EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

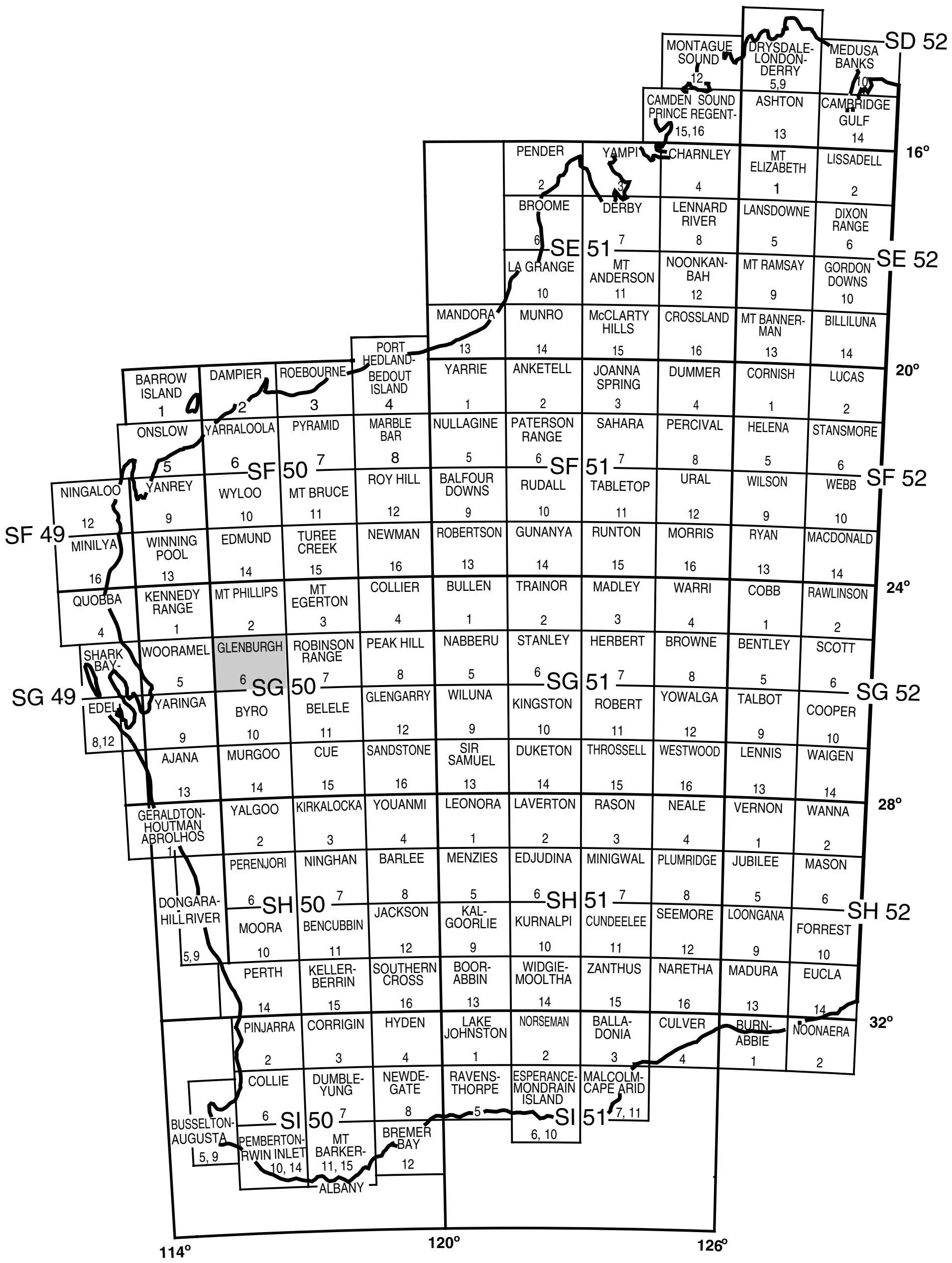
GEOLOGY OF THE GLENBURGH 1:100 000 SHEET

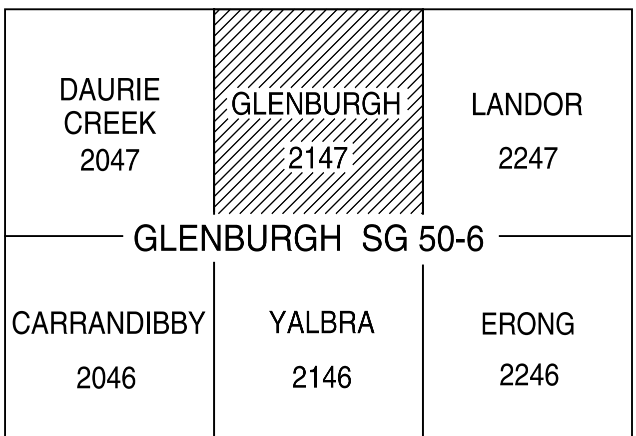
by S. A. Occhipinti and S. Sheppard

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY





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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE GLENBURGH 1:100 000 SHEET

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S. A. Occhipinti and S. Sheppard

Perth 2001

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Cover photograph:
Metamorphosed medium-grained porphyritic biotite granodiorite intruding metamorphosed fine-grained mesocratic tonalite (MGA 441440E 7202250N). Both rock types are part of the 2005–1985 Ma foliated and gneissic granite of the Dalgaringa Supersuite.

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by

S. A. Occhipinti and S. Sheppard

Abstract

The GLENBURGH 1:100 000 map sheet covers the southern part of the Palaeoproterozoic Gascoyne Complex and includes the Glenburgh Terrane. The Glenburgh Terrane on GLENBURGH mainly comprises uppermost Archaean to Palaeoproterozoic granitic rocks. These include the Halfway Gneiss, which is a granitic gneiss with c. 2550 Ma and c. 2000 Ma protolith ages, and tonalitic and granodioritic rocks of the 2005–1970 Ma Dalgaringa Supersuite (including the Nardoo Granite). Supracrustal rocks interlayered with the Halfway Gneiss, and within the Dalgaringa Supersuite, form part of the Moogie Metamorphics.

The southern part of the Glenburgh Terrane underwent two periods of medium- to high-grade metamorphism during the Glenburgh Orogeny between 2000 and 1960 Ma. The Glenburgh Orogeny reflects collision between the Glenburgh Terrane and the Archaean Yilgarn Craton. In the northern part of GLENBURGH, large-scale, originally subhorizontal, layer-parallel shear zones developed between the Halfway Gneiss and Moogie Metamorphics. The Halfway Gneiss contains a fabric predating the subhorizontal shear zones, implying that it was deformed before being juxtaposed against the Moogie Metamorphics.

During the Capricorn Orogeny, at 1830–1780 Ma, rocks of the Halfway Gneiss, Moogie Metamorphics, and Dalgaringa Supersuite were variably deformed and metamorphosed at greenschist facies. In the northern part of GLENBURGH, the Halfway Gneiss and Moogie Metamorphics were deformed into large-scale, easterly trending folds, whereas structures of this age are only locally developed in the southern part. The Capricorn Orogeny was accompanied by intrusion of voluminous monzogranite and granodiorite of the Moorarie Supersuite.

Siliciclastic rocks of the Mount James Formation were deposited at or after 1800 Ma within discrete depocentres, and deformed during the waning stages of the Capricorn Orogeny. Carbonate and siliciclastic rocks of the Edmund Group (Bangemall Supergroup) were deposited on the Glenburgh Terrane after c. 1640 Ma. Glacigene sediments of the Carnarvon Basin were deposited on the Gascoyne Complex and Bangemall Supergroup from the Late Carboniferous to Early Permian.

KEYWORDS: Palaeoproterozoic, Gascoyne Complex, Glenburgh Terrane, Glenburgh Orogeny, Halfway Gneiss, Moogie Metamorphics, Dalgaringa Supersuite, Capricorn Orogeny, Moorarie Supersuite, Palaeoproterozoic, Mount James Formation, Edmund Group, Bangemall Supergroup, regional geology.

Introduction

Location, access, and previous work

The GLENBURGH* 1:100 000 map sheet (SG 50-6, 2147) occupies the north-central part of the GLENBURGH 1:250 000 map sheet, and is bounded by latitudes 25°00' and 25°30'S and longitudes 116°00' and 116°30'E (Fig. 1).

Sheep and beef-cattle grazing on the Glenburgh, Dalgety Downs, Dairy Creek, and Mooloo Downs pastoral leases is the main commercial activity on GLENBURGH, although in recent years the sale of feral goats has also been undertaken by the pastoralists. Dalgety Downs Homestead is in the central part of the sheet area, and Glenburgh Homestead in the southwestern part. Two unsealed, but well-maintained, roads service the sheet area. The Glenburgh and Dalgety Downs Homesteads are linked by the Glenburgh – Dalgety Downs – Landor road, which also provides access to Meekatharra, 285 km southeast of GLENBURGH. Gascoyne Junction, 110 km west-northwest of GLENBURGH, is reached via the

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

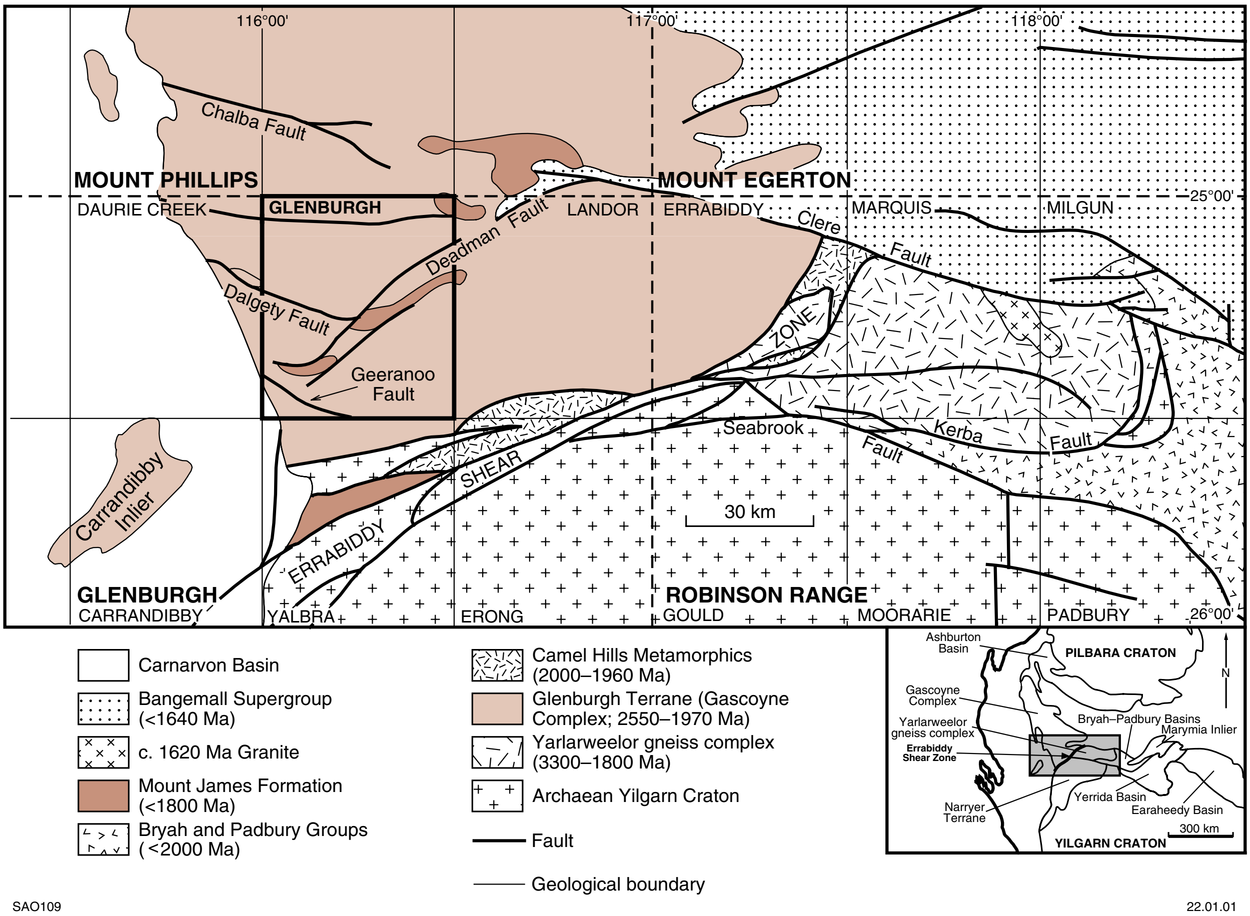

Figure 1. Simplified geology map showing the relationship of major tectonic units in the region and the location of GLENBURGH. The Gascoyne Complex (including the Glenburgh Terrane) and the northwestern margin of the Yilgarn Craton (Errabiddy Shear Zone) were extensively intruded by c. 1800 Ma granite

Carnarvon–Mullewa road. Station tracks provide year-round access to most parts of the sheet area away from the main roads, but access can be difficult in rough terrain.

The earliest geological observations in the area were made in the 1890s and summarized by Maitland and Montgomery (1924). The first geological map of the area was produced by the Bureau of Mineral Resources (Condon, 1962), and incorporated earlier reconnaissance work by Johnson (1950). Daniels (1975) undertook photogeology and reconnaissance work in the area, and de Laeter (1976) published the results of geochronology work from that study. Williams et al. (1983b) described the results of systematic regional mapping on the GLENBURGH 1:250 000 sheet, and Williams (1986) included the sheet area in a report on the Gascoyne Complex. Fletcher et al. (1983) and Libby et al. (1986) published geochronological work undertaken in conjunction with the regional mapping. Myers (1990) reviewed and described the geology of the region based on existing work and his own reconnaissance mapping.

GLENBURGH was remapped in 1998 and 1999. This was a continuation of remapping on the northeastern part of the GLENBURGH 1:250 000 sheet, and on the ROBINSON RANGE 1:250 000 sheet farther east (Occhipinti et al., 1998b; Occhipinti and Myers, 1999; Sheppard and Swager, 1999; Sheppard and Occhipinti, 2000). Preliminary results from this remapping are also presented in Occhipinti et al. (1999a,b) and Sheppard et al. (1999a,b). Nelson (1998, 1999, 2000) presented the results of geochronological work undertaken in conjunction with the remapping.

Physiography, vegetation, and climate

The physiography of the GLENBURGH 1:250 000 sheet area was described by Williams et al. (1983b). For the most part, the landscape on GLENBURGH consists of low hills of variably rugged outcrop (Fig. 2), which form the northern side of the drainage divide between the Gascoyne River and the Murchison River to the south. Incised, dendritic creeks dissect uplands of Palaeoproterozoic metamorphosed igneous and sedimentary rocks. The most prominent hills are formed by steep

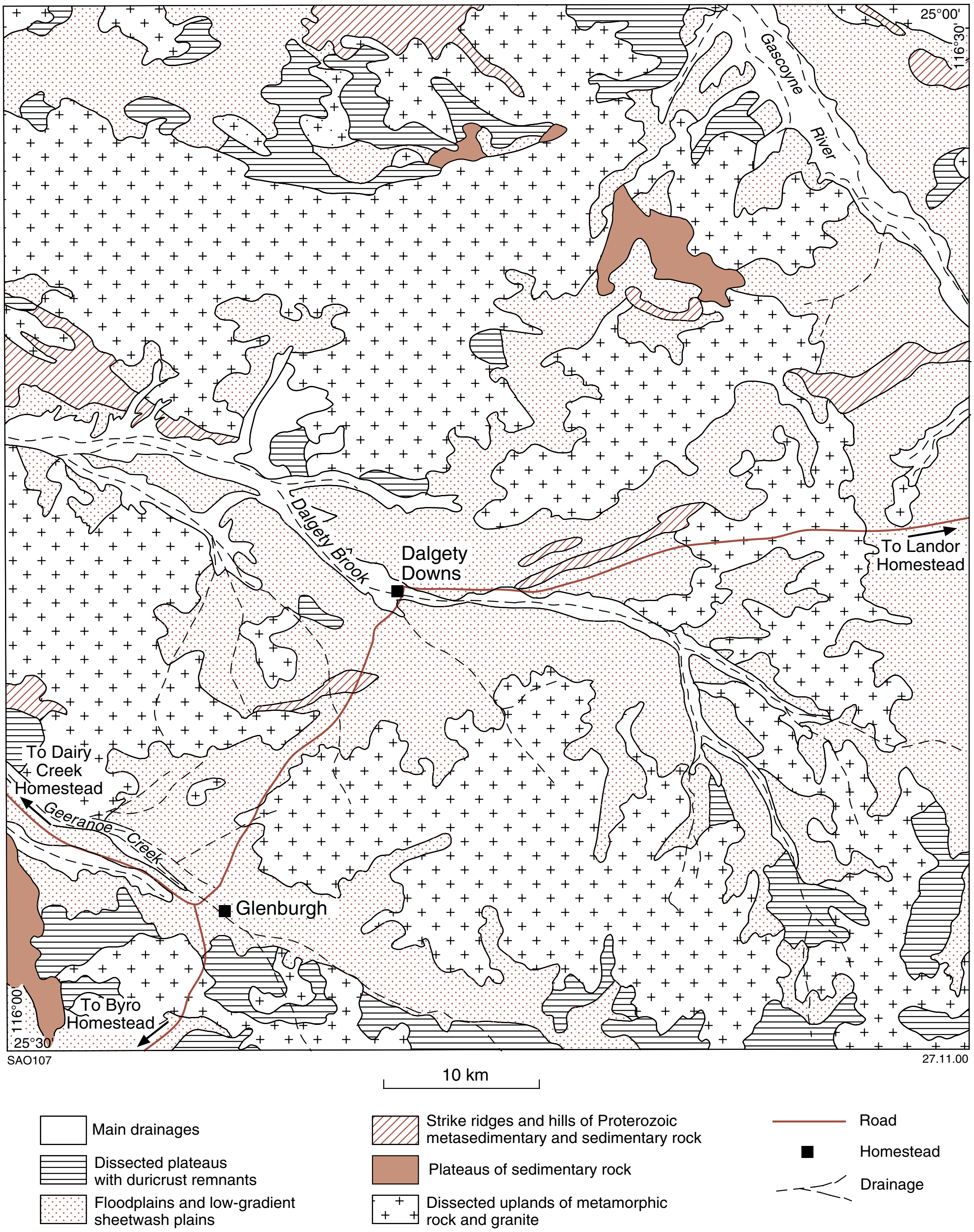

Figure 2. Physiography and drainage sketch map of GLENBURGH

ridges underlain by quartz-rich sedimentary rock or quartz veins. Other physiographic units recognized on GLENBURGH consist of the main drainages, including the surrounding low-gradient sheetwash plains, and high-gradient slope deposits adjacent to actively eroding outcrop. A partly incised plateau of ferruginous duricrust is best preserved in the southwestern part of the sheet area.

GLENBURGH is situated in the Gascoyne Region of the Eremaean Province (Beard, 1981). 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. Acacia and mulga scrub dominate the poor stony soils of the uplands. Rock fuchsia bush, turpentine bush, and green cassia are abundant on low rocky hill slopes. The drainage systems are lined by flannel bush, turpentine bush, red grevillea, ghost gums, river red gums, and mulga. Gidgee, miniritchie, and various other types of acacia are also abundant (Mitchell and Wilcox, 1988).

GLENBURGH has an arid climate, with hot dry summers (average daily maximum temperature of 40°C in January)* and mild winters (average daily maximum temperature of 22°C in July). The area has a mean annual rainfall of about 200 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. During winter, rain results from the interaction of strong cold fronts from the southwest with tropical cloud bands originating from the north-northwest. All creeks on GLENBURGH are ephemeral, and the Gascoyne River flows only after heavy rain.

Geological setting

GLENBURGH lies wholly within the southern part of the Palaeoproterozoic Gascoyne Complex (Figs 1 and 3), which is part of the Proterozoic Capricorn Orogen. The Capricorn Orogen initially formed during collision and suturing of the Archaean Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990; Krapez, 1999). The orogen includes a number of Palaeoproterozoic sedimentary basins farther east, as well as the deformed margins of the Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990; Martin et al., 1998; Occhipinti et al., 1998b; Occhipinti et al., 1999a).

The main tectonic unit on GLENBURGH is the 2550–1970 Ma Glenburgh Terrane of the Gascoyne Complex (Sheppard and Occhipinti, 2000). The Glenburgh Terrane on GLENBURGH is intruded by the 1830–1780 Ma Moorarie Supersuite, and unconformably overlain by scattered outcrops of the c. 1800 Ma Mount James Formation and outliers of the Palaeoproterozoic–Mesoproterozoic Bangemall Supergroup.

The Glenburgh Terrane comprises 2550–2000 Ma granitic rocks of the Halfway Gneiss, 2005–1970 Ma† granitic rocks of the Dalgaringa Supersuite (Sheppard et al., 1999b), and metasedimentary rocks of the Moogie Metamorphics. Although the Glenburgh Terrane includes uppermost Archaean rocks (c. 2550 Ma), these are younger than any dated rocks from the Yilgarn and Pilbara Cratons. Granites‡ of the Dalgaringa Supersuite do not intrude the northwestern margin of the Yilgarn Craton. Rocks of the Glenburgh Terrane, therefore, may have formed part of an exotic terrane (Sheppard et al., 1999b). The relationship of the Glenburgh Terrane to the rest of the Gascoyne Complex to the north is unknown.

South of GLENBURGH, the Glenburgh Terrane is in faulted contact with Palaeoproterozoic metasedimentary and meta-igneous rocks of the Camel Hills Metamorphics, which have maximum ages of c. 2000 Ma (Sheppard and Occhipinti, 2000). The Camel Hills Metamorphics is confined to the Errabiddy Shear Zone, which marks the boundary between the Yilgarn Craton and Gascoyne Complex. The metamorphic rocks largely consist of the Petter Calc-silicate and Quartpot Pelite. Detrital zircon ages from the Petter Calc-silicate suggest that the protoliths were derived from the Yilgarn Craton, whereas the Quartpot Pelite was mainly sourced from Palaeoproterozoic rocks that could have included the Glenburgh Terrane (Nelson, 1999, 2000). Farther east, sedimentary rocks of the Yerrida Group were deposited on the northern margin of the Yilgarn Craton at c. 2300 Ma (Pirajno and Adamides, 2000; Pirajno and Occhipinti, 2000).

During the Glenburgh Orogeny, at 2000–1960 Ma, the Glenburgh Terrane and Camel Hills Metamorphics were deformed and metamorphosed at medium to high grade (Occhipinti et al., 1999b), and the northwestern edge of the Yilgarn Craton was deformed. The Glenburgh Terrane was also probably thrust over the Yilgarn Craton from the west or northwest, and this collision resulted in the formation of the Errabiddy Shear Zone (Fig. 1). The c. 2000 Ma Bryah Basin to the east, which includes abundant mafic extrusive and intrusive rocks, had probably developed by this time in a 'rift-type setting' along the northern margin of the Yilgarn Craton (Pirajno et al., 2000). The Padbury Basin, which developed on top of the Bryah Basin, may have formed as a retro-arc foreland basin (Martin, 1994) to the Glenburgh Orogeny. The end of orogenic activity was marked by intrusion of monzogranite and syenogranite of the c. 1960 Ma Bertibubba suite into the northwestern margin of the Yilgarn Craton, and intrusion of trondhjemite, leucogranodiorite, and monzogranite dykes into the southern Glenburgh Terrane and Camel Hills Metamorphics.

The Glenburgh Terrane and Camel Hills Metamorphics were further deformed and metamorphosed at medium to low grade during the Capricorn Orogeny at 1830–1780 Ma, and intruded by granites of the Moorarie Supersuite (Occhipinti et al., 1999a; Occhipinti et al., 1999b; Sheppard and Occhipinti, 2000). Discrete shear zones, which either formed or were reactivated at this time, cut the northwestern margin of the Yilgarn Craton (Sheppard and Occhipinti, 2000). The northern part of the Yilgarn Craton, in the ROBINSON RANGE 1:250 000 sheet area, was pervasively deformed and metamorphosed at high grade, and is referred to as the Yarlarweelor gneiss complex (Occhipinti et al., 1998b; Occhipinti and Myers, 1999; Sheppard and Swager, 1999). Granites of the Moorarie Supersuite also extensively intruded the Yarlarweelor gneiss complex (Sheppard et al., 1999a,b).

Siliciclastic sedimentary rocks of the Mount James Formation were deposited in a series of small fault-bounded basins on top of the Gascoyne Complex (including both the Glenburgh Terrane and Camel Hills Metamorphics) and the northwestern edge of the Yilgarn

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

† Wrongly labelled as 2000–1975 Ma on the map.

‡ In these notes the term 'granite' is used to refer to any coarse-grained, quartz-bearing plutonic rock. Recommended IUGS terminology is used to refer to specific rock compositions (e.g. monzogranite and syenogranite; Streckeisen, 1976).

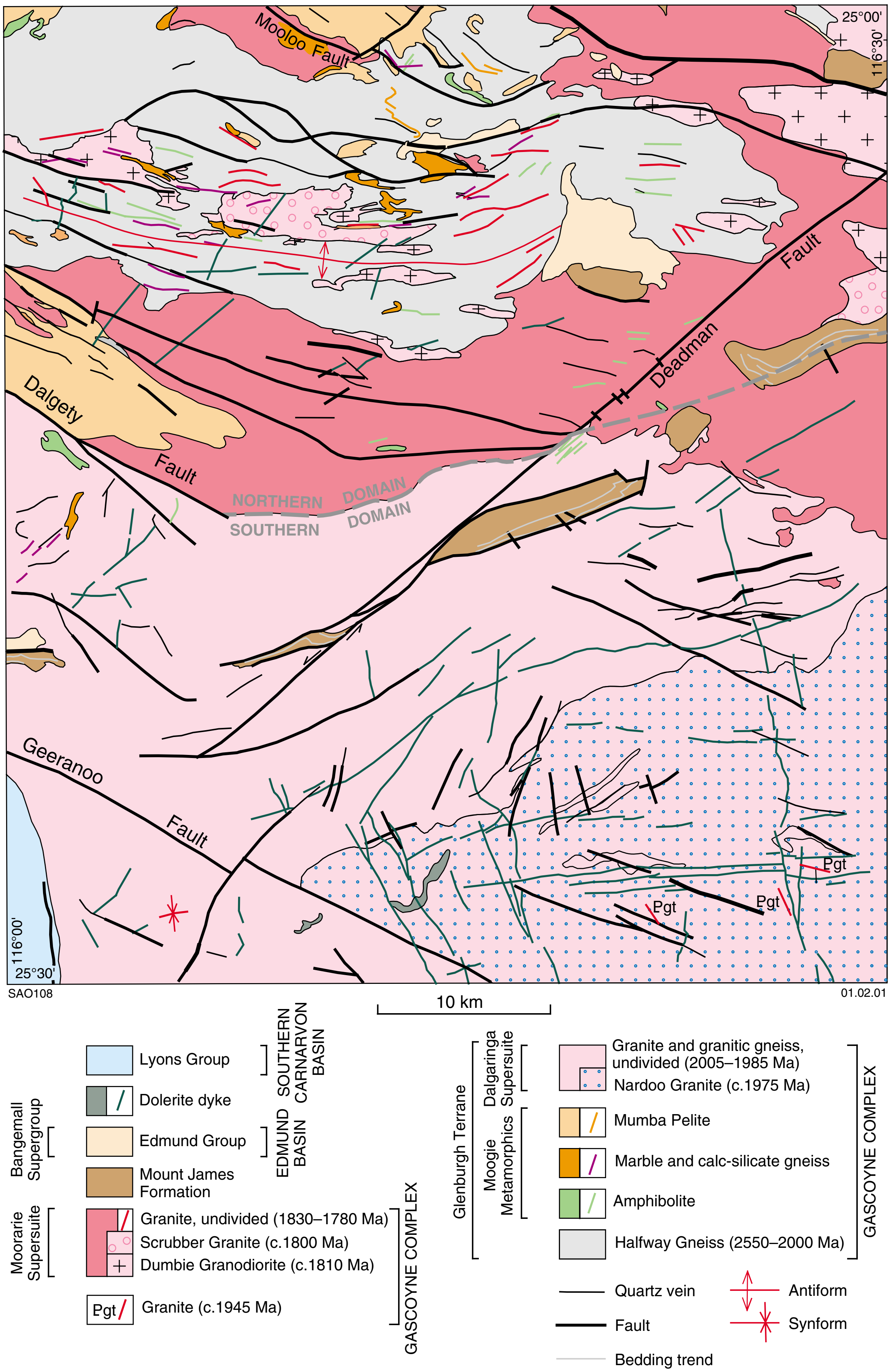

Figure 3. Simplified solid geology map of Glenburgh, showing the structural interpretation

Craton (Figs 1 and 3). These sedimentary rocks were probably deposited during the latter stages of the Capricorn Orogeny (Occhipinti et al., 1999b). During the latest Palaeoproterozoic to Mesoproterozoic, sedimentary rocks of the Edmund Group (Bangemall Supergroup) were deposited on the Gascoyne Complex, Yilgarn Craton, Mount James Formation, and the the Bryah and Padbury Basins. Rocks of the Edmund Group (Bangemall Supergroup) were intruded by uppermost Mesoproterozoic dolerite sills, and then deformed during the Edmundian Orogeny between c. 1020 Ma (Wingate, M., 1999, written comm.) and c. 750 Ma (Sheppard and Occhipinti, 2000; Wingate and Giddings, 2000). Upper Carboniferous to Lower Permian glacigene rocks of the Carnarvon Basin were deposited on top of all other tectonic units and locally folded and faulted into northerly trending structures.

Gascoyne Complex

Granites and metamorphic rocks of the Gascoyne Complex form part of the Capricorn Orogen, which is a major tectonic zone recording collision of the Glenburgh Terrane with the Yilgarn Craton (Occhipinti et al., 1999a; Occhipinti et al., 1999b), and subsequent collision of the combined Yilgarn Craton and Glenburgh Terrane with the Pilbara Craton (Tyler and Thorne, 1990). Williams (1986) suggested that the southern part of the Gascoyne Complex consisted mainly of reworked Archaean gneisses of the Yilgarn Craton. In contrast, Myers (1990) interpreted the southern part of the Gascoyne Complex as para-autochthonous Yilgarn Craton interleaved with Proterozoic rocks (his Zone B). These interpretations were contradicted, however, by the failure of reconnaissance sensitive high-resolution ion microprobe (SHRIMP) U–Pb dating to identify Archaean crust in the southern margin of the Gascoyne Complex (Nutman and Kinny, 1994).

Remapping of the LANDOR, ERRABIDDY, and GLENBURGH map sheets, combined with SHRIMP U–Pb zircon geochronology (Nelson, 1998, 1999, 2000), indicates that the southern margin of the Gascoyne Complex (Fig. 1) comprises mainly Palaeoproterozoic meta-igneous and metasedimentary rocks. Some c. 2550 Ma Archaean foliated to gneissic granites in the northern part of GLENBURGH (Occhipinti et al., 1999a; Occhipinti et al., 1999b; Nelson, 2000), however, appear to be tectonically interleaved with, and juxtaposed against, the Palaeoproterozoic rocks (Figs 1 and 3). In the Carrandibby Inlier, about 50 km southwest of GLENBURGH, Nutman and Kinny (1994) also reported a c. 2500 Ma age for granitic gneiss. These uppermost Archaean foliated to gneissic granites are younger than any dated rocks from the northwestern part of the Yilgarn Craton, which are all older than c. 2600 Ma (Wiedenbeck and Watkins, 1993; Myers, 1995; Schiøtte and Campbell, 1996). In addition, the Pilbara Craton does not contain granite dated at younger than c. 2750 Ma (Nelson et al., 1999). Rocks of the southern Gascoyne Complex, therefore, may be part of a terrane separate from the Archaean Yilgarn and Pilbara Cratons.

The southern part of the Gascoyne Complex can be divided into three main units: the Glenburgh Terrane, Camel Hills Metamorphics, and Moorarie Supersuite. The Glenburgh Terrane consists of uppermost Archaean – Palaeoproterozoic granitic gneiss forming the Halfway Gneiss interleaved with metasedimentary rocks of the Moogie Metamorphics, and the 2005–1970 Ma granitic gneiss and granite of the Dalgaringa Supersuite. The Moogie Metamorphics consists of medium- to low-grade metasedimentary and mafic meta-igneous rocks, forming large outcrops within the granitic gneiss or discontinuous lenses within granite or granitic gneiss. Palaeoproterozoic medium- to high-grade metasedimentary rocks of the Camel Hills Metamorphics are not present on GLENBURGH, being confined to the Errabiddy Shear Zone; their relationship to the Moogie Metamorphics is unknown.

The Halfway Gneiss, Dalgaringa Supersuite, Moogie Metamorphics, and Camel Hills Metamorphics were deformed and metamorphosed during the 2000–1960 Ma Glenburgh Orogeny (Occhipinti et al., 1999a; Occhipinti et al., 1999b; Sheppard et al., 1999a,b). Subsequently, during the Capricorn Orogeny at 1830–1780 Ma, the rocks were deformed and metamorphosed at low to medium grade, and intruded by voluminous granite and pegmatite dykes, plugs, and sheets of the Moorarie Supersuite (Sheppard et al., 1999a).

Glenburgh Terrane

Upper Archaean to Palaeoproterozoic Halfway Gneiss

The Halfway Gneiss (*Ænha*, *Ænhal*, *Ænham*)* comprises augen gneiss and banded granitic gneiss outcropping in a 6–10 km-wide easterly trending belt in the northern part of GLENBURGH (Fig. 3), and extending about 17 km to the west onto DAURIE CREEK (Fig. 1). When the GLENBURGH sheet was published (Occhipinti and Sheppard, 2000), only latest Archaean ages had been obtained from granite protoliths to the Halfway Gneiss (Nelson, 2000). However, further geochronological work by Nelson (in prep.; sample GSWA 168947, see below) demonstrated that the gneiss has Palaeoproterozoic granitic components. On future maps the age letter code *Æ* will be used for the Halfway Gneiss.

The banded granitic gneiss of the Halfway Gneiss consists of several interlayered rock types (Fig. 4a–c) heterogeneously deformed and metamorphosed to at least amphibolite facies. Despite the metamorphism, original igneous components can be recognized in areas of low strain. The Halfway Gneiss includes a few granitic elements that can be correlated with the Dalgaringa Supersuite. The granitic gneiss is commonly weathered and poorly exposed on GLENBURGH, but can be well exposed in low rocky hills dissected by a close-spaced network of dendritic creeks.

The Halfway Gneiss comprises interlayered leucocratic granitic gneiss and foliated leucocratic granite, mesocratic granitic gneiss, pale-grey granitic gneiss and foliated granite, gneissic to foliated porphyritic granodiorite, and pegmatite (*Ænha*). There are no sharp

* Labelled as *Anha*, *Anhal*, and *Anham* on the map.

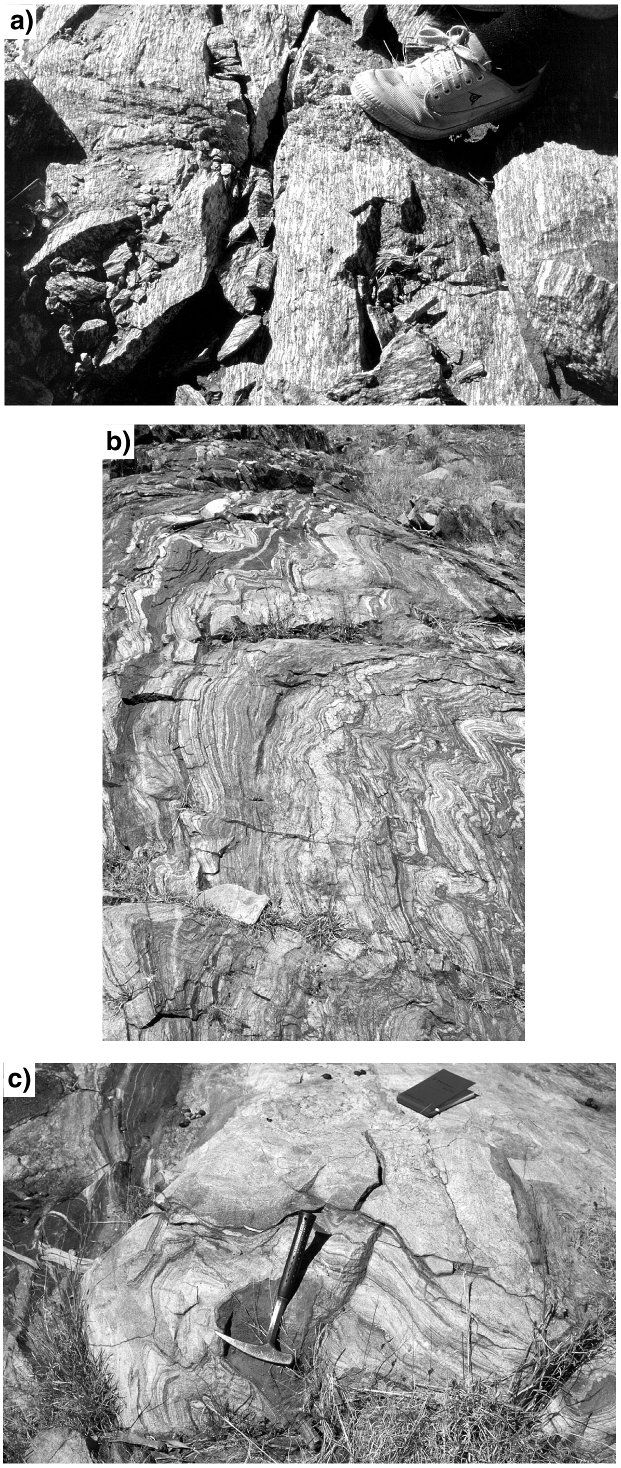

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Figure 4. Rock types of the Halfway Gneiss:
a) well-foliated biotite granodiorite (augen gneiss) dated at 2544 ± 5 Ma (from about 1 km southeast of Middle Well, MGA 413616E 7225303N; GSWA 164309);
b) pegmatite-banded mesocratic granitic gneiss. The dark-grey fine-grained tonalitic layer on the left was dated at 2550 ± 7 Ma (from immediately west of Dunnawah Well, MGA 401310E 7223430N; GSWA 142988);
c) leucocratic granitic gneiss with minor interlayered mesocratic granitic gneiss (MGA 417040E 7221050N)

boundaries between the various rock types as they are interleaved at both mesoscopic and megascopic scales. Contacts between the various rock types are typically tectonic, although in places igneous intrusive relationships between individual granitic protoliths are preserved. Two mappable units are recognized within the Halfway Gneiss: the leucocratic granitic gneiss and foliated granite (*Ænhal*), and mesocratic granitic gneiss (*Ænham*). Mapped boundaries of the leucocratic and mesocratic gneisses define areas of dominance of one gneiss type over the others. In areas where neither mesocratic nor leucocratic gneiss dominate, the gneiss is mapped as a general granitic gneiss unit (*Ænha*).

Three samples of the Halfway Gneiss were collected for SHRIMP U–Pb zircon dating. An augen gneiss derived from biotite granodiorite (GSWA 164309; Fig. 4a) was collected about 1 km southeast of Middle Well (MGA 413616E 7225303N*; Nelson, 2000). Most of the zircons (17 of 22) define an igneous crystallization age of 2544 ± 5 Ma for the granodiorite precursor (Nelson, 2000). Nelson (2000) suggested that five zircons defining an older population at 2563 ± 8 Ma may represent xenocrysts. Nelson (2000) also dated the tonalitic component of a mesocratic, banded granitic gneiss (GSWA 142988; Fig. 4b) immediately west of Dunnawah Well. This sample contains several concordant zircon populations. The youngest population consists of five analyses of five zircons with a pooled age of 2550 ± 7 Ma. Six analyses of six zircons define a date of 2663 ± 7 Ma, four analyses of a further four zircons define a date of 2709 ± 10 Ma, whereas the remaining zircons are c. 3300 Ma or older. Nelson (2000) suggested that the 2663 ± 7 Ma date is the igneous crystallization age of the tonalite precursor, and the 2550 ± 7 Ma date corresponds to the age of thin pegmatite veins in the sample. However, pegmatite veins comprise less than 5% of the sample, so that the youngest population at 2550 ± 7 Ma probably represents the igneous crystallization age of the tonalite precursor. Nutman and Kinny (1994) dated a granitic gneiss from the Carrandibby Inlier, about 50 km southwest of GLENBURGH, at c. 2500 Ma. This gneiss may be a continuation of the Halfway Gneiss on GLENBURGH.

More recently, Nelson (in prep.) dated a leucocratic granitic gneiss (GSWA 168947) derived from biotite monzogranite from an area on DAURIE CREEK (MGA 381950E, 7230840N), west of GLENBURGH. The igneous crystallization age of the precursor granite to the gneiss was defined as 2006 ± 6 Ma from a single population of 19 concordant to slightly discordant analyses on 19 zircons (Nelson, in prep.). The c. 2006 Ma age suggests that some granite of the Dalgaringa Supersuite has been included in the Halfway Gneiss. The original relationship of the c. 2006 Ma component to the c. 2550 Ma components of the Halfway Gneiss is unknown, although they now appear to be tectonically interleaved.

The Halfway Gneiss is also tectonically interleaved with calc-silicate gneiss, amphibolite, actinolite schist, tremolite schist, and pelitic schist of the Moogie Metamorphics. The original relationship between these

* Map Grid of Australia (MGA) coordinates of localities mentioned in the text are listed in the Appendix.

supracrustal rocks and the Halfway Gneiss is unknown, although regional structural observations suggest that at least some parts of the Halfway Gneiss are older.

The Halfway Gneiss is extensively intruded by sheets and dykes of the Dumbie Granodiorite (*ɆgMdu*), plutons, dykes, and veins of the Scrubber Granite (*ɆgMsc*), and medium-grained biotite(–muscovite) granite (*ɆgMe*), all of which are part of the Moorarie Supersuite.

All the constituent rock types of the Halfway Gneiss display a variety of textures reflecting different strain states and overprinting by lower grade metamorphic events. In thin section most samples show evidence for extensive static recrystallization at low metamorphic grade, including recrystallization of quartz to fine polygonal aggregates, replacement of plagioclase by albite–oligoclase, sericite, and epidote, and replacement of magnetite and ilmenite by epidote and titanite respectively, in association with alteration of plagioclase.

Leucocratic granitic gneiss (Ænhal)

Leucocratic granitic gneiss (*Ænhal*; Fig. 4c) is the most abundant rock type making up the Halfway Gneiss. The rock is medium grained, with thin discontinuous layers of biotite giving it a flaser texture and defining the foliation or gneissic layering. The gneiss ranges from weakly to moderately pegmatite banded. Lower strain domains of the gneiss consist of foliated, coarse-grained porphyritic biotite granite, and minor foliated fine- to medium-grained, even-textured granite. Precursors to the gneiss range in composition from granodiorite to monzogranite. The porphyritic granite contains about 10–30% round and squat, 1–3 cm-long, tabular phenocrysts of microperthite, in a groundmass of plagioclase, quartz, microperthite, and a few percent biotite, with or without muscovite. The rocks commonly contain micrographic and myrmekitic textures.

Mesocratic granitic gneiss (Ænham)

Mesocratic granitic gneiss (*Ænham*; Fig. 4a,b) is a fine- or medium-grained, pegmatite-banded, dark-grey rock. Lower strain domains of the gneiss consist of foliated, fine-grained, weakly porphyritic tonalite and medium-grained, strongly porphyritic tonalite. Fine-grained rocks typically contain about 10% round plagioclase phenocrysts, a few millimetres in diameter. Medium-grained rocks contain up to 30% round plagioclase phenocrysts, about 5–20 mm in diameter. The groundmass consists of plagioclase, quartz, and biotite (15–20% of the rock), with accessory apatite and zircon. Some amoeboid textures are present, implying metamorphism at medium to high grade. Quartz and plagioclase commonly define a grain-flattening fabric.

Undivided Halfway Gneiss (Ænha)

Undivided Halfway Gneiss (*Ænha*), which is a mixture of leucocratic and mesocratic granitic gneisses and pale-grey granitic gneiss, outcrops over a large area in the northern part of GLENBURGH. Several components of the Halfway Gneiss and their original igneous crosscutting relationships are preserved at a small outcrop 4.5 km east-southeast (MGA 405800E 7229350N) of 2 Mile Well. Well-foliated, fine-grained, even-textured to locally porphyritic biotite granitic gneiss is cut by leucocratic medium- to coarse-grained pegmatite. Both rock types are foliated and folded about F_{2g} and F_{1n} folds (see **Glenburgh Orogeny** and **Capricorn Orogeny**).

The fine-grained biotite granitic gneiss at the above locality consists of plagioclase, quartz, biotite, K-feldspar, and epidote, with accessory zircon and titanite. The zircon is commonly euhedral and zoned. The gneissic layering in the fine-grained gneiss is typically defined by large amounts of biotite- or epidote-rich layers, alternating with quartz- and feldspar-rich layers. Plagioclase often forms large porphyroclasts (up to 7 mm in diameter) enclosed by mica or quartz. In a few layers, quartz grains are flattened and display undulose extinction, whereas in other layers quartz grains are largely polygonal, exhibiting triple junctions. Biotite, commonly with zircon inclusions, defines the foliation and a mineral lineation, and may be completely pseudomorphed by pale-green chlorite. Fine-grained sericite and epidote variably replace plagioclase and K-feldspar. Medium-grained, pale-yellow to green epidote commonly forms small clots or clusters throughout the gneiss.

Pale-grey granitic gneiss and foliated granite is abundant south and southeast of Dunnawah Well. The rock is typically fine to medium grained, and weakly to moderately pegmatite banded. In lower strain domains it consists of medium-grained, even-textured or weakly porphyritic biotite granite, and can be difficult to distinguish from medium-grained biotite(–muscovite) granite (*ɆgMe*) of the Moorarie Supersuite. The precursor to the pale-grey granitic gneiss consists of medium-grained granodiorite and quartz-rich leucocratic tonalite. Biotite constitutes about 10% of the rocks. Moderately to strongly deformed samples have a grain-flattening fabric defined by quartz and plagioclase, and a foliation defined by biotite.

Palaeoproterozoic Moogie Metamorphics

The Moogie Metamorphics is a newly defined unit named after Moogie Well in the western part of GLENBURGH. The unit includes pelitic schist, quartzite, calc-silicate gneiss, marble, amphibolite, ultramafic schist, and metamorphosed banded iron-formation. These metasedimentary and metamorphosed mafic and ultramafic igneous rocks were previously included within the 'Morrissey Metamorphic Suite' (Williams et al., 1983b; Williams, 1986). The 'Morrissey Metamorphic Suite' was defined on the MOUNT PHILLIPS 1:250 000 sheet, representing a group of metamorphosed and deformed Proterozoic sedimentary rocks thought to outcrop throughout the Gascoyne Complex (Williams et al., 1983a). These rocks were considered partly equivalent to sedimentary rocks of the Wyloo Group to the north, and sedimentary rocks of the Yerrida and Bryah Groups ('Glengarry Group' of Gee, 1979; Pirajno et al., 1998) to the east and southeast.

The 'Morrissey Metamorphic Suite' included rocks now assigned to the Camel Hills Metamorphics (Fig. 1) on ERRABIDDY and LANDOR (Sheppard and Occhipinti, 2000), and the Padbury Group on MOORARIE (Occhipinti and Myers, 1999). Many components included in the 'Morrissey Metamorphic Suite' by Williams (1986) are separated by large areas of granite and major faults. In addition, it is probable that not all metasedimentary rocks in the Gascoyne Complex are of the same age or were metamorphosed at the same time. This also applies to the formation of the metamorphosed mafic and ultramafic igneous rocks in the region. Therefore, the meta-sedimentary and meta-igneous rocks on GLENBURGH have been grouped into the Moogie Metamorphics (Fig. 3).

On DAURIE CREEK to the west, the Moogie Metamorphics is dominated by quartzite, which is derived from quartz sandstone and forms large strike ridges. Calc-silicate gneiss and marble also form part of this unit. The quartzite, calc-silicate gneiss, and marble probably formed a coherent sedimentary package because the marble and calc-silicate gneisses on DAURIE CREEK show bedding traces, both internally and against the quartzite. The Mumba Pelite is also interlayered with the calc-silicate gneiss and marble, suggesting that they are all part of a single sedimentary package. All units have been multiply deformed and variably metamorphosed to prograde amphibolite or granulite facies and retrograde greenschist facies.

The Mumba Pelite includes pelitic schist and quartzite, and forms the main component of the Moogie Metamorphics on GLENBURGH. Amphibolite and ultramafic schist are locally tectonically interleaved with the Mumba Pelite, although their original relationship with the precursor sedimentary rocks is unknown.

The age of the Moogie Metamorphics is poorly constrained. It is intruded by granites of the Dalgaringa Supersuite and therefore must be older than c. 2005 Ma. Rocks of the Moogie Metamorphics are faulted against the Halfway Gneiss, so the relative age of the two units is uncertain. Early, originally subhorizontal folds that deform bedding within the Moogie Metamorphics also deform a well-developed gneissic layering in the Halfway Gneiss. If the two units initially developed in the same terrane, then the Moogie Metamorphics must be younger than the Halfway Gneiss. However, if the two units initially developed in separate terranes and were juxtaposed by layer-parallel deformation (D_{2g} of the Glenburgh Orogeny; Table 1), then it is not possible to establish their relative ages.

Supracrustal rocks

Undivided supracrustal rocks of the Moogie Metamorphics include amphibolite, ultramafic schist, metamorphosed banded iron-formation, calc-silicate gneiss, and marble. These rocks have been variably metamorphosed and deformed. They form xenoliths in, and are tectonically interleaved with, granitoid rocks of the Dalgaringa Supersuite, and appear to be tectonically interleaved with granitic gneiss of the Halfway Gneiss. High-grade pelitic rocks in the Paradise Well area are associated with abundant mafic granulite, but their outcrops are too small to show on the map and they are included within a unit of the foliated and gneissic granites (*ⱣmDa*).

Amphibolite (*ⱣmM(a)*, *ⱣmM(ao)*)

Lenses and strips of fine- and medium-grained amphibolite (*ⱣmM(a)*) are extensively interleaved with the Halfway Gneiss, 2005–1970 Ma foliated and gneissic granite of the Dalgaringa Supersuite, and the Mumba Pelite. Amphibolite also forms xenoliths within granite of the Moorarie Supersuite. They are particularly abundant in a wide, northeasterly trending belt between Paradise Well and Carradarra Well, south of Meerawana Well, and 2 km west of Watson Bore. Higher grade equivalents of the amphibolites are associated with mafic granulite and pelite between Paradise Well and Condamine Well. The amphibolite and mafic granulite form low rubbly hills that have a dark-brown colour on aerial photographs.

In most areas the amphibolites constitute up to a few percent of the outcrop. Most of the amphibolite layers are less than 2 m wide and can be traced along strike for about 50 m. About 2 km west of Watson Bore, numerous layers of amphibolite outcrop in a zone about 2 to 3 km long and 2 km wide. These amphibolites may be repeated by isoclinal folding or faulting subparallel to the regional foliation, but this cannot be established due to the rubbly nature of the outcrop. The mafic granulites are tightly or isoclinally folded around Paradise Well, and layers are repeated throughout the area. Locally, the mafic rocks contain wine-red garnet porphyroblasts, up to 2 cm in diameter, enclosed by a layer-parallel foliation.

Contacts between the amphibolites and foliated to gneissic granites of the Dalgaringa Supersuite and Halfway Gneiss are commonly tectonic and parallel to the foliation or compositional banding in the granitic rocks. Locally, a few mafic layers are discordant at a low angle to the foliation or layering in the granites, indicating that at least a few of the amphibolites were mafic dykes. It is possible that in the Dalgaringa Supersuite the amphibolites formed xenoliths in the granite that were subsequently deformed with the granite to form the gneisses. However, most of the amphibolites have a weak compositional banding parallel to the foliation or gneissic layering in the surrounding granitic rocks. The amphibolites and their compositional banding are folded along with the granitic rocks. The amphibolites are intruded by sheets and veins of leucocratic biotite granite and pegmatite (*ⱣgDp*) and by the Nardoo Granite.

Metamorphosed coarse-grained gabbroic rocks (*ⱣmM(ao)*) outcrop in the northwestern corner of GLENBURGH. These rocks form rubbly hilly outcrops and appear to be largely undeformed. The medium- to coarse-grained, even-textured ('gabbroic-textured') mafic rocks consist of plagioclase and tremolite–actinolite, with accessory titanite. Within outcrops of even-textured granite of the Moorarie Supersuite (*ⱣgMe*), a few of the amphibolite (*ⱣmM(a)*) xenoliths form small knobbly hills and contain gabbroic textures; however, their aerial photograph patterns are commonly indistinguishable from amphibolite in the same area, and they are not included in the gabbroic unit (*ⱣmM(ao)*).

Most of the amphibolites are fine to medium grained and even textured, with a weak compositional banding. They have a polygonal texture and are composed of olive-green or brown hornblende and plagioclase (labradorite

Table 1. Summary of deformation and metamorphic events on Glenburgh

Deformation event	*Metamorphic event*	*Age*	*Location*	*Domain*	*Structures*
Pre-Glenburgh Orogeny (>2000 Ma)		c. 2550 Ma	Formation of granite protoliths to Halfway Gneiss		
		?	Deposition of protoliths to Moogie Metamorphics		
Glenburgh Orogeny (1960–2000 Ma)					
D_{1g}	M_{1g}; medium to high grade	<2000 Ma	Foliation in gneissic and foliated granite of the Dalgaringa Supersuite	SGT	S_{1g}
?		?	Gneissosity in Halfway Gneiss	NGT	
	Continuation of M_{1g}; high grade, up to granulite facies	c. 1990 Ma	Metamorphism and local folding of c. 2000 Ma granitic rocks and coeval intrusion of pegmatite, quartz diorite, and monzogranite	SGT	
		c. 1975 Ma	Intrusion of the Nardoo Granite into older granitic rocks	SGT	
D_{2g}	M_{2g}; epidote–amphibolite facies		Deformation of Nardoo Granite. Local retrogression of high-grade assemblages in Dalgaringa Supersuite. Folding of 2000–1990 Ma foliated and gneissic granites and mafic gneisses of the Dalgaringa Supersuite	SGT	F_{2g}, S_{2g}
	Medium to high grade; ?amphibolite facies	?	Juxtaposition of the Halfway Gneiss and the Mumba Pelite; formation of flat faults and mylonite zones; subhorizontal folds in Moogie Metamorphics and Halfway Gneiss; foliation in Moogie Metamorphics	NGT	?S_{2g}
		c. 1950 Ma	Intrusion of dykes of leucocratic granodiorite, biotite trondhjemite, and monzogranite	SGT	
Capricorn Orogeny (1830–1780 Ma)					
D_{1n}	M_{1n}	c. 1825 Ma	Intrusion of plugs, sheets, and veins of granitic rocks	SGT	F_{1n}, S_{1n}
		c. 1810 Ma	Intrusion of sheets and veins of Dumbie Granodiorite Upright folding in Moogie Metamorphics and Halfway Gneiss Local foliation in c. 1825 Ma Moorarie Supersuite	NGT, ?SGT NGT SGT	
		c. 1800 Ma	Intrusion of Scrubber Granite. Local deformation of the Scrubber Granite	NGT, ?SGT	
		?>1800 Ma	Deposition of Mount James Formation sediments	NGT, SGT	
Local extension		?>1640 Ma	Coplanar deformation with D_{1n} [(a)] possible into tight asymmetric folds; deformation of Mount James Formation	NGT, SGT	
		?1640 Ma	Deposition of Bangemall Supergroup in intracratonic sag over the Gascoyne Complex (including Glenburgh Terrane)		
			Extension, intrusion of dolerite sills into the Bangemall Superbasin		
Edmundian Orogeny (1020–750 Ma)					
D_{1e}	Subgreenschist facies	<c. 1020 Ma	Deformation of Edmund Group, coplanar with D_{1n} in Glenburgh Terrane	SGT, NGT	F_{1e}, S_{1e}
D_{2e}	?	>750 Ma	Deformation of the Edmund Group	SGT, NGT	S_{2e}
		750 Ma	Extension, intrusion of northerly trending dolerite dykes (Mundine dyke swarm)		
Carnarvon Basin		320–270 Ma	Deposition of Lyons Group		

NOTE: SGT: Southern Domain of Glenburgh Terrane
NGT: Northern Domain of Glenburgh Terrane
(a) Alternatively, the Mount James Formation may have been deformed during the Edmundian Orogeny

or andesine), with minor quartz and ilmenite or titanite. Clinopyroxene is typically absent, but constitutes up to 15% of the rock in a few samples. Clinopyroxene forms cores to olive-green hornblende; rare samples contain clinopyroxene oikocrysts with blebby inclusions of plagioclase and quartz, and narrow rims of hornblende. A small number of samples consist of quartz amphibolite; these rocks contain about 15% quartz, and the plagioclase is andesine in composition. The quartz amphibolites were probably derived from metamorphism of a diorite or quartz diorite protolith.

The minerals within the amphibolites and quartz amphibolites are replaced by variable amounts of greenish-blue hornblende or actinolite, sodic plagioclase, and epidote. The degree of overprinting by this lower grade assemblage varies from weak to near complete. The lower grade assemblage is common in the northern half of GLENBURGH, and in the eastern part between Dalgety Brook and the Dalgety Downs – Landor road.

Actinolite schist and tremolite schist (ꞒmM(u))

In the northwestern part of GLENBURGH, layers and lenses of actinolite schist and tremolite schist (*ꞒmM(u)*) after ultramafic rock are common in an east-southeasterly trending belt extending from around Dunnawah Well to east of Geringee Bore. In the northeastern part of GLENBURGH, a few layers of ultramafic schist are present between Ti Tree Well and Puckford Bore. The layers range from about 10 m wide and 500 m long to about 50 m wide and more than 2 km long. Contacts between the schists and the enclosing granitic gneisses are tectonic. Both types of schist weather to a reddish-brown exterior and form knolls or low, narrow ridges. Actinolite schists are dark green on fresh surfaces, whereas tremolite schists are pale green. Actinolite schists comprise 90% or more actinolite, with minor interstitial clinozoisite, albite, and titanite. Tremolite schists may be composed entirely of tremolite, or of tremolite, serpentine, talc, and minor calcite. Cores of green hornblende to tremolite are common in rocks composed solely of tremolite. The precursors to the schists were probably pyroxenite and olivine pyroxenite.

Metamorphosed banded iron-formation (ꞒmM(i))

In the southeastern part of GLENBURGH, several layers of very weathered, metamorphosed banded iron-formation (*ꞒmM(i)*) form prominent narrow ridges about 2.5 km north and 3 km northeast of Paradise Well. The layers are up to 10 m thick and can be traced along strike for between 0.4 and 1.5 km. The northern half of GLENBURGH has rare small lenses (2–3 m wide and less than 20 m long) of metamorphosed iron formation. About 1.5 km north of Middle Well in the northwestern part of GLENBURGH, the metamorphosed banded iron-formation is associated with the pelitic schist and consists of iron oxide (after magnetite) and quartz.

Calc-silicate gneiss (ꞒmM(k)) and marble (ꞒmM(km))

Calc-silicate gneiss (*ꞒmM(k)*) and marble (*ꞒmM(km)*) are minor, but widespread, rock types on GLENBURGH. The rocks form narrow lenses, mostly interleaved with the Halfway Gneiss and foliated and gneissic granites of the Dalgaringa Supersuite. Most calc-silicate and marble layers are between 50 and 200 m wide and 0.3 to 2 km long. Calc-silicate layers are dark brown on aerial photographs and outcrop as low, rocky strike ridges. Layers of marble may have a white or dark-grey pattern on aerial photographs, and outcrop as low, blocky, rugged hills within the granitic gneiss.

In the northern part of GLENBURGH, lenses of calc-silicate gneiss and marble appear to be faulted against the Halfway Gneiss and contain a moderate- to well-developed gneissic layering that is folded with the Halfway Gneiss. The calc-silicate gneiss and marble are locally intruded by granite of the Moorarie Supersuite, for example, about 5 km southwest (MGA 419600 7223250) of Hectors Bore, where veins of monzogranite cut calc-silicate rock, and 2.5 km south (MGA 413400 7223700) of Middle Well, where leucocratic coarse-grained granite and pegmatite cut marble. At the latter locality the marble forms a lens about 100 m long, and is one of a series of lenses or pods of marble in this zone.

East of Hectors Bore, the marble outcrop (*ꞒmM(km)*) is difficult to differentiate from massive dolostone near the base of the Palaeoproterozoic to Mesoproterozoic Irregully Formation (Edmund Group).

In the southeastern part of GLENBURGH, several rafts of calc-silicate gneiss are present in foliated and gneissic granite of the Nardoo Granite. Most layers of calc-silicate and quartzite gneiss are less than 3 m wide and up to a few hundred metres long. Calc-silicate and quartzite gneiss layers, up to about 100 m thick and nearly 1 km long, outcrop southeast and east of Ghnyndad Bore (MGA 433600E 7189300N and 436800E 7190800N respectively). Contacts between the calc-silicate and quartzite gneiss and foliated to gneissic granites of the Dalgaringa Supersuite are either not exposed or tectonic. Calc-silicate and quartzite gneiss is intruded by the Nardoo Granite and leucocratic biotite granite and pegmatite, which may belong to the 1830–1780 Ma Moorarie Supersuite.

Calc-silicate gneiss is composed of two main rock types: fine- to medium-grained amphibole- or diopside-rich gneiss (*ꞒmM(k)*) and subordinate medium-grained massive marble (*ꞒmM(km)*). The amphibole and diopside gneisses are green on a fresh surface, but weather to a reddish-brown exterior. They are typically compositionally layered, with alternations of amphibole- or diopside-rich and quartz-rich layers, up to several centimetres thick. The marbles are white or cream on fresh surfaces, but weather to a pale- or dark-grey exterior. Medium-grained anorthosite is a very minor component of the calc-silicate gneiss.

In the southern part of GLENBURGH, the amphibole- and diopside-rich gneisses are composed of weakly pleochroic pargasite or diopside, with quartz, subordinate plagioclase, and minor amounts of titanite. A few samples contain epidote rather than plagioclase. Most of the rocks display amoeboid and polygonal granoblastic textures. In the northern part of GLENBURGH, equivalent rocks contain abundant actinolite–tremolite and epidote, but no diopside.

The most common assemblage is epidote, with subordinate actinolite–tremolite, albite, calcite, quartz, and titanite. Some layers are composed of actinolite, epidote, and titanite.

The marbles have a polygonal texture and are mainly composed of dolomite, with or without quartz. There are rare amoeboid granoblastic rocks composed of calcite, dolomite, garnet, forsterite, clinohumite, serpentine, and accessory opaque minerals. Forsterite forms cores to pale-yellow to orange-yellow clinohumite. Serpentine also partly replaces forsterite. Domains of coarser grained calcite–dolomite–forsterite are probably relicts from a higher grade metamorphic event. In some areas in the northern part of GLENBURGH, abundant magnesium-rich chlorite replaces biotite within the marble.

Mumba Pelite (ĿmMm, ĿmMmq)

The Mumba Pelite (*ĿmMm*) forms two parallel belts, each up to about 6 km wide, in the northern part of GLENBURGH. The belts outcrop north of the Dalgety Fault and north of the Mooloo Fault (Fig. 3). They mainly trend east-southeasterly, but in the central-northern part the northern belt is folded into a west-southwesterly orientation. These belts continue westward onto DAURIE CREEK and northward onto the MOUNT PHILLIPS 1:250 000 sheet.

On GLENBURGH the Mumba Pelite consists of quartz–sericite(–chlorite–biotite) schist, chloritoid-bearing schist (Fig. 5a,b), and lesser amounts of quartzite, feldspathic metasandstone, calc-silicate gneiss, and amphibolite. The Mumba Pelite forms rocky strike ridges and hills up to 500 m high; the highest ridges are defined by outcrops of quartzite. Most rocks, in particular the chloritoid-bearing schist, are commonly weathered and ferruginized.

Southwest of Mia Well, the Mumba Pelite is intruded by a large sheet of foliated, medium-grained, biotite–muscovite granite (*ĿmMe*), as well as a sheet and numerous veins and dykes of variably deformed muscovite pegmatite (*ĿmMp*).

Compositional layering within the schist is commonly well developed and appears to represent bedding (Fig. 5a). For the most part the compositional layering is only 2 mm – 1 cm thick, although local graded bedding in quartz metasandstone is up to 10 cm thick. The Mumba Pelite also has a well-developed bedding-parallel foliation. Primary compositional layering is typically indicated by the presence of more or less chloritoid in the S_1 foliation, which is subparallel to the S_0 foliation. At a locality to the west on DAURIE CREEK (MGA 394260E 7217900N), bedding is largely defined by variable amounts of magnetite in the layering. Large porphyroblasts of magnetite up to 1 cm in diameter are present in a few layers; chloritoid is less abundant in these rocks.

Locally, the pelitic schist contains abundant garnet porphyroblasts, although these are commonly pseudomorphed by chloritoid(–chlorite–quartz). In sample GSWA 164347 (MGA 412400E 7227800N) garnet forms amoeboid-textured porphyroblasts, which are anhedral and contain deep embayments locally filled with chlorite and epidote. The garnet also contains inclusions of epidote.

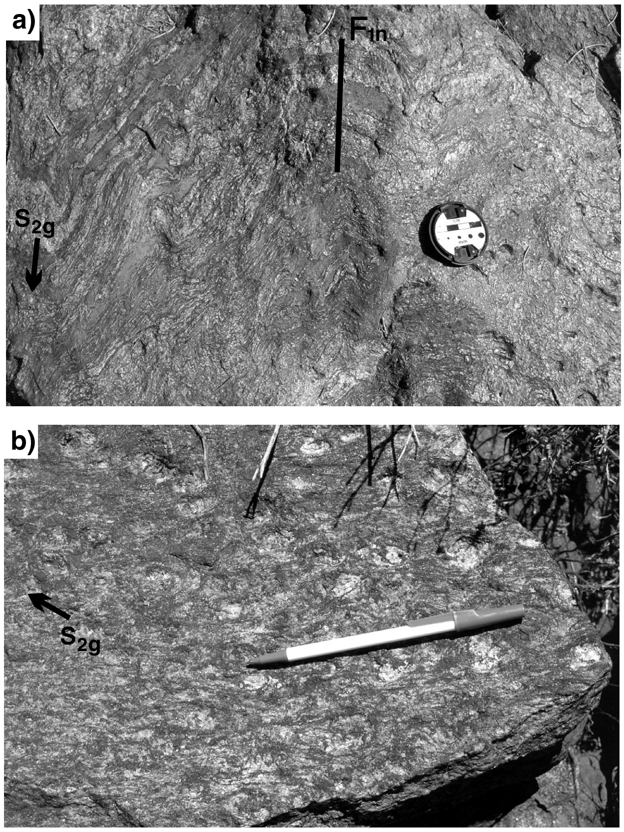

Figure 5. Metasedimentary schist of the Mumba Pelite: a) chloritoid–bearing schist with a well-developed S_{2g} foliation, developed subparallel to bedding (defined by compositional variations). The schist is folded about an upright, closed, moderately plunging F_{1n} fold (MGA 425900E 7230440N); b) chloritoid-bearing schist with porphyroblasts of feldspar now pseudomorphed by sericite (MGA 403140E 7213950N)

Small crystals of plagioclase are scattered throughout the schist. Accessory minerals include titanite, which form large crystals with amoeboid texture. Biotite is elongate and defines the foliation. Chlorite, although abundant, is not always aligned and locally replaces biotite or garnet (or both).

The chloritoid-bearing schist, which is most abundant just north of the Dalgety Fault, consists of two main rock types: quartz–sericite–albite–chloritoid(–chlorite) schist and chloritoid–chlorite–sericite–quartz–albite (–garnet) schist. A few transitional rock types are present. In outcrop, both rock types commonly show a millimetre- or centimetre-scale compositional layering containing a subparallel fabric and folding by regional F_{1n} folds (Fig. 5a).

Quartz–sericite–albite–chloritoid(–chlorite) schist is pale green when fresh or brown when weathered. Chloritoid comprises about 10–15% of these rocks, commonly forming ‘clots’ or ‘clusters’, or small (<1.5 mm long) dark-green to black chloritoid porphyroblasts. The chloritoid is commonly aligned in the foliation, but also forms randomly oriented porphyroblasts that overprint the foliation, which is most often defined by sericite and chlorite. Occasionally, chloritoid porphyroblasts are enclosed by the foliation.

Chloritoid–chlorite–sericite–quartz–albite(–garnet) schists are dark green on fresh surfaces, with a reddish-brown exterior. Fresh outcrops of these rocks are present north of the Dalgety Fault as well as north of the Mooloo Fault. The rocks commonly have a 'knobbly' appearance due to knots of fine-grained sericite up to 1 cm in diameter that are enclosed by the foliation. A few of the sericite knots contain relict orthoclase (Fig. 5b). Chloritoid comprises 30% or more of these rocks, forming randomly oriented porphyroblasts that overprint the foliation, which is commonly defined by chlorite and sericite. Garnet is rare, forming colourless xenoblastic crystals in a few samples. Accessory minerals comprise rutile and apatite.

Quartzite gneiss and quartzofeldspathic schist (*ƁmMmq*) derived from sedimentary rocks are interlayered with the pelitic rocks. Metamorphosed quartz sandstone, feldspathic sandstone, and feldspathic granule conglomerate typically form layers less than 20 cm thick. Metasandstone and granule metaconglomerate are the predominant rock types in places, such as immediately north of Moogie Well. The metasandstone and granule metaconglomerate appear to be internally bedded, and local cross-bedding and graded bedding are preserved. The quartzite gneiss largely consists of quartz, with minor amounts of sericite. In the metamorphosed feldspathic sandstone, feldspar is mostly or wholly replaced by sericite, therefore, these rocks now consist of quartz with variable amounts of sericite and chlorite.

Palaeoproterozoic Dalgaringa Supersuite

The Dalgaringa Supersuite consists of massive, foliated, and gneissic granites dated at 2005–1970 Ma (Sheppard et al., 1999b). On Glenburgh the supersuite comprises two episodes of magmatism, separated by a deformation and high-grade regional metamorphic event. The two magmatic episodes are represented by 2005–1985 Ma foliated to gneissic quartz diorite, tonalite, granodiorite, and monzogranite (Fig. 6a,b), and c. 1975 Ma tonalite and granodiorite of the Nardoo Granite. Between these two magmatic episodes, and after the deformation and regional metamorphism, sheets of foliated leucocratic monzogranite intruded the early foliated to gneissic granites.

Foliated and gneissic 2005–1985 Ma granites outcrop over a wide area in the southern part of Glenburgh. To the east, in the southwestern corner of Landor, these granites are locally present as inclusions in the Nardoo Granite. They may also underlie Cainozoic units of the Macadam Plains in the eastern half of Landor. Foliated and gneissic granites of the same age (Nelson, in prep.) also outcrop extensively within the Carrandibby Inlier southwest of Glenburgh (Fig. 1), and are included in the Halfway Gneiss on northern Glenburgh.

Foliated to gneissic granites (ƁgDg, ƁgDgf, ƁgDf, ƁgDp, ƁgDn, ƁgDa, ƁgDm)

Foliated and gneissic granites outcrop in a wide, easterly to east-northeasterly trending belt in the southern part of Glenburgh (Fig. 3). The rocks range from strongly deformed and completely recrystallized foliated and gneissic granite, in zones of high strain, to statically recrystallized granites with preserved intrusive relationships in areas of low strain. All the rocks have been metamorphosed at medium to high grade; however, the following discussion only uses metamorphic terminology where the rocks have undergone substantial strain. Many rocks display compositional layering.

The foliated to gneissic granites are divided into a number of units that are composites of different rock types. In outcrop the individual rock types comprise sheets, dykes, and veins, and cannot themselves be represented as separate units on the map. The boundaries between the mapped units are typically gradational, and mark changes in the abundance of one or more main rock types. The boundaries are commonly parallel to the regional tectonic fabric. The different units cannot be readily distinguished on aerial photographs.

The foliated to gneissic granites comprise five main rock types:

- fine- to medium-grained, mesocratic quartz diorite, tonalite, and diorite (collectively referred to as 'tonalite');
- fine- to medium-grained, pale-grey biotite monzogranite and leucocratic tonalite ('fine-grained granite');
- medium-grained, variably porphyritic tonalite and granodiorite ('mafic granodiorite');
- medium-grained, leucocratic biotite monzogranite and granodiorite ('felsic granodiorite');
- coarse-grained, leucocratic biotite granite and pegmatite (*ƁgDp*; 'pegmatite').

Veins and sheets of coarse-grained leucocratic biotite granite and pegmatite (*ƁgDp*) consistently intrude the other four rock types. All these rock types, including the pegmatite, are extensively intruded by medium-grained leucocratic monzogranite (*ƁgDm*). All rock types in the Dalgaringa Supersuite commonly have a blotchy appearance due to the presence of clots (0.5 – 2 cm in diameter) of fine-grained biotite after garnet. The foliated and gneissic granites are tectonically interleaved with amphibolite and calc-silicate gneiss.

In zones of moderate to high strain the rocks are pegmatite banded and strongly resemble Archaean mesocratic granitic gneiss in the Narryer Terrane (Occhipinti et al., 1998b; Sheppard and Swager, 1999). Williams et al. (1983b) and Williams (1986) interpreted the foliated and gneissic granites as a migmatite produced during Proterozoic high-grade metamorphism and anatexis of Archaean granites. However, SHRIMP U–Pb zircon dating of several samples collected during this study (Nelson, 1999) indicates that all the rocks are Palaeoproterozoic in age. The foliated and gneissic granites represent a major magmatic event between 2005 and 1985 Ma.

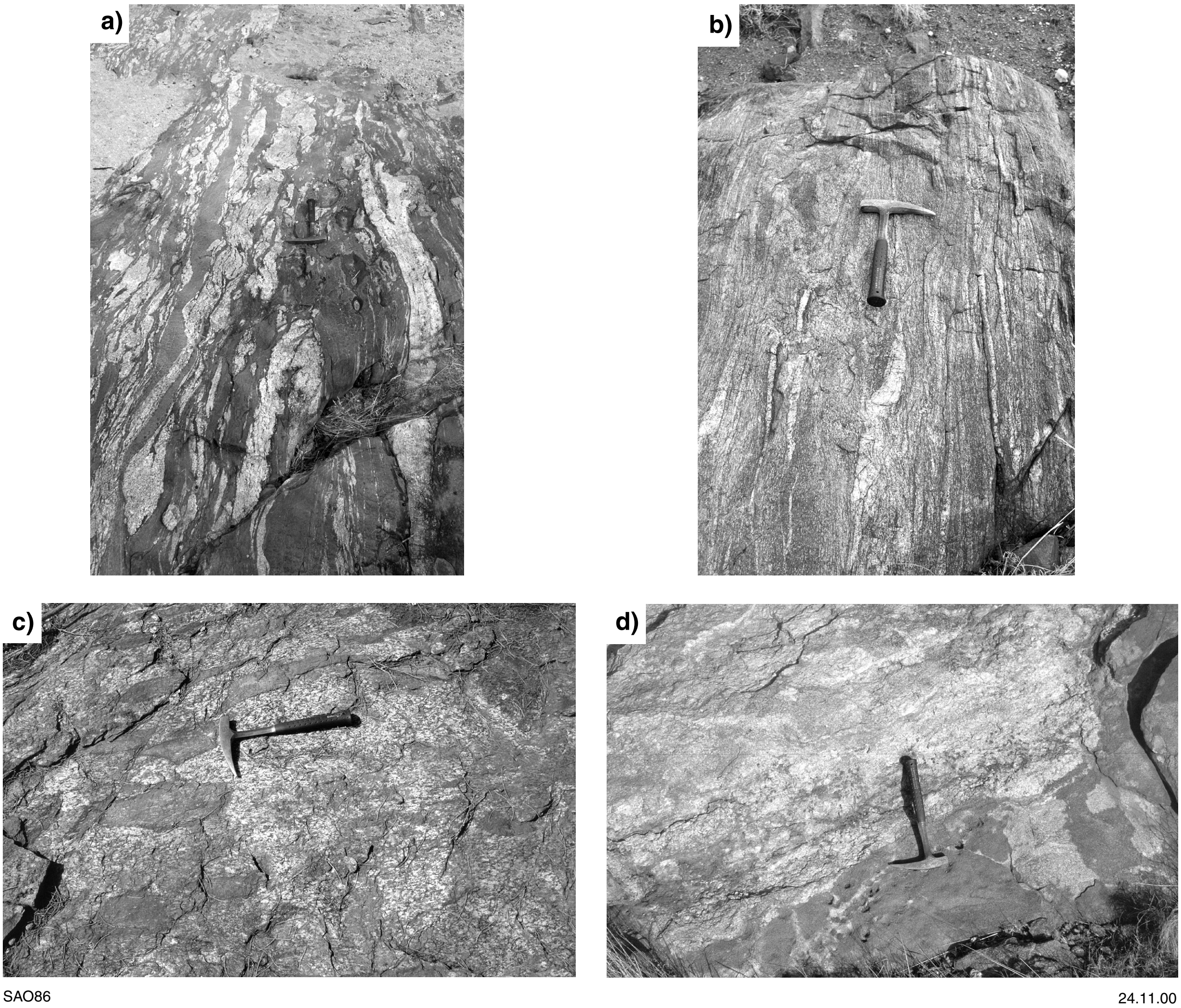

Figure 6. Metamorphosed and deformed granitic rocks of the Dalgaringa Supersuite: a) pegmatite-banded tonalite gneiss (MGA 421840E 7189950N); b) pegmatite-banded monzogranite gneiss (MGA 432640E 7186250N); c) mesocratic or mafic granodiorite with inclusions of fine-grained tonalite (MGA 441140E 7200950N); d) thick sheet of metamorphosed biotite pegmatite dated at 1994 ± 2 Ma, intruding metamorphosed biotite monzogranite. Pitted surface in monzogranite marks weathering-out of biotite clots after garnet (MGA 428740E 7192650N)

Rock types

Tonalite

Fine-grained mesocratic tonalite is consistently intruded by all the other foliated and gneissic granites (Fig. 6a). Contacts between the tonalite and amphibolite layers are typically tectonic, but in places amphibolite intrudes the granitic rocks; therefore, at least some of the amphibolites were mafic dykes. Weathered surfaces on the tonalite are typically dark grey and pitted. Fine-grained metamorphosed diorite and quartz diorite are distinguished from amphibolite by the absence of quartz in the latter.

Two samples of fine- to medium-grained, mesocratic tonalite on GLENBURGH were dated. The first sample, GSWA 142926, is a fine-grained metatonalite from a low-strain zone about 5 km northwest (MGA 443430E 7200110N) of Mulunka Well, with a crystallization age of 2002 ± 3 Ma (Nelson, 1999). The second sample, GSWA 142933, is a high-grade metadiorite from about 350 m south of Meerawana Well, with a crystallization age of 1989 ± 3 Ma (Nelson, 1999).

Quartz diorite, tonalite, and diorite have textures that range from anhedral granular in massive samples through to amoeboid and granoblastic in compositionally layered rocks. The rocks are composed of plagioclase, biotite, and quartz, and minor amounts of magnetite and ilmenite. Green hornblende, with optically continuous rims of sodic hornblende, is present in many samples. Quartz typically constitutes about 10–20% of the rocks, and thus most rocks are quartz diorite. Most plagioclase crystals consist of unzoned andesine, but a few relict coarser plagioclase crystals display normal and oscillatory zoning. One of the dated samples (GSWA 142933) has a granoblastic to amoeboid texture and is composed of andesine, clinopyroxene, biotite, and quartz. Accessory minerals in most samples consist of apatite, zircon, and metamict and altered allanite.

Fine-grained granite

Fine-grained, pale-grey granite is commonly interlayered with the tonalite. In areas of low strain, preserved igneous relationships show that the fine-grained granite intruded the tonalite. Locally, preserved net-vein textures imply that there is little age difference between the two rock types. The fine-grained granites are pale grey and contain biotite crystals disseminated through the groundmass and as clots. Preferential weathering of biotite clots in the granites typically gives the rocks a strongly pitted appearance.

A sample of fine-grained biotite monzogranite (GSWA 142927) from about 5 km northwest (MGA 443460E 7200070N) of Mulunka Well gave a SHRIMP U–Pb zircon date of 1999 ± 5 Ma (Nelson, 1999), which is interpreted as the age of igneous crystallization. This age is indistinguishable from that of tonalite sample GSWA 142926, which is net-veined by the monzogranite.

The fine-grained granite consists of either biotite monzogranite (Fig. 6b) or leucocratic biotite tonalite. These two rock types are not readily distinguished in the field. The rocks range from massive and statically recrystallized through to strongly foliated or gneissic and finely pegmatite banded. Monzogranite consists of quartz, microcline, oligoclase and a few percent biotite. Leucocratic tonalite consists of oligoclase–andesine, quartz, and a few percent biotite.

Mafic and felsic granodiorite

Sheets of medium-grained, variably porphyritic tonalite and granodiorite (mafic granodiorite; Fig. 6c), and medium-grained, leucocratic biotite monzogranite and granodiorite (felsic granodiorite) intrude or are tectonically interleaved with the mesocratic tonalite and fine-grained granite. The mafic and felsic granodiorites intrude and contain lenticular and angular inclusions of foliated tonalite. Larger inclusions of tonalite, up to 1 m long, typically have a blocky shape.

The mafic granodiorite is undated; however, it has the same field relationships as the felsic granodiorite, and the two rock types locally grade into each other, suggesting that they are essentially coeval. A sample of foliated monzogranite (i.e. felsic granodiorite; GSWA 142925) from 300 m south of Challenger Well has a magmatic crystallization age of 2002 ± 3 Ma (Nelson, 1999).

Rocks referred to as mafic granodiorite in the field consist of anhedral granular or polygonal-textured, metamorphosed tonalite or K-poor granodiorite. Samples comprise a few percent relict igneous plagioclase phenocrysts in a matrix of fine-grained plagioclase, quartz, and biotite, with or without greenish-blue hornblende. Relict igneous plagioclase crystals display normal zoning, whereas finer grained plagioclase in the matrix is unzoned. Magnetite is a widespread minor mineral, and zircon, apatite, and allanite are the main accessory minerals. Mafic clots prominent in hand specimen are composed of fine-grained biotite(–magnetite–epidote).

Rocks called felsic granodiorite in the field consist of anhedral granular or xenoblastic biotite monzogranite or K-rich granodiorite. The rocks are composed of microcline, plagioclase, quartz, and about 10% biotite. Most of the rocks are fine grained, but a few domains of medium- to coarse-grained microcline and plagioclase with rims of myrmekite are preserved. Xenoblastic porphyroblasts of garnet are preserved in a few samples. Most crystals are replaced by fine-grained, brownish-green biotite. Opaque minerals are uncommon, and mainly replaced by epidote and titanite. Zircon, apatite, and allanite are accessory minerals.

Pegmatite (*ᵽgDp*)

Sheets and veins of leucocratic pegmatite (*ᵽgDp*) are ubiquitous in the foliated and gneissic granites of the Dalgaringa Supersuite. Where abundant, they give the rocks a gneissic appearance. Individual pegmatite sheets are up to 3 or 4 m thick. Williams (1986) interpreted the sheets and veins of pegmatite as leucosome veins within ‘migmatites’. A sample from a sheet of coarse-grained, leucocratic biotite pegmatite (*ᵽgDp*) about 3 km south (MGA 428800E 7192730N) of Fred Well has an igneous crystallization age of 1994 ± 2 Ma (GSWA 142930; Nelson, 1999; Fig. 6d). The pegmatite forms a sheet that intrudes fine- to medium-grained, mesocratic quartz diorite, tonalite, and diorite, and fine- to medium-grained, pale-grey biotite monzogranite and leucocratic tonalite.

The pegmatite and leucocratic granite sheets are composed of metamorphosed and recrystallized subsolvus pegmatite and monzogranite. Recrystallized hypersolvus pegmatite (plagioclase bearing) and metatrondhjemite are minor rock types. Subsolvus pegmatite and monzogranite are composed of microcline (or microperthite) and quartz, subordinate plagioclase, and minor amounts of biotite and garnet. Garnet is commonly replaced by a brownish-green biotite. Myrmekitic textures are widespread.

Map units

The five main rock types described above comprising the foliated to gneissic granites have been grouped into several mappable units.

Mafic and felsic granodiorite (*ᵽgDg*, *ᵽgDgf*)

The largest unit (*ᵽgDg*; Fig. 6a–d) is dominated by medium-grained tonalite and granodiorite (mafic granodiorite) and leucocratic biotite monzogranite and granodiorite (felsic granodiorite). The unit also contains subordinate fine-grained tonalite and granite. Exposure is good, and typically consists of boulders and pavements on low hills and rises. Tors and small whalebacks are common in low-strain zones. The mafic and felsic granodiorite that constitute this unit resemble the mafic and felsic phases of the Nardoo Granite, such that they cannot always be confidently distinguished from each other. However, geochronology demonstrates that the granodiorites are older than the Nardoo Granite.

A subset of the largest unit (*ᵽgDg*), consisting mainly of medium-grained, leucocratic biotite monzogranite and granodiorite (felsic granodiorite, *ᵽgDgf*), is extensively exposed as sheets up to several hundred metres thick around Hadlam Well and Challenger Well. Elsewhere, it typically forms lenses within the other larger units. Exposure is very good, consisting of small rocky hills and ridges covered in boulders and tors. This unit is commonly distinguishable on aerial photographs when it is enclosed in units dominated by fine-grained mesocratic tonalite and fine-grained granite.

Fine-grained tonalite and granite (*ᵽgDf*)

Interlayered fine-grained mesocratic tonalite and fine-grained pale-grey granite (*ᵽgDf*) form a large northeasterly trending belt, up to several kilometres wide, extending from southeast of Paradise Well to northeast of Carradarra Well. The unit also forms a large screen in the Nardoo Granite, several kilometres long and nearly 1 km wide, north of Salt Well. Mafic and felsic granodiorite are subordinate or minor rock types in this unit. Sheets and veins of pegmatite and leucocratic biotite granite (*ᵽgDp*) extensively intrude the unit. Exposure mainly consists of weathered boulders and pavements on low rises and hills.

Fine-grained tonalite (*ᵽgDn*)

Fine-grained mesocratic tonalite (*ᵽgDn*) forms strips or lenses a few hundred metres wide and up to 3 km long. Fine-grained granite is only a minor component of this unit, and this distinguishes it from the interlayered tonalite and granite unit (*ᵽgDf*). Mafic and felsic granodiorite are typically minor components. In the southern part of GLENBURGH, this unit is common between Meerawana Well and Ghnyndad Bore. The rocks of this unit commonly have a strongly banded appearance due to the presence of abundant veins and sheets of pegmatite and leucocratic biotite granite (*ᵽgDp*).

Granodiorite, mafic granulite, and pelite (*ᵽgDa*)

The area around Paradise Well contains a distinctive association of mafic and felsic granodiorite, with abundant layers of mafic granulite and minor pelite (*ᵽgDa*). Mafic granulite layers may make up as much as 30% of the outcrop and give the unit a dark-brown colour on aerial photographs. This unit (*ᵽgDa*) also contains rare lenses of diatexite migmatite, up to 100 m long and 10 m wide, and pelitic granofels. Our mapping could not substantiate earlier suggestions that gneissic rocks in the Paradise Well area largely consist of high-grade pelitic gneiss (Williams et al., 1983b; Williams, 1986). In addition, the amount of migmatite suggested by Williams (1986) is overstated because he interpreted crosscutting pegmatite veins in granitic gneiss as anatectic melt in situ, and regarded a few igneous textures as metamorphic and having formed during migmatization of country rock.

The rare lenses of diatexite around Paradise Well consist of medium-grained, siliceous leucosome (interpreted as melt) with layers or fragments of dark-grey, biotite(–garnet)-rich rock (restite). Where the proportion of leucosome is about 50%, restite forms semicontinuous layers (Fig. 7a), but at higher proportions of leucosome (up to 80%), restite forms equidimensional to lenticular fragments between 1 and 20 cm long (Fig. 7b). Pelitic granofels is a fine- to medium-grained rock, with porphyroblasts of almandine garnet about 1 cm in diameter.

Leucocratic biotite monzogranite (*ᵽgDm*)

Leucocratic biotite monzogranite (*ᵽgDm*) is extensively exposed in the southwestern corner of GLENBURGH. West of the Deadman Fault, it forms a pluton at least 35 km^2 in area, containing numerous rafts and screens of interlayered fine-grained mesocratic tonalite and fine-grained granite (*ᵽgDf*). These rafts are mostly less than 2 km long, although one very large strip is more than 4 km long and up to 500 m wide. East of the Deadman Fault and south of Geeranoo Creek in the southernmost part of GLENBURGH, leucocratic biotite monzogranite forms sheets that extensively intrude interlayered tonalite and fine-grained granite (*ᵽgDf*). The pluton and sheets commonly form low rocky hills. Exposure is good, but commonly weathered, as this area is just below an old

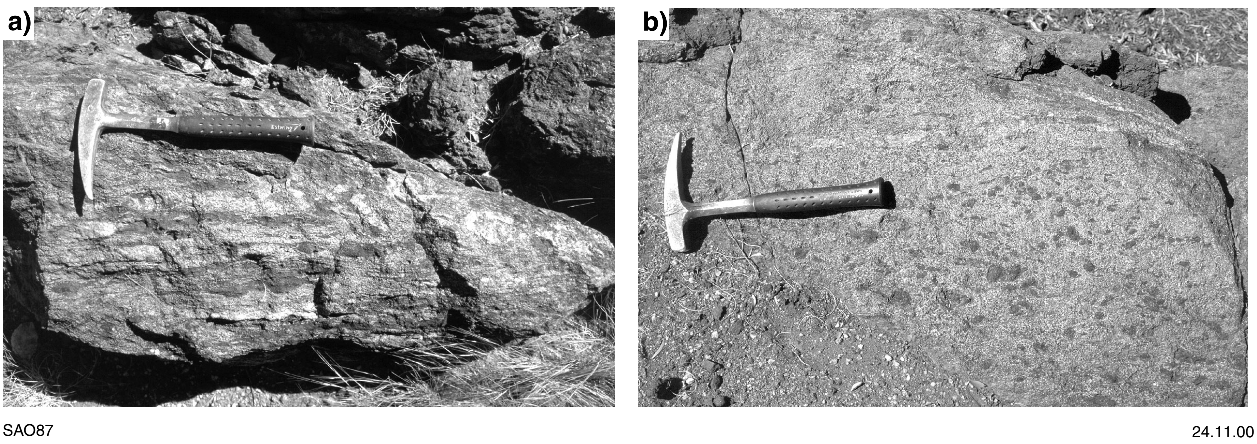

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Figure 7. Migmatitic pelitic gneiss from around Paradise Well (MGA 414040E 7191950N): a) schollen migmatite with diatexite melt and dark biotite-rich restite; b) diatexite with clots of biotite-rich restite

land surface marked by ferruginous duricrust (*Rf*). Several sheets up to 200 m thick are also present between Meerawana Well and Carradarra Well.

An igneous crystallization age of 1987 ± 4 Ma was determined by SHRIMP U–Pb zircon dating (Nelson, 1999) for a sample of leucocratic monzogranite (GSWA 142923) from about 5 km southwest of Glenburgh Homestead and about 100 m west of the Carnarvon–Mullewa road. This age is indistinguishable from that of the metadiorite sample GSWA 142933 (1989 ± 3 Ma) from the foliated and gneissic granites that the leucocratic biotite monzogranite intrudes. However, the pluton and sheets of the leucocratic biotite monzogranite contain folded inclusions and rafts of foliated and gneissic tonalite and granite. Veins and sheets of the leucocratic monzogranite also cut the foliation and gneissic layering in the older rocks, indicating that intrusion of the leucocratic monzogranite followed an episode of regional deformation and metamorphism.

Most of this unit consists of foliated, medium-grained, leucocratic biotite monzogranite. Much of the unit has a blotchy texture due to the presence of clots, up to 5 cm in diameter, of fine-grained biotite after garnet.

Nardoo Granite (ⱣgDna, ⱣgDnam)

The Nardoo Granite is a newly defined unit named after Nardoo Well near the eastern edge of GLENBURGH, and is equivalent to the gneissic biotite–hornblende granodiorite of the Dalgety Gneiss Dome of Williams (1986). The Nardoo Granite typically consists of foliated or locally gneissic, medium-grained, biotite tonalite and granodiorite (Fig. 8a), although the granite is undeformed and massive locally (Fig. 8b). The granite forms an elliptical, east-northeasterly trending intrusion at least 45 km long and up to 20 km wide, the bulk of which is exposed on GLENBURGH. The Nardoo Granite is also exposed in the southwestern corner of LANDOR to the east. Isolated outcrops of fresh granodiorite west of Dispute Bore in the eastern part of LANDOR are also interpreted as part of the Nardoo Granite. If this interpretation is correct, then the Nardoo Granite may be more than 75 km long and underlie an area of more than 1000 km^2. The Nardoo Granite forms a gently undulating land surface with boulders, tors, and whalebacks, amongst locally derived sandy colluvial and sheetwash deposits. In the south-eastern corner of GLENBURGH, fresh granite is exposed beneath an old dissected land surface marked by ferruginous duricrust, saprolite, and weathered rock.

The Nardoo Granite consists of two intrusive phases:

- medium-grained, even-textured or porphyritic, mesocratic biotite tonalite and subordinate quartz diorite (*ⱣgDna*);
- medium-grained, weakly porphyritic leucocratic biotite tonalite, and minor granodiorite (*ⱣgDnam*).

Contacts between the two phases are commonly sharp, but the two rock types grade into each other in places. In low-strain zones, irregular veins and dykes of leucocratic tonalite consistently intrude the mesocratic tonalite. Nevertheless, SHRIMP U–Pb zircon dating on GLENBURGH

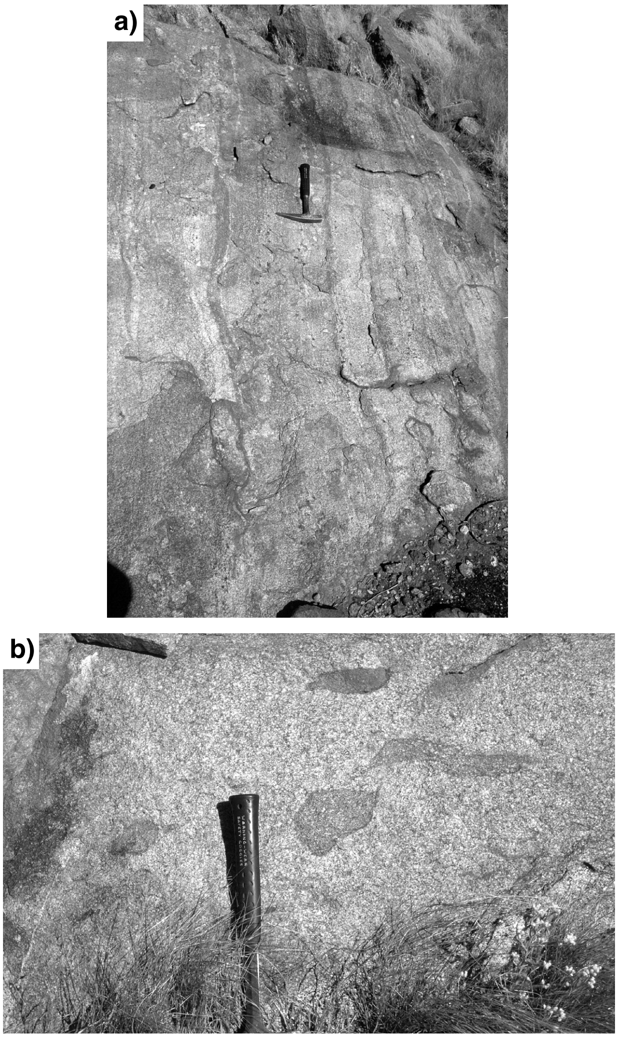

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Figure 8. Nardoo Granite: a) well-foliated and banded Nardoo Granite (MGA 444240E 7180450N); b) massive, medium-grained weakly porphyritic leucocratic tonalite with inclusions of the mesocratic medium-grained tonalite phase (MGA 431640E 7186750N)

indicates that the two phases have indistinguishable ages. A sample of the mesocratic tonalite (GSWA 142932) has a SHRIMP U–Pb age of 1977 ± 4 Ma, compared with a sample of leucocratic tonalite (GSWA 142928) dated at 1974 ± 4 Ma (Nelson, 1999).

The Nardoo Granite intrudes foliated and gneissic granite dated at 2005–1985 Ma (see **Foliated to gneissic granites**), and interlayered amphibolite and calc-silicate gneiss, and contains several large rafts of foliated and gneissic granite up to 7 km long and 1 km wide. Inclusions of fine-grained, pegmatite-banded tonalite, fine-grained granite, and amphibolite are widespread in the Nardoo Granite. These inclusions, and the gneissic fabric within them, are commonly folded about an axial surface parallel to a penetrative foliation. These relationships indicate that the Nardoo Granite was intruded after deformation and high-grade metamorphism that occurred between c. 1985 and c. 1975 Ma. Therefore, the granite cannot have formed as a para-autochthonous diapir following partial melting of the enclosing foliated and gneissic granites as suggested by Williams (1986).

The two main intrusive phases of the Nardoo Granite correspond in part to the two-fold subdivision of the early stage gneissic granitoids southeast of Dalgety Downs Homestead outlined by Williams et al. (1983b). Medium-grained mesocratic biotite tonalite and subordinate quartz diorite (*ⱣgDna*) is the slightly more abundant of the two phases and predominates in the northern half of the intrusion. Medium-grained, weakly porphyritic leucocratic biotite tonalite (*ⱣgDnam)* is the main rock type in the southern part of the intrusion. Locally, the two phases are intermingled or tectonically interleaved at outcrop scale.

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

Most samples of the mesocratic tonalite and quartz diorite (*ⱣgDna*) are variably foliated and recrystallized. The rocks consist of plagioclase (andesine–oligoclase) and subordinate quartz and biotite, with accessory apatite, zircon, and allanite. Some samples contain a few percent microcline. Biotite is chocolate brown and constitutes about 20% of most rocks. Many biotite crystals have crystallographically oriented inclusions of acicular ?rutile. A few samples contain prominent euhedral zoned crystals of zircon, up to 400 µm long.

Samples of the leucocratic tonalite (*ⱣgDnam*) are commonly less recrystallized than the mesocratic tonalite and quartz diorite. The leucocratic tonalite is composed of plagioclase, quartz, biotite, up to about 8% microperthite, and accessory apatite, allanite, and zircon. Most samples contain a few percent microcline. A few plagioclase crystals preserve normal igneous zoning; cores of sodic andesine (An_{35}) are zoned to rims of calcic oligoclase (An_{25}). The chocolate-brown biotite forms about 10% of the rocks, with many crystals containing crystallographically oriented inclusions of acicular ?rutile. Biotite is typically the sole mafic mineral, although a few samples contain olive-green hornblende, which is possibly igneous in origin. The hornblende is rimmed by an optically continuous greenish-blue hornblende.

Palaeoproterozoic leucocratic granodiorite and trondhjemite (*Ɐgt*)

Dykes of massive leucocratic granodiorite and trondhjemite (*Ɐgt*), about 1–3 m wide and up to 400 m long, intrude the leucocratic phase of the Nardoo Granite (*ⱣgDnam*) in the southern part of GLENBURGH. The dykes are widespread, but only locally abundant. Most of the dykes cut the foliation in the Nardoo Granite and strike in one of two orientations: 100–110° or 140–150°. An igneous crystallization age of 1945 ± 14 Ma was determined by SHRIMP U–Pb zircon dating (Nelson, 1999) for a dyke about 4.5 km west-southwest of Nardoo Well (MGA 445050E 7186390N; GSWA 142929). The dykes are composed of plagioclase, quartz, and minor amounts of biotite (7–8%), with or without a few percent microcline. Small amounts (about 1–2%) of primary muscovite are present in some samples.

Southwest of GLENBURGH, on CARRANDIBBY, a porphyritic biotite monzogranite dyke trending 010° and intruding other c. 2000 Ma rocks of the Dalgaringa Supersuite has been dated as c. 1954 ± 5 Ma (Nelson, in prep.). These granite dykes are common on CARRANDIBBY, and probably form the same unit as the leucocratic granodiorite and trondhjemite (*Ɐgt*) on GLENBURGH.

Glenburgh Orogeny

In the southern part of the Gascoyne Complex, Occhipinti et al. (1999a) and Sheppard et al. (1999b) identified two main deformation and regional metamorphic events between c. 1985 and c. 1945 Ma. These events are much older than the Capricorn Orogeny, which is dated at 1830–1780 Ma on MARQUIS and MOORARIE east of GLENBURGH (Occhipinti et al., 1998b; Occhipinti and Myers, 1999; Sheppard and Swager, 1999), and probably reflect the 2000–1960 Ma Glenburgh Orogeny (Occhipinti et al., 1999b). Occhipinti et al. (1999a) suggested that the Glenburgh Orogeny reflects southeastward-directed convergence and accretion of the Glenburgh Terrane (a Late Archaean to Palaeoproterozoic microcontinent) onto the passive northwestern margin of the Yilgarn Craton, forming the Errabiddy Shear Zone. The deformation and metamorphic history of GLENBURGH is summarized in Table 1.

On GLENBURGH the Glenburgh Terrane can be separated into two main structural domains: the northern and southern domains (Table 1). The boundary between these two domains roughly corresponds to the Dalgety Fault and Deadman Fault (Fig. 3), although outcrop north of the easterly trending Mount James Formation in the central-western part of GLENBURGH is included in the northern domain. The northern domain consists of the Halfway Gneiss and Moogie Metamorphics, and the southern domain consists of the Dalgaringa Supersuite and lesser amounts of the Moogie Metamorphics. All these rocks are intruded by granite of the Moorarie Supersuite, and overlain by the Mount James Formation and Bangemall Supergroup.

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Figure 9. Weakly foliated sheet of Nardoo Granite with inclusion of folded metamorphosed fine-grained tonalite, with the fold-axial surface subparallel to the foliation trend (MGA 425940E 7187550N)

Deformation and metamorphism (D_{1g}/M_{1g})

The development of the D_{1g} deformation event is different in the northern and southern domains of the Glenburgh Terrane (Table 1). Throughout the southern domain the D_{1g} event is well developed and has been dated. In the northern domain one fabric is assigned to the D_{1g} event, although this fabric has not been dated and its correlation with the D_{1g} event in the southern domain is uncertain.

The oldest dated fabric in the Glenburgh Terrane is in the southern domain. This is a regionally extensive, heterogeneously developed foliation or gneissic layering (S_{1g}) in the 2005–1985 Ma foliated and gneissic granites of the Dalgaringa Supersuite. Locally, this fabric is folded into rare, mesoscale, moderately to steeply plunging, upright, tight to isoclinal, easterly trending folds, which are cut by c. 1990 Ma monzogranite, quartz diorite or pegmatite intrusions. These folds are not developed everywhere within the southern domain. Because the age of the foliation and folding are indistinguishable from each other, based on available geochronological constraints, they have both been attributed to a continuous D_{1g} event. The monzogranite, quartz diorite, and pegmatite were metamorphosed at high grade during the M_{1g} event. These granites commonly intrude as dykes that trend subparallel to the easterly trending D_{1g} folds, therefore, their intrusion and metamorphism may have been largely concomitant with the folding (see below). Veins of the c. 1975 Ma Nardoo Granite cut this fabric, and the Nardoo Granite contains inclusions of pegmatite-banded granitic gneiss containing the S_{1g} fabric (Fig. 9). The Nardoo Granite, therefore, was intruded after deformation and high-grade metamorphism (D_{1g}/M_{1g}) that occurred between c. 2000 Ma and c. 1975 Ma.

The oldest fabric in the northern domain is a gneissosity (S_{1g}) in the Halfway Gneiss. This fabric is folded with axial surfaces subparallel to flat or gently dipping D_{2g} faults forming the contact between the Halfway Gneiss and the Moogie Metamorphics. The development of the gneissic fabric and D_{1g} in the southern domain are regarded here as the same deformation event, occurring during the Glenburgh Orogeny; however, the fabric has not yet been dated and its correlation with D_{1g} is still uncertain. Given that the ages of the protolith granites to the granitic gneiss are between c. 2550 Ma and c. 2000 Ma (see **Upper Archaean to Palaeoproterozoic Halfway Gneiss**), the fabric may have developed any time after that, and before intrusion of granites of the Moorarie Supersuite at c. 1800 Ma.

Metatonalite of the Dalgaringa Supersuite in the southern domain is commonly fine grained and contains an M_{1g} mineral assemblage of quartz, plagioclase, and reddish-brown biotite, with or without opaque minerals. These rocks are commonly weakly banded and contain an anhedral granular texture. A metamorphosed quartz diorite dated at c. 1989 Ma that forms a dyke subparallel to S_{1g} in the southern domain, just south of Meerawanna Well, consists of plagioclase, clinopyroxene, biotite, and orthopyroxene, indicating that metamorphic grade reached granulite facies. Although this rock contains a metamorphic mineral assemblage, the texture appears closer to that of an igneous rock, perhaps indicating that it was intruded under high-grade metamorphic conditions.

A blotchy texture characteristic of many of the foliated and gneissic granites of the Dalgaringa Supersuite may have formed during the M_{1g} event. The blotches consist of fine-grained green biotite that has partially or completely pseudomorphed porphyroblasts of garnet (Fig. 10). Monzogranite dykes 2 km south-southwest of Glenburgh Homestead display the blotchy texture and are dated at c. 1990 Ma. They intrude subparallel to the axial surfaces of tight to isoclinal, moderately plunging D_{1g} folds developed in a banded biotite tonalite gneiss.

Amphibolite layers that form part of the Moogie Metamorphics are interleaved with foliated and gneissic granites of the Dalgaringa Supersuite, and have assemblages indicative of middle to upper amphibolite-facies metamorphism. The layers commonly consist of green

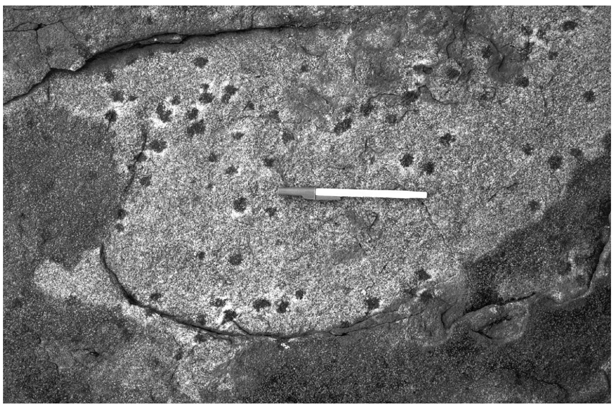

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Figure 10. Metamorphosed granite of the Dalgaringa Supersuite with biotite clots after garnet (MGA 434640E 7183650N)

hornblende and plagioclase (labradorite or andesine), or green hornblende, plagioclase (labradorite or andesine), and clinopyroxene. Both these assemblages contain minor amounts of quartz, and ilmenite or titanite. Clinopyroxene forms cores to hornblende, suggesting that it is a relict from the igneous protolith or from an earlier metamorphic event. Amphibolites from the southern edge of the sheet area and from south of Meerawana Well have an amoeboid granoblastic texture and assemblages of brown hornblende, plagioclase (labradorite), clinopyroxene, and minor amounts of quartz and ilmenite. These assemblages and textures are consistent with higher grade metamorphism at the transition between amphibolite and granulite facies (Bucher and Frey, 1994). Mafic gneisses between Paradise Well and Condamine Well, in the southwestern part of GLENBURGH, contain assemblages of hypersthene, clinopyroxene, and plagioclase (labradorite–bytownite) with minor amounts of brown hornblende, quartz, and ilmenite, or plagioclase, clinopyroxene, and hypersthene with minor amounts of garnet. These assemblages are indicative of metamorphism to granulite facies (Bucher and Frey, 1994), and are attributed to the M_{1g} event.

Amphibole- and diopside-rich calc-silicate gneisses contain two main assemblages that formed during the M_{1g} event: pargasite–quartz–plagioclase–titanite or diopside–quartz–plagioclase–titanite. Locally, these rocks contain xenoblastic garnet. Most rocks display amoeboid and polygonal granoblastic textures. Marbles contain domains of dolomite, calcite, clinopyroxene, and garnet, or dolomite, calcite, forsterite, and clinohumite, with an amoeboid granoblastic texture, preserved between finer grained overprinting assemblages. Assemblages with clinohumite, which may represent replacement of forsterite due to metasomatism (during M_{2g}), have only been identified in the southern domain.

Small outcrops of pelitic gneiss are only identified around Paradise Well and form rare discontinuous lenses or possible xenoliths within granitic rocks of the Dalgaringa Supersuite. Locally, the pelitic gneiss is migmatized and consists of diatexite (Fig. 7) as schollen migmatite with a mesosome of dark biotite-rich restite. The diatexite contains a melt phase (leucosome) that formed in situ, and consists dominantly of cordierite, quartz, and biotite with minor amounts of K-feldspar and spinel. Some pelitic gneiss (e.g. GSWA 144823), consisting of biotite, garnet, orthopyroxene, plagioclase, quartz, cordierite, K-feldspar, fibrolite, ?epidote, allanite, and ilmenite, may represent the palaeosome to the migmatite. Within the palaeosome, polygonal granoblastic textures are defined by euhedral garnet, plagioclase, quartz, orthopyroxene, and cordierite, which probably represent an equilibrium assemblage. Orthopyroxene forms small xenoblastic crystals and is locally abundant within biotite-rich domains, where it is also aligned in the foliation, or included in garnet. Garnet also contains inclusions of biotite or cordierite. Locally, small euhedral crystals of orthopyroxene partially replace biotite. This may be due to the reaction: biotite + 3quartz $\rightarrow$3orthopyroxene + K-feldspar + H_2O (Miyashiro, 1994, p. 298).

Fibrolite or fine-grained sillimanite is present between grain boundaries of the garnet and plagioclase, biotite and quartz, and garnet and biotite, and is locally abundant in biotite-rich domains. The K-feldspar is rare and present amongst granoblastic plagioclase grains.

The presence of orthopyroxene indicates metamorphism to granulite-facies conditions at temperatures above 750 or 800°C (Spear, 1993; Bucher and Frey, 1994). This is supported by the presence of garnet (?almandine), cordierite (?magnesium end member), and orthopyroxene in equilibrium. Blight and Barley (1981) described pelitic rocks from the same area with an assemblage of quartz, cordierite, plagioclase, garnet, sillimanite, and biotite, and minor amounts of microcline and opaque minerals. They calculated that this assemblage formed either at 838°C and 650 MPa pressure, using the calibration of Currie (1971), or at 562°C and 660 MPa pressure, using the calibration of Wells (1979). Recalculation of the data of Blight and Barley (1981) using THERMOCALC (Holland and Powell, 1990), and assuming that the garnet–cordierite–sillimanite–quartz assemblage they described is in equilibrium, indicates that the mineral assemblage developed at 750–900°C and 500–700 MPa pressure. The garnet–quartz–plagioclase–orthopyroxene–cordierite assemblage described above is probably a low-alumina equivalent of the assemblage described by Blight and Barley (1981), as both define similar pressure and temperature stability fields (Fitzsimmons, I., 2000, written comm.).

The melt within the diatexite has locally broken down to form lower grade assemblages of phlogopite–quartz (–fibrolite), and phlogopite and quartz as symplectites (Fig. 11). The symplectites of phlogopite and quartz are developed between microperthite or K-feldspar and biotite in the migmatitic gneisses, indicating grain-boundary reactions between them (Fig. 11). Myrmekite is also present after K-feldspar (GSWA 164328). In a few places, relict green spinel is present within fine intergrowths of retrograde andalusite and magnetite. Retrograde biotite or pale-green phlogopite developed between magnetite –andalusite intergrowths after spinel and cordierite. Fibrolite is also common in these samples and is well developed between cordierite and quartz, and cordierite and biotite, and is in contact with phlogopite around grain boundaries. Locally, opaque minerals (?ilmenite) form small aggregates and crystals that rim brown biotite, indicating that they may have exsolved out of biotite.

These textures may be represented by the retrograde reaction: cordierite + spinel + Fe-rich biotite (annite) + K-feldspar + quartz + water-rich fluid $\rightarrow$magnetite + andalusite + Mg-biotite (phlogopite) + quartz.

The cordierite, spinel, and K-feldspar are part of the 'melt' in the migmatized pelitic gneiss, although it is likely that the Fe-rich biotite (annite) is a relict of the precursor unmelted pelite or 'paleosome'. These constituents reacted at lower pressures and temperatures or due to either the release of H_2O during melt crystallization or addition of H_2O from an external source to form the lower grade mineral assemblage listed as the 'products' in the above reaction.

The presence of fibrolite or fine-grained sillimanite indicates a possible increase in temperature or pressure (or

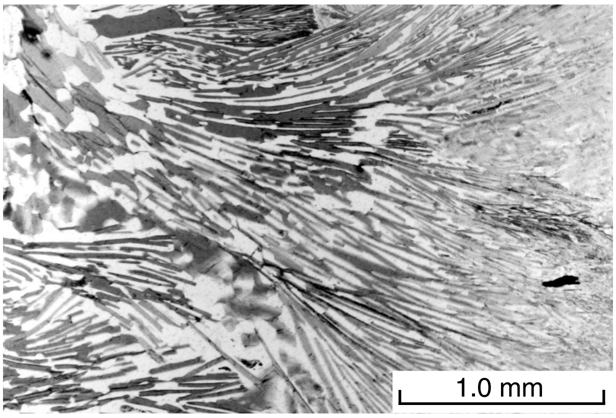

Figure 11. Symplectite of phlogopite and quartz (GSWA 164328)

both) to move from the andalusite into the sillimanite stability field.

The presence of mafic granulites around Paradise Well and strips of pelitic granulite and pelitic migmatite indicate that the rocks in the southern domain, including granites of the Dalgaringa Supersuite, were locally metamorphosed at very high grade during the D_{1g} event. Away from the Paradise Well area, however, amphibolite-facies assemblages dominate in the southern domain. These amphibolites are probably not the product of retrogression of granulite-facies rocks because most of the Dalgaringa Supersuite and its supracrustal xenoliths do not contain any indication of higher grade mineral development. Therefore, rocks metamorphosed to both amphibolite and granulite facies were juxtaposed after this high-grade metamorphism.

Only amphibolite-facies assemblages were identified in rocks in the northern domain; however, pervasive later (c. 1800 Ma) retrogression has hindered identification of earlier metamorphic fabrics and assemblages.

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

In the southern domain, mesoscopic upright folds (F_{2g}) are widespread in the foliated and gneissic granites, interleaved amphibolite, mafic granulite, and calc-silicate and quartzite gneisses. Most of the folds are tight or isoclinal, but are open to close in local zones of low D_{2n} strain. The F_{2g} folds trend westerly or southwesterly, and plunge moderately to very steeply to the east and northeast or to the west and southwest. It is possible that the folds originally developed as northerly or northeasterly trending structures, and have been refolded or rotated during the Capricorn Orogeny. Large-scale fold structures have not been identified.

In the Nardoo Granite a penetrative foliation (S_{2g}) is defined by biotite or, in places, a gneissosity typically produced by lenses and veins (up to a few centimetres thick) of pegmatite with clots of fine-grained biotite after ?garnet. Quartz is flattened in the foliation of strongly foliated or gneissic rocks. Mineral assemblages formed during the M_{2g} event consist of biotite, oligoclase–andesine, and epidote. In a few samples these assemblages are associated with rims of greenish-blue hornblende on olive-green hornblende crystals of probable igneous origin. The composition of the plagioclase, together with the presence of epidote, suggests that the rocks were metamorphosed to epidote–amphibolite facies, transitional between greenschist and amphibolite facies (Miyashiro, 1994). The presence of probable garnet porphyroblasts in the pegmatite veins is consistent with epidote–amphibolite-facies metamorphism.

The effects of the M_{2g} event are commonly difficult to differentiate from effects of the M_{1g} event. The mafic granulites and amphibolites with M_{1g} assemblages contain little evidence of the M_{2g} event. This may be because little or no fluid infiltration occurred to drive retrograde metamorphism in M_{2g} conditions. Locally, the effects of M_{2g} in the amphibolites probably consist of optically continuous rims of greenish-blue hornblende on the olive-green hornblende, and associated development of fine-grained andesine, epidote, and titanite.

High-grade assemblages in the calc-silicate gneisses that formed during M_{1g} are overprinted to varying degrees by lower grade assemblages; however, it is not clear how much of this recrystallization and new mineral growth is related to M_{2g}, and how much to younger events. In the amphibole- and diopside-rich gneisses, pargasite (amphibole) and diopside show incipient replacement along rims and fractures to tremolite, and plagioclase is partially replaced by clinozoisite and a more sodic plagioclase. In marble, in the southern part of GLENBURGH, the dolomite, calcite, and forsterite assemblage is replaced by finer grained clinohumite, chlorite, and calcite. The appearance of clinohumite may be related to the reaction: forsterite + dolomite + $H_2O \rightarrow$ clinohumite + calcite + CO_2.

This could be due to later fluid infiltration metasomatism that may have been driven by granite melts in the region, particularly as fluorine would have to be added to the marble in order for clinohumite to crystallize.

In pelitic gneiss in the Paradise Well area (GSWA 144823), pinitization of cordierite, exsolution of ?ilmenite out of brown biotite, and crystallization of fibrolite may have occurred during the M_{2g} event, although the actual timing of these reactions is unknown.

Flat faults between the Halfway Gneiss and the Mumba Pelite and a well-developed mylonitic fabric in the Halfway Gneiss provide evidence for thrusting in the northern domain. The mylonitic fabric, which is well developed between Mia Well and Dunnawah Well, contains rotated feldspar porphyroblasts and some S–C fabrics that indicate a possible south-over-north movement direction. The flat faults and mylonitic fabric deform the S_{1g} foliation and, therefore, developed during the D_{2g} event. Small discontinuous outcrops of the Moogie Metamorphics within the Halfway Gneiss are probably also in faulted contact with the gneiss. In most cases, however, faults have not been shown on GLENBURGH to avoid overcrowding.

The first regional foliation in the Mumba Pelite (S_{2g}) of the Moogie Metamorphics is a subhorizontal or gently dipping foliation that formed subparallel to bedding during D_{2g}/M_{2g}. This is particularly well developed north of the Dalgety Fault (Fig. 5a), and is subparallel to the early faults in the Halfway Gneiss, and at the faulted contact between the Halfway Gneiss and Moogie Metamorphics. The S_{2g} foliation is axial planar to subhorizontal folds of bedding in quartzite, locally observed in the Moogie Metamorphics on DAURIE CREEK, west of GLENBURGH.

Locally, the Mumba Pelite contains lenses of quartz and magnetite aggregates, which may have formed an original bedding surface, but have broken up (sheared) and deformed during subsequent deformation (D_{1n}). The original mineral assemblages developed during the M_{2g} event in the Mumba Pelite are typically completely overprinted by lower grade mineral assemblages. Locally, garnet developed during M_{2g} forms stable grain boundaries with quartz, forming an 'annealed' texture. Mats of sericite may represent completely pseudomorphed sillimanite or ?staurolite. Chloritoid and chlorite locally partially or completely pseudomorphed garnet, and chlorite may have pseudomorphed biotite. This suggests that the Mumba Pelite was probably metamorphosed at medium grade (?amphibolite facies) during the M_{2g} event.

Palaeoproterozoic Moorarie Supersuite

The Moorarie Supersuite comprises dykes, sheets, plugs, and plutons of granite and pegmatite dated at between 1830 and 1780 Ma. In the southern Capricorn Orogen, these granites and pegmatites extensively intrude the Glenburgh Terrane, Camel Hills Metamorphics, and reworked Archaean gneisses of the Yarlarweelor gneiss complex farther east. Dykes and plugs of granite and pegmatite belonging to the supersuite also intrude the northwestern margin of the Yilgarn Craton. The granites and pegmatites were emplaced during and after deformation and regional metamorphism associated with the Capricorn Orogeny (Occhipinti et al., 1998b). The Capricorn Orogeny reflects collision of the Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990). Therefore, the intrusions belonging to the Moorarie Supersuite were probably emplaced in a collisional to post-collisional setting.

Intrusions of the Moorarie Supersuite emplaced into the Yarlarweelor gneiss complex and Camel Hills Metamorphics typically consist of veins, sheets, dykes, and plugs. Most of the intrusions are leucocratic, and pegmatites are abundant. In the Gascoyne Complex, granites of the Moorarie Supersuite also form large plutons, some of which are dominated by mesocratic granodiorite. Intrusions of the Moorarie Supersuite are widespread throughout the Gascoyne Complex on GLENBURGH (Fig. 3), but are voluminous only in the northern half. In the southern part of GLENBURGH, the intrusions consist of dykes and veins, and rare plugs.

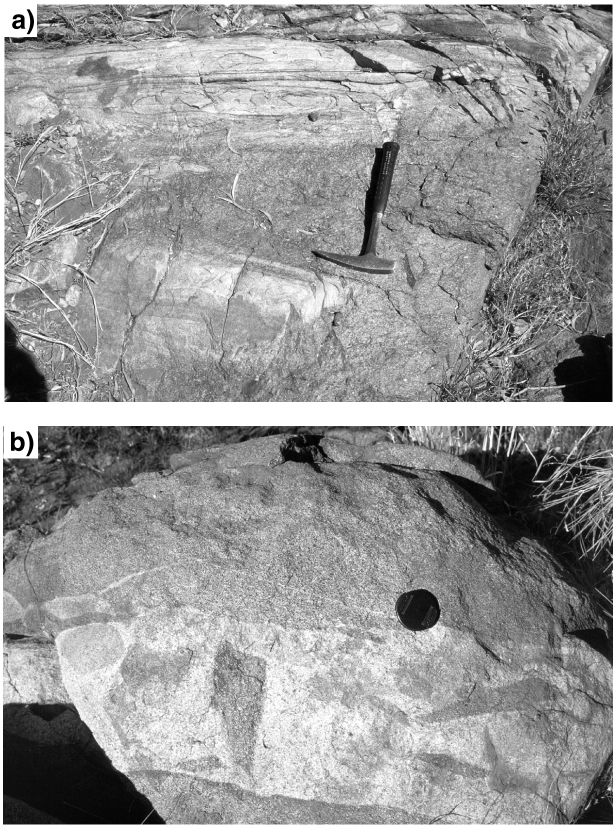

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Figure 12. Granites of the Moorarie Supersuite: a) porphyritic granodiorite of the Dumbie Granodiorite intruding leucocratic granitic gneiss of the Halfway Gneiss (MGA 417040E 7221050N); b) dyke of the Scrubber Granite intruding the Dumbie Granodiorite (MGA 413440E 7224250N)

Dumbie Granodiorite (*ⱣgMdu*)

The Dumbie Granodiorite (*ⱣgMdu*) is a newly defined unit named after Dumbie Well in the northern part of GLENBURGH, where the unit is extensively exposed. In the northeastern corner of GLENBURGH and on the adjacent northwestern corner of LANDOR, the Dumbie Granodiorite forms a large pluton that extends farther north onto the MOUNT PHILLIPS 1:250 000 sheet area. On the remainder of GLENBURGH the Dumbie Granodiorite forms large sheets intruded subparallel to the regional structural grain, and numerous dykes. The Dumbie Granodiorite outcrops as boulders, tors, and scattered whalebacks. The unit consists of porphyritic fine- to medium-grained granodiorite, with tabular phenocrysts of sanidine.

The Dumbie Granodiorite intrudes the Halfway Gneiss (Fig. 12a), and calc-silicate gneiss and interleaved amphibolite, actinolite schist, and tremolite schist of the Moogie Metamorphics. The unit is intruded by veins and dykes of medium-grained biotite(–muscovite) granite (*ⱣgMe*) and coarse-grained granite and pegmatite (*ⱣgMp*), and is intruded by the c. 1796 Ma Scrubber Granite (Fig. 12b). The main pluton and sheets of Dumbie Granodiorite are foliated, whereas the dykes cutting the regional structural grain at a high angle may be foliated or massive.

The Dumbie Granodiorite was sampled at two localities for SHRIMP U–Pb zircon dating. A sample from the main pluton on PINK HILLS (GSWA 159987) has an igneous crystallization age of 1810 ± 9 Ma, and a sample (GSWA 159995) from a large sheet about 1 km southeast of Middle Well on GLENBURGH (MGA 413600E 725500N) has an indistinguishable age of 1811 ± 6 Ma (Nelson, 2000).

The most abundant rock type in the Dumbie Granodiorite is a grey, fine- to medium-grained granodiorite (or less commonly monzogranite) with up to 30% thin tabular phenocrysts of sanidine up to 1 cm long. In places the phenocrysts are oval in shape. Sanidine phenocrysts contain numerous small inclusions of round quartz and subhedral plagioclase. A few phenocrysts have minor development of microperthite. The groundmass consists of anhedral granular, fine-grained plagioclase, quartz, green–brown biotite, and minor microcline. Accessory minerals comprise magnetite, ilmenite, allanite, zircon, and apatite. Locally, the Dumbie Granodiorite contains small clusters of fine magnetite crystals. Hydrated allanite is a prominent accessory mineral forming brown prismatic crystals up to 1.5 mm long.

The rocks show evidence of static or dynamic recrystallization: plagioclase is extensively replaced by albite–oligoclase, epidote, and sericite; quartz consists of fine-grained polygonal aggregates; and ilmenite and magnetite are rimmed or replaced by titanite and epidote respectively.

Scrubber Granite (*ꝒgMsc*)

The Scrubber Granite (*ꝒgMsc*) forms an extensive unit in the Glenburgh Terrane of the Gascoyne Complex, extending 75 km in an east–west direction across the GLENBURGH 1:250 000 sheet, from ERRABIDDY westward onto GLENBURGH and then to DAURIE CREEK. The unit is also present northeast of GLENBURGH on CANDOLLE, on the MOUNT EGERTON 1:250 000 sheet. On GLENBURGH the most abundant outcrop of the Scrubber Granite (*ꝒgMsc*) is 2 km southeast of Middle Well where abundant sheets, up to 3 km wide, intruded rocks of the Halfway Gneiss and Dumbie Granodiorite (Fig. 12b).

In the northern part of GLENBURGH, sheets and veins of the Scrubber Granite are typically of medium-grained, even-textured biotite(–tourmaline–muscovite) monzogranite. The granite sheets are easterly trending and typically outcrop as whalebacks with minor scattered tors. Locally, the Scrubber Granite is well foliated, but commonly massive. Tourmaline and quartz typically form swarms of ovoid clusters within the granite, although they are not common on GLENBURGH. West of GLENBURGH, on DAURIE CREEK, individual isolated clusters and loose interconnected clusters of tourmaline–quartz aggregates are very common within the Scrubber Granite. Texturally, the clusters are medium grained and even textured like their host granite; however, feldspar and biotite are either not present or only rare components. Veins of quartz and tourmaline locally cut the Scrubber Granite.

A sample of Scrubber Granite (GSWA 159996) from about 2.5 km southeast (MGA 413186E 7224116N) of Middle Well has an igneous crystallization age of 1796 ± 6 Ma (Nelson, 2000) determined by SHRIMP U–Pb zircon dating. This age is within error of that for the Scrubber Granite on LANDOR, which has been dated at 1807 ± 7 Ma (Nelson, in prep.). These ages are similar to igneous crystallization ages of between 1810 and 1795 Ma for dykes and sheets of medium-grained, biotite granite (*ꝒgMe*, *ꝒgMke*) on MOORARIE and MARQUIS (Occhipinti and Myers, 1999; Sheppard and Swager, 1999).

Medium-grained biotite(–muscovite) granite (*ꝒgMe*)

Medium-grained biotite(–muscovite) granite (*ꝒgMe*) forms a large, elongate, east-southeasterly trending pluton between Mia Well in the northwestern part of GLENBURGH and Burrin Bore in the central part. Elsewhere in the northern half of GLENBURGH, medium-grained biotite (–muscovite) granite forms sheets, veins, and dykes. This unit is much less abundant in the southern half of the sheet area, forming scattered veins and dykes that are commonly too small to be shown on the map. Most of the unit is composed of pale-grey, massive, medium-grained, even-textured biotite(–muscovite) monzogranite. The rock is typically even textured, but granite containing 5–10% rounded microcline phenocrysts up to 7 mm in diameter is also common. The unit typically forms low rises and hills, and outcrops as boulders and tors.

Medium-grained biotite(–muscovite) granite (*ꝒgMe*) intrudes the Halfway Gneiss, Moogie Metamorphics, foliated and gneissic granites of the Dalgaringa Supersuite, Nardoo Granite, and Dumbie Granodiorite. The plutons of medium-grained biotite(–muscovite) granite in the northern part of GLENBURGH contain numerous screens or large rafts of country rock. The unit is intruded by veins and dykes of biotite- and tourmaline-bearing pegmatite (*ꝒgMp*).

Medium-grained biotite(–muscovite) granite mainly ranges in composition from monzogranite to granodiorite, but locally consists of leucocratic tonalite. The textures of the rocks range from foliated to massive, but all show extensive recrystallization at low-grade conditions. The original igneous mineralogy is quartz, plagioclase, microcline, and biotite, with or without muscovite. The micas make up less than 10% of the rock. Accessory minerals are magnetite, minor amounts of ilmenite, allanite, and zircon.

Veins and sheets of fine- to medium-grained, pale-grey biotite granite intrude granitic gneisses of the Halfway Gneiss. The biotite granite is part of the Moorarie Supersuite, but it does not always form a mappable unit. The granite cuts the gneissic layering in the granitic gneisses at a low angle. This relationship is well exposed in creek pavements about 2 km north (MGA 417030E 7221020N) of Geringee Bore. About 200 m to the northeast (MGA 417200E 7220920N), an igneous crystallization age of 1815 ± 4 Ma was determined by SHRIMP U–Pb zircon dating for a dyke (GSWA 159724; Nelson, 2000). The dyke is a strongly recrystallized biotite granodiorite, with a foliation defined by fine-grained biotite and a grain-flattening fabric defined by quartz.

Medium-grained, porphyritic biotite granite (ⱣgMep)

Pale-grey, massive, medium-grained, porphyritic biotite monzogranite (*ⱣgMep*) forms an elongate, southeasterly trending plug, about 4 km long and 1.5 km wide, between Mia Well and Errawarra Well in the northwestern part of GLENBURGH. The unit contains up to 30% squat tabular and round phenocrysts of K-feldspar up to 6 cm in diameter. In places, medium-grained, porphyritic biotite granite is transitional to medium-grained biotite(–muscovite) granite (*ⱣgMe*), but the porphyritic phase locally intrudes the even-textured phase (e.g. about 2 km southeast of Mia Well, MGA 405800E 7218200N). The medium-grained, porphyritic biotite granite is intruded by numerous veins and dykes of muscovite- and biotite-bearing pegmatite and leucocratic granite. The porphyritic granite locally contains schlieren and small lenticular inclusions of biotite-rich mafic rock.

Coarse-grained granite and pegmatite (ⱣgMp)

Dykes and veins of coarse-grained granite and pegmatite (*ⱣgMp*) extensively intrude rocks of the Gascoyne Complex on GLENBURGH. The coarse-grained granite and pegmatite is part of a widespread magmatic event present in all tectonic units in the southern part of the Capricorn Orogen. Coarse-grained granite and pegmatite intrude reworked Archaean gneiss of the Yarlarweelor gneiss complex, rocks in the northern edge of the Yilgarn Craton, metasedimentary rocks of the Camel Hills Metamorphics, and the Gascoyne Complex. On MARQUIS and MOORARIE to the east, coarse-grained granite and pegmatite was emplaced during medium- to high-grade regional metamorphism and deformation at 1813 ± 8 Ma (Occhipinti et al., 1998a; Occhipinti and Myers, 1999; Sheppard and Swager, 1999).

Dykes and veins of coarse-grained granite and pegmatite are common along the southern edge of GLENBURGH, where they intrude all rocks of the Dalgaringa Supersuite as well as amphibolite and calc-silicate gneiss. The dykes form localized swarms, for example in the southern part of GLENBURGH, between Dardoo Well and Salt Well and east-northeast of Parrot Bore. Most dykes are between 0.5 and 2 m wide, but larger dykes up to 4 m wide can be traced for about 1 km along strike. Most of the dykes strike between 150 and 180°. Biotite is normally the sole mafic mineral in the coarse-grained granite, whereas the pegmatite contains biotite or muscovite (or both). Many of the dykes in the northern part of GLENBURGH are tourmaline bearing.

Leucocratic muscovite–biotite granite (ⱣgMv)

On GLENBURGH leucocratic muscovite–biotite granite (*ⱣgMv*) is mainly confined to a small (about 1 km^2) plug about 4 km north-northeast of Challenger Well (MGA 443900E 7204800N), and to two main outcrops west of Gregory Bore, both in the eastern part of GLENBURGH.

The small plug is about 1 km in diameter, but veins and dykes of fine-grained leucocratic muscovite–biotite granite extend up to about 2 km from the plug. The plug is massive or weakly foliated, and intrudes foliated and gneissic granites of the Dalgaringa Supersuite. A sample from this plug (GSWA 142924) gave a SHRIMP U–Pb zircon age of 1827 ± 14 Ma (Nelson, 1999).

Sheets of leucocratic muscovite–biotite granite intrude granitic gneiss of the Dalgaringa Supersuite east of Gregory Bore. These granite sheets intrude the granitic gneiss subparallel to fold-axial surfaces in the gneiss and are also locally well foliated. A sample of one of these granite sheets (GSWA 142931) gave a SHRIMP U–Pb zircon age of 1824 ± 9 Ma (Nelson, 1999).

The c. 1825 Ma age of the leucocratic muscovite–biotite granite on GLENBURGH is older than the 1802 ± 9 Ma age of a leucocratic muscovite–biotite granite plug on ERRABIDDY (Sheppard and Occhipinti, 2000). The plug and veins on GLENBURGH are composed of cream or pale-grey, fine- to medium-grained, leucocratic biotite–muscovite granodiorite, consisting mainly of plagioclase, quartz, K-feldspar, biotite, and muscovite granodiorite that has been deformed and metamorphosed at greenschist facies.

Altered granite (ⱣgMa)

Altered granite (*ⱣgMa*) of the Moorarie Supersuite west-northwest of Puckford Bore is unconformably overlain by rocks of the Edmund Group. The altered granite is locally well foliated, medium grained, and even textured, and commonly consists of quartz–sericite–pyrite(–hematite). The mineralogy reflects pervasive alteration, and it probably had a similar composition to the granite (*ⱣgMe*) that it is in contact with on GLENBURGH before it was altered.

Mount James Formation (Ᵽjc, Ᵽjt, Ᵽjy)

The Mount James Formation comprises deformed and metamorphosed siliciclastic sedimentary rocks, outcropping as several strips throughout the Gascoyne Complex. On GLENBURGH it typically outcrops along steeply dipping faults.

The nature and origin of the Mount James Formation (Drew, 1999) is problematic. Hunter (1990) suggested that a correlation between the Mount James Formation and parts of the Padbury Group (Padbury Basin), Mount Minnie Group, and Capricorn Formation of the Ashburton Basin could be made on the basis of lithological and structural relationships. Occhipinti et al. (1996) and Sheppard and Occhipinti (2000) suggested that the Mount James Formation should not be correlated with the Padbury Group, as the Padbury Group is more complexly deformed. It is also probable that the <2000 Ma Padbury Group is older than the Mount James Formation (see below). The Padbury Group outcrops in the Padbury Basin, which is a distinctive tectonic unit confined to the west by the Errabiddy Shear Zone and its faulted boundary with the Yarlarweelor gneiss complex, and to the east by the Goodin Fault (Pirajno and Occhipinti, 2000). The Mount James Formation outcrops along elongate discontinuous fault zones that may have controlled initial sedimentation (Hunter, 1990), whereas individual formations of the Padbury Group are not fault bounded.

The age of the Mount James Formation is unclear. Nelson (in prep.) found that SHRIMP U–Pb ages on detrital zircons in one sample of quartzite (GSWA 168937) from the Mount James Formation contained two populations of zircons: one at c. 1960 Ma and the other at c. 1800 Ma. Thus, c. 1800 Ma provides a maximum age for the formation. The Mount James Formation is overlain, with a high-angle unconformity, by the Mesoproterozoic Bangemall Supergroup (Williams et al., 1983b). A possible deformed unconformity between the Mount James Formation and the Bangemall Supergroup is in the western part of GLENBURGH, about 3 km west of Sonny Well. Regional structural correlations imply an unconformity between higher grade, more steeply dipping, metamorphosed siliciclastic rocks of the Mount James Formation and the low-grade, gently to moderately dipping siltstone and dolostone of the Bangemall Supergroup. The maximum age of the lower part of the Bangemall Supergroup is 1640 Ma (Nelson, 1995), thus providing a minimum age for the Mount James Formation.

Hunter (1990) suggested that the Mount James Formation consisted of a basal conglomerate overlain by quartzite and arkosic and conglomeratic sandstone that locally onlaps the basement. Recent mapping, however, has shown that the Mount James Formation succession cannot always be correlated between different fault-bounded lenses (Sheppard and Occhipinti, 2000; this work). The Mount James Formation is tightly folded, and in the northern part of GLENBURGH contains tight easterly trending, gently inclined, moderately to steeply plunging folds in the quartzite. Discontinuous asymmetric folds in the central part of GLENBURGH also deform the formation. The Mount James Formation has been metamorphosed at subgreenschist to low-greenschist facies conditions and its sedimentary protolith is easily discernible.

On GLENBURGH, and in part on adjacent map sheets, the Mount James Formation consists of quartzite, metamorphosed arkosic sandstone to quartz–sericite phyllite, metamorphosed quartz-pebble to cobble conglomerate, metamorphosed polymictic conglomerate, and quartz–chlorite–sericite phyllite. The quartzite (*Ᵽjt*) forms steep hills or ridges, commonly with scree tops of broken-up quartzite. Cross-bedding is present locally, for example, trough cross-bedding indicates younging to the north about 1 km southeast of Fitzpatrick Well in the central part of GLENBURGH. In a few places the quartzite appears to grade into a metamorphosed arkosic sandstone that comprises mostly quartz and sericite and locally contains conglomeratic lenses. This and the occasionally observed cross-bedding indicate that the quartzite is probably a silicified and metamorphosed quartz-rich sandstone. Original rounded to subrounded, sand-sized quartz grains within quartzite of the Mount James Formation are recrystallized to form almost polygonal quartz grains with seriate grain boundaries and undulose extinction. In many cases the quartz grains are slightly elongate, defining a foliation in the rock, with well-defined triple junctions still present between quartz grain boundaries. Minor amounts of detrital sphene or tourmaline are commonly present in the quartzite. Sericite is commonly interspersed throughout the quartzite, defining a weak foliation, but still only constituting about 3% of the quartzite.

Quartz–sericite phyllite (*Ᵽjy*) or metamorphosed arkosic sandstone outcrops below the quartzite in the Mount Puckford area in the eastern part of GLENBURGH. These are typically well foliated and folded into upright tight folds. Conglomeratic layers within this unit range from 1 to 2 m in thickness. Chlorite–quartz–sericite phyllite *(Ᵽjy)* with accessary tourmaline and hematite is present west of Sonny Well in the western part of GLENBURGH. These rocks locally contain a well-developed crenulation cleavage, indicating open folding perpendicular to the easterly trending strike of the bedding. Quartz domains separate chlorite domains and consist of slightly elongated quartz grains with an almost polygonal ‘triple junction’ texture between grains. Quartz grains show only a slight undulose extinction. Locally, minor amounts of quartz-pebble conglomerate are present about 1 km northwest of Sonny Well. The quartzite pebbles are subrounded to subangular and between 1 and 50 cm long. The matrix is a silty sandstone consisting of quartz, chlorite, and sericite. Finely laminated quartz–sericite phyllite and graphite–quartz–sericite phyllite outcrop southeast of Fitzpatrick Well in the central part of GLENBURGH (Fig. 13a). The laminations are up to 3 mm wide. These rocks locally contain ovoid patches, which may represent concretions developed during diagenesis.

In the northern part of GLENBURGH, matrix-supported, quartz-pebble conglomerate (*Ᵽyc*) with a matrix of arkosic sandstone overlies a thin layer of well-laminated siltstone (Fig. 13b). East of GLENBURGH and north of the Dalgety Fault, a quartz-pebble conglomerate unconformably overlies the Moogie Metamorphics. This conglomerate commonly contains pebble- to cobble-sized quartzite clasts, although it contains amphibolite clasts close to its contact with amphibolite of the Moogie Metamorphics, indicating (at least in part) a local provenance. The matrix-supported conglomerate in the northern part of GLENBURGH unconformably overlies granite of the Moorarie Supersuite, and contains subangular to subrounded quartzite pebbles and cobbles. The clasts appear to have undergone plane strain or been flattened and locally show aspect ratios of between 3 and 4. The long axes of the pebbles are aligned subparallel to the foliation, supporting deformation; however, the lack of any obvious asymmetry suggests that the quartz pebbles have not undergone any rotational strain.

Rare thin lenses of conglomerate are locally present within the phyllite (*Ᵽjy*) and quartzite (*Ᵽjt*) units; for example, a thin lens of quartz-pebble conglomerate is present within siltstone and silty sandstone in the western part of GLENBURGH, about 2 km east (MGA 401700E

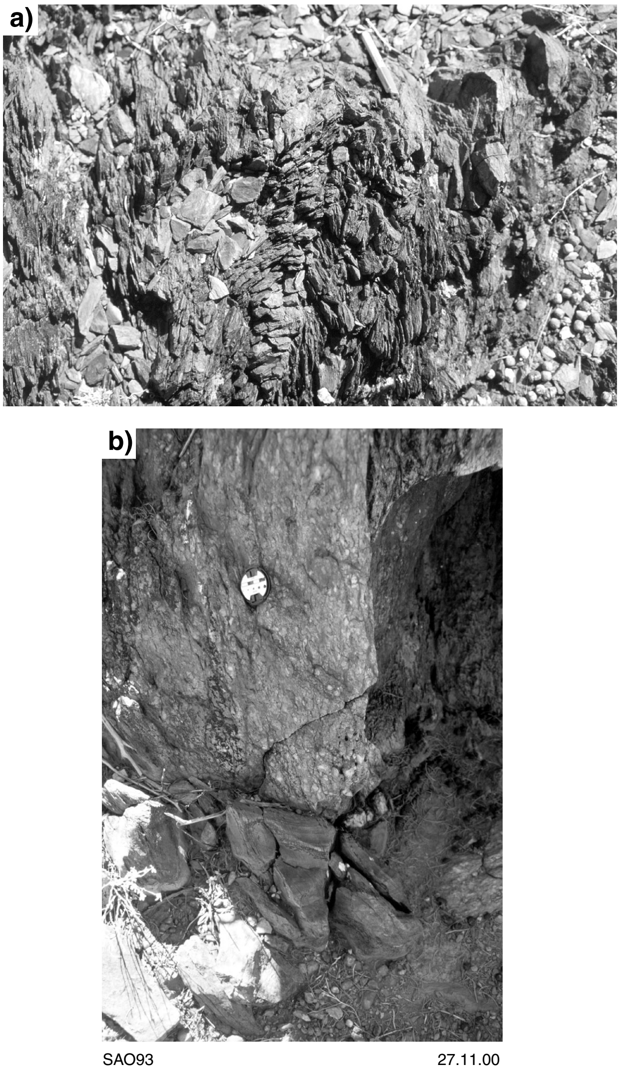

Figure 13. Metasedimentary rocks of the Mount James Formation: a) folded siltstone east-northeast of Fitzpatrick Well (MGA 434470E 7207750N); b) quartz-pebble conglomerate overlying well-laminated siltstone (MGA 442990E 7213730N)

7197900N) of Sonny Well. The conglomerate is matrix supported and contains subrounded to angular clasts. Locally, within this horizon, the conglomerate clasts appear to have undergone dextral strike-slip shearing, although for the most part they remain weakly deformed.

Capricorn Orogeny

The 1830–1780 Ma Capricorn Orogeny reflects oblique convergence between the Pilbara and Yilgarn Cratons (Tyler and Thorne, 1990; Occhipinti et al., 1999a). GLENBURGH lies in the southern part of the Capricorn Orogen, which includes the Yarlarweelor gneiss complex, Glenburgh Terrane, and Errabiddy Shear Zone. The Errabiddy Shear Zone, which separates the Glenburgh Terrane, northern Yilgarn Craton, and Yarlarweelor gneiss complex, was deformed during the Capricorn Orogeny.

The Yarlarweelor gneiss complex is the part of the northwestern margin of the Yilgarn Craton that was extensively reworked and intruded by voluminous granite and pegmatite at 1820–1800 Ma (Occhipinti et al., 1998b). Granite and pegmatite sheets and veins intruded into the Yarlarweelor gneiss complex were pervasively deformed into D_{1n} (DP2 of Occhipinti and Myers, 1999; Sheppard and Swager, 1999) tight to open, easterly to northerly trending folds, and metamorphosed at medium to high grade. East-southeasterly trending dextral strike-slip movement and north–south compression in the region included both early ductile and late brittle stages, and led to the formation of fault-bend folds in the region in both the Yarlarweelor gneiss complex and the overlying Palaeoproterozoic supracrustal rocks during the Capricorn Orogeny.

The uppermost Archaean to Palaeoproterozoic Glenburgh Terrane, which had been accreted onto the northwestern or western margin of the Yilgarn Craton by c. 1960 Ma, was deformed, metamorphosed, and intruded by granites during the Capricorn Orogeny. Tight to isoclinal D_{1n} folds that developed in the Camel Hills Metamorphics at this time were refolded within the Errabiddy Shear Zone, from easterly trending in the south to northerly trending in the north (Sheppard and Occhipinti, 2000), possibly in the later stages of the Capricorn Orogeny. The Palaeoproterozoic Bryah and Padbury Groups (of the Bryah and Padbury Basins), which may have overlain the Yarlarweelor gneiss complex (Pirajno and Occhipinti, 2000) prior to the Capricorn Orogeny, were also pervasively deformed. These rocks were locally interleaved with the Yarlarweelor gneiss complex, and locally intruded by felsic granite (Martin, 1994; Reddy, S., 1999, written comm.) that may be part of the Moorarie Supersuite.

Deformation (D_{1n})

Only one period of deformation and metamorphism has been attributed to the Capricorn Orogeny on GLENBURGH (Table 1), although this deformation (D_{1n}) may have been long lived or continuous, rather than representing a discrete event. The most widespread D_{1n} structures on GLENBURGH are upright, open to close, shallowly to moderately plunging folds, and a pervasive easterly trending foliation. These mesoscopic folds are common in the Halfway Gneiss (northern domain; Fig. 4b,c), and the Mumba Pelite (Fig. 5a), but also include macroscopic folds south of Dunnawah Well. The Halfway Gneiss forms an elongate easterly trending dome that is interpreted as a regional-scale D_{1n} antiform refolded (probably during the Edmundian Orogeny) about a northerly trending axis. In the Mumba Pelite, in the central-northern part of GLENBURGH and just north of the Dalgety Fault, well-developed small-scale D_{1n} folds and S_{1n} crenulations deform an earlier S_{2g} bedding-parallel fabric. The S_{1n} foliation is well developed in the northern domain on GLENBURGH, particularly in sheets of the c. 1810 Ma Dumbie Granodiorite, which commonly contain a pervasive L–S or L-tectonite fabric, but are only rarely folded.

The age of the S_{1n} foliation in the northern domain is constrained by SHRIMP U–Pb zircon dating of intrusions belonging to the Moorarie Supersuite. The commonly foliated Dumbie Granodiorite on GLENBURGH and LANDOR, which is dated at 1811 ± 6 Ma and 1810 ± 9 Ma, provides a maximum age for the deformation. A minimum age for the deformation is provided by plutons and dykes of the Scrubber Granite (*ĿgMsc*) dated at 1796 ± 6 Ma, which are commonly massive, slightly discordant to S_{1n}, and locally cut faults that deform the Dumbie Granodiorite.

In the southern domain, the D_{1n} foliation is typically subparallel to the regional structural trend established during the Glenburgh Orogeny. The c. 1827 Ma biotite–muscovite granite plug in the central-eastern part of GLENBURGH contains a weak foliation, as do sheets of a similar granite to the north (dated at c. 1824 Ma) that have been intruded subparallel to ?D_{2g} fold-axial surfaces locally developed in the Dalgaringa Supersuite. Northerly trending Glenburgh Orogeny fabrics dated at 2000–1950 Ma in the Carrandibby Inlier southwest of GLENBURGH suggest that in the southwestern corner of GLENBURGH, the effect of the Capricorn Orogeny was to rotate earlier fabrics developed during the Glenburgh Orogeny into easterly trending structures. In the southeastern part of GLENBURGH, a mesoscopic-scale fold structure in the Nardoo Granite about 1 km north (MGA 432536E 7185253N) of Salt Well may have formed during the Capricorn Orogeny.

Large-scale faults on GLENBURGH cannot be unambiguously attributed to the Capricorn Orogeny. This is because of the overprinting effects of the Neoproterozoic Edmundian Orogeny, the possibility of earlier developed structures in the Glenburgh Orogeny, and the absence of relationships to igneous intrusions that could constrain the age of fault movements. However, the area north of the Dalgety Fault (Fig. 3), dominated by easterly trending sheets of granite of the Moorarie Supersuite, may represent a fault or shear zone that developed during the Capricorn Orogeny and has effectively been 'stitched' by granite. Alternatively, as this fault zone represents the broad boundary between the coherently deformed Halfway Gneiss and heterogeneously deformed plutons of the Dalgaringa Supersuite, it may have developed during the older Glenburgh Orogeny. In this case, however, it still appears to have been 'stitched' by granite during the Capricorn Orogeny.

Movement on some small-scale faults in the northern part of GLENBURGH must have occurred between c. 1810 Ma and c. 1800 Ma because as they deform the c. 1810 Ma Dumbie Granodiorite, but are cut by the c. 1796 Ma Scrubber Granite. Easterly and southeasterly trending faults may have influenced deposition of the Mount James Formation. A few dykes of coarse-grained granite and pegmatite of the Moorarie Supersuite (*ĿgMp*) are associated with conjugate shears in two orientations: 100–110° and 150–160°. This is consistent with north-northwest to south-southeast compression, possibly related to dextral strike-slip deformation during the Capricorn Orogeny.

Deformation of the Mount James Formation

The Mount James Formation commonly forms lenticular outcrops along easterly to northeasterly trending faults on GLENBURGH. Deformed and metamorphosed rocks of the Mount James Formation are unconformably overlain by rocks of the Mesoproterozoic Edmund Group. The Mount James Formation is not cut by granites of the Moorarie Supersuite. As the youngest granites mapped so far in contact with the Mount James Formation are c. 1796 Ma old, and the maximum age for the Edmund Group, which overlies the Mount James Formation, is c. 1640 Ma, the Mount James Formation was deposited and deformed between 1796 and 1640 Ma. Deposition of the Mount James Formation might correspond to the waning stages of the Capricorn Orogeny.

Tight folds in the Mount James Formation, parallel to the trend of adjacent faults, are present northeast of Fitzpatrick Well (Fig. 13a) in the central part of GLENBURGH, and about 3 km southeast (MGA 399600E 7220000N) of Weedarrah Well on DAURIE CREEK, west of GLENBURGH. In the latter area, folds in the conglomerate of the Mount James Formation are coplanar, but not co-axial, with folds in the underlying Mumba Pelite. A few hundred metres east of the Dairy Creek – Cobra road (MGA 394200E 721800N), there is a deformed unconformity where the Mount James Formation is folded into a shallow to moderately plunging syncline. Below the unconformity, the Mumba Pelite is folded about moderately to steeply plunging folds. The Mumba Pelite is not as tightly folded further south and fold hinges commonly plunge shallowly to moderately, suggesting that folds were 'tightened-up' close to faults during deformation of the Mount James Formation.

On GLENBURGH fine-grained units such as the quartz–chlorite–muscovite phyllite are well foliated parallel to the fold-axial surfaces. Coarser grained, silicic units such as the quartzite have not developed a strong foliation, although they define regional-scale folds.

Structures that affect the Mount James Formation are not always observed in the basement. An asymmetric, moderately plunging syncline contains overturned beds on the southern limb near the fold hinge northeast of Fitzpatrick Bore, and is faulted against rocks of the Dalgaringa Supersuite; however, the underlying rocks are not folded and are massive and unfoliated. Southwest and northwest of Sonny Well, in the western part of GLENBURGH, an easterly trending foliation in the Mount James Formation is oblique to the north-northwesterly trending pervasive foliation in the underlying foliated granite and granitic gneiss of the Dalgaringa Supersuite. The foliation in the Mount James Formation is apparently refolded about northerly trending open folds. This later folding is not observed in rocks of the underlying Dalgaringa Supersuite. These relationships imply that the Mount James Formation may have been deformed above a decollement separating it from the underlying Glenburgh Terrane rocks.

Metamorphism (M_{1n})

Rocks on GLENBURGH, including granites of the Moorarie Supersuite, show evidence of dynamic or static recrystallization under greenschist-facies conditions. This low-grade metamorphic overprint (M_{1n}) is more pervasive in the northern domain of GLENBURGH than in the southern domain. Retrogression may have accompanied fluid infiltration, partly associated with volatiles released from the Moorarie Supersuite granites in the northern domain.

Higher grade assemblages in the Moogie Metamorphics are partially or wholly overprinted by greenschist-facies assemblages. The best indicators of metamorphic grade during M_{1n} are the amphibolites or mafic gneisses of the Moogie Metamorphics. For example, a few amphibolites contain euhedral garnet wholly or partially replaced by chlorite, or chlorite, chloritoid, and minor amounts of quartz. The latter reaction occurs below about 500°C in the presence of H_2O (Bucher and Frey, 1994). In addition to this, amphibolites and quartz amphibolites contain rims of greenish-blue hornblende or actinolite on hornblende and clinopyroxene, together with replacement of plagioclase by ?oligoclase, epidote, and sericite. Ilmenite is commonly rimmed or wholly replaced by titanite. In the southern domain these reactions may have occurred during M_{2g}; in the northern domain they are more likely to have occurred during M_{1n}.

In the northern part of GLENBURGH, lenses of ultramafic rock are now composed of actinolite and minor amounts of clinozoisite, albite, and titanite, or tremolite, with or without serpentine, talc, and minor calcite. Of the calc-silicate gneisses, the amphibole- and diopside-rich gneisses are partly or wholly replaced by assemblages of actinolite–tremolite, epidote, albite, calcite, and titanite. Forsterite and clinohumite are commonly partly serpentinized in the marble. Serpentine only replaces forsterite below 400°C (Deer et al., 1966), that is, in the greenschist facies.

The widespread presence of chloritoid in the Mumba Pelite is an indicator of greenschist-facies metamorphism because in quartz-saturated rocks, chloritoid is unstable at about 550°C and decomposes to form garnet and staurolite (Bucher and Frey, 1994). The mineral assemblage quartz–magnetite–chloritoid is stable above temperatures of 300°C at low to high pressures (Bucher and Frey, 1994), and this is also indicative of greenschist-facies metamorphism. Greenschist-facies assemblages in the Mumba Pelite have completely replaced higher grade assemblages developed during the Glenburgh Orogeny. The presence of original bedding in a few samples of the Mumba Pelite is accentuated by the presence of minerals such as magnetite and chloritoid in different layers.

The Mumba Pelite now commonly consists of chloritoid-bearing schist, quartzofeldspathic schist, and quartzite. Quartzofeldspathic schist consists mostly of sericite and quartz, with minor amounts of biotite and feldspar. Chloritoid-bearing schist is variable and consists of a variety of rock types, including quartz–sericite–chloritoid(–chlorite) schist, quartz–magnetite–sericite–chloritoid(–chlorite) schist, and chloritoid–quartz–sericite schist. Chloritoid-bearing schist locally contains garnet or

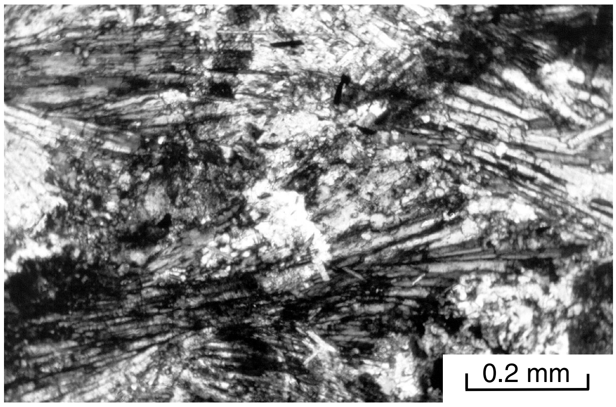

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Figure 14. Chloritoid-bearing schist of the Mumba Pelite (GSWA 159962; MGA 425900E 7230400N). The chloritoid exhibits 'bow-tie' texture. Other minerals in the sample include quartz and sericite (cross-polarized light)

tourmaline. Accessory minerals commonly include opaque minerals and tourmaline. Sericite commonly forms fine-grained aggregates with minor quartz, which may represent pseudomorphs of a higher grade mineral such as staurolite or sillimanite. Chloritoid, although sometimes aligned in the foliation of the rock, typically forms clumps and sprays and exhibits 'bow-tie' texture (Fig. 14). The chloritoid ranges from colourless to pale green or bright blue. The coloured varieties are strongly pleochroic.

All the granitic rocks, including the Halfway Gneiss, foliated to gneissic granites of the Dalgaringa Supersuite, Nardoo Granite, and granites of the Moorarie Supersuite, show similar mineralogical responses to the low-grade M_{1n} event. Igneous or high-grade metamorphic plagioclase is recrystallized to albite–oligoclase (An_{8-13}), sericite, and clinozoisite, quartz to fine-grained polygonal aggregates, biotite to fine crystals or partly replaced by chlorite, and myrmekitic and micrographic textures are widely developed.

Palaeoproterozoic to Mesoproterozoic geology

Bangemall Supergroup

The Bangemall Supergroup consists of the Edmund and Collier Groups (Martin et al., 1999). It was previously known as the 'Bangemall Group' with the Edmund and Collier Groups as subgroups (Muhling and Brakel, 1985; Cooper et al., 1998). Evidence of a major unconformity between the Edmund Group and the overlying Collier Group on the EDMUND, TUREE CREEK, and MOUNT EGERTON 1:250 000 sheets was the basis for raising these former subgroups to group status, and thus the 'Bangemall Group' to supergroup status (Martin et al., 1999). The 'Bangemall Group' was considered to be deposited in the Bangemall Basin (Muhling and Brakel, 1985), whereas the Edmund and Collier Groups are considered to have been deposited in the Edmund and Collier Basins respectively (Martin et al., 1999).

The Edmund and Collier Groups mainly comprise fine-grained siliciclastic and carbonate sedimentary rocks. These rocks typically rest unconformably on granitic and supracrustal rocks of the Archaean Yilgarn Craton, granitic and metamorphic rocks of the uppermost Archaean to Palaeoproterozoic Gascoyne Complex, and Palaeoproterozoic metasedimentary and meta-igneous rocks of the Bryah and Padbury Groups. In the western part of the Bangemall Basin, the Bangemall Supergroup is overlain by glacigene units of the Phanerozoic Carnarvon Basin (Williams et al., 1983b; Hocking et al., 1987), whereas to the east it is overlain by the Neoproterozoic–Palaeozoic Officer Basin (Williams, 1990).

The ages of the Edmund and Collier Groups are poorly constrained. They both unconformably overlie c. 1800 Ma granite of the Gascoyne Complex, and are overlain by rocks of the Neoproterozoic–Palaeozoic Officer Basin.

The maximum age of the Edmund Group is c. 1640 Ma, based on a SHRIMP U–Pb zircon date for the Tangadee Rhyolite near the base of the Bangemall Supergroup (Nelson, 1995). This date is controversial, however, because it is based on only two zircon analyses, with six other zircon analyses from the same sample (thought to be xenocrysts) giving an age of c. 1800 Ma. Nelson (1995) suggested that the c. 1640 Ma age may be a maximum age for emplacement of the rhyolite as all the analysed zircons from the sample could be xenocrysts.

A minimum age of c. 1020 Ma for the Edmund Group is provided by a U–Pb SHRIMP baddeleyite age for dolerite sills (Wingate, M., 1999, written comm.) that intruded lithified rocks of the Edmund Group. The relationship between the c. 1020 Ma dolerite sills and the Collier Group is unknown. However, the minimum age of the Collier Group is 755 ± 3 Ma, based on the U–Pb SHRIMP baddeleyite age (Wingate and Giddings, 2000) of northeasterly trending dolerite dykes of the extensive Mundine Well dyke swarm that intrude both the Collier and Edmund Groups.

The Edmund Group is the only part of the Bangemall Supergroup on GLENBURGH, forming small outliers over the Gascoyne Complex and Mount James Formation.

Edmund Group

The Edmund Group unconformably overlies rocks of the Archaean Yilgarn Craton, Gascoyne Complex, and Mount James Formation. East of GLENBURGH on ERRABIDDY, the base of the Edmund Group is the Tringadee Formation; however, on GLENBURGH and to the north on EDMUND, the base is considered to be the Yilgatherra Formation, which is overlain by the Irregully Formation (Martin et al., 1999).

Only the Yilgatherra Formation, Irregully Formation, and minor unassigned siliciclastic sedimentary rocks are present on GLENBURGH.

Yilgatherra Formation (ⱣMEy)

The Yilgatherra Formation (*ⱣMEy*) consists of sandstone, only a few metres thick, overlain by or interbedded with siltstone (Martin et al., 2000). The Yilgatherra Formation is overlain by the Irregully Formation. On GLENBURGH the Yilgatherra Formation outcrops just west of Hectors Bore in the northern part of GLENBURGH, and consists of massive, matrix-supported, arkosic quartz-pebble conglomerate, arkosic or quartz sandstone, silty sandstone, and siltstone, and is associated with local uranium mineralization. The quartz-pebble conglomerate is moderately sorted and contains angular to subrounded quartz clasts up to 4 cm in diameter. Most of the clasts are small (1–2 cm) and in places the outcrop consists of gritty arkosic sandstone. The siltstone and silty sandstone is yellow or yellowy-brown around areas of mineralization.

Irregully Formation (ⱣMEi)

The Irregully Formation (*ⱣMEi*) dominantly consists of dolomite interbedded with minor siliciclastic rocks, and has been interpreted as a fringing carbonate-platform deposit (Copp, 1998). In the northern part of GLENBURGH, interbedded dolostone and well-laminated calcareous siltstone forms a shallow to moderately dipping unit that is apparently conformable on the Yilgatherra Formation. In the central-western part of GLENBURGH, massive dolostone of the Irregully Formation is in faulted contact with the underlying Mount James Formation. The dolostone in this area is interbedded with massive reddish-brown quartz sandstone.

Dolostone and interbedded calcareous siltstone in the northern part of GLENBURGH, around Hectors Bore and northeast of Ti Tree Well, is well laminated and forms a sequence about 800 m thick. In this area the dolostone is typically grey, laminated, and probably stromatolitic. Tabular biostromes of conical stromatolites (Fig. 15a) 2 km northeast of Ti Tree Well and in the northwestern part of the Edmund Basin (Grey, 1985; Copp, 1998) are identified as *Conophyton* form indt. by K. Grey (2000, written comm.).

The Irregully Formation also contains undulatory and pseudocolumnar ?stromatolitic beds, particularly in the Hectors Bore area in the northern part of GLENBURGH. These are interbedded with calcareous siltstone and intraclastic breccia. The intraclastic breccias typically form matrix-supported and poorly sorted tabular beds (Fig. 15b). Clasts of laminated siltstone and dolostone are angular and elongate or tabular in shape, and in places the ends of clasts have a feather-like appearance. The matrix of the intraclastic breccia is calcareous siltstone to calcareous silty sandstone. The silty sandstone contains angular quartz grains that are locally granule sized. Mosaic breccias are defined by a jigsaw-fit texture in the Hectors Bore area, but are not as common as the intraclastic breccias.

Sedimentary structures, such as flute structures, cross-bedding, and graded bedding, in the Irregully Formation in the northern part of GLENBURGH indicate that beds of the Irregully Formation were upward facing. Palaeocurrent directions could not be determined.

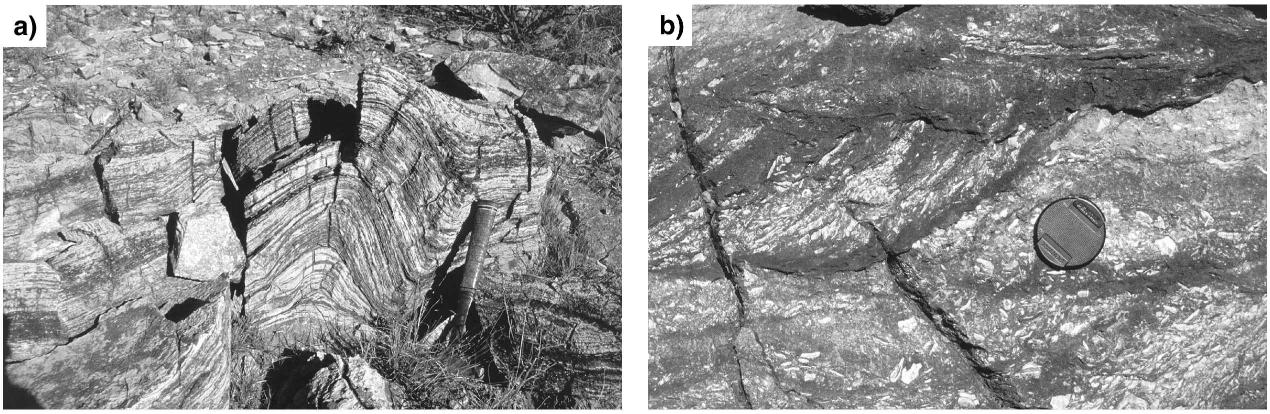

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Figure 15. Dolostone of the Edmund Group: a) stromatolite, *Conophyton* bed in the Irregully Formation (MGA 428540E 7228030N); b) cross-stratified intraclastic breccia (MGA 423480E 7227030N)

Unassigned units of the Edmund Group (ⱣME(t), ⱣME(s))

Unassigned siliciclastic rocks in the northern part of GLENBURGH include quartz sandstone (*ⱣME(t)*) and siltstone (*ⱣME(s)*) near Dumbie Well, and quartz sandstone 3 km west of Wilson Bore. In the northeastern part of the map sheet (MGA 444900E 7234200N), an unconformity is present between moderately to steeply dipping laminated quartz sandstone (interbedded with silty sandstone) and the steeply dipping Dumbie Granodiorite. The gently to moderately dipping quartz sandstone (*ⱣME(t)*) west of Wilson Bore is a few metres thick and unconformably overlies the Halfway Gneiss and deformed Mount James Formation. These quartz sandstones locally contain cross-bedding and symmetric ripples. There is possible large-scale (?eolian) cross-bedding 3 km northeast of Wilson Bore, although outcrop is commonly poor and this interpretation is equivocal.

Given the nature of these unassigned units, it is likely that they form part of the Yilgatherra Formation; however, its relationship to the Irregully Formation and other rocks of the Edmund Group is unknown so the units have not been assigned to any formation on GLENBURGH.

Neoproterozoic Edmundian Orogeny

The Neoproterozoic Edmundian Orogeny (Halligan and Daniels, 1964) deformed rocks of the Bangemall Supergroup and underlying units, as well as a few dolerite sills intruding the Edmund Group. Sedimentary rocks of the Edmund Group and the dolerite sills, north and east of GLENBURGH, are folded into broad dome-and-basin structures. Deformation in underlying rocks is difficult to determine. This may be due to the Edmundian structures being coplanar with those developed during the earlier Capricorn Orogeny. However, it is probable that much of the strain in the 'basement rocks' was taken up by the reactivation of structures developed earlier.

The Edmundian Orogeny resulted in north–south shortening to form easterly to southeasterly trending, open to tight, upright folds and faults. Myers et al. (1996) suggested that this may have been the result of the collision between the North and Western Australian Cratons between 1300 and 1100 Ma; however, dolerite sills intruded into and folded with the Edmund Group are dated at c. 1020 Ma (Wingate, M., 1999, written comm.). The Bangemall Supergroup is refolded about a northerly trending axis to form dome-and-basin structures. North-northeasterly trending dolerite dykes of the Mundine Well dyke swarm cut the folds and are dated at 755 ± 3 Ma (Wingate and Giddings, 2000), providing a younger limit on the age of deformation. Thus the Edmundian Orogeny occurred between 1020 and 755 Ma.

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

In the Hectors Bore area in the northern part of GLENBURGH, an easterly trending (D_{1e}) synform in deformed dolostone is refolded about a northerly trending open fold (D_{2e}). To the south, east of Sonny Well, an easterly trending (D_{1e}) reverse fault separates the overthrusted Mount James Formation from the Irregully Formation. Locally, an easterly trending slaty cleavage (S_{1e}) is well developed in siltstone north of the Dumbie Well area. The doubly plunging nature of the regional-scale D_{1n} antiform in the Halfway Gneiss reflects refolding about a northerly trending F_{2e} fold-axial surface.

Other structures on GLENBURGH that may be attributed to the Edmundian Orogeny include several large-scale northerly and easterly trending fault zones, particularly in the northern half of the sheet area. Easterly trending normal faults in the northern part of GLENBURGH may have formed during development of the Edmund Basin and undergone some reactivation to form local reverse faults. For example, southeast of Geringee Bore, an easterly trending fault cuts granite of the Moorarie Supersuite and indicates both normal and reverse movement along the same structure. Although it is possible that this fault originally developed as a compressional structure during the Capricorn Orogeny, and was later reactivated during development of the Edmund Basin, the reverse movement may have also developed during the Edmundian Orogeny.

Dolerite dykes (*d*)

Dolerite dykes intrude all the Upper Archaean and Proterozoic rocks on GLENBURGH, with the exception of the Mount James Formation. The latter may be an artefact of the limited outcrop of the Mount James Formation on GLENBURGH. The dykes typically trend either east northeasterly to easterly or north-northwesterly to northerly. A few dykes in both these orientations show appreciable swings in strike, perhaps reflecting the presence of earlier fault structures. Most of the dolerite dykes range from about 2 to 10 m in thickness; however, larger dykes may be 50–100 m wide, such as those east of Carradarra Well and southeast of Boornamulla Well in the southern part of GLENBURGH. The largest dykes can be traced discontinuously along strike for up to 15 km.

The northerly to northeasterly trending dolerite dykes are part of the Mundine Well dyke swarm (Hickman and Lipple, 1978; Tyler, 1990), which intrude various tectonic units, including Mesoproterozoic rocks of the Bangemall Superbasin. A sample from a dyke intruding the Bangemall Supergroup was dated at 755 ± 3 Ma using SHRIMP U–Pb dating of zircon and baddeleyite (Wingate and Giddings, 2000). On GLENBURGH a few of the northerly trending dolerite dykes intrude easterly trending dykes, or are emplaced into faults or fractures that cut the easterly trending dykes, although the reverse is true locally. Easterly trending dykes and, in places, northerly trending dykes are cut by easterly or east-southeasterly trending faults.

The dolerite dykes are massive, and range from fine grained and aphyric to medium grained ($\leq$2 mm) with scattered plagioclase phenocrysts. All the dykes have subophitic and intergranular textures. A few northerly trending dykes have a spaced cleavage parallel to the dyke walls. Most of the larger dykes show zoning from fine-grained margins to medium-grained interiors. The rocks are composed of plagioclase, pale-purple to pale-brown titaniferous augite, iron oxides, and minor amounts of green hornblende and interstitial quartz. Minor micrographic intergrowths of quartz and feldspar interstitial to plagioclase are also present. Augite crystals are commonly zoned from colourless cores to pale-purple or pale-brown exteriors. Titaniferous augite has fine lamellar exsolution of orthopyroxene. Hornblende forms rims to some crystals of augite.

Two samples from easterly trending dykes in the southeastern part of GLENBURGH show complete replacement of igneous minerals by a low-grade metamorphic assemblage. Subophitic igneous texture is locally preserved. The rocks are massive and composed of fine-grained actinolite, oligoclase, epidote, and minor amounts of titanite. Accessory amounts of reddish-brown biotite may be present.

Palaeozoic geology

Upper Carboniferous to Lower Permian Carnarvon Basin

Lyons Group (*CPL*)

The Lyons Group (*CPL*, 'Lyons Formation' of van de Graaff et al., 1977; Williams et al., 1983b) is a glacigene succession of the Carnarvon Basin (Hocking et al., 1987) that unconformably overlies the Glenburgh Terrane (Gascoyne Complex). The Lyons Group is exposed in the southwestern part of GLENBURGH as a northerly trending strip dominated by matrix-supported cobble to boulder conglomerate (?tillite) with lesser amounts of sandstone and mudstone. The conglomerate forms rubbly outcrop and subcrop of mainly pebbly and boulder debris of weathered-out glacial erratics. The glacial erratics typically consist of rounded quartz pebbles, locally striated cobbles, and boulders. Immature sandstone, siltstone, and shale form the matrix; however, these rocks are commonly weathered on GLENBURGH. Elsewhere on the GLENBURGH 1:250 000 sheet, near the ruins of Coordewandy Homestead, varvoid shale has been reported in the Lyons Group but it was not observed during this study.

Quartz veins (*q*)

Quartz veins of various ages outcrop over GLENBURGH and commonly mark major faults or fault zones. The quartz veins are white or blue, and range from massive to foliated or gneissic. In the northern half of GLENBURGH, a few quartz veins also contain minor amounts of black tourmaline. The outcrop pattern of a series of offset quartz veins between 2 Mile Well and Wilson Bore may mark the presence of a large-scale duplex structure. Mylonitized quartz veins are common on GLENBURGH, particularly in the northern part of the sheet. Where quartz veins are deformed, they form quartzite and are difficult to distinguish from quartzite derived from deformed and metamorphosed quartz sandstone.

Cainozoic geology

The Cainozoic geology on GLENBURGH has been divided into 13 units, including Quaternary deposits. The units have been assigned to either depositional or relict regimes, and are similar to those on the GLENBURGH 1:250 000 regolith materials map sheet (Sanders et al., 1998).

Alluvial deposits (*A*) of sand, gravel, clay, and silt are extensively developed in the main river channels and their larger tributaries. Alluvial deposits commonly grade into overbank (A_f) and sheetwash deposits (*W*) of sand, silt, and gravel. Lake deposits (*L*), containing sand, silt, and clay, are restricted to a small lake (<0.5 km^2) southwest of Dalgety Downs Homestead. Calcrete (*Ak*) forms extensive outcrops around drainage channels on the eastern edge of GLENBURGH and in the central part south of Dalgety Downs Homestead. Eolian deposits (*S*) of sand with minor silt and clay are restricted to two small areas in the southeast and southwest. Colluvium (*C1*) forms extensive scree slopes around all the uplands of rock outcrops on GLENBURGH. In flat areas and on gentle slopes, most colluvium forms a veneer of gravel-sized, angular or rounded fragments within sand or silt, either over rock or older consolidated colluvium (*C2*). In some areas, particularly the central-eastern part of GLENBURGH, colluvium is dominated by quartz-vein debris (*C1q*). These deposits typically form where abundant quartz veins are present. Ferruginous gravel, sand, and silt (*C1f*) is restricted to a very small area on the northern edge of GLENBURGH, forming scree slopes of degraded ferruginous duricrust.

Consolidated gravel, sand, and silt, and hardpan (*C2*) is well developed around incised creeks on GLENBURGH, in particular around Geeranoo Creek and Dalgety Brook. Ferruginous duricrust and hardpan (*Rf*) forms a residual plateau in the southwestern corner of the sheet area. This duricrust represents the northeastern edge of an old land surface that is exposed over a large area farther west and south. Underneath the duricrust surface, weathered quartzofeldspathic rock (*Rg*) is exposed along much of the southern edge of GLENBURGH. Weathered quartzofeldspathic rock also forms large areas in the northern part of the sheet area. Silcrete and brecciated siliceous caprock (*Rz*) is restricted to two small areas about 6 km east-northeast of Dalgety Downs Homestead.

Economic geology

Gold

Helix Resources NL identified a northeasterly striking zone of gold mineralization nearly 20 km long in the southeastern part of GLENBURGH (Gold Gazette, 23 October 1995; Paydirt, July 1995). This zone extends from east of Bubba Burndy Bore to just south of Condamine Well, and includes the Apollo, Zone 102, and Zone 126 prospects. The Apollo prospect is about 1 km west, and Zone 102 and Zone 126 about 3.5 and 5 km east-northeast, of Victoria Bore respectively. Helix Resources interpreted the host rocks as meta-sedimentary and mafic meta-igneous rocks. Our work, however, indicates that the rocks within the zone of gold mineralization consist of granitic gneiss of the Dalgaringa Supersuite, amphibolite and mafic granulite, and minor migmatitic pelitic rocks. Helix Resources announced an inferred resource estimated as 1.28 Mt gold at 2.5 g/t, for a total of about 103 000 oz (3204 kg) of contained gold (Gold Gazette, 23 October 1995; Paydirt, July 1995).

The areas around shallow copper workings 3.5 km south-southeast and 10.5 km south-southwest of Dalgety Downs Homestead were drilled by Endeavour Resources for gold and copper. The highest recorded value was 1.91 g/t gold from 2 to 4 m in one drillhole (Endeavour Resources, 1988).

Barite

Barite veins in ‘gneissic adamellite’ of the Dumbie Granodiorite were identified by the Universal Milling Company Ltd in 1976–77 at the Pentalls prospect in the northwestern part of GLENBURGH (Universal Milling Company Ltd, 1977). Traces of malachite and fluorite were also reported. The veins are about 30 m long and between 0.6 and 1.2 m wide, although one composite vein is about 100 m long and inferred to contain 3600 t of barite.

Copper

Several copper prospects, and a few copper occurrences, have been identified on GLENBURGH (Marston, 1979; Williams et al., 1983b, Clarke and Williams, 1986). The only recorded production is 12.17 t of ore that yielded 1.62 t of copper (Low, 1963), which probably came from small workings about 5 km southeast of Dalgety Downs Homestead (Williams et al., 1983b). Patchy malachite, chrysocolla, and ?azurite are hosted in a northeasterly trending quartz vein that cuts foliated to gneissic granodiorite. There are also shallow workings for copper about 3.5 km south-southeast and 10 km south-southwest of Dalgety Downs Homestead.

In the northwestern part of GLENBURGH several occurrences of copper mineralization were discovered during the first edition 1:250 000 mapping (Williams et al., 1983b). These occurrences consist of malachite, chrysocolla, and ?azurite associated with quartz veins. In addition, moolooite, a hydrated copper oxalate was discovered and identified on GLENBURGH in a sulfide-bearing quartz outcrop 12 km east of Mooloo Downs Homestead (Clarke and Williams, 1986). A further occurrence of moolooite was found during regional mapping on a metre-scale east-southeasterly trending quartz vein outcropping on the western side of a track between Dunnawah Well and Mia Well (MGA 401400E 7222450N).

Base metals

Exploration by CRA Exploration for base metals between Bunbury Well and Dumbie Well in the northern part of GLENBURGH identified a few gossans, sulfidic quartzite, and massive magnetite(–hematite) pods (CRA Exploration Pty Ltd, 1985). However, follow-up rock-chip and stream-sediment sampling did not detect any mineralization. Pasminco Exploration identified zinc and lead anomalies associated with garnetiferous quartzite and gossans in the Mumba Pelite west of GLENBURGH (Pasminco Exploration, 1995).

Uranium

Williams et al. (1983b) reported traces of carnotite ($K_2(UO_2)_2(VO_4)_2.3H_2O$) in colluvium overlying Bangemall Supergroup rocks near Hectors Bore in the northern part of GLENBURGH. Extensive exploration for unconformity vein-type uranium deposits failed to locate any significant mineralization (Urangesellschaft Australia Pty Ltd, 1983; PNC Exploration (Australia) Pty Ltd, 1996). Urangesellschaft Australia Pty Ltd (1983) identified only very low grade mineralization restricted to weathered bedrock. The uranium is contained in carnotite (Williams et al., 1983b), although small black crystals of ?uraninite may be locally present.

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Appendix

Gazetteer of localities on GLENBURGH

Locality	*MGA coordinates* *Easting*	*Northing*
Boornamulla Well	422000	7185900
Bubba Burndy Bore	401100	7188400
Bunbury Well (abd)	411050	7231800
Burrin Bore	424400	7209800
Carradarra Well	426200	7195700
Challenger Well	441100	7201400
Condamine Well	419300	7198300
Dalgety Downs Homestead	420300	7203700
Dardoo Well (abd)	427000	7183900
Dumbie Well	434300	7230800
Dunnawah Well	401400	7223400
Errawarra Well	407200	7214900
Fitzpatrick Bore (PD)	428700	7207500
Fitzpatrick Well (PD)	429300	7206200
Fred Well	429700	7195300
Geringee Bore	416900	7218900
Ghnyndad Bore (abd)	430400	7190700
Glenburgh Homestead	410700	7186800
Gregory Bore	449300	7208400
Hadlam Well	435300	7202000
Hectors Bore	422400	7226800
Meerawana Well	421300	7190300
Mia Well	403400	7219600
Middle Well (abd)	413100	7226100
Moogie Well (abd)	405700	7212900
Mount Puckford	447000	7216500
Mulunka Well	447700	7197600
Nardoo Well	449400	7188100
New Well	406600	7224100
Paradise Well	414400	7191800
Parrot Bore	443800	7180900
Puckford Bore	442100	7217900
Salt Well	432600	7184200
Sonny Well	402900	7197300
Ti Tree Well (abd)	426800	7226800
2 Mile Well	401700	7230400
Victoria Bore	411000	7191500
Watson Bore	434600	7210100
Wilson Bore	428200	7222200

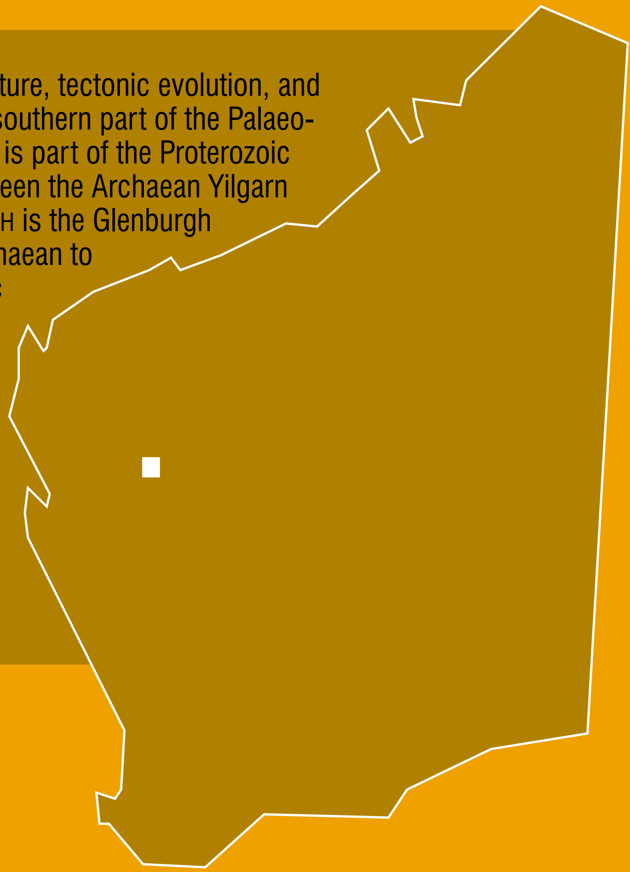
NOTES: abd: abandoned
PD: position doubtful

OCCHIPINTI, SHEPPARD

Geology of the Glenburgh 1:100 000 sheet

EXPLANATORY NOTES

These Explanatory Notes describe the stratigraphy, structure, tectonic evolution, and mineralization of the GLENBURGH 1:100 000 sheet in the southern part of the Palaeoproterozoic Gascoyne Complex. The Gascoyne Complex is part of the Proterozoic Capricorn Orogen, a major orogenic belt developed between the Archaean Yilgarn and Pilbara Cratons. The main tectonic unit on GLENBURGH is the Glenburgh Terrane, comprising granitic rocks of the uppermost Archaean to Palaeoproterozoic Halfway Gneiss and Palaeoproterozoic Dalgaringa Supersuite, and metasedimentary rocks of the Palaeoproterozoic Moogie Metamorphics. The Glenburgh Terrane is intruded by the Moorarie Supersuite and unconformably overlain by the Mount James Formation and Bangemall Supergroup. Rocks on GLENBURGH were deformed and metamorphosed during the 2000–1960 Ma Glenburgh Orogeny and the 1830–1780 Ma Capricorn Orogeny. GLENBURGH contains gold, copper, base metal, uranium, and barite mineralization.



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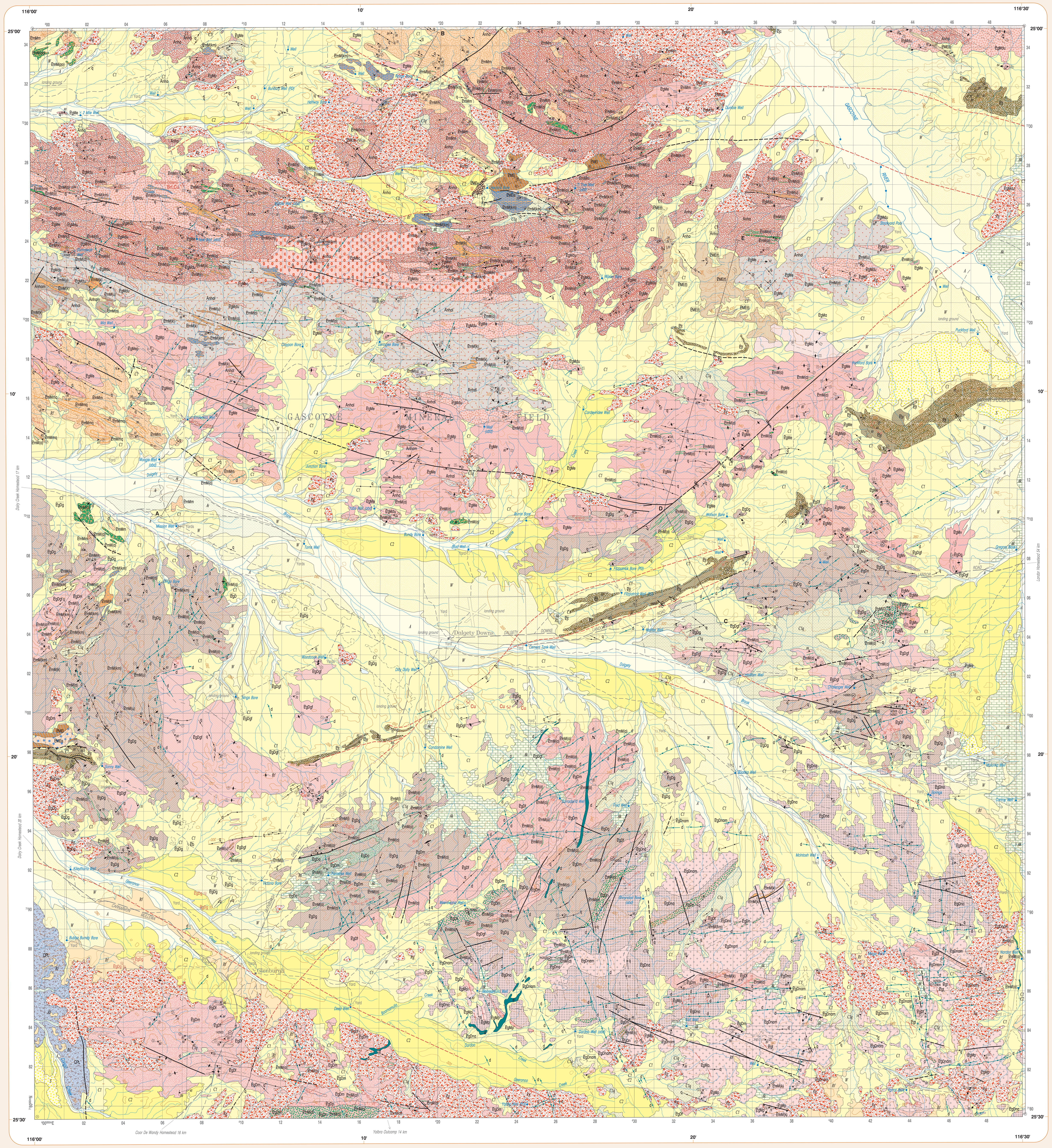
AUSTRALIA 1:100 000

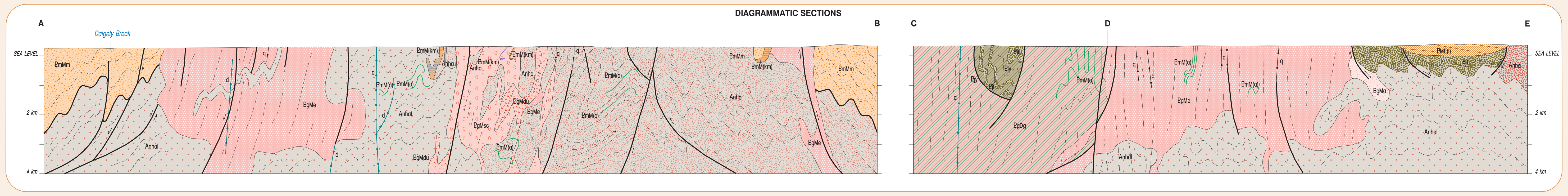
GLENBURGH

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET 2147



DIAGRAMMATIC SECTIONS



C1 | C1f | C1q | W | A | Ar | Ak | L | S

Colluvial units
- *C1* Unconsolidated silt, sand, and gravel forming scree slopes
- *C1f* Ferruginous gravel, sand, and silt on scree slopes; degraded ferruginous duricrust; minor proximal transported ironstone rubble
- *C1q* Quartz-vein debris forming scree slopes

Sheetwash unit
- *W* Clay, silt, sand, and gravel fans on low-gradient slopes

Alluvial units
- *A* Unconsolidated clay, silt, sand, and gravel in channels
- *Ar* Unconsolidated clay, silt, sand, and gravel in recognizable drainage systems and on floodplains
- *Ak* Calcrete developed in and adjacent to alluvial channels

Lacustrine unit
- *L* Silt, clay, and sand in ephemeral lake

Sandplain unit
- *S* Eolian sand with minor silt and clay; includes low, vegetated dunes

C2 | Rf | Rg | Rz

Colluvial unit
- *C2* Dissected and consolidated gravel, sand, and silt, and hardpan

Relict units
- *Rf* Ferruginous duricrust and hardpan forming residual plateaus over weathered rock
- *Rg* Weathered quartzofeldspathic rock with locally derived sand and sandy clays
- *Rz* Silcrete and brecciated siliceous caprock

CPL **Lyons Group:** immature sandstone, and siltstone, shale, tillite, and varvoid shale; contains numerous glacial erratics — SOUTHERN CARNARVON BASIN

q Quartz and quartz–tourmaline veins, of various ages; locally strongly deformed and may include strongly deformed quartzite

d Dolerite dyke; fine- to medium-grained, even-textured or weakly porphyritic; subophitic and intergranular texture; dashed where interpreted from aeromagnetic data, – negative anomaly

PHANEROZOIC — CAINOZOIC — QUATERNARY; PALAEOZOIC — CARBONIFEROUS – PERMIAN

Edmundian Orogeny (1020–750 Ma)

MESOPROTEROZOIC — Bangemall Supergroup — Edmund Group — EDMUND BASIN

IRREGULLY FORMATION

YILGATHERRA FORMATION

Capricorn Orogeny (1830–1780 Ma)

MOUNT JAMES FORMATION

SCRUBBER GRANITE

DUMBIE GRANODIORITE

Glenburgh Orogeny (2000–1960 Ma)

NARDOO GRANITE

MUMBA PELITE

PALAEOPROTEROZOIC — Moorarie Supersuite — Dalgaringa Supersuite — Moogie Metamorphics — GASCOYNE COMPLEX

HALFWAY GNEISS

ARCHAEAN

Geological boundary
- exposed
- concealed

Structural symbols are labelled according to the sequence of deformation events, where known
- Edmundian Orogeny (1020–750 Ma)
  - D_{1e}
- Capricorn Orogeny (1830–1780 Ma)
  - D_{1n}
- Glenburgh Orogeny (2000–1960 Ma)
  - D_{2g}
  - D_{1g}

Fault
- exposed
- normal, tick on downthrown side
- thrust, triangle on upthrown side, showing dip
- concealed
- concealed, position uncertain
- concealed, interpreted from aeromagnetic data
- strike-slip, showing relative horizontal displacement

Strongly foliated rock

Fold, showing axial trace and generalized plunge direction
- anticline, exposed
- syncline; exposed, concealed

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

Small-scale fold axial surface, showing trend and plunge
- unspecified
- antiform
- synform
- Z-vergence
- S-vergence
- M-vergence

Locality of superposed fold

Bedding, showing strike and dip
- inclined
- overturned
- trend of bedding

Way-up indicator
- sedimentary structure

Foliation, showing strike and dip
- inclined
- vertical

Gneissic banding, showing strike and dip
- inclined
- vertical

Trend of foliation or gneissic banding

Cleavage, showing strike and dip
- inclined
- vertical

Crenulation cleavage, showing strike and dip
- inclined
- vertical

Shear-sense indicator
- dextral
- sinistral
- showing dip of foliation
  - inclined
  - vertical

Stretching lineation, showing trend and plunge

Axis of crenulation, showing trend and plunge

Bedding—cleavage intersection lineation, showing trend and plunge

Airphoto lineament
- structural

Aeromagnetic lineament

Stromatolite fossil locality

Isotopic age determination site with identification number — 142988

Formed road

Track

Fence, generally with track

Homestead — Glenburgh

Yard — Yard

Breakaway

Sand dune

Contour, height in metres — 480

Watercourse with ephemeral pool or waterhole

Spring — Spring

Bore, well — Bore, Well

Windpump

Abandoned — (abd)

Position doubtful — (PD)

Mine, abandoned

Opencut — Mooloo Downs

Quarry or pit

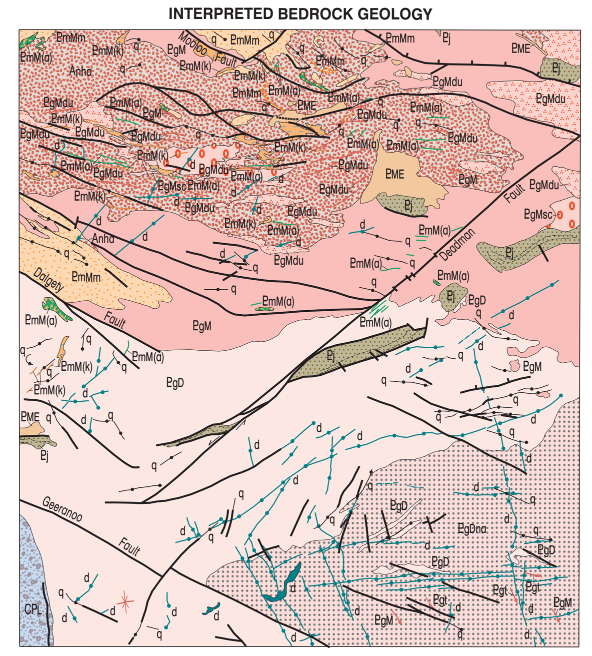
Prospect — Cu

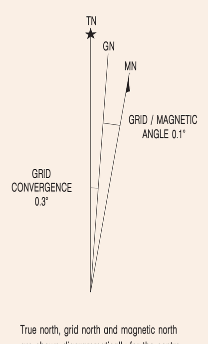
Mineral exploration drillhole, showing subsurface data — ᵽgDg

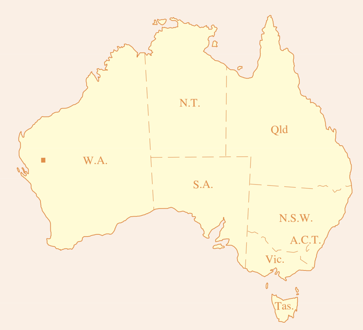
Mineral exploration drill line, showing subsurface data — ᵽgDg

Mineral occurrence
- Barite — Brt
- Copper — Cu

INTERPRETED BEDROCK GEOLOGY







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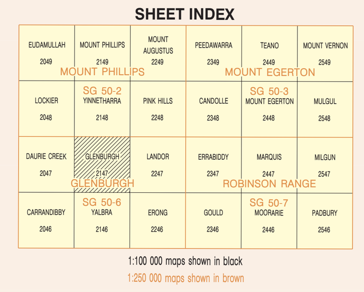

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Department of Industry and Resources

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MINISTER FOR STATE DEVELOPMENT

JIM LIMERICK
DIRECTOR GENERAL

Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

SCALE 1:100 000

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

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Map Grid Australia 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

GLENBURGH

SHEET 2147 — FIRST EDITION 2000

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