EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

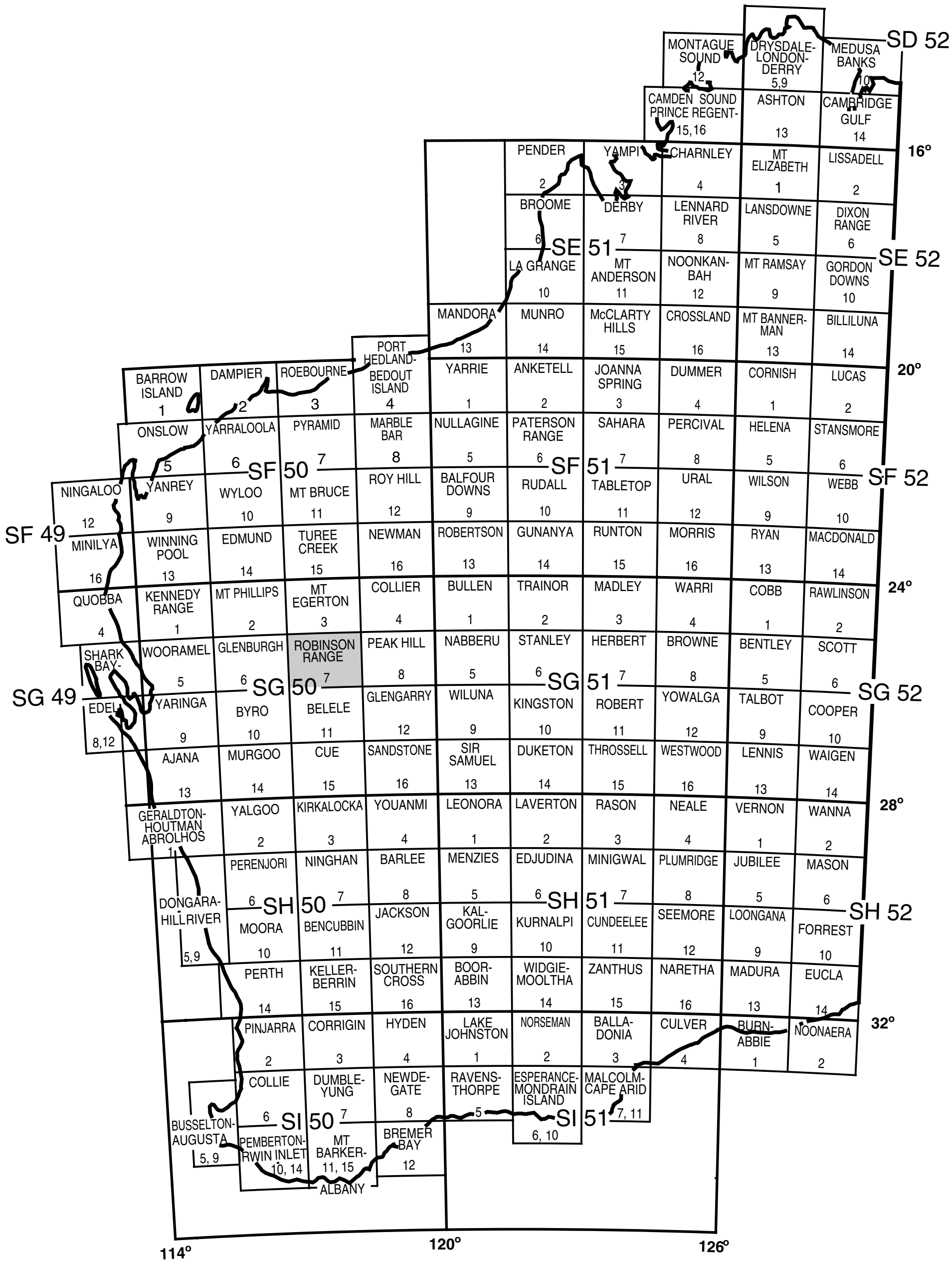
GEOLOGY OF THE MOORARIE 1:100 000 SHEET

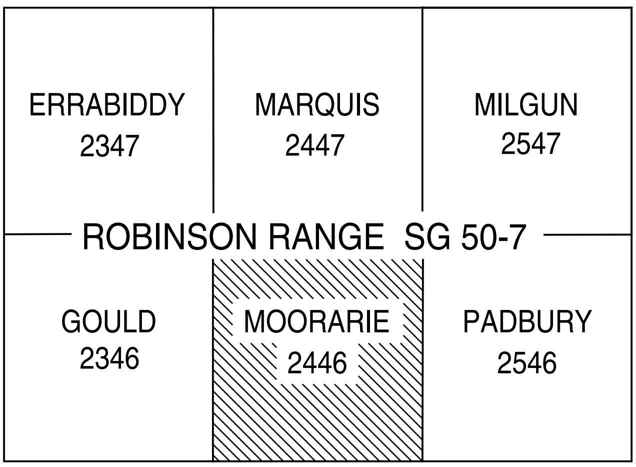
by S. A. Occhipinti and J. S. Myers

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY





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OF THE MOORARIE
1:100 000 SHEET

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S. A. Occhipinti and J. S. Myers

Perth 1999

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Cover photograph:
Massive, even-textured, medium-grained monzogranite (Kerba Granite) of the Moorarie Supersuite, 3 km southeast of Tommy Bore (AMG 819747) in the northern part of the MOORARIE 1:100 000 map sheet.

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by

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Abstract

The MOORARIE 1:100 000 map sheet covers the boundary between the northern edge of the Archaean Yilgarn Craton and the southern part of the Palaeoproterozoic Capricorn Orogen.

In this area, the Yilgarn Craton comprises parts of the Narryer granite–gneiss and Murchison granite–greenstone terranes, which were juxtaposed during the late Archaean. On MOORARIE these terranes are separated by a northerly trending fault. The Narryer Terrane is mainly composed of granitic gneiss, with both early and late Archaean protolith ages. Layers of supracrustal rocks are tectonically interleaved with this granitic gneiss, and both were deformed together before the intrusion of late Archaean granite. The Murchison Terrane comprises middle to late Archaean granite, greenstones, and granitic gneiss.

The northeastern part of the Narryer Terrane, north of the Seabrook Fault, was deformed in a ductile regime, metamorphosed at high grade, and intruded by voluminous granitic magmas at c. 1800 Ma during the Capricorn Orogeny. This reworked portion of the Narryer Terrane is termed the Yarlarweelor gneiss complex. The southern part of the Yarlarweelor gneiss complex is in faulted contact with the Bryah and Padbury Groups, and the southern part of the Narryer Terrane, in which Palaeoproterozoic deformation is minor and commonly restricted to faults and shear zones. The Bryah and Padbury Groups mainly comprise mafic and ultramafic igneous rocks and sedimentary rocks respectively, all metamorphosed to greenschist facies. On MOORARIE all the exposed contacts between these groups are faults.

The currently mined talc deposit at Mount Seabrook formed during low-grade metasomatism in structures parallel to the regional Palaeoproterozoic faults.

KEYWORDS: Archaean, Yilgarn Craton, Narryer Terrane, Murchison Terrane, Yarlarweelor gneiss complex, Capricorn Orogeny, Bryah Group, Padbury Group, deformation, regional geology.

Introduction

Location, access, and previous work

The MOORARIE* 1:100 000 map sheet (SG 50-7, 2446) occupies the south-central part of the ROBINSON RANGE 1:250 000 map sheet, and is bounded by latitudes 26°00' and 25°30'S and longitudes 117°30' and 118°00'E (Fig. 1).

The geology of MOORARIE was previously described by Elias and Williams (1980). The general geology of the region was also discussed by Maitland (1898), Montgomery (1910), Johnson (1950), Elias and Williams (1980), and Myers (1989).

The Mount Seabrook talc mine is the only operating mine on MOORARIE. Beef-cattle grazing on the Mount Gould, Yarlarweelor, and Moorarie pastoral leases is the only other commercial venture. The Moorarie Homestead is in the southern part of the sheet, the Yarlarweelor Homestead in the northeast, and the Trillbar Homestead (on the Mount Gould pastoral lease) in the central northern part.

The nearest town to MOORARIE is Meekatharra, located 125 km to the south-southeast. Two unsealed, but well-maintained, roads provide access to the area — the Mount Clere – Meekatharra and Carnarvon–Meekatharra roads — which connect with the Great Northern Highway north of and at Meekatharra respectively. Station tracks provide

* Capitalized names refer to standard 1:100 000 map sheets, unless otherwise indicated.

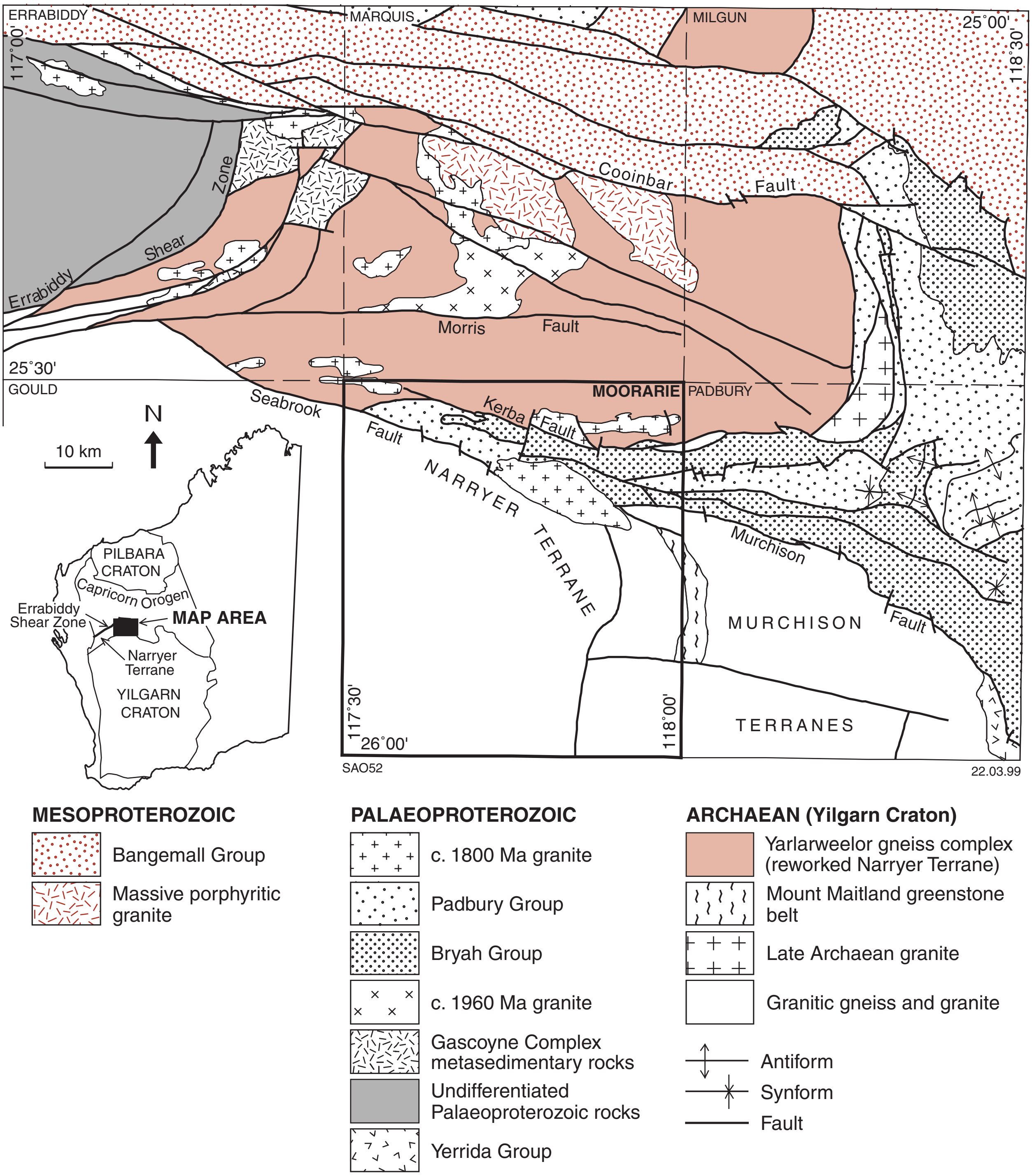

Figure 1. Simplified regional geological map showing the location of MOORARIE

some reasonable access away from the main roads, but access is very poor over rough terrane in the northernmost part of the map sheet.

Mapping of MOORARIE was carried out during 1996, and concentrated on the Archaean rocks of the Yilgarn Craton and Palaeoproterozoic sedimentary and igneous rocks. Remapping of MOORARIE and MARQUIS (which adjoins to the north; Sheppard and Swager, 1999) was a continuation of mapping completed in the Bryah and Padbury Basins (to the east) in 1995 (Occhipinti et al., 1998a). This work provides a geological traverse from the granitic gneiss, granite, and greenstones of the Archaean Yilgarn Craton, through Palaeoproterozoic and Mesoproterozoic igneous rocks intruding the Yilgarn Craton, across Palaeoproterozoic supracrustal rocks of the Bryah and Padbury Basins, into the Mesoproterozoic Bangemall Basin (Fig. 1).

Climate and vegetation

MOORARIE has an arid climate, with a mean annual rainfall between 190 and 240 mm. Cyclones and thunderstorms occurring between November and April provide summer rainfall. During winter, rain results from strong cold fronts from the southwest that are either associated with low pressure cells or interacting with tropical cloud bands originating from the north-northwest (Curry et al., 1994).

Vegetation in the area is diverse, and depends on the condition of the pastoral land, proximity to drainage systems, and, in some cases, rock type. Perennials such as flannel bush (*Solanum lasiphyllum*), turpentine bush (*Eremophila macmillaniana*), red grevillea (*Grevillea deflexa*), ghost gums, river red gums, and mulga (*Acacia aneura*) are locally abundant along drainage systems. Gidgee (*Acacia pruinocarpa*), miniritchie (*Acacia grasbyi*), and various other types of acacia are also abundant in the area (Mitchell and Wilcox, 1988).

Physiography

Physiographic units recognized on MOORARIE include the main drainages surrounded by low-gradient sheetwash plains, and high-gradient slope deposits adjacent to areas of actively eroding outcrop. The divide between the Murchison and Gascoyne river drainages is just north of MOORARIE, on MARQUIS. For the most part, the landscape on MOORARIE consists of low-gradient sheetwash plains that drain towards the Murchison and Yalgar rivers, which meet 2 km southwest of Moorarie Homestead in the southwestern part of the sheet (Fig. 2). The central divide, in the northern part of the map sheet, consists of rugged outcrops of Archaean granitic gneiss and granite–greenstones, and Palaeoproterozoic metamorphosed sedimentary and mafic igneous rocks, dissected by incised dendritic creeks. Extensive colluvial deposits surround these outcrops. Palaeoproterozoic iron formations in the north form the most prominent hills on MOORARIE.

Geological setting

MOORARIE lies within the northwestern part of the Yilgarn Craton (Figs 1 and 3), which is subdivided into the Murchison and Narryer Terranes. The Murchison Terrane (Myers, 1993) mainly consists of low-grade granites and greenstones that formed between c. 3000 and 2650 Ma. In contrast, the Narryer Terrane contains extensive granitic gneisses that include remnants of c. 3730–3300 Ma granite interleaved with late Archaean supracrustal rocks. The Murchison and Narryer Terranes represent parts of two different rafts of continental crust that were amalgamated at c. 2650 Ma (Myers, 1993, 1995). The Narryer Terrane was intensely deformed and metamorphosed to high grade during this collisional event. The northern part of the Narryer Terrane was further deformed and metamorphosed, and extensively intruded by sheets of Palaeoproterozoic granite, during the Palaeoproterozoic Capricorn Orogeny.

The Capricorn Orogen resulted from the collision and amalgamation of the Archaean Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990, 1994; Myers, 1993). Prior to the collision, Palaeoproterozoic shelf deposits were laid down on the rifted continental margin of the Yilgarn Craton. These shelf deposits include sedimentary and mafic rocks of the Yerrida Group, east of MOORARIE (Pirajno et al., 1998), that are in faulted contact with mafic and sedimentary rocks of the Palaeoproterozoic Bryah and Padbury Groups. The Bryah and Padbury Groups were deformed into a fold-and-thrust belt during the Capricorn Orogeny.

To the northwest, the Gascoyne Complex forms the core of the Capricorn Orogen (Williams, 1986). Medium- to high-grade metasedimentary and metavolcanic rocks are tectonically interleaved with granitic gneisses and extensively intruded by granitic plutons (Williams, 1986; Myers, 1990a). The Narryer Terrane, Gascoyne Complex, and the Bryah and Padbury Basins are unconformably overlain by the Mesoproterozoic Bangemall Basin.

Archaean geology

Yilgarn Craton

Archaean rocks of the Yilgarn Craton outcrop in the northern, southern, and western parts of MOORARIE (Figs 1 and 3), and are subdivided into the Murchison and Narryer Terranes. The Narryer Terrane forms the northwestern part of the Yilgarn Craton, and represents one of the largest known fragments of early Archaean (>3.3 Ga) crust on Earth. The terrane comprises several groups of gneiss, derived from early to late Archaean granites, interleaved with metasedimentary rocks and mafic and ultramafic igneous rocks. All of these rocks were repeatedly deformed and metamorphosed, and extensively intruded by granites, in the late Archaean (Myers, 1990b). The northeastern part of the Narryer Terrane, north of the Seabrook Fault, was pervasively deformed in a ductile regime and intruded by granite during the Palaeoproterozoic. This portion of the Narryer Terrane is here termed the Yarlarweelor gneiss complex (Figs 1 and 3).

The Yarlarweelor gneiss complex is bounded by the Seabrook Fault to the south and the Errabiddy Shear Zone to the west (Fig. 1). The Seabrook Fault also separates the Narryer Terrane from the Palaeoproterozoic Padbury and Bryah Basins. In contrast, within the granitic gneisses of the Narryer Terrane, the Seabrook Fault is less well defined, either because it was a more ductile, broad shear zone or because it may have been stitched by Palaeoproterozoic granite sheets. These sheets extensively intruded the Archaean gneisses north of the Seabrook Fault. Palaeoproterozoic magmatism is absent south of this fault.

The name 'Yarlarweelor gneiss belt' was introduced by Elias and Williams (1980) to describe all the

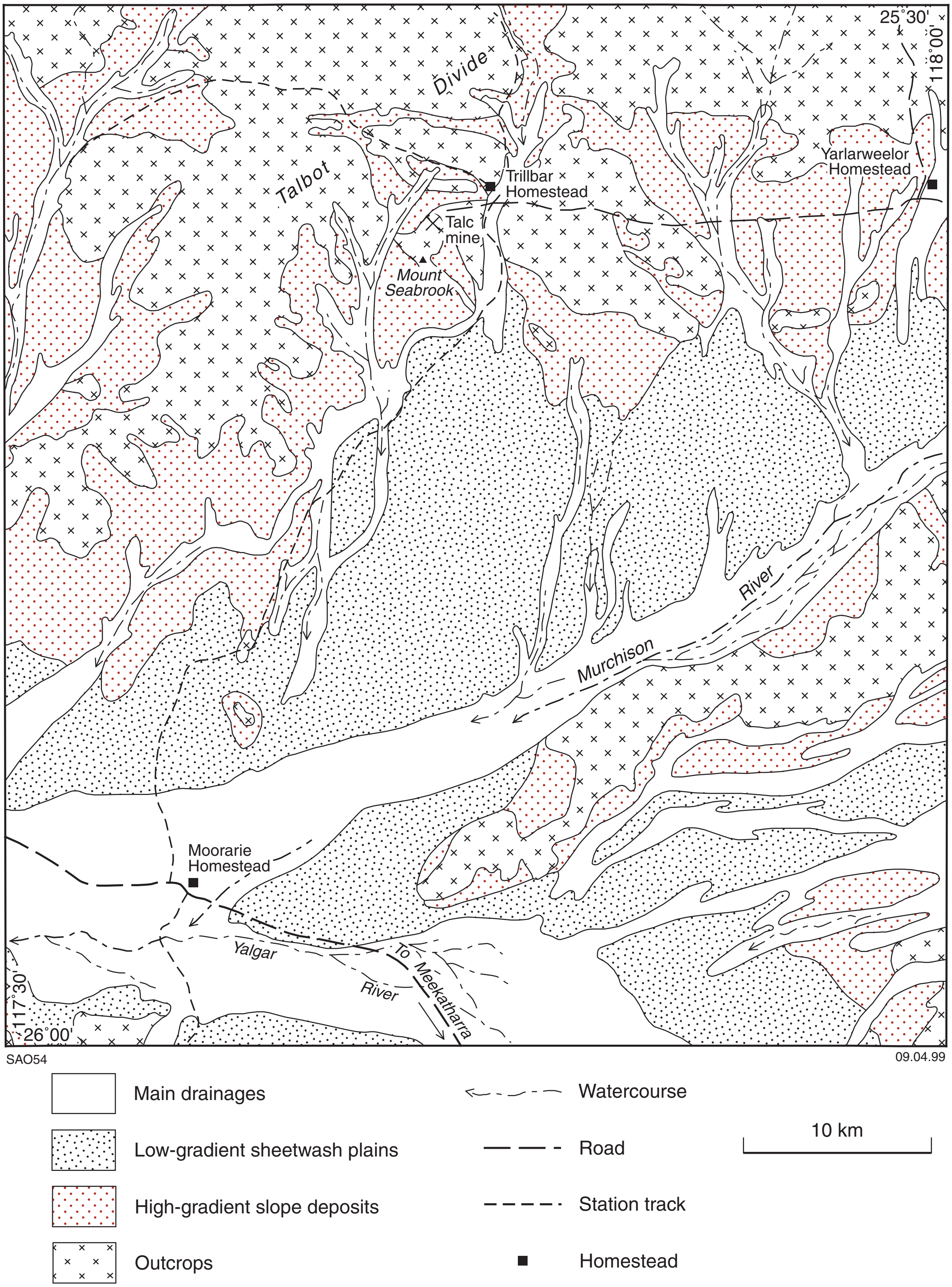

Figure 2. Physiography of MOORARIE

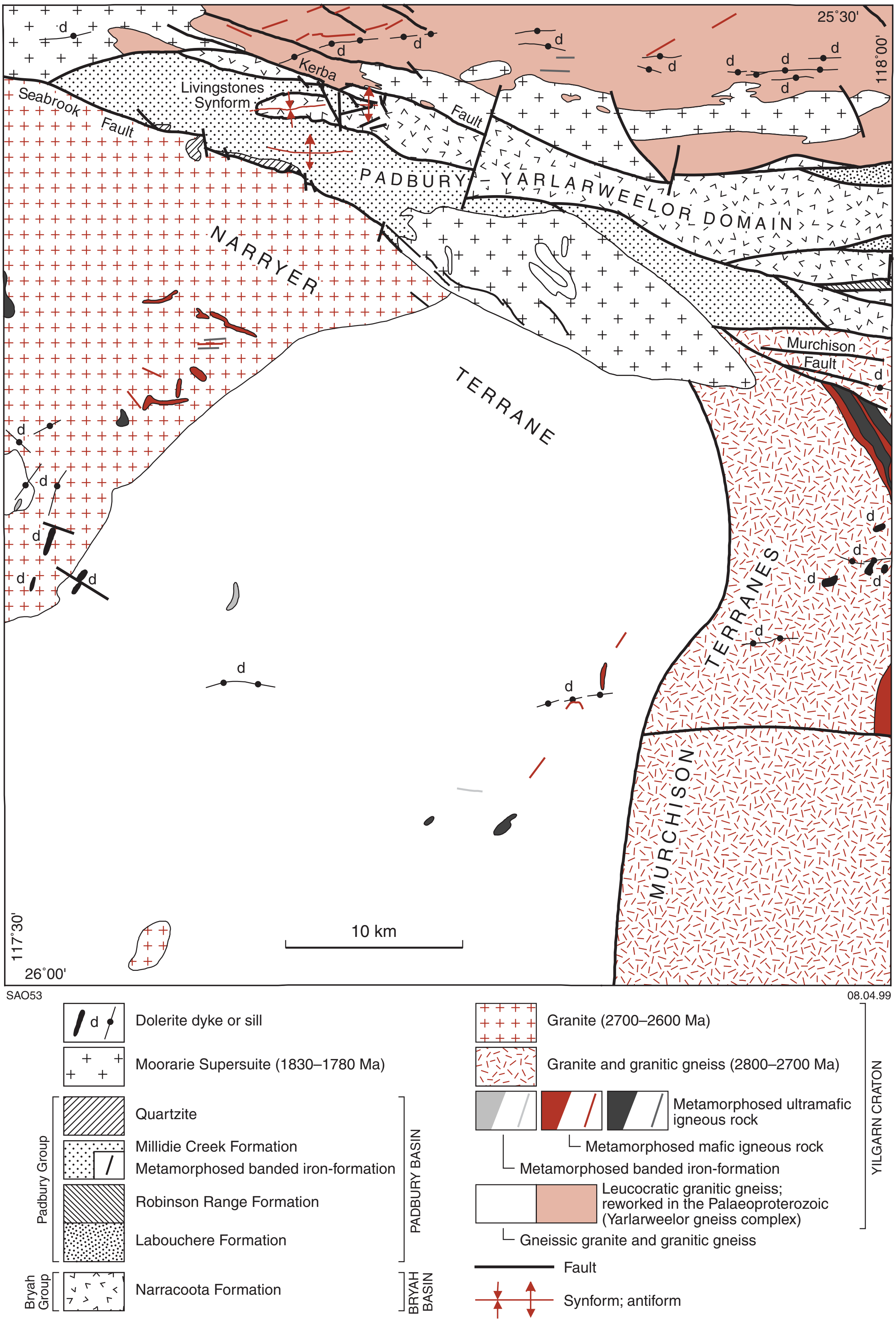

Figure 3. Simplified solid geological map of MOORARIE

gneisses that lie between the Errabiddy Fault and the Bullbadger Fault (southwest of MOORARIE on GOULD). This original definition is modified here to include only that area of the Narryer Terrane that has been extensively deformed, metamorphosed, and intruded by granite during the Palaeoproterozoic, and does not include any of the little-deformed or undeformed late Archaean granite plutons south of the Seabrook Fault. In addition, the name Yarlarweelor gneiss complex is preferred over 'Yarlarweelor gneiss belt'.

North and northwest of the Narryer Terrane, the Gascoyne Complex has been interpreted as consisting of Archaean granitic gneisses and Palaeoproterozoic metasedimentary and meta-igneous rocks that were all deformed, metamorphosed to medium or high grade, and intruded by granite during the Palaeoproterozoic Capricorn Orogeny (Williams, 1986; Myers, 1990a). The Gascoyne Complex is separated from the Narryer Terrane by the Errabiddy Shear Zone, and considered to be allochthonous to the Narryer Terrane (Myers, 1990a). The Yarlarweelor gneiss complex is in faulted contact with the Archaean Murchison Terrane and the Palaeoproterozoic Padbury and Bryah Basins (Occhipinti et al., 1996).

In the Yarlarweelor gneiss complex the granitic gneisses are mostly monzogranitic in composition, but can be broadly subdivided into leucocratic granitic gneiss and mesocratic biotite-rich granitic gneiss. They contain numerous thin layers of metamorphosed supracrustal rocks, and locally contain abundant xenoliths of metamorphosed gabbro, pyroxenite, and peridotite or dunite. Nelson (1998, 1999) reported sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon ages of 3292 ± 4 Ma and 2656 ± 4 Ma for protoliths to a leucocratic granitic gneiss northeast of Four Corners Well on MOORARIE (AMG 649774)*, and protolith ages of c. 3350 and c. 2650 Ma for a mesocratic biotite-rich granitic gneiss to the north on MARQUIS (Sheppard and Swager, 1999). These rocks were repeatedly deformed and metamorphosed to high grade during both the late Archaean and Palaeoproterozoic.

Granitoid rocks of the Narryer Terrane in the western part of MOORARIE form large intrusive bodies. They are monzogranitic in composition, and can be subdivided into a commonly massive, undeformed porphyritic granite and a massive to foliated granite. The ages of these granites are unknown, but inferred to be late Archaean from new SHRIMP U–Pb zircon dating of similar rocks to the west on GOULD (Nelson, 1999).

Archaean rocks south of the Murchison River, in the eastern part of MOORARIE, form part of the Murchison Terrane and comprise low-grade granite–greenstones, which are in tectonic contact with the high-grade gneiss of the Narryer Terrane (Figs 1 and 3). The granite–greenstones are also bounded by Palaeoproterozoic faults — by a east-southeasterly trending fault to the north, and by the Yalgar Fault, an easterly trending, steep, dextral transcurrent fault along the Yalgar River, south of MOORARIE.

Granitic gneiss (*Angl, Ængl*)

Archaean leucocratic gneissic granite and granitic gneiss (*Angl*) is widespread throughout the Narryer Terrane in the northern and southeastern parts of MOORARIE. In the northern part of MOORARIE, the leucocratic granitic gneiss is a component of the Yarlarweelor gneiss complex (*Ængl*). This unit contains both Archaean and Palaeoproterozoic granitoid rocks and forms a composite Archaean–Palaeoproterozoic rock unit. The granitic gneiss and gneissic granite contain tectonic fabrics that parallel the discontinuous lenses of supracrustal rocks.

Heterogeneously deformed gneissic granite and granitic gneiss (*Angl*) form low outcrops in the central western part of MOORARIE. These gneissic rocks consist of quartz, plagioclase, microcline, and biotite, and are locally intruded by coarse-grained biotite granite and porphyritic granite (*Agrb*). The leucocratic granitic gneiss (*Ængl*) mainly consists of strongly deformed monzogranite, and is intruded by Palaeoproterozoic coarse-grained granite and pegmatite sheets and veins in the northern part of MOORARIE (see **Moorarie Supersuite**). These younger granite sheets are indistinguishable on the map scale because they range in thickness from one metre to hundreds of metres. They are included with the leucocratic granitic gneiss unit because their boundaries with the gneiss are often diffuse. On MOORARIE the leucocratic granitic gneiss is the major component of this unit and consists of quartz, plagioclase, microcline, and biotite, with accessory zircon and apatite. Locally, the feldspar and plagioclase are retrogessed to sericite.

The Palaeoproterozoic coarse-grained granite and pegmatite sheets within the leucocratic granitic gneiss unit typically trend parallel to the main tectonic fabric, but locally cross-cut it at a low angle. Veins of the same rock cross-cut the leucocratic granitic gneiss, and locally the layer-parallel granite sheets and veins, at a high angle. The main tectonic fabric in the gneiss developed during late Archaean deformation, but was modified and rotated into parallelism with the Palaeoproterozoic structures during later deformation. Peak metamorphic conditions reached upper amphibolite facies during and after the Archaean deformation, resulting in the development of granoblastic textures.

Elsewhere in the Narryer Terrane, granulite facies assemblages are prevalent, and contained within the same late Archaean tectonic fabrics (Muhling, 1990).

* 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. AMG coordinates for localities mentioned in the text are listed in the Appendix.

Mafic and ultramafic rocks

On MOORARIE mafic and ultramafic rocks are present in both the Narryer and Murchison Terranes. In the Narryer Terrane, mafic and ultramafic rocks form xenoliths in granite in the central western part of the map sheet and tectonic slices within granitic gneiss of the Yarlarweelor gneiss complex in the northern part of the map sheet. On the eastern edge of MOORARIE, mafic and ultramafic rocks outcrop in the Mount Maitland greenstone belt (Fig. 1) of the Murchison Terrane. The belt consists of a 3 km-thick succession of metamorphosed ultramafic, mafic, and felsic volcanic rocks and interleaved sedimentary rocks, all metamorphosed to upper greenschist facies. These rocks include heterogeneously deformed and metamorphosed basalt, gabbro, pyroxenite, peridotite, and dunite, and may be part of the Luke Creek Group recognized by Watkins and Hickman (1990). Layered mafic–ultramafic igneous rocks are present in the Narryer Terrane in the central western and central southern parts of MOORARIE.

Ultramafic rocks (Au, Aul, Aup, Aur, Auz)

Metamorphosed ultramafic rocks (*Au, Aup, Aur*) are present as abundant inclusions in the granitic gneiss and granite (*Angl, Ængl*). Most of the ultramafic rocks outcrop as narrow, discontinuous belts of inclusions in the granitic gneisses, between Midnight Bore and Tommy Bore in the north and Bogieman Bore and Biddy Well in the southeast. The ultramafic rocks have a wide range in composition, but can be broadly subdivided into two main types: metadunite or metaperidotite, and metapyroxenite. The metadunite or metaperidotite unit (*Aup*) includes serpentinite, which consists of serpentine, magnetite, talc, sphene, and calcite or olivine–plagioclase–serpentine–talc–tremolite–magnetite gneiss, with accessory sphene. The tremolite schist (*Aur*) is interpreted as a meta-pyroxenite and commonly consists of tremolite–clinopyroxene–serpentine–calcite–sphene gneiss or tremolite–actinolite–talc schist. Silicified ultramafic rock (*Auz*), after metaperidotite or serpentinite, forms small isolated pods that outcrop in the western part of MOORARIE. In the central western and southeastern parts, 1–5 m-wide layers of pyroxenite and gabbro form a layered mafic–ultramafic succession (*Aul*).

Mafic rocks (Abs, Abao, Aban, Abd, Abu)

In the northern part of MOORARIE, mafic schist (*Abs*) and amphibolite gneiss (*Aban*) are widespread throughout the Yarlarweelor gneiss belt. They form layers ranging in thickness from a few metres to a few hundred metres within the granitic gneiss. The amphibolite gneiss (*Aban*) is either a coarse-grained granoblastic rock consisting of hornblende, clinopyroxene, tremolite, and plagioclase or a schistose rock consisting of hornblende, tremolite, and plagioclase. The mafic schist (*Abs*) typically consists of actinolite, feldspar, epidote, sphene, and quartz. The lack of clinopyroxene and hornblende and the schistose nature of the mafic schists suggest possible retrogression of the amphibolite gneiss (*Aban*) related to the development of the schistose rocks in high-strain zones. Some amphibolite and mafic schist bodies cross-cut layering within the granitic gneiss, indicating that they may have originated as mafic dykes, but they are also folded with the gneiss.

In the central western part of MOORARIE, amphibolite representing metamorphosed gabbro, microgabbro, and basalt (*Abao*), and mafic schist (*Abs*) outcrop within foliated granite (*Age*). Layering can be seen within this unit throughout the area. In places, where individual layers are too thin to show on the map, units of layered metamorphosed gabbro and pyroxenite are mapped as metamorphosed pyroxenite and gabbro (*Aul*). Thinner layers of interleaved metagabbro, metapyroxenite, and serpentinite (*Abu*) are up to 20 m thick.

On MOORARIE the only rocks of the Mount Maitland greenstone belt that are exposed are tremolite schist (*Aur*), basalt and dolerite (*Abd*), and banded iron-formation. The tremolite schist probably developed after ultramafic rocks and is dominated by tremolite, with additional chlorite, epidote, zoisite, feldspar, and quartz. Basalt (*Abd*) has a partly preserved subophitic texture, and commonly consists of tremolite–actinolite, quartz, epidote, and sphene. Doleritic lenses (*Abd*) within the basalt may represent the central parts of thick lava flows and low-strain zones, rather than intrusive rocks. The dolerite shows abundant ‘spotted’ textures where amphibole replaces pyroxene phenocrysts.

Banded iron-formation (*Aci*)

Metamorphosed banded iron-formation (*Aci*) forms a minor component of the supracrustal rocks within the Narryer Terrane on MOORARIE, and is mainly composed of alternating thin (2–5 mm-wide) bands of silica and iron oxides (magnetite and hematite). In the southeastern part of MOORARIE, between Jelimba Well and Hennessey Well, banded iron-formation consists of alternating bands of carbonate, ilmenite, and magnetite–hematite intergrowths. This isolated exposure of carbonate-bearing banded iron-formation is interbedded with the more abundant banded iron-formation containing silica and iron oxides.

In the eastern part of MOORARIE, banded iron-formation is associated with ferruginous chert outcrops within the Mount Maitland greenstone belt of the Murchison Terrane. These rocks locally show intra-folial folding, commonly bounded by bedding-parallel detachments, as well as a younger generation of small-scale folds.

Metasedimentary rocks (*Asl, Asq, Asqk, Asql*)

Metasedimentary rocks are widespread in the Narryer Terrane as thin layers within the granitic gneisses. The layers range in thickness from several centimetres to several metres, and include quartzite and calc-silicate gneiss. These layers are only marked on the map where they are tens of metres thick; elsewhere they are included in the granitic gneiss. Locally, these metasedimentary rocks are associated with banded iron-formation. SHRIMP U–Pb ages of detrital zircons in quartzites from a number of localities throughout the Narryer Terrane range from c. 4300 Ma (the oldest known traces of terrestrial rocks) to c. 3100 Ma (Froude et al., 1983; Compston and Pidgeon, 1986; Kinny et al., 1988; Nutman et al., 1991). These quartzites and other spatially associated supracrustal rocks are therefore thought to be late Archaean deposits.

Quartzite (*Asq*) and calc-silicate gneiss (*Asl*) are most abundant in the northeastern corner of MOORARIE. The quartzite is dominantly a homogeneous quartz-rich rock; however, a small outcrop of quartz–kyanite schist (*Asqk*) is present in the western part of MOORARIE. Calc-silicate gneiss contains a range of assemblages including quartz, clinopyroxene, tremolite, feldspar, sericite, and accessory sphene and apatite. Tremolite and sericite formed during retrograde metamorphism from the breakdown of clinopyroxene and feldspar respectively. In places, 1 to 10 m-thick units of quartzite and calc-silicate (*Asql*) are interlayered.

Biotite monzogranite (*Agf*)

A low, northwesterly trending ridge south of the Murchison River, between Hennessey Well and Walebie Well, largely consists of late Archaean biotite monzogranite (*Agf*) of the Murchison Terrane. The granite ranges from massive to foliated, and is locally mylonitic. The foliation swings from northeasterly in the west to northerly in the east. The granite is commonly medium grained, but locally contains K-feldspar phenocrysts and minor biotite. In some places the feldspar and biotite are partly replaced by sericite.

Granite (*Age, Agrb*)

Heterogeneously deformed biotite monzogranite (*Age*) of the Narryer Terrane outcrops in the western part of MOORARIE. This granite outcrops as low hills and along small breakaways in a belt that extends south-southwesterly from Three Corners Bore into the Curran Bore area. The granite is poorly exposed and, for the most part, covered by a thin layer of colluvium and quartz vein rubble. Between Bedaburra Pool and Southern Cross Well, a massive, even-textured, fine- to medium-grained biotite monzogranite (*Age*) outcrops in a few places amongst quartz-vein rubble. This massive biotite monzogranite was previously thought to be Proterozoic in age (Elias et al., 1980), but to the west, on GOULD, a similar even-grained biotite granite has recently been dated by SHRIMP U–Pb in zircon as c. 2.7 Ga (Nelson, 1998).

The biotite monzogranite (*Age*) unit of the Narryer Terrane ranges from strongly foliated in the central western part of MOORARIE to massive and extensively fractured and intruded by quartz veins in the north-western part. Where strongly foliated, the unit locally developed into a quartz–sericite schist and, locally, quartz veins trend parallel to the foliation. In the northwestern part of the map sheet, quartz veins that cut a massive granite trend parallel to the foliation in the biotite granite further east. This suggests that the quartz veins fill fractures in the massive granite that developed synchronously with the foliation in the well-foliated biotite monzogranite to the east, but in a more brittle regime. Alternatively, they may have intruded fractures developed during a later phase of deformation.

The Rocky Bore Granite consists of medium-grained porphyritic biotite monzogranite with tabular K-feldspar phenocrysts that are up to 3 cm in length (*Agrb*). The unit outcrops north and south of Fort William Well, and around and 4 km southeast of Buddarri Well. This granite locally intruded gneissic granite (*Angl*).

Archaean structure

The combined geological history of MOORARIE and MARQUIS (to the north) is summarized in Table 1. The Murchison and Narryer Terranes shared a common late Archaean history of deformation and metamorphism. On MOORARIE the Murchison Terrane and the southern part of the Narryer Terrane (Figs 1 and 3) were only locally deformed during the Palaeoproterozoic Capricorn Orogeny in fault and mylonite zones, whereas the northeastern part of the Narryer Terrane was extensively reworked to form the Yarlarweelor gneiss complex.

Williams and Myers (1987) reported three periods of Archaean deformation in the Narryer Terrane. These deformations can be recognized in the Narryer Terrane in the southeastern part of MOORARIE. The D_1 deformational event produced a well-developed S_1 gneissosity, which is folded about F_2 subhorizontal folds and refolded about north-northeasterly trending F_3 upright folds (Fig. 4). A faulted contact between the Murchison and Narryer Terranes in the southwestern part of the map sheet is northerly trending, subparallel to the single pervasive foliation within the granite of the Murchison Terrane.

In the Yarlarweelor gneiss complex, late Archaean structures were pervasively rotated into the Palaeo-proterozoic structure. The Archaean folds are best preserved in the granitic gneisses (*Angl* and *Ængl*), and are most easily seen in Palaeoproterozoic fold hinges, particularly in areas of lowest Palaeoproterozoic strain. In these areas, 1–2 m-wide, tight to isoclinal subhorizontal folds (F_2) with shallow plunges deformed a well-developed S_1 gneissosity in the granitic gneiss. These folds trend either easterly or northeasterly on MOORARIE, parallel to the Palaeoproterozoic structural trend. Their original orientations probably were easterly trending. The axial surfaces of the F_2 folds are parallel to the dominant S_2 fabric in the granitic gneiss. In some tight Palaeoproterozoic fold hinges, 'arrowhead-shaped' fold interference structures (type 2 of Ramsay, 1967) are developed, with F_2 structures refolded about Palaeo-proterozoic F_{2n*} folds (see **Capricorn Orogeny**; Fig. 5).

* 'n' refers to Palaeoproterozoic Capricorn Orogeny deformation.

Table 1. Summary of the geological history of Marquis and Moorarie

Age (Ma)	*Geological event*
?	Intrusion of easterly trending dolerite dykes into the Yarlarweelor gneiss complex and the Bangemall Basin. Northerly trending kinks and open folds
?	Reactivation of east-southeasterly trending faults, and associated static low-grade metamorphism (M_4). 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 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 biotite monzogranite sheets 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
c. 2000	Deposition of volcanic and sedimentary rocks of the Bryah and Padbury Basins
2640–2610	Intrusion of biotite monzogranite plugs and plutons into the Narryer Terrane (Yilgarn Craton)
3000–2610	Murchison Terrane: formation of granite–greenstone terrane (Yilgarn Craton)
3400–2640	Narryer Terrane (Yilgarn Craton): Intrusion of granite protoliths into the leucocratic and mesocratic granitic gneisses. Deformation (D_2–D_3) and high-grade metamorphism; development of gneissic layering


SAO57 23.03.99

Figure 4. Well-developed S_1 gneissosity in Archaean quartzite gneiss folded about F_2 and refolded around F_3 folds, Narryer Terrane, about 5 km northeast of Walalaya Well (AMG 754348)

SAO58 23.03.99

Figure 5. Mushroom-shaped interference fold between F_2 and F_{2n} structures in granitic gneiss, Yarlarweelor gneiss complex, 100 m east of Midnight Bore (AMG 879775)

Palaeoproterozoic geology

Palaeoproterozoic rocks on MOORARIE include variably metamorphosed mafic and ultramafic igneous rocks, sedimentary rocks, and granitoid rocks. The granitoid rocks are of two main types: metamorphosed and heterogeneously deformed coarse-grained, even-textured, and locally porphyritic biotite monzogranite and pegmatite; and fine- to medium-grained, even-textured biotite monzogranite. The mafic and ultramafic igneous rocks and sedimentary rocks make up the Bryah and Padbury Groups. The Bryah Group consists of mafic and ultramafic igneous rocks, clastic sedimentary rocks, and banded iron-formation deposited in a rift-basin setting (Bryah Basin). The Padbury Group consists of clastic sedimentary and chemical sedimentary rocks deposited on top of the Bryah Group in a foreland basin setting (Padbury Basin; Martin, 1994, 1999). On MOORARIE the Bryah Group is in tectonic contact with the Narryer Terrane and Padbury Group (Figs 1 and 3). The Bryah and Padbury Groups were deformed and metamorphosed during the Palaeoproterozoic Capricorn Orogeny, and are unconformably overlain by the Mesoproterozoic Bangemall Group.

Bryah Group

The Bryah Group comprises deformed and metamorphosed mafic and ultramafic igneous rocks and chemical and siliciclastic sedimentary rocks. These rocks comprise four formations (Pirajno et al., 1996), one of which, the Narracoota Formation, is present on MOORARIE.

The age of the Bryah Group is unclear. A SHRIMP U–Pb age on detrital zircon provided a maximum age for the Ravelstone Formation on BRYAH of 2014 ± 22 Ma (Nelson, 1996). Windh (1992) obtained a Pb–Pb isochron age of 1920 ± 35 Ma on inferred syngenetic pyrite from the Narracoota Formation, which may represent a minimum age for deposition. This age and Pb–Pb ages of 1.7 Ga from galena from the Mikhaburra mine on BRYAH (Narracoota Formation; Pirajno and Occhipinti, 1998) may represent the ages of mineralizing events in the Bryah Group.

Narracoota Formation (*PAn*)

The Narracoota Formation (*PAn*) consists largely of metabasaltic rocks, which occupy most of the southern half of BRYAH (Pirajno and Occhipinti, 1998) and extend westward onto PADBURY and MOORARIE, where it is in tectonic contact with the Millidie Formation of the Padbury Group. Hynes and Gee (1986) and Pirajno et al. (1998) discussed the nature of the metabasaltic rocks in detail.

According to Hynes and Gee (1986), the mafic rocks of the Narracoota Formation have fairly uniform chemistry and are of mid-ocean ridge basalt affinity, although the original mafic materials may have been emplaced through rifted continental crust.

Hynes and Gee (1986) also noted the presence of ultramafic members (high-Mg basalt or komatiite).

Pirajno and Occhipinti (1998) suggested that the Narracoota Formation could be subdivided into two main metabasite lithotypes based on field observations, geochemistry, and petrology. These lithotypes are mafic and ultramafic schists, and metabasaltic hyaloclastite. The mafic and ultramafic schists commonly contain a pervasive schistosity, although metadolerite dykes and sills, metabasaltic breccia, and minor metapyroxenite lenses that are present within these mafic schists on PADBURY and BRYAH are largely undeformed. The metabasaltic hyaloclastite forms extensive outcrops in the southern part of BRYAH, and typically contains a volcanic breccia texture.

On MOORARIE the Narracoota Formation (*ꝐAn*) consists of metamorphosed basalt, mafic and ultramafic schist, gabbro, and microgabbro. Mafic and ultramafic rocks in the Trillbar Homestead area were previously interpreted as an Archaean greenstone belt (Elias and Williams, 1980) or an exotic obducted sheet of metagabbroic and ultramafic rocks (Trillbar complex of Myers, 1989). These rocks are here considered to be part of the package of mafic and ultramafic igneous rocks that form the Narracoota Formation because they are petrologically similar to, and outcrop along strike from, outcrops of the Narracoota Formation on PADBURY. West of Trillbar Homestead, they consist of layered mafic and ultramafic igneous rocks. The layered igneous rocks are of two main types: rhythmically layered gabbro (melanocratic and leucocratic), pyroxenite, and peridotite (with individual layers up to 2 m thick) that outcrop 5 km west of Trillbar Homestead; and a zone of more thickly layered gabbro, dunite, and pyroxenite (with individual layers up to 100 m thick) that outcrops 4 km east of Four Corners Well.

Where individual layers are very thin (i.e. in rhythmically layered sections), the separate igneous rock types have been grouped together and mapped as 'layered igneous rocks'.

Pirajno et al. (1998) reported that the Narracoota Formation gradually becomes more ultramafic from east to west, and attributed this to increased rifting in the same direction. This and the presence of layered mafic–ultramafic igneous rocks that differentiated in a magma chamber suggest that the depth of exposure of the Narracoota Formation increases from east to west, and that the deepest part of this formation observed in outcrop is therefore on MOORARIE.

Mafic rocks (ꝐAnb, ꝐAno)

Metabasalt (*ꝐAnb*) is present west of Trillbar Homestead and at Red Hill. West of Trillbar Homestead, the metabasalt forms low outcrops, and larger outcrops form prominent hills between Thompson Bore and Four Corners Well. In this area the metabasalt is blocky in appearance, and locally contains fragmental textures and amygdales now filled with chlorite. Cross-cutting veins of fine-grained epidote are present throughout this massive unit. The metabasalt dominantly consists of fine-grained actinolite, carbonate or epidote, feldspar, and chlorite, with accessory sphene and opaque minerals. The autobrecciated metabasalt largely consists of small (less than 1 cm across), angular clasts of a fine-grained rock composed of actinolite, sphene, feldspar, quartz, and opaque minerals in a matrix of fine-grained epidote, sphene, and quartz.

At Red Hill metamorphosed basalt is fine grained, with amygdaloidal and autobrecciated textures. These rocks were previously mapped as Mesoproterozoic dolerite sills (Elias et al., 1980), but their proximity to outcrops of the Narracoota Formation on PADBURY and evidence for a volcanic origin suggest that they are volcanic rocks of the Narracoota Formation. They consist dominantly of tremolite, with epidote, feldspar, minor quartz, and chlorite, and accessory rutile. Local small pods of microgabbro at Red Hill, with the same mineralogy as the basalts, may represent either the thicker parts of flows or sills intruded into the lavas.

Metamorphosed gabbro, microgabbro, leucogabbro, and melanogabbro (*ꝐAno*) outcrop between Trillbar Homestead and Friday Pool. Although these rocks have been metamorphosed, faulted, and folded, they are largely undeformed internally. Locally, tremolite–actinolite schist is developed in higher strain zones marginal to the massive metagabbroic outcrops. About 4 km northwest of Thompson Bore, a tightly folded metagabbro is locally sheared and metamorphosed to actinolite–tremolite schist in high-strain zones parallel to the axial surface of the Livingstone Synform. Metamorphosed gabbro and microgabbro contain igneous clinopyroxene (augite) and plagioclase that have been pervasively replaced by tremolite–actinolite and sericite respectively. Leucogabbro, which outcrops about 2 km northeast of Thompson Bore and 5 km northwest of Trillbar Homestead, locally contains a relict igneous composition of plagioclase and pyroxene.

Ultramafic rocks (ꝐAnu, ꝐAnx, ꝐAns)

Ultramafic schist (*ꝐAnu*) is present within the most intensely deformed parts of the Narracoota Formation. The diverse mineralogy of the schist reflects the probable protolith, but the schist typically consists of fine-grained actinolite–tremolite, talc, chlorite, and magnetite. The presence of ultramafic schist under chalcedony, about 2 km north of Winja Well, has been confirmed by extensive rotary air blast (RAB) drilling. West-northwest of Thompson Bore, silcrete is well developed over ultramafic schist at the faulted contact between the Narracoota Formation (Bryah Group) and Millidie Formation (Padbury Group).

Layers of metamorphosed pyroxenite and peridotite (*#Anx*) are exposed west of Trillbar Homestead. The original igneous petrology of these rocks is completely replaced by metamorphic mineral assemblages so that these rocks contain tremolite, talc, magnetite, and chlorite.

Massive serpentinite (*#Ans*), representing metamorphosed dunite, outcrops about 4 km east-southeast of Four Corners Well, where it is in contact with gabbro. The nature of this contact is unknown, but it may be igneous.

Layered mafic–ultramafic igneous rocks (ⱣAnl)

Rhythmically layered mafic–ultramafic igneous rocks (*ⱣAnl*) outcrop 5 km northwest of Trillbar Homestead, where the layering is oriented at a low angle to the foliation. These rocks include rhythmically layered gabbro, melanogabbro, leucogabbro, pyroxenite, and peridotite, which are all metamorphosed to greenschist facies. They consist of serpentinite–tremolite–talc, tremolite–talc–magnetite, tremolite–actinolite, or actinolite–feldspar rock. Original igneous textures are well preserved in some of the layers, for example, olivine–?pyroxene cumulate in metaperidotite is completely pseudomorphed and overprinted by tremolite and sphene.

The rhythmically layered mafic and ultramafic rocks have also been folded and faulted, and locally contain two well-developed foliations. Repetitions of rhythmically layered successions throughout this area could, therefore, be due to structural duplications and repeated magma injections.

Padbury Group

The Padbury Group comprises siliciclastic, carbonate, and chemical sedimentary rocks, and is divided into the Labouchere, Wilthorpe, Robinson Range, and Millidie Creek Formations (Occhipinti et al., 1996). The relationship of the Padbury Group to the Bryah Group is controversial. Windh (1992) and Martin (1994) suggested that the basal unit of the Padbury Group, the Labouchere Formation, unconformably overlies the Horseshoe Formation, which is the uppermost unit of the Bryah Group. This is based on regional mapping in the Fortnum – Dandys Well area on MILGUN, where an apparently low-angle truncation of an iron-formation marker unit in the Horseshoe Formation is observed against the quartz wacke of the Labouchere Formation. Elsewhere, contacts between the Bryah and Padbury Groups have variously been described as unconformities (Gee, 1979, 1987; Windh, 1992), or faults and shears (Pirajno and Occhipinti, 1998; Occhipinti et al., 1996).

The age of the Padbury Group is poorly constrained. The Padbury Group is younger than the underlying Bryah Group, which has a maximum depositional age of 2014 ± 22 Ma (Nelson, 1997), and older than the overlying Bangemall Group, which has a maximum age of 1.65 Ga (Nelson, 1995). SHRIMP U–Pb ages from detrital zircons in the Wilthorpe Formation of the Padbury Group provide a maximum depositional age of 1996 ± 35 Ma (Nelson, 1997).

Units mapped as sedimentary rocks of the Padbury Group on MOORARIE were previously correlated with the Morrissey Metamorphics, which outcrop to the northwest (Elias and Williams, 1980; Williams, 1986), as they were thought to be medium- to high-grade metamorphic rocks. These rocks are only metamorphosed to greenschist facies, and sedimentary structures can be observed locally. They are now correlated with the Millidie Creek Formation of the Padbury Group because of lithological similarities between the sedimentary rocks on MOORARIE and those on PADBURY (Occhipinti et al., 1998a) and MILGUN (Swager and Myers, in prep.).

Millidie Creek Formation (*ⱣPm, ⱣPms, ⱣPmc, ⱣPmp, ⱣPmt, ⱣPmi*)

Quartz–chlorite–muscovite schist, with accessory tourmaline and hematite, and muscovite–quartz schist, with porphyroblasts of pyrite (*ⱣPm*), are common components of the Millidie Creek Formation on MOORARIE. They are associated with metaferruginous shale (phyllite; *ⱣPmp*) and minor metamorphosed banded iron-formation (*ⱣPmi*). Folded quartz-vein ridges mark contacts with the Narracoota Formation and are interpreted to be faults. About 3 km west-northwest of Thompson Well, a steeply plunging synform folds such a faulted contact between the Millidie Creek and Narracoota Formations.

Metamorphosed dolomitic sandstone and quartz–chlorite–carbonate schist (*ⱣPms*) with accessory tourmaline and iron oxides is interbedded with muscovite–quartz schist in the Livingstones Find area. South of this, dolomite, locally interbedded with chlorite–quartz phyllite, (*ⱣPmc*) was previously mapped as part of the Bangemall Group (Elias et al., 1980), and outcrops in discontinuous lenses west of Three Corners Bore. This unit is now considered to be part of the Padbury Group because it outcrops along strike from metadolomitic sandstone within the Mount Seabrook talc mine and has been deformed with the rest of the Padbury Group. West of this area, RAB drillholes through Cainozoic cover indicate the presence of talc schist *(ⱣPmt)*, possibly associated with dolomitic rocks. At the Mount Seabrook mine, metadolomitic sandstone has broken down to form talc schist in high-strain zones, suggesting that the talc developed due to hydrothermal alteration of dolomite (Monks, 1993).

Metamorphosed banded iron-formation *(ⱣPmi)* forms a minor component of the Millidie Creek Formation on MOORARIE. The unit consists of very fine bands (2–5 mm wide) of iron-rich and silica-rich layers, and is folded isoclinally. About 3 km southeast of Seabrook Well, the banded iron-formation is a xenolith in Proterozoic granite.

Unassigned units of the Padbury Group (*ⱣP(q)*)

One unit of the Padbury Group remains unassigned to any formation. This foliated quartzite and quartz–

sericite–biotite phyllite with minor quartz–fuchsite schist (*ⱣP(q)*) outcrops along and adjacent to a fault between 5 and 15 km northwest of Mount Seabrook mine. This unit has been assigned to the Padbury Group because of its spatial relationship to the Millidie Creek Formation in this area; however, it is possible that it constitutes a sedimentary unit separate from the Padbury and Bryah Basins.

Moorarie Supersuite (*ⱣgMp, ⱣgMw, ⱣgMkb, ⱣgMe*)

On Moorarie Palaeoproterozoic granites are of two main types: metamorphosed and heterogeneously deformed coarse-grained, even-textured, and locally porphyritic biotite monzogranite and pegmatite (foliated, coarse-grained granite, *ⱣgMp*); and fine- to medium-grained, even-textured, biotite monzogranite (the Kerba Granite, *ⱣgMkb*, and granitic dykes). Poorly exposed and typically deeply weathered biotite(–?muscovite) granite (*ⱣgMw*) that outcrops east of Mount Seabrook mine is both even grained and porphyritic; however, due to the poor outcrop the relationship between these two granitic types or phases is unknown. SHRIMP U–Pb age dating on zircon provides ages of 1813 ± 8 Ma and 1808 ± 6 Ma for the foliated coarse-grained and porphyritic granite (*ⱣgMp*) and the Kerba Granite (*ⱣgMkb*) respectively (Nelson, 1998). On Marquis a granite dyke (*ⱣgMe*) that cross-cuts the porphyritic granite (*ⱣgMp*) is dated as 1797 ± 4 Ma, (Nelson, 1998).

The Kerba Granite (*ⱣgMkb*) is a thick granite sheet that extends from about 4.5 km west of Kerba Bore to 6 km southeast of Top Minniarra Well. The granite consists of K-feldspar, plagioclase, quartz, and biotite, with accessory apatite, opaque minerals, and zircon. Fine-grained muscovite (sericite) partially replaces feldspar, plagioclase, and biotite grains. The Kerba Granite is mainly massive, and outcrops as tors and pavements. Locally, the granite is deformed, particularly close to the Kerba Fault and its contact with the Narracoota Formation, where the granite is well foliated to mylonitic. In the area east of Kerba Bore and south of Tommy Bore, the Kerba Granite contains abundant inclusions of Archaean granitic gneiss, but individual inclusions are too small to show on the map.

The foliated coarse-grained granite and pegmatite (*ⱣgMp*) forms abundant sheets and veins that intruded Archaean granitic gneiss. These rocks consist of K-feldspar, plagioclase, quartz, and biotite with accessory apatite and zircon. Retrograde sericite is locally crystallized around the feldspar or biotite grains. The granite sheets intruded the granitic gneiss at a low angle to the gneissic foliation, and range in thickness from one metre to several metres. Locally, the granite is folded with the gneiss. This unit appears to have been metamorphosed at medium to high grade as granoblastic textures are commonly well developed, with some grains displaying deep embayments and lobate texture. Locally, biotite monzogranite dykes (*ⱣgMe*) cut across the granitic gneiss and sheets of foliated, coarse-grained granite and pegmatite (*ⱣgMp*) at a high angle.

Capricorn Orogeny

The northeastern part of the Narryer Terrane was extensively reworked during the Palaeoproterozoic Capricorn Orogeny, which was a period of oblique collision between the Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990, 1994; Occhipinti et al., 1998b). This reworking formed the Yarlarweelor gneiss complex (see **Yilgarn Craton**). The overlying Palaeoproterozoic Bryah and Padbury Basins were also pervasively deformed during this period, and locally interleaved with the underlying Narryer Terrane. Granite was extensively intruded into the Yarlarweelor gneiss complex at 1820–1800 Ma (Occhipinti et al., 1998b). Sheets and veins intruded into the gneisses were pervasively deformed into D_{2n} tight to open folds (see **D_{2n} structures**), and metamorphosed to medium to high grades. These folds may have originally been northeasterly trending. East-southeasterly trending, dextral strike-slip D_{3n} movement (represented by large faults and quartz veins in the northern part of Moorarie) and north–south compression in the region included both early ductile and late brittle stages. This deformation produced fault-bend folds in the region in both the Yarlarweelor gneiss complex and the overlying Palaeoproterozoic supracrustal rocks.

The regional geology on Moorarie is divided into three structural domains. These are the Padbury–Yarlarweelor domain, Narryer Terrane, and Murchison Terrane (Fig. 1).

Contacts between the three domains are inferred to be faults. The Padbury–Yarlarweelor domain and Narryer Terrane are in faulted contact south of Mount Seabrook and Livingstones Find. This contact is not exposed northwest of Livingstones Find, but is inferred to be a fault. The contact between the Murchison and Narryer Terranes is also faulted. The northern part of the Murchison Terrane is separated from the Padbury–Yarlarweelor domain by the steep, easterly trending Murchison Fault.

A northerly trending terrane boundary between the Narryer and Murchison Terrane rocks in the south-eastern part of Moorarie is probably late Archaean in age. In this area the main structural fabric in the Murchison and Narryer Terrane rocks is subparallel to this boundary and interpreted to be an Archaean fabric. On Padbury the Mount Maitland greenstone belt within the Murchison Terrane swings from northerly trending to north-northwesterly trending in the northern part of the belt. This curvature is interpreted to have developed due to drag during sinistral strike-slip Palaeoproterozoic movement along the Murchison Fault (Occhipinti et al., 1998a).

The Padbury–Yarlarweelor domain contains the Archaean granitic gneisses and granitoid rocks of the Narryer Terrane and the Palaeoproterozoic Bryah and Padbury Groups and granite. In the northern part of Moorarie, the Yarlarweelor gneiss complex dominantly consists of granitic gneiss. The pervasive gneissic foliation within these rocks is Archaean in age;

however, these rocks were re-oriented and locally recrystallized during the Palaeoproterozoic. In the central western part of MOORARIE, the main fabric in foliated Archaean granite of the Narryer Terrane is either late Archaean or Palaeoproterozoic in age. Contacts between the Bryah and Padbury Groups and these Archaean rocks are faulted.

Padbury–Yarlarweelor domain

The structural, metamorphic, and magmatic evolution of the Padbury–Yarlarweelor domain is included in Table 1. A major fold structure in the Padbury–Yarlarweelor domain is the Livingstone Synform. This structure is interpreted to be an F_{2n} fold, as it folds both an older foliation (S_{1n}) and a faulted contact between the Narracoota Formation (of the Bryah Group) and Millidie Creek Formation (of the Padbury Group). Major faults within this domain trend west-northwesterly and include the Kerba and Seabrook Faults. The Kerba Fault separates the Narracoota Formation from the Narryer Terrane and Kerba Granite, and the Seabrook Fault separates Padbury Group sedimentary rocks from Archaean granite and gneiss.

At least one Palaeoproterozoic folding event (D_{2n}) is recorded in the Padbury–Yarlarweelor domain, where it folds a D_{1n} foliation and fault about the easterly trending Livingstone Synform (Fig. 3). East of MOORARIE, in the Bryah and Padbury Basins, three folding events have been observed (Occhipinti et al., 1998b). Two of these folding events (D_{2n} and D_{3n}) produced upright tight–isoclinal folds and have been interpreted as having developed either synchronously or sequentially during a single progressive deformation event (Occhipinti et al., 1998b). The earliest folding event observed by Occhipinti et al. (1998b) includes easterly trending subhorizontal folds in the Padbury and Bryah Groups. On MOORARIE, this deformation may be responsible for the tectonic interleaving of these groups and their tectonic juxtaposition with the Archaean Narryer Terrane.

D_{1n} structures

The first Palaeoproterozoic deformation event (D_{1n}) produced a pervasive schistosity in the mafic–ultramafic rocks of the Narracoota Formation and clastic rocks of the Padbury Group. Tectonic interleaving within the Bryah and Padbury Groups and possible interleaving of these groups between the Archaean Narryer Terrane rocks may have occurred at this time. The D_{1n} structures are not recognized in the Palaeoproterozoic granite sheets and dykes.

D_{2n} structures

The second deformation (D_{2n}) deformed a pervasive S_{1n} foliation, producing large-scale, shallowly to steeply plunging, east to northeasterly trending F_{2n} folds on MOORARIE. Large-scale, prominent F_{2n} folds were produced in the Palaeoproterozoic Bryah and Padbury Basins. On BRYAH, the Robinson Syncline is a steeply inclined tight–isoclinal fold that trends easterly (Pirajno and Occhipinti, 1998). On MOORARIE, the Livingstone Synform is a steep, easterly plunging, tight fold (Fig. 3). This may be part of a larger scale fold structure that is confined between the Kerba and Seabrook Faults in the north and south respectively. Locally, a well-developed S_{2n} crenulation cleavage is present in the mafic and ultramafic schist of the Narracoota Formation and the metasedimentary rocks (Millidie Creek Formation).

Within the granitic gneisses, open to isoclinal, easterly to northeasterly trending, shallow to steeply plunging folds are well developed. These folds plunge easterly–northeasterly or westerly–west-southwesterly, indicating that on a regional scale they are doubly plunging, probably due to refolding. These F_{2n} folds deformed both the Archaean gneiss and Palaeoproterozoic granite sheets that intruded the gneiss. They refold tight to isoclinal, subhorizontal to shallowly plunging folds in the Archaean granitic gneisses that are interpreted to have developed during the Archaean. These refolded mesoscale Archaean folds can be observed in the area about 3 km northwest of Kerba Bore and at Top Minniarra Well (Fig. 6). In the Midnight Bore area, numerous mushroom-shaped fold interference structures (type 2 fold interference patterns of Ramsay, 1967) are present in steeply inclined F_{2n} fold hinges (Fig. 5).

From west to east on MOORARIE the D_{2n} structural fabric rotates from easterly to northeasterly trending. This rotation is probably due to refolding about a fault-bend fold and it is probable that the D_{2n} fabric was originally northeasterly trending.

D_{3n} structure

The tectonic fabric of the Narryer Terrane swings from northerly trending in the south on BYRO (Myers, 1997), to easterly trending on MOORARIE (in the Yarlarweelor gneiss complex of the Narryer Terrane), and then to northeasterly and northerly trending on MILGUN and MARQUIS (Fig. 1). This rotation can be interpreted as reflecting a dextral shear movement, with the change in orientation of the tectonic fabric reflecting deformation around a fault-bend fold. On MARQUIS and MOORARIE, the age of this deformation has been bracketed as Palaeoproterozoic by 1808 ± 6 Ma and 1797 ± 4 Ma U–Pb SHRIMP zircon dates on granitic intrusions that pre-date and post-date the deformation (Nelson, 1999). The 1808 ± 6 Ma age is on a biotite monzogranite sheet that is only locally deformed by the shear fabric. The 1797 ± 4 Ma age, however, is representative of monzogranite dykes trending between 140° and 170° or 080° and 110°, which locally have a sigmoidal shape consistent with emplacement during dextral strike-slip faulting.

The Kerba and Seabrook Faults may be D_{1n}, D_{2n}, or D_{3n} structures, or D_{1n} structures reworked during subsequent deformation events. Within the Kerba Fault, ultramafic schist has an ultramylonitic fabric. North of the Kerba Fault, a mylonitic fabric is locally developed

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Figure 6. Isoclinal F_{2n} fold in Archaean granitic gneiss in Yarlarweelor gneiss complex at Top Minniara Well (AMG 909751)

in the Archaean granitic gneisses. Small-scale, dextral strike-slip shear-sense indicators in gneissic granite and mesoscale dextral shearing within the Yarlarweelor gneiss complex are apparent only a few hundred metres north of its faulted contact with mafic and ultramafic rocks of the Narracoota Formation. Locally, close to this contact within the granitic gneiss, steeply inclined shear indicators around feldspar porphyroclasts indicate southward thrust movement, with the Yarlarweelor gneiss complex thrust over the Palaeoproterozoic Bryah Group.

East-southeasterly trending, dextral strike-slip faults cut the fabric in the Archaean gneisses and Palaeoproterozoic granite. Locally, vertically plunging lineations are associated with this faulting, which probably represents brittle dextral movements in the basement during the late stages of the Capricorn Orogeny.

Narryer Terrane

The Narryer Terrane is dominated by Archaean granite, with lesser outcrops of Archaean granitic gneiss. A belt of foliated granite that outcrops southwest of Livingstones Find and extends southwest to the Curran Bore area commonly contains one pervasive foliation trending subparallel to the Seabrook Fault. Between Bedaburra Pool and Southern Cross Well, the same biotite granite is massive, but extensively fractured, with abundant southeasterly trending quartz veins dominating the landscape. Porphyritic granite in the Fort William Well area is commonly massive and undeformed. The southeasterly trending foliation within the Archaean granite may be either a late Archaean D_3 foliation or may have developed during the Palaeoproterozoic (during D_{1n} or D_{2n}), as it is subparallel to the contact with the Palaeoproterozoic Padbury Group.

Metamorphism

The Palaeoproterozoic Padbury and Bryah Groups on MOORARIE are metamorphosed to middle greenschist facies conditions. Original clastic or volcanic textures are commonly preserved, but locally obliterated through weathering or pervasive metamorphism and deformation, or both. In the western part of PADBURY, the Padbury and Bryah Groups are metamorphosed to lower amphibolite facies along contacts with the Yarlarweelor gneiss complex. On MOORARIE mylonites and quartz veins outcrop along the Kerba Fault, which is the boundary between the Kerba Granite and the Narracoota Formation. Southwest of Kerba Pool an isolated outcrop of mylonite comprises quartz, kyanite, tremolite, and feldspar, indicating possible upper-greenschist facies metamorphism. In this case, the pressure of metamorphism is estimated to have been between 3 and 4 kbar (Spear, 1993).

The S_{1n} foliation is mainly defined by the alignment of muscovite or sericite and chlorite. This foliation is crenulated and, locally, a well-developed crenulation cleavage (S_{2n}) is defined by the alignment of muscovite or sericite and chlorite, indicating no change in metamorphic grade between the D_{1n} and D_{2n} events.

Greenschist facies metamorphism in the Narracoota Formation is marked by pervasive crystallization of actinolite–tremolite(–talc–chlorite) assemblages, particularly in the mafic and ultramafic schists. In zones where the Narracoota Formation is least sheared and original volcanic textures are still preserved (e.g. metagabbro and metaperidotite east of Trillbar Homestead), the original igneous assemblages have still recrystallized under greenschist-facies conditions.

Edmundian Orogeny

On PADBURY, late northerly trending structures include mesoscopic chevron folds, kinks, and faults. These structures developed locally throughout the Padbury–Narryer domain, and trend between 330 and 045° in the northern part of MOORARIE, but are not present in the central western part. The development of such structures suggests an east–west compression. Northerly trending, large-scale folds that refold easterly trending folds are well developed in the Bangemall Basin to the north on MOUNT EGERTON (Muhling et al., 1977). It is possible that on MOORARIE the northerly trending kinks and faults developed at the same time as those in the Bangemall Basin, during the Neoproterozoic Edmundian Orogeny.

Dolerite dykes (*d*)

On MOORARIE, roughly easterly trending dolerite dykes (*d*) intruded the Yarlarweelor gneiss complex and the early to late Archaean rocks of the Narryer Terrane (Yilgarn Craton). The dolerite dykes range from about 2 to 60 m in thickness and are up to about 4 km long. The age of the dolerite dykes is unknown, but to the north, on MARQUIS, they intruded the Discretion Granite, which is dated at 1619 ± 15 Ma.

The dolerite dykes are massive, fine to medium grained, and locally contain plagioclase phenocrysts that are less than 3 mm across. Locally, the dykes are zoned, with fine-grained margins and medium-grained interiors.

Quartz veins (*q*)

Quartz veins (*q*) on MOORARIE fill fractures, commonly associated with large-scale faults. These quartz veins range from containing bucky white quartz to locally containing a mylonitic fabric, suggesting that quartz intruded faults or fractures throughout the area, any time from the Palaeoproterozoic through to the Phanerozoic.

Cainozoic geology

The Cainozoic geology on MOORARIE is divided into 12 units. These are broadly consistent with those on the ROBINSON RANGE 1:250 000 regolith-materials map sheet (Bradley et al., 1997).

Alluvial deposits (*Qa*) consist of sand, gravel, clay, and silt in the main river channels and floodplains. Calcrete (*Qak*) forms extensive outcrops along the Murchison River and some of its tributaries. Extensive clay and silt are present in claypans (*Qac*) in the southeastern part of MOORARIE. Colluvium (*Qc*) is prominent around the flat-topped granite hills, iron-formation hills, and other rock outcrops. In flat areas and on gentle slopes, most colluvium forms a thin veneer of gravel-sized angular or rounded fragments within sand or silt over rock or older, consolidated colluvium (*Czc*). Where colluvium is dominated by quartz vein debris, it is referred to as *Qcq*. These deposits are commonly in areas where abundant quartz veins are also present. Sheetwash deposits of alluvium and colluvium (*Qw*) comprise sand, silt, and clay.

Laterite (*Czrf*) mainly comprises ferruginous duricrust. Ferruginous rubble (*Qcf*) developed over iron-rich rock comprises highly ferruginized and weathered rock (including laterite) and transported fragments of laterite duricrust. Chalcedony caps ultramafic rocks (*Czru*), 1.5 km north of Winja Well. Here, the chalcedony is mainly rubble and largely ferruginized. East-southeast of Winja Well, silcrete (*Czrz*) is well developed over both meta-ultramafic and metasedimentary rocks. Where silcrete has formed over ultramafic rocks, small outcrops of weathered ultramafic schist are often present.

Weathered quartzofeldspathic rock (*Czeg*) with locally derived sand and sandy clays is well developed over the granitic gneisses in the northwestern part of MOORARIE. This unit developed due to the in situ weathering and subsequent breakdown of the granitic gneiss.

Economic geology

Moorarie lies in the Peak Hill and Murchison Mineral Fields. The only operating mine on Moorarie is the Mount Seabrook talc mine. Old gold workings at Livingstones Find were in operation in the late 1930s, but have not been mined since.

Talc

Talc at the Mount Seabrook mine has been documented by Abeysinghe (1996). The mine produces cosmetic-quality talc that is mostly sold overseas. A commercial treatment plant was established in 1973 and mining of this commodity has continued on and off since then, depending mainly on the demand for the talc. The talc is a product of metasomatism (Monks, 1993) of Palaeoproterozoic metadolomitic sandstone (Millidie Creek Formation) in high-strain zones. Talc schist is present within metasedimentary rocks in an easterly trending zone that extends from 5 km west of Livingstones Find to 5 km northwest of Minniara Well.

Gold

The only gold prospect on Moorarie is Livingstones Find, where 13.3 kg of gold was produced between 1935 and 1939. A series of narrow, deep shafts only a few metres long trend at about 110°, parallel to the regional strike, indicating that the gold was probably mined out of thin quartz veins that cut the metasedimentary schist of the Millidie Creek Formation in the area.

Barite

Barite is present in the southwestern part of Moorarie, about 2 km south-southeast of Curran Bore, where it has been mined from narrow, deep shafts. The barite forms lamellar plate-like crystals in easterly trending veins that cut medium- to coarse-grained, even-textured granite.

Nickel

Exploration for nickel was carried out in the early 1970s in areas of ultramafic rock outcrop in the Narracoota Formation, east of Trillbar Homestead. No significant mineralization was found.

Construction material

Road metal is taken from within the mafic and ultramafic rocks of the Narracoota Formation, about 2 km east-southeast of the Trillbar Homestead on the northern side of the Yarlarweelor Homestead – Mount Seabrook mine road.

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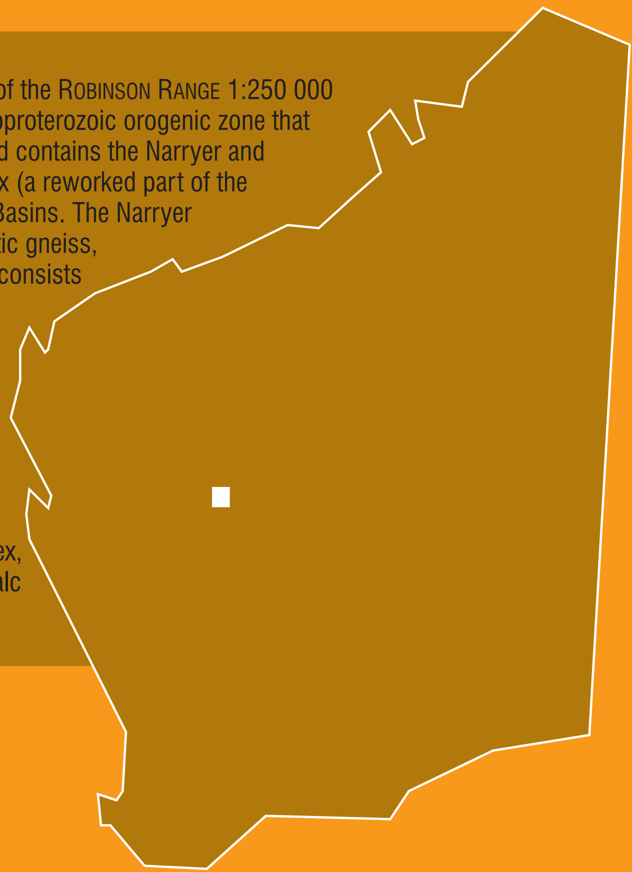
Appendix

Gazetteer of localities

Locality	Latitude (S)	Longitude (E)	AMG (E)	AMG (N)
Bedaburra Pool	25°34'18"	117°31'50"	553300	7171650
Biddy Well	25°56'51"	117°46'27"	577500	7129900
Bogieman Bore	25°46'56"	117°52'31"	587750	7148125
Buddarri Well	25°41'29"	117°30'26"	550900	7149400
Curran Bore	25°46'21"	117°30'27"	550900	7158400
Fort William Well	25°45'24"	117°30'43"	551350	7151150
Four Corners Well	25°31'39"	117°36'22"	560900	7176500
Friday Pool	25°30'29"	117°35'39"	559700	7178650
Hennessey Well	25°52'01"	117°53'50"	589900	7138750
Jelimba Well	25°51'26"	117°44'55"	575000	7139900
Kerba Bore	25°32'23"	117°44'57"	575268	7175073
Kerba Pool	25°32'53"	117°45'47"	576650	7174150
Livingstones Find	25°31'15"	117°40'22"	567600	7177200
Midnight Bore	25°31'07"	117°51'46"	586687	7177346
Minniara Well	25°37'47"	117°53'34"	589622	7165000
Moorarie Homestead	25°55'19"	117°35'55"	559950	7132800
Mount Seabrook mine	25°35'57"	117°43'30"	572800	7168500
Petter Well	25°29'32"	117°42'11"	570667	7180358
Red Hill	25°37'43"	117°57'05"	595500	7165100
Seabrook Well	25°38'08"	117°45'04"	575400	7164450
Southern Cross Well	25°34'34"	117°36'34"	561200	7171100
Thompson Bore	25°34'03"	117°41'57"	570236	7172033
Three Corners Bore	25°35'16"	117°40'23"	567600	7169800
Tommy Bore	25°31'37"	117°47'43"	579898	7176445
Top Minniarra Well	25°32'18"	117°54'17"	590900	7175100
Trillbar Homestead	25°34'54"	117°45'31"	576200	7170400
Walalaya Well	25°56'16"	117°43'12"	572100	7131000
Walebie Well	25°43'16"	117°57'07"	595500	7154850
Winja Well	25°35'33"	117°47'34"	579600	7169200
Yalarweelor Homestead	25°34'42"	117°59'29"	599580	7170630

The Moorarie 1:100 000 sheet covers the south central portion of the Robinson Range 1:250 000 sheet. The sheet lies within the Capricorn Orogen, a major Palaeoproterozoic orogenic zone that developed between the Archaean Yilgarn and Pilbara Cratons, and contains the Narryer and Murchison terranes (Yilgarn Craton), Yarlarweelor gneiss complex (a reworked part of the Narryer Terrane), and the Palaeoproterozoic Bryah and Padbury Basins. The Narryer and Murchison terranes are mainly composed of Archaean granitic gneiss, granite, and greenstone rocks. The Yarlarweelor gneiss complex consists of Archaean granitic gneisses that were deformed and metamorphosed, and intruded by numerous granite and pegmatite sheets and dykes, during the Palaeoproterozoic Capricorn Orogeny. Metamorphosed mafic igneous and sedimentary rocks of the Bryah and Padbury Basins are in faulted contact with rocks of the Yarlarweelor gneiss complex along the east-southeasterly trending Kerba Fault. South of this fault another east-southeasterly trending structure, the Seabrook Fault, is a major tectonic boundary between the Yarlarweelor gneiss complex, Narryer Terrane, and Bryah and Padbury Basins. The Seabrook talc deposit lies within metasedimentary rocks of the Padbury Group.



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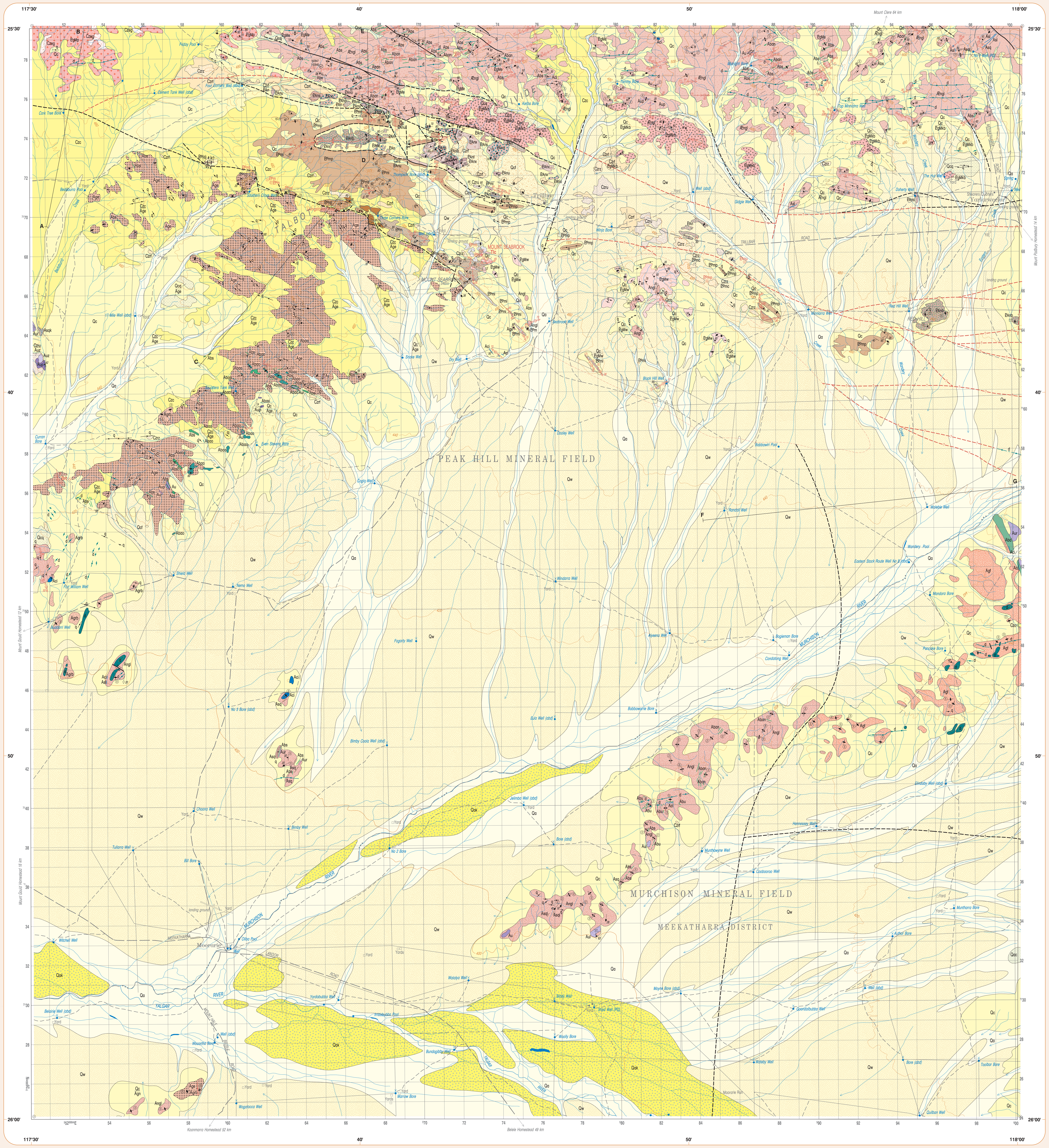
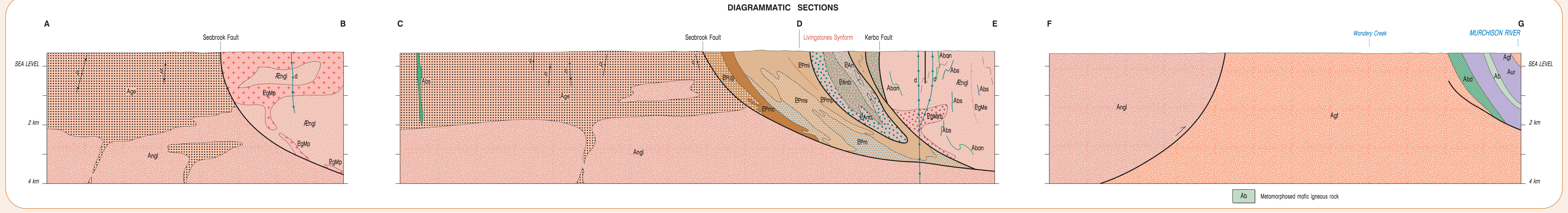
MOORARIE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTIONS



QUATERNARY — CAINOZOIC — PHANEROZOIC

Qa Alluvium — unconsolidated clay, silt, sand, and gravel in channels and floodplains
Qac Clay and silt in claypans
Qak Calcrete forming in alluvial channels
Qw Sheetwash — clay, silt, sand, and gravel
Qc Colluvium — unconsolidated gravel, sand, and silt as scree
Qcf Ferruginous rubble and colluvium — degraded lateritic duricrust
Qcq Quartz-vein rubble as scree

Czc Colluvium — dissected deposits of consolidated gravel, sand, and silt
Czeg Weathered quartzofeldspathic rock with locally derived sand and sandy clays
Czrf Ferruginous duricrust and hardpan forming residual plateaus over weathered rock
Czru Chalcedony over ultramafic rock
Czrz Silcrete

q Quartz vein

d Dolerite dyke; fine- to medium-grained, locally with plagioclase phenocrysts; dashed where interpreted from aeromagnetic data
- negative anomaly

Edmundian Orogeny (<1050 Ma)
Capricorn Orogeny (1830–1780 Ma)

PROTEROZOIC — PALAEOPROTEROZOIC

Moorarie Supersuite

1797±4 Ma ⱣgMe Even-textured biotite granite; medium-grained; massive to weakly foliated
1808±6 Ma ⱣgMkb KERBA GRANITE: even-textured, medium-grained biotite monzogranite; locally foliated
ⱣgMw Even-textured, medium-grained biotite granite; locally porphyritic biotite granite; generally deeply weathered; may include ⱣgMe

1813±8 Ma ⱣgMp Porphyritic and even-textured sheets and veins of coarse-grained biotite monzogranite and pegmatite; locally gneissic and garnet-bearing

Padbury Group — PADBURY BASIN

ⱣP(q) Foliated quartzite, locally with fuchsite; quartz–sericite–biotite phyllite

<2000 Ma
ⱣPm MILLIDIE CREEK FORMATION: quartz–chlorite–muscovite–(tourmaline–hematite) schist; muscovite–quartz schist with porphyroblasts of pyrite
ⱣPmi Metamorphosed banded iron-formation
ⱣPmc Metamorphosed dolomite; locally interbedded with chlorite–quartz phyllite
ⱣPms Metamorphosed dolomitic sandstone and quartz–chlorite–carbonate schist
ⱣPmp Quartz–sericite–hematite phyllite and quartz–muscovite schist
ⱣPmt Talc schist; locally with lenses of metamorphosed dolomitic sandstone (subsurface only)

Bryah Group — BRYAH BASIN

<2000 Ma
ⱣAn NARRACOOTA FORMATION; metamorphosed basalt, gabbro, microgabbro, and mafic and ultramafic schist
ⱣAnb Metabasalt with local fragmental textures and amygdales; minor microgabbro and gabbro
ⱣAno Metamorphosed gabbro, microgabbro, leucogabbro, and melanogabbro
ⱣAnu Ultramafic schist; tremolite–talc–chlorite–magnetite rock
ⱣAnx Metamorphosed pyroxenite and peridotite, and tremolite–talc–magnetite–chlorite rock
ⱣAns Serpentinite
ⱣAnl Metamorphosed peridotite, pyroxenite, and gabbro; rhythmically layered

ARCHAEAN — YILGARN CRATON

Age Even-textured, fine- to medium-grained biotite monzogranite; massive to strongly foliated; local quartz–sericite schist
2615±2 Ma Agrb ROCKY BORE GRANITE: porphyritic monzogranite with tabular feldspar phenocrysts; medium-grained

c. 2800 Agf Foliated biotite monzogranite; even-textured to porphyritic, medium-grained

Asl Calc-silicate gneiss; quartz–diopside–feldspar–tremolite rock
Asq Quartzite
Asqk Quartz–kyanite schist
Asql Quartzite and calc-silicate gneiss

Aci Metamorphosed banded iron-formation; quartz–magnetite gneiss; minor carbonate-bearing banded iron-formation

Aban Amphibolite gneiss; clinopyroxene–plagioclase–hornblende–tremolite rock; granoblastic texture
Abao Amphibolite after gabbro, microgabbro, and minor basalt
Abd Basalt and dolerite; locally pyroxene-phyric; rare banded iron-formation and lenses of quartz–epidote rock; metamorphosed
Abs Mafic schist; actinolite–feldspar–epidote–sphene–quartz schist; includes metamorphosed gabbro, microgabbro, and minor basalt
Abu Metagabbro and mafic schist interleaved with metapyroxenite, serpentinite, and ultramafic schist

Au Ultramafic schist; metapyroxenite and serpentinite
Aul Metamorphosed pyroxenite and gabbro, layered
Aup Serpentinized peridotite or dunite, and serpentinite–tremolite–calcite–sphene rock; locally with relict olivine
Aur Tremolite and tremolite–talc schist, and metapyroxenite
Auz Ultramafic rock; variably silicified

3300–1810 Ma Ængl Leucocratic granitic gneiss; quartz–plagioclase–microline–biotite rock derived from 3300–2640 Ma biotite granite and granitic gneiss (Angl), and sheets and veins of coarse-grained granite and pegmatite (ⱣgMp); all deformed and metamorphosed at 1810 Ma
3300–2640 Ma Angl Gneissic granite and granitic gneiss; predominantly leucocratic; deformed by D_1–D_2; locally intruded by coarse-grained granite and porphyritic granite (Agrb), later deformed by D_3

Geological boundary
- exposed
- concealed
- concealed, interpreted

Structural symbols are labelled according to the sequence of deformation events, where known
- Edmundian Orogeny (<1050 Ma)
  - D_{2e}
- Capricorn Orogeny (1830–1780 Ma)
  - D_{2n}
  - D_{1n}
- Archaean deformation events
  - D_3
  - D_2

Fault
- exposed
- concealed
- concealed, position uncertain
- concealed, interpreted from aeromagnetic data
- horizontal relative displacement

Fold, showing axial trace and generalized plunge direction
- antiform
- synform

Small-scale fold axial surface, showing strike and dip
- inclined
- vertical

Small-scale fold axis, showing trend and plunge
- antiform
- synform
- Z-vergence

Locality of superposed folds

Bedding, showing strike and dip
- inclined

Igneous layering, showing strike and dip
- inclined
- vertical

Way-up indicator
- igneous layering
- sedimentary structure
- cross-bedding

Metamorphic foliation, showing strike and dip
- inclined
- vertical

Strongly foliated rock

Gneissic banding, showing strike and dip
- inclined
- vertical
- trend of gneissic banding

Crenulation cleavage, showing strike and dip
- inclined
- vertical

Shear sense indicator
- dextral
- sinistral

Lineation, showing trend and plunge direction
- stretching lineation
  - inclined
- bedding–cleavage intersection
  - inclined
- axis of crenulation

Fracture, joint, or extension vein, showing strike and dip
- inclined
- vertical

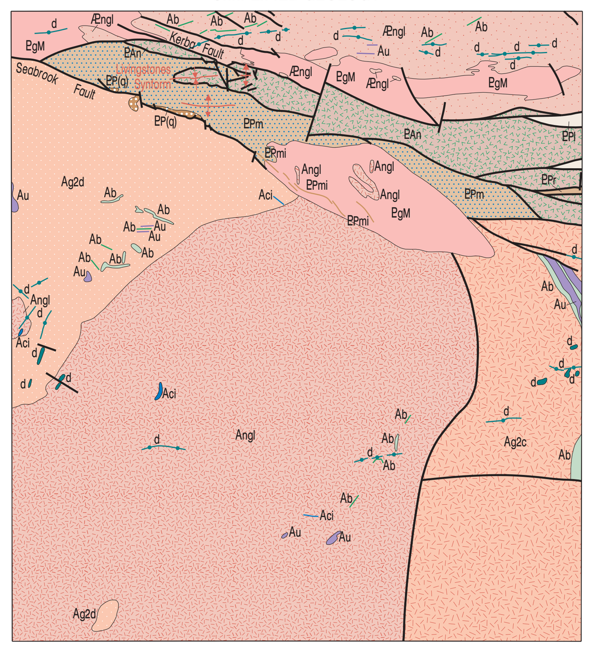
Isotopic age determination site with identification number — 142851

Formed road
Track
Fence, generally with track
Homestead — Moorarie
Building
Yard — Yard
Breakaway
Contour line, 20 metre interval — 420

Watercourse with ephemeral pools or waterholes
Pool — Pool
Spring — Spring
Bore, well — Bore, Well
Windpump
*bandoned — (abd)
Position doubtful — (PD)

Mineral field boundary
Mining centre — MOUNT SEABROOK
Opencut — Livingstones Find
Quarry or pit
Opencut
Tailings or stockpile
Mineral exploration drillhole showing subsurface data — ⱣPm
Mineral occurrence
- Barite — Brt
- Talc — Tlc

SIMPLIFIED GEOLOGY



d Dolerite dyke or sill
ⱣgM Moorarie Supersuite (1830–1780 Ma)
Padbury Group — PADBURY BASIN
ⱣP(q) Quartzite
ⱣPm Millidie Creek Formation
ⱣPmi Metamorphosed banded iron-formation
ⱣPr Robinson Range Formation
ⱣPl Labouchere Formation
Bryah Group — BRYAH BASIN
ⱣAn Narracoota Formation
YILGARN CRATON
Ag2d Granite (2d represents 2700–2600 Ma)*
Ag2c Granite and granitic gneiss (2c represents 2800–2700 Ma)*
Aci Metamorphosed banded iron-formation
Ab Metamorphosed mafic igneous rock
Au Metamorphosed ultramafic igneous rock
Ængl Leucocratic granitic gneiss; reworked in the Palaeoproterozoic
Angl Gneissic granite and granitic gneiss

* Refer to Geological Map of Western Australia 1998

SCALE 1:500 000
0 5 10 15 20
Kilometres

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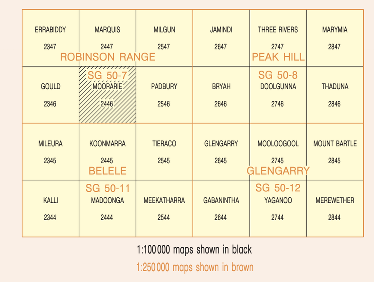
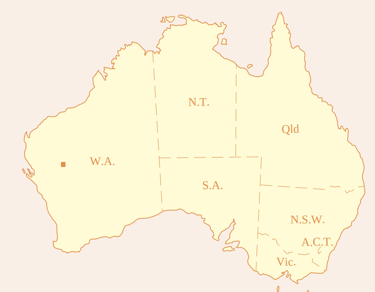
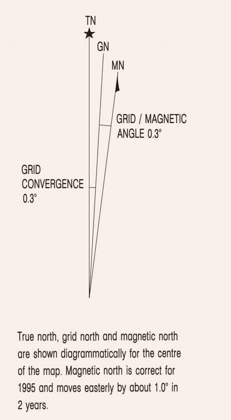


1:100 000 maps shown in black
1:250 000 maps shown in brown





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MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:100 000

1000 0 1 2 3 4 5 6 7 8 9 10
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 50

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

MOORARIE

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