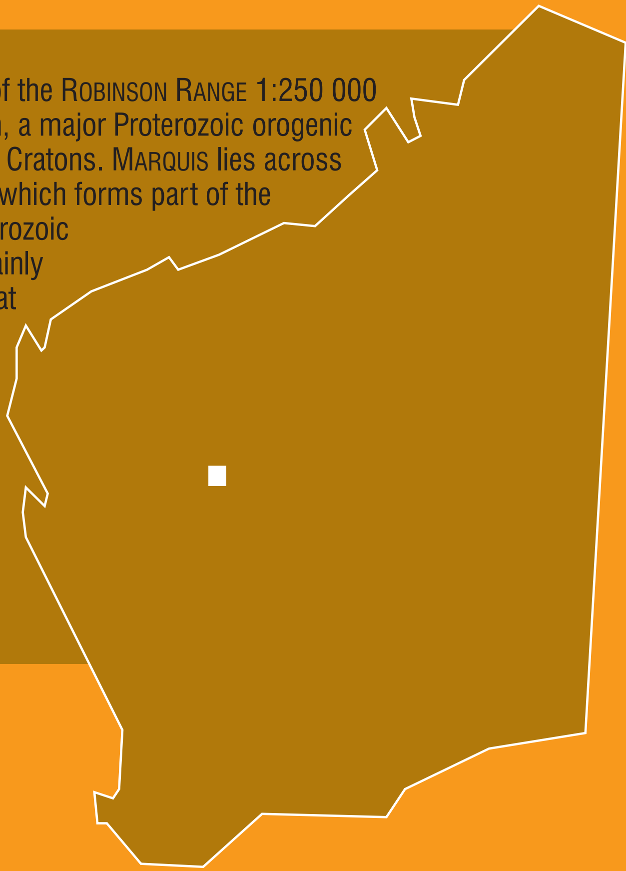
WILLIAMS, I. R., 1990, The Bangemall Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 308–329.

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., and HOCKING, R. M., 1983, Glenburgh, Western Australia: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 25p.

The MARQUIS 1:100 000 sheet covers the northern part of the ROBINSON RANGE 1:250 000 sheet. The sheet lies entirely within the Capricorn Orogen, a major Proterozoic orogenic belt developed between the Archaean Yilgarn and Pilbara Cratons. MARQUIS lies across the boundary between the Yarlarweelor gneiss complex, which forms part of the Narryer Terrane of the Yilgarn Craton, and the Mesoproterozoic Bangemall Basin. The Yarlarweelor gneiss complex is mainly composed of Archaean granitic gneisses and granites that were deformed and metamorphosed, and intruded by granite and pegmatite sheets and dykes, during the Palaeoproterozoic Capricorn Orogeny. Sedimentary rocks of the Bangemall Basin are in faulted contact with rocks of the Yarlarweelor gneiss complex. Major east-southeasterly trending faults, such as those that define the southern margin of the Bangemall Basin on MARQUIS, initially formed in the Palaeoproterozoic and were reactivated in the Mesoproterozoic and Neoproterozoic.



Further details of geological publications and maps produced by the Geological Survey of Western Australia can be obtained by contacting:

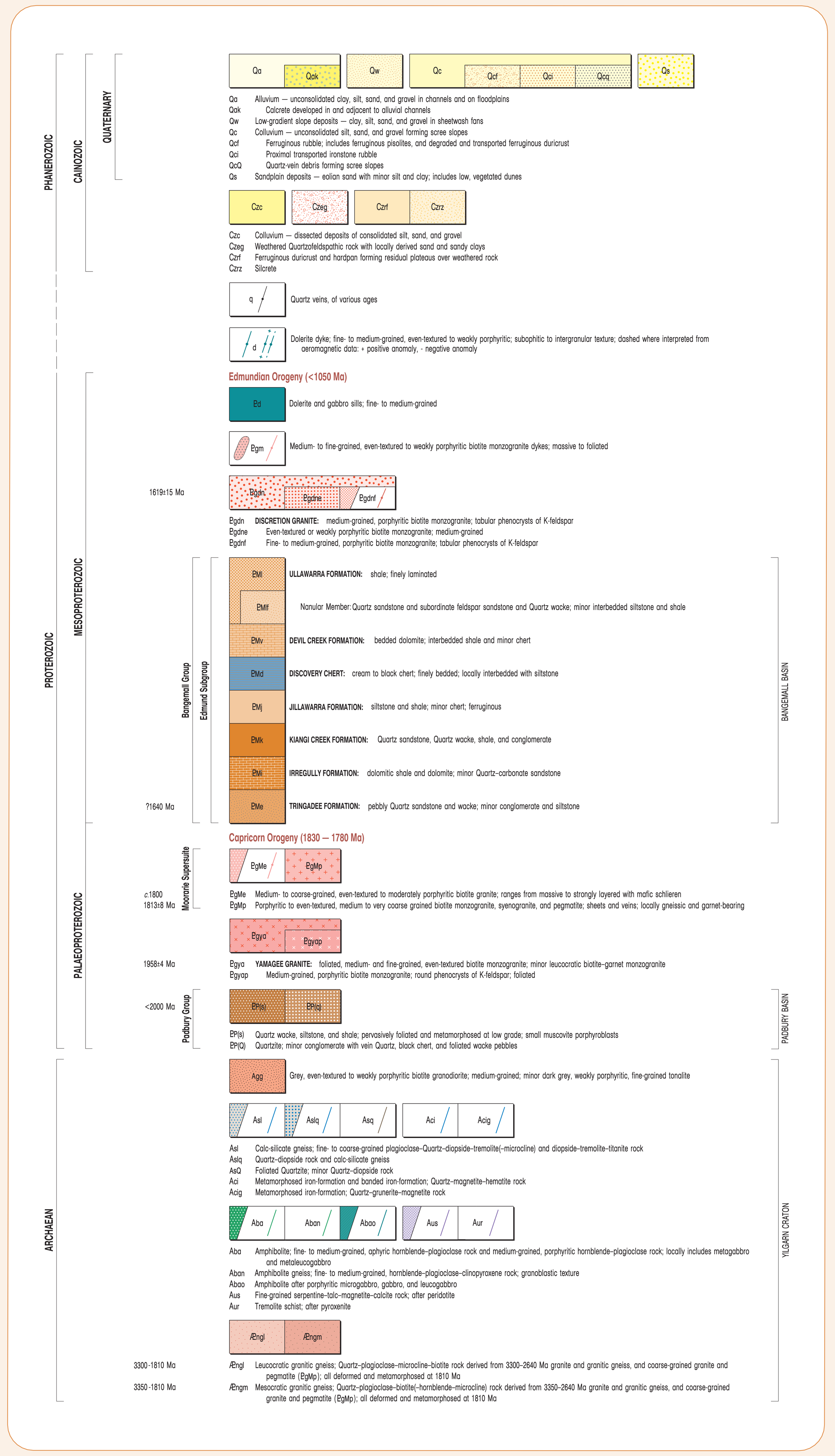
Information Centre
Department of Minerals and Energy
100 Plain Street
East Perth WA 6004
Phone: (08) 9222 3459   Fax: (08) 9222 3444
www.dme.wa.gov.au

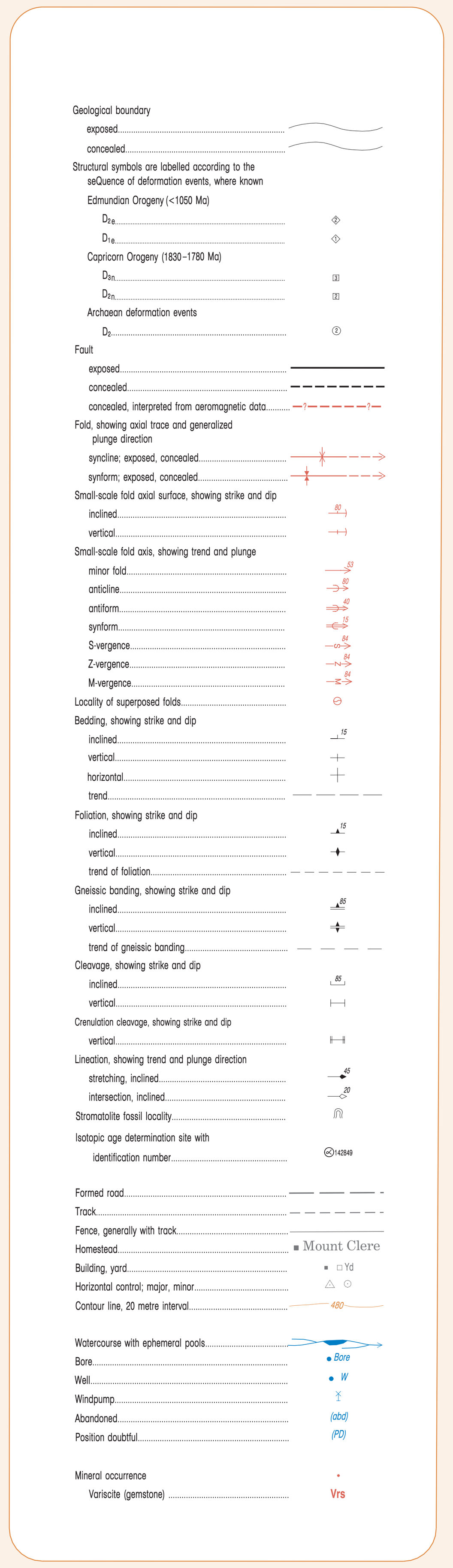
AUSTRALIA 1 : 100 000 GEOLOGICAL SERIES

MARQUIS

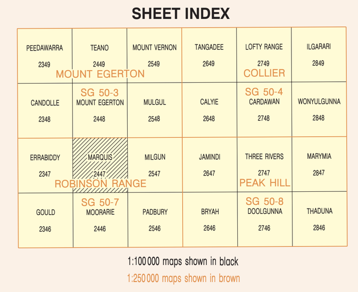
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

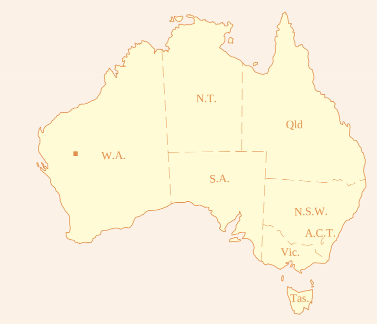
SHEET 2447



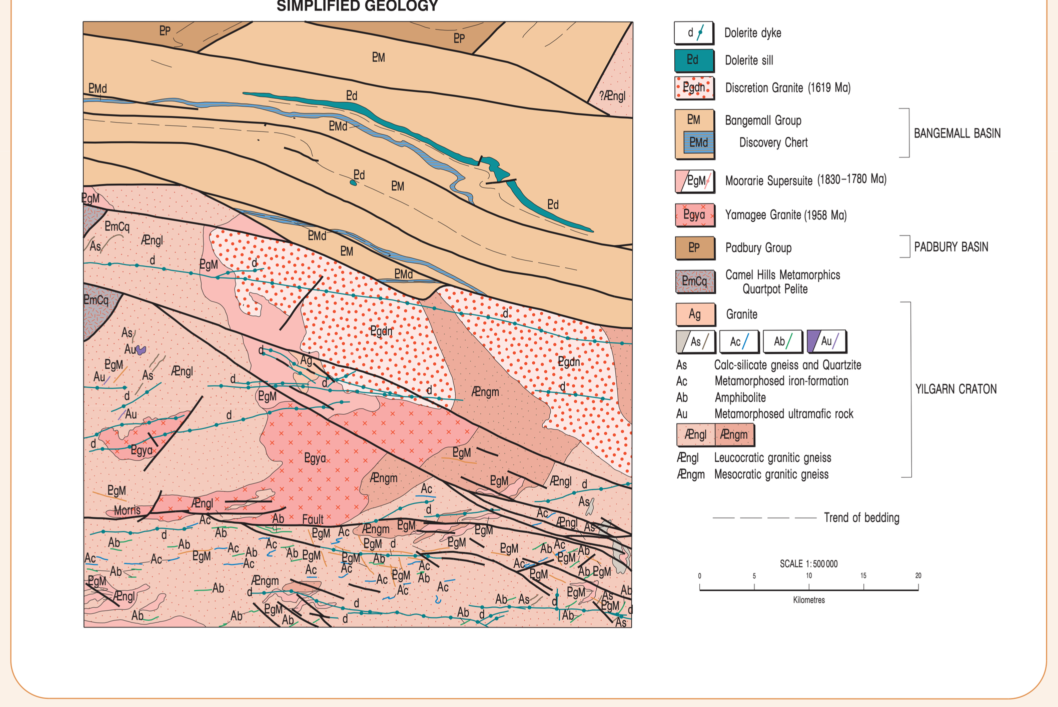


SHEET INDEX

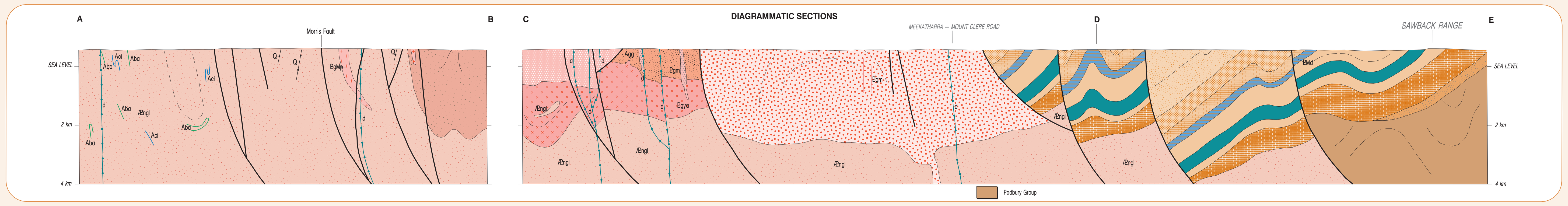


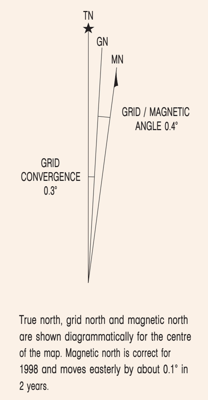


SIMPLIFIED GEOLOGY



DIAGRAMMATIC SECTIONS





Compiled by S. Sheppard, C. P. Swager, and S. A. Occhipinti 1997

Geology by S. Sheppard, J. S. Myers, and C. P. Swager 1996

Edited by F. Apidopoulos and G. Loan

Cartography by D. Ladbrook and K. Greenberg

Topography from the Department of Land Administration Sheet SG 50-7, 2447, with modifications from geological field survey

Published by the Geological Survey of Western Australia. Copies available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, WA, 6004. Phone (08) 9222 3459, Fax (08) 9222 3444

This map is also available in digital form

Printed by the Sands Print Group, Western Australia

The recommended reference for this map is:
SHEPPARD, S., SWAGER, C. P., MYERS, J. S., and OCCHIPINTI, S. A., 1999, MarQuis, W. A. Sheet 2447: Western Australia Geological Survey, 1:100 000 Geological Series

Department of
Industry and Resources

Geological Survey of
Western Australia

CLIVE BROWN, M.L.A.
MINISTER FOR STATE DEVELOPMENT

JIM LIMERICK
DIRECTOR GENERAL

TIM GRIFFIN
DIRECTOR

SCALE 1:100 000

Metres — Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 51

The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

Reference points to align maps based on the previous datum, AGD84, have been placed near the map corners

MARQUIS

SHEET 2447 FIRST EDITION 1999

Version 1.1 — April 2003