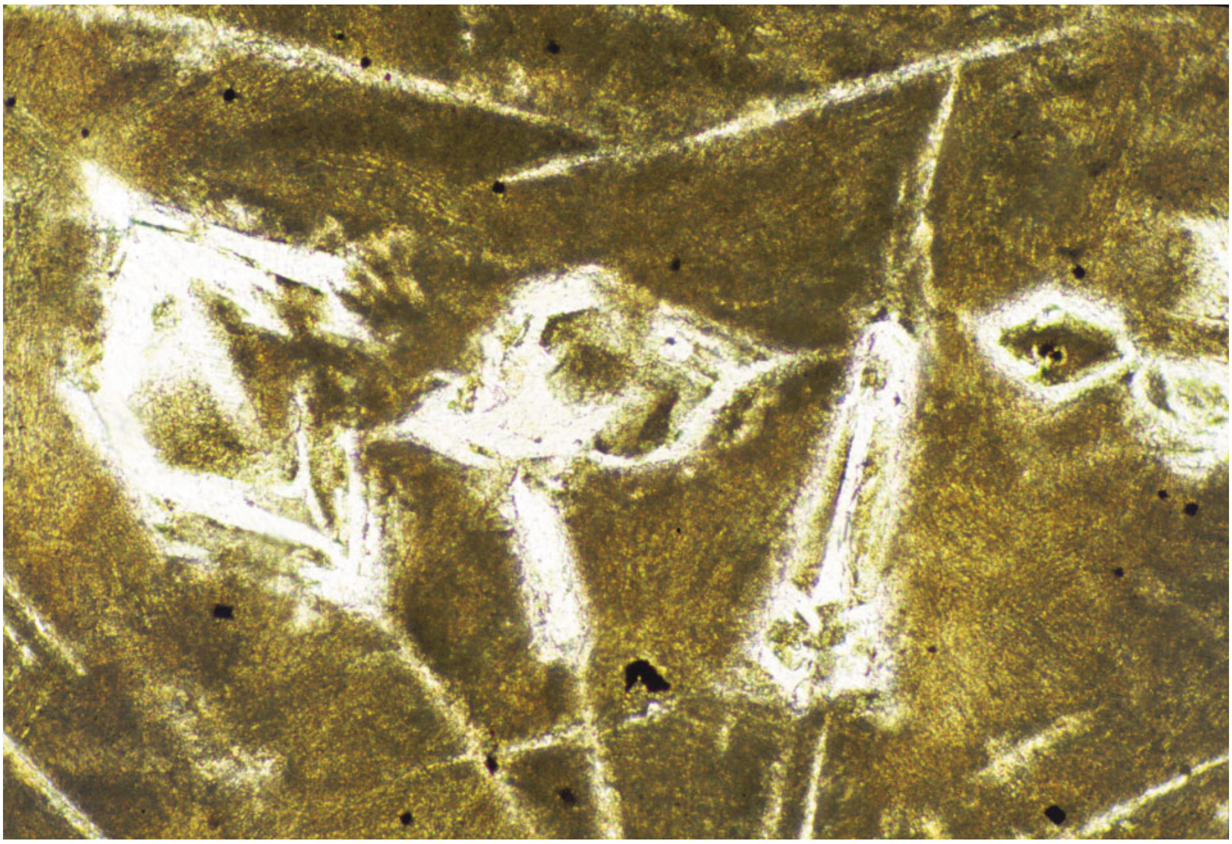
EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE MILLROSE 1:100 000 SHEET

by T. R. Farrell and S. Wyche

1:100 000 GEOLOGICAL SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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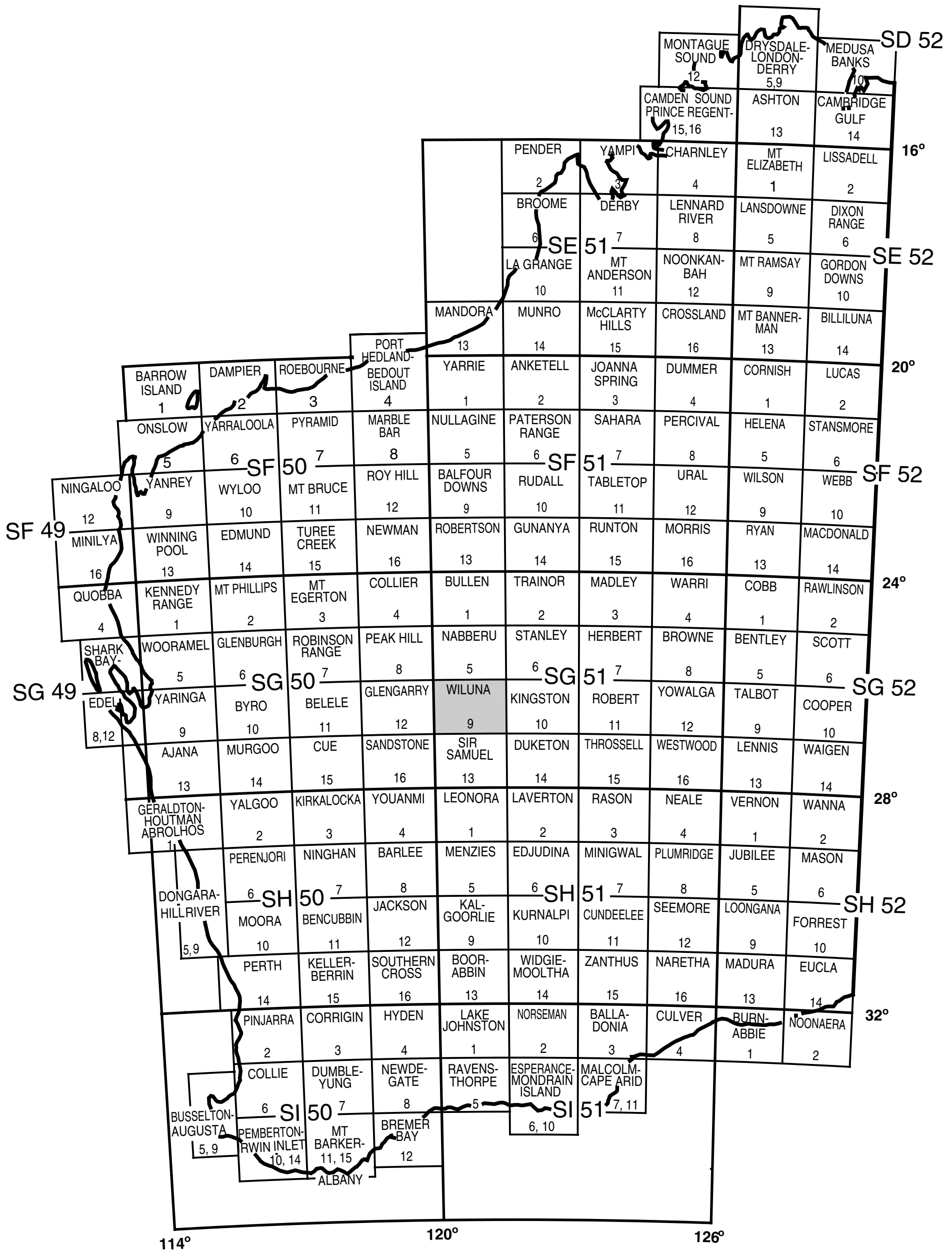

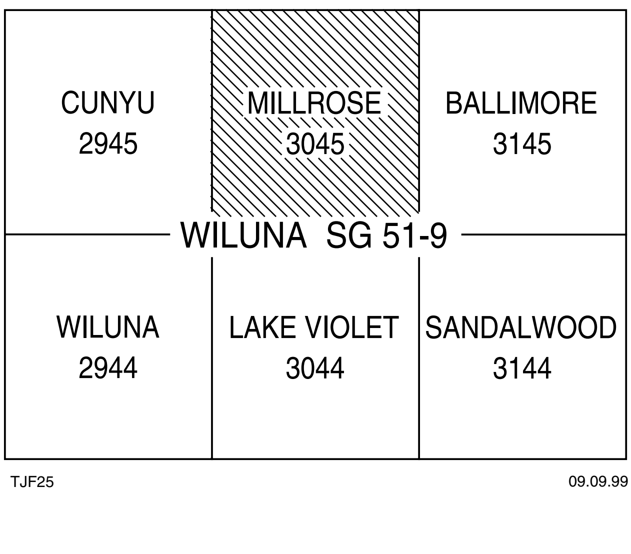

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE MILLROSE 1:100 000 SHEET

by
T. R. Farrell and S. Wyche

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Cover photograph:
Photomicrograph of chlorite pseudomorphs of skeletal olivine crystals set in a fine-grained devitrified groundmass in a metamorphosed high-Mg basalt. Sample from drillhole chips from the Rose Hills area (AMG 712693).

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Geology of the Millrose 1:100 000 sheet

by

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Abstract

The MILLROSE 1:100 000 geological sheet includes much of the northern end of the Yandal greenstone belt, and adjacent granitoid rocks and gneisses. The Yandal belt bifurcates just south of the MILLROSE sheet to form a western greenstone sequence, the Jundee domain, and an eastern greenstone sequence, the Millrose domain.

The Jundee domain is the larger of the two greenstone sequences and contains three broad lithological packages: an eastern mafic–ultramafic sequence, a central felsic volcanic – sedimentary sequence, and a western sequence containing mafic rocks and banded iron-formation. The Millrose domain is relatively narrow and the poor exposure, deep weathering, and strong deformation preclude determination of the stratigraphy.

Large areas of granitoid rock and gneiss flank the greenstone sequences. Monzogranite is the predominant granitoid type, although there are also intrusions of more mafic granitoid rocks, including monzonite and syenite. Areas of gneiss are dominated by quartzofeldspathic gneiss and deformed monzogranite, but also contain minor amounts of amphibolite, mafic gneiss, metamorphosed banded iron-formation, and monzonite.

The region has a complex tectonic history, with evidence for at least four phases of Archaean deformation (D_1–D_4). In addition, late faults and fracture zones of ?Proterozoic age cut across all major lithotectonic units. Metamorphism of the greenstones is typically of low grade, whereas the gneisses reflect upper amphibolite-facies metamorphism.

The Jundee–Nimary gold deposit in the central part of the Jundee domain contains total inferred, indicated, and measured resources of about 210 t (6.76 Moz) of gold.

KEYWORDS: Archaean, regional geology, Yilgarn, Eastern Goldfields, Jundee, Nimary, Yandal, gold, greenstone, gneiss

Introduction

The MILLROSE* 1:100 000 sheet (SG 51-9, 3045) covers the area between latitudes 26°00' and 26°30'S, and longitudes 120°30' and 121°00'E (Fig. 1). MILLROSE occupies the central-northern part of the WILUNA 1:250 000 sheet, and is named after Millrose, a pastoral station in the eastern part of the sheet area. The nearest town is Wiluna, about 29 km west-southwest of the southwestern corner of MILLROSE.

Mapping of MILLROSE was carried out between April and August 1995 using 1:25 000-scale colour aerial photographs, commissioned by the Western Australian Department of Land Administration (DOLA) in 1994–95, complemented by Landsat TM5 (Thematic Mapper) images, and 400-m line-spaced aeromagnetic data acquired by the Australian Geological Survey Organisation (AGSO) and the Geological Survey of Western Australia (GSWA) in 1994.

Access

Access to MILLROSE is either by the Jundee Road, which services Jundee Homestead and the Jundee–Nimary gold mine, or by the Lake Violet – Granite Peak Road, which passes through southeastern MILLROSE, close to Millrose Homestead (Fig. 2). Most areas underlain by greenstone are readily accessible along station tracks and mineral

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

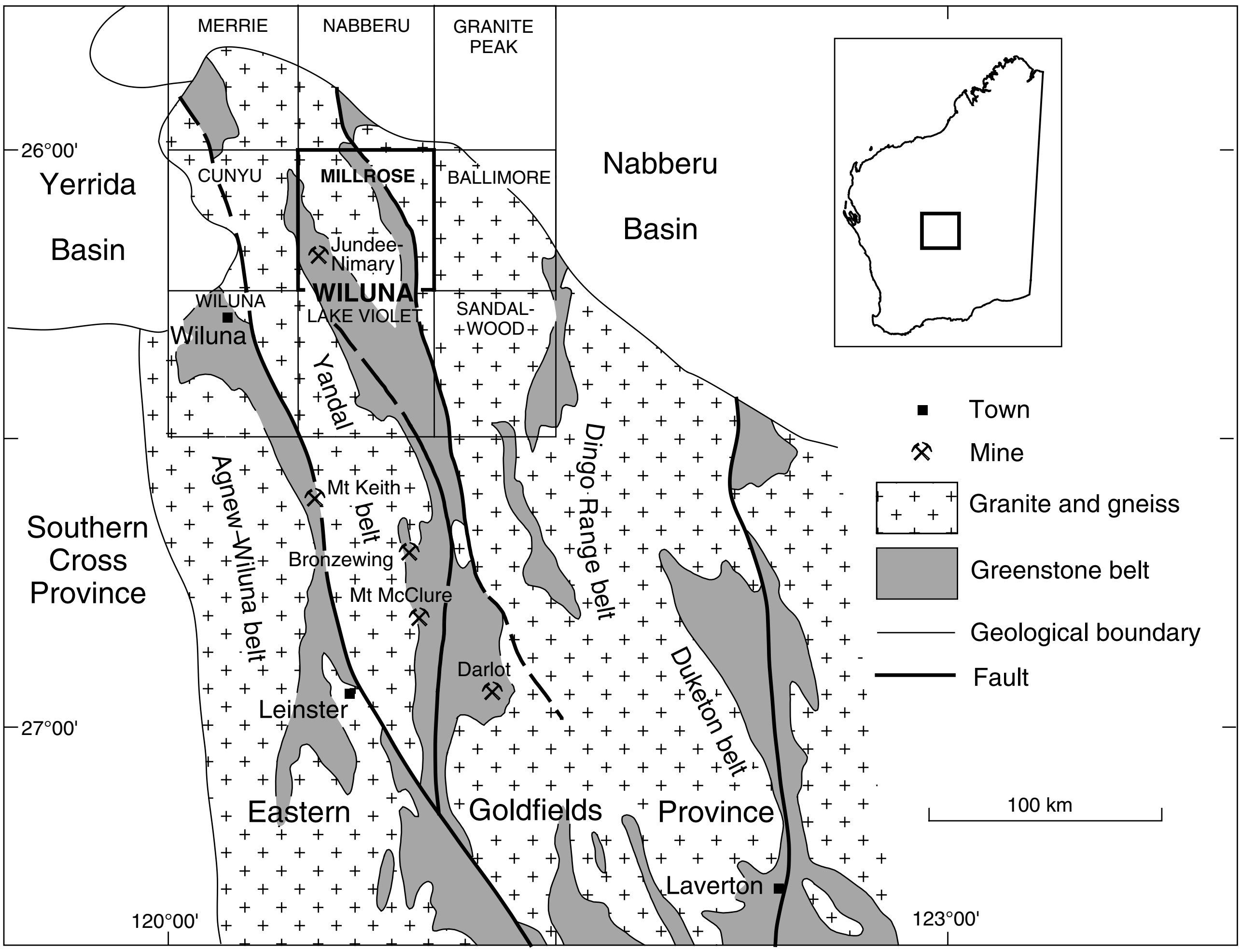

Figure 1. Location of MILLROSE in the northern part of the Eastern Goldfields Province

exploration gridlines. Access to areas in the north that are underlain by granitoid rocks is difficult due to a lack of tracks and fence lines.

Climate and vegetation

The climate is semi-arid to arid. Data for Wiluna show that January is the hottest month, with an average maximum temperature of 37.7°C and an average minimum of 21.1°C. Daily maxima commonly exceed 40°C in summer. Winters are cool to mild, with occasional frosts. The coldest month, July, has an average maximum of 19.1°C, and a minimum of 5.3°C. The average annual rainfall is about 246 mm, most of which falls between January and April.

MILLROSE lies in the northeastern part of the Murchison Region (or Austin Botanical District) of the Eremaean Province of Beard (1990). The region is characterized by extensive mulga scrub. Mulga (*Acacia aneura*) is the dominant species throughout, but there are also other acacia species, local areas of eucalypts, and a variety of shrubs, herbs, and grasses. Broad areas of sandplain over granitoid rocks have vegetation similar to the Great Victoria Desert region to the east, with extensive areas of spinifex cover.

Physiography

Most of MILLROSE is flat to gently undulating, and large areas are covered by sandplains. The main physiographic features, shown in Figure 2, are: a line of low hills and breakaways in the south (Rose Hills); the Lake Ward drainage in the central and central-eastern parts; and a broad upland with scattered breakaways in the northwestern corner. The altitude ranges from about 540 m above the Australian Height Datum (AHD) around Lake Ward to just above 600 m in the northwestern corner of MILLROSE.

Areas underlain by granitoid rocks are dominated by sandplains, lake sediments or patchy, weathered outcrop with scattered breakaways. In contrast, areas underlain by greenstone have extensive deposits of distal sheetwash, and low uplands of weathered rock and ferruginous debris.

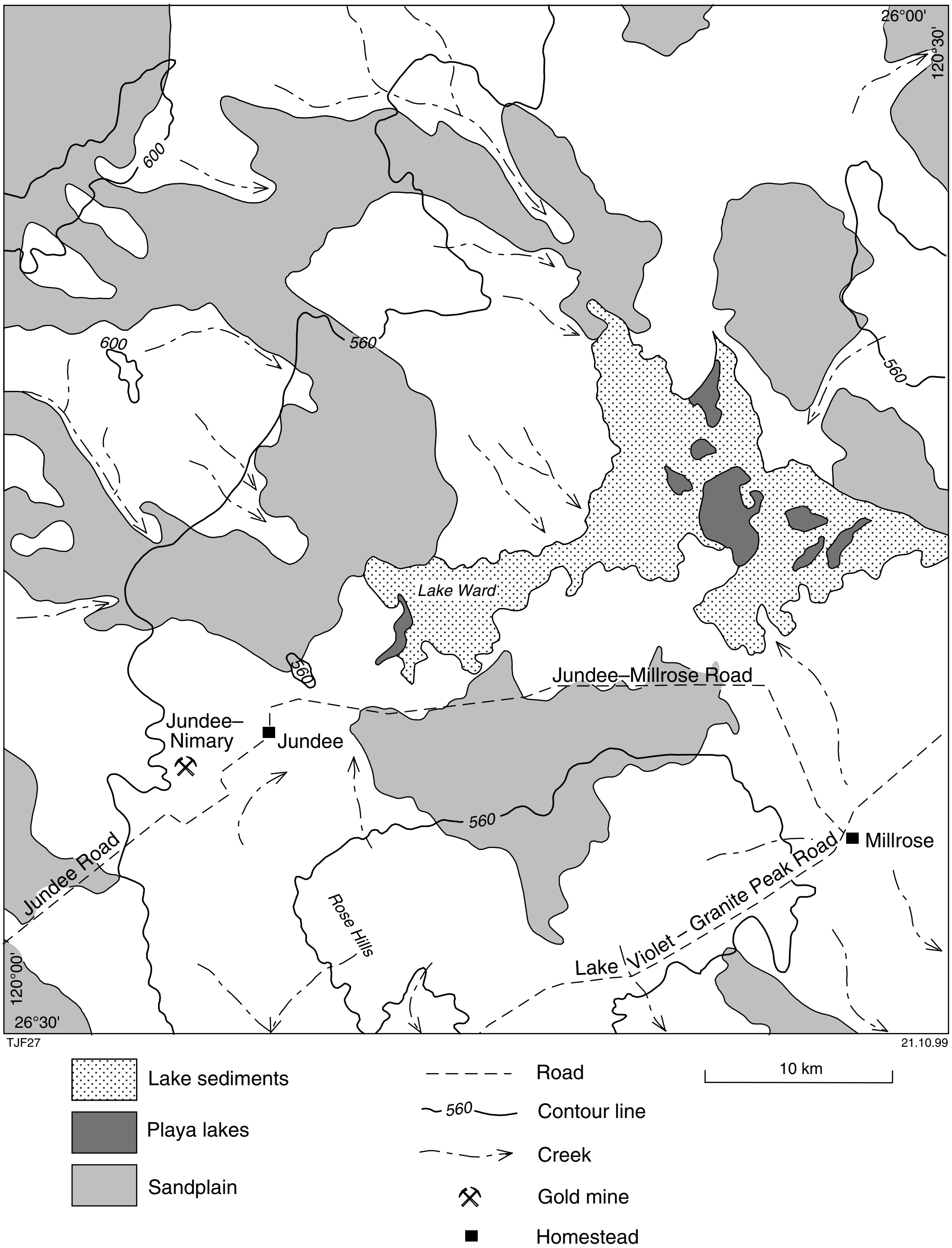

Figure 2. Simplified physiographic map of MILLROSE

Previous work

The Explanatory Notes that accompanied the first edition of the WILUNA 1:250 000 geological map sheet (Elias and Bunting, 1982) described the limited amount of geological work carried out on MILLROSE and surrounding areas. Since the publication of that map, mineral exploration activity has focused on the search for gold in the greenstones. The discovery of the Jundee–Nimary gold deposit (Lewington, 1995; Wright and Herbison, 1995; Phillips et al., 1998a,b; Byass and MacLean, 1998; Vearncombe, 1998) resulted in a significant increase in drilling and other exploration activity, particularly in the western part of MILLROSE.

Precambrian geology

Regional setting

MILLROSE lies in the northernmost part of the Eastern Goldfields Province (Fig. 1; Griffin, 1990), which is a major subdivision of the Archaean Yilgarn Craton (Gee et al., 1981; Myers and Swager, 1997). The Eastern Goldfields Province is a typical granite–greenstone terrain characterized by large areas of monzogranite, multiply deformed quartzofeldspathic gneiss, elongate, north to northwesterly trending greenstone belts, and late polymictic conglomerate.

The greenstone belts in the Eastern Goldfields Province contain diverse assemblages of supracrustal rocks, including abundant komatiite and high-Mg basalt (Griffin, 1990). Exposure of the greenstone belts is poor and the deformation is complex. Upright folds, a subvertical foliation, and major north to northwesterly trending shear zones are the dominant structures. All the greenstones are metamorphosed, typically to greenschist facies, but narrow zones of amphibolite facies are also present along granite–greenstone contacts (Binns et al., 1976).

Quartzofeldspathic gneisses — with associated, subordinate banded iron-formation (BIF), amphibolite, calc-silicate gneiss, and layered mafic gneiss — are amongst the oldest rocks in the northern part of the Eastern Goldfields Province (c. 2750–2700 Ma; Nelson, 1997, 1998; AGSO, unpublished data). The gneisses are highly deformed and metamorphosed, intruded by granitoids, and may represent samples of greenstone basement.

MILLROSE covers the northern end of the Yandal greenstone belt, and extensive areas of adjacent granitoid rock and gneiss (Fig. 1). Ages of the greenstones in the Yandal belt are inferred to be c. 2700–2670 Ma, based on sensitive high-resolution ion microprobe (SHRIMP) U–Pb dating of felsic rocks (Nelson, 1997, 1998). The belt is split into two arms at its northern end. In these Notes the western sequence is informally referred to as the Jundee domain, and the eastern sequence, the Millrose domain (called the Lake Violet and Millrose greenstone belts respectively, in Griffin, 1990).

Granitoid rocks in the northern part of the Eastern Goldfields Province are younger than the gneisses and most of the greenstones (c. 2685–2635 Ma; Nelson, 1997, 1998), and show various degrees of deformation. Peak granitoid magmatism occurred at c. 2665–2645 Ma (Nelson, 1997, 1998). Monzogranite and granodiorite are the dominant granitoid types, although there are volumetrically minor amounts of tonalite, diorite, monzonite, and syenite. Chemically, the granitoids can be subdivided into two main groups, the low-calcium and high-calcium granites, and three minor groups, high-HFSE (high field-strength elements) granites, syenites, and mafic granites (Champion and Sheraton, 1997).

All Archaean rocks in the northern part of the Eastern Goldfields Province underwent extensive fracturing, quartz veining, and intrusion by mafic dykes during the Proterozoic. Many of the mafic dykes form prominent, linear aeromagnetic features, and there may be as many as four discrete sets of dykes. Late-stage, easterly trending faults cut across all other structures, and are spatially related to small, possibly fault bound, Proterozoic sedimentary basins.

Archaean rock types

Gneisses (*Anq, Angb, Anc, Anqk*)

A large proportion (~65 %) of MILLROSE is underlain by gneiss and granitoid rock (mainly monzogranite). These rock types occupy extensive areas between the two arms of the Yandal belt, and along the eastern side of MILLROSE (Figs 3 and 4). Strongly deformed granitoid rock and gneiss are also exposed in the southwestern corner of MILLROSE.

The relationships between the granitoid rocks and gneisses are not always clear due to poor exposure and deep weathering. There are many areas with scattered outcrops of both granitoid rock and gneiss, where it is not possible for the two rock types to be shown separately. Such areas have been mapped using combined rock codes (e.g. *Agnq* and *Angb*) to indicate an intimate mixture of two rock types.

The gneisses are the oldest known rocks on MILLROSE (Nelson, 1997, 1998; AGSO, unpublished data) and inferred to be remnants of an early felsic crust that possibly forms the basement to the greenstone belts. These age relationships are consistent with observations on MILLROSE that gneisses contain evidence for deformation events not found in other rock types, and that gneisses are intruded by granitoid dykes and sheets (see **Structural geology**).

Quartzofeldspathic gneiss (*Anq*) is the most abundant type of gneiss on MILLROSE. The unit is a major component of the layered sequence (*Angb*) near Amees Bore (AMG 541019*), and is well exposed in two areas about 6 km northeast of Turnup Bore (AMG 591025 and 576015). Deeply weathered quartzofeldspathic gneiss, intimately associated with weathered, foliated granitoid rocks (*Agnq*, see **Granitoid rocks**), occupies a broad area on the northeastern side of the Jundee domain, and forms a major part of the large domal structure east of Lignan Well, in the eastern part of MILLROSE. Quartzofeldspathic gneiss is also associated with strongly foliated granitoid rocks close to the greenstone margin in the southwestern corner of MILLROSE (*Agf*, see **Granitoid rocks**).

The best exposures of gneiss lie northeast of Turnup Bore. Quartzofeldspathic gneiss, the dominant rock type in this area, is associated with granitoid rocks, and commonly contains thin layers and lenses of amphibolite

* Localities are specified by the Australian Map Grid (AMG) standard six-figure reference system whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on this sheet, to within 100 m. AMG coordinates of localities mentioned in the text are listed in the Appendix.

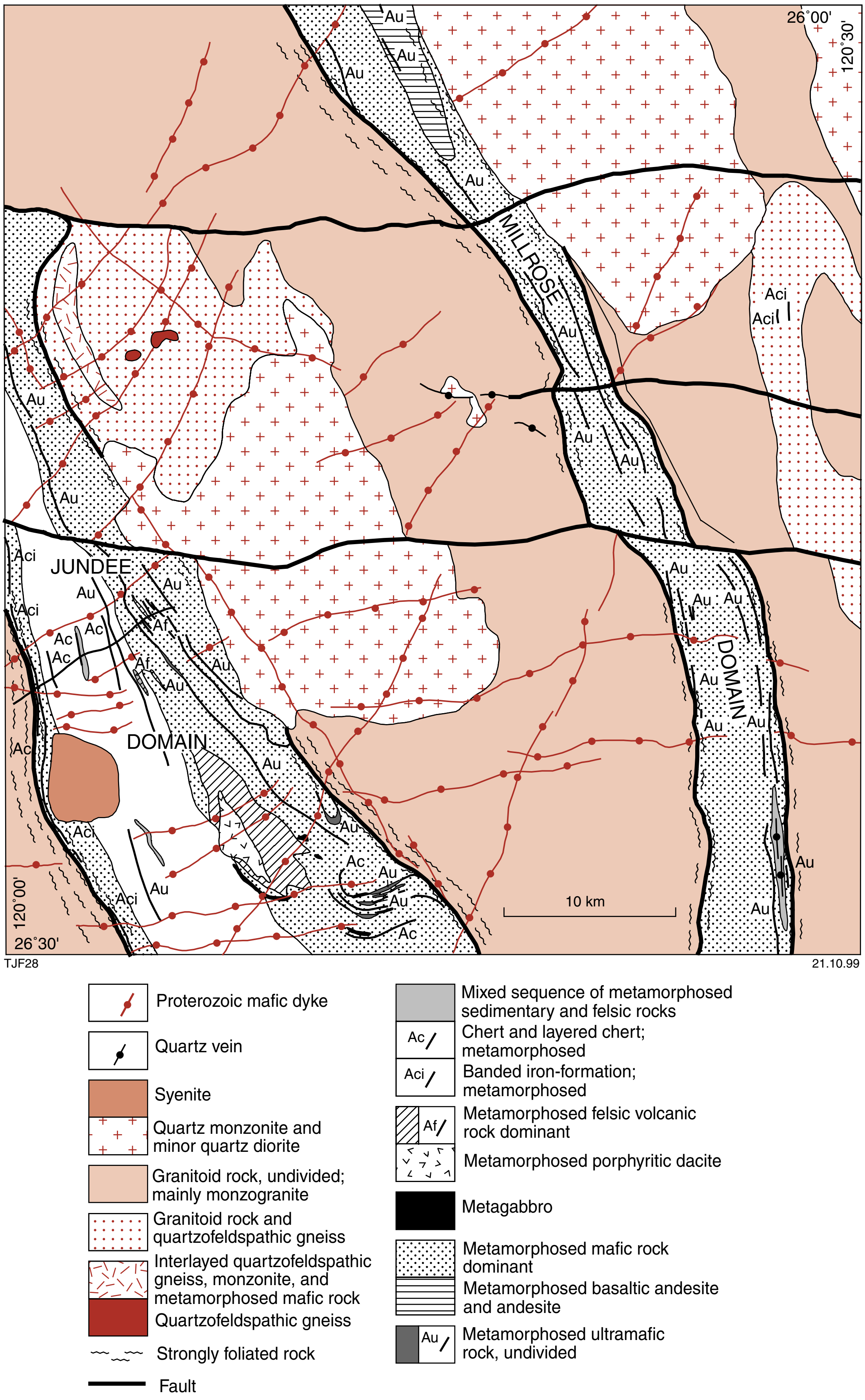

Figure 3. Simplified geological interpretation map of MILLROSE

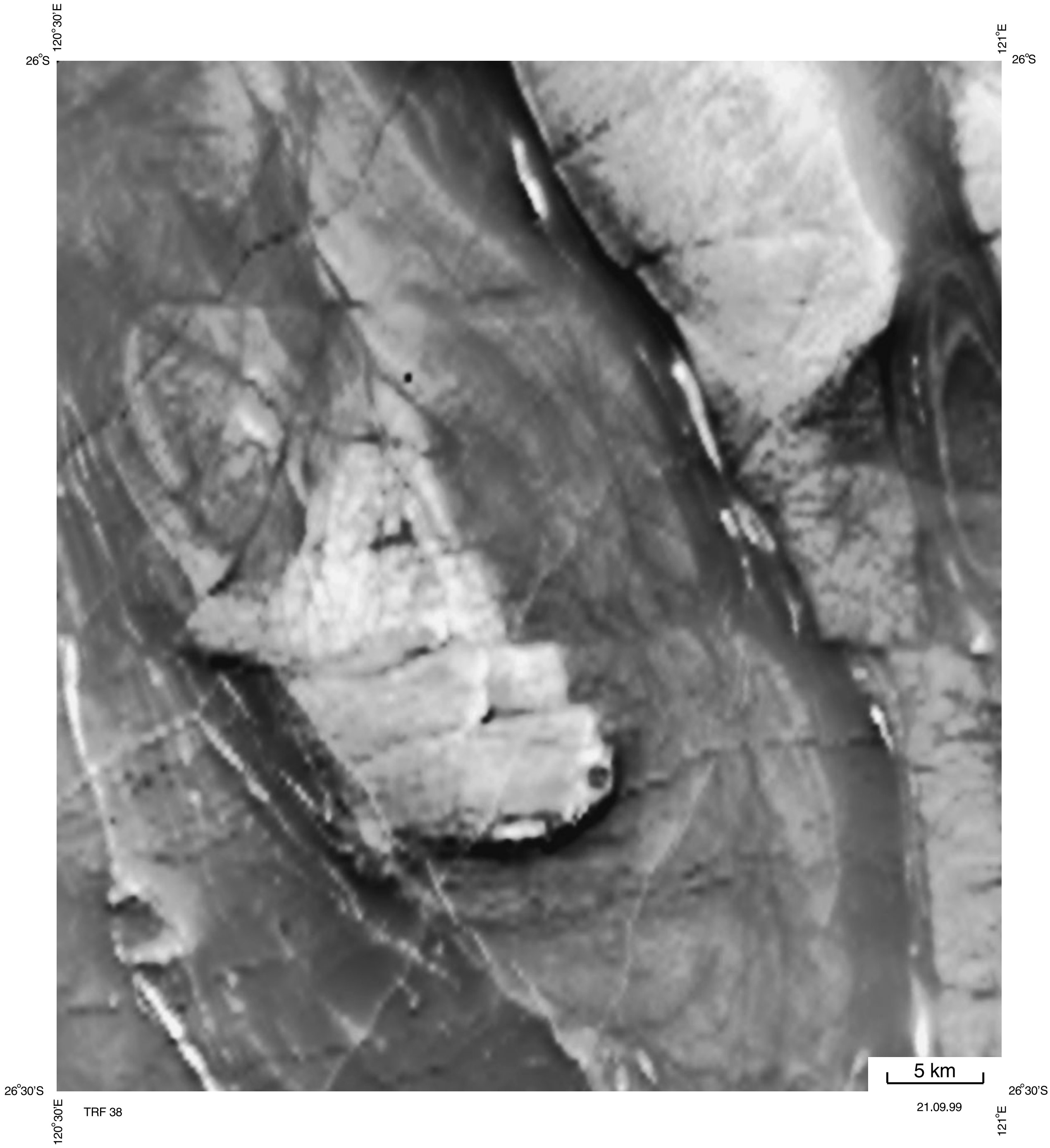

Figure 4. Grey-scale aeromagnetic map of total magnetic intensity for MILLROSE (400 m line spacing; AGSO–GSWA data, 1994)

(*Aba*, see **Mafic rocks**) or calc-silicate gneiss (*Anc*). The mafic layers are mappable over distances of several hundred metres and appear to delineate a relict, westerly trending structural grain. At one location (AMG 591028), there is a pod of mafic rock with a marginal K-feldspar-phyric variant. This rock is closely associated with epidote-rich calc-silicate gneiss and K-feldspar–epidote–quartz gneiss (altered ?quartzofeldspathic gneiss).

Quartzofeldspathic gneiss (*Anq*) is a texturally and mineralogically heterogeneous rock, and typically contains a diffuse layering defined by subtle variations in the abundance of mafic minerals, and by the alignment of biotite-rich schlieren, vague leucocratic layers and lenses, and thin discordant leucosomes (Fig. 5). In many places, quartzofeldspathic gneiss contains various-sized leucocratic patches, and diffuse layers tens of millimetres thick. These leucocratic zones commonly contain small, irregular biotite-rich clots (up to 10 mm in diameter) or biotite schlieren, or both. A distinctive local variant is 'flecky' gneiss, which contains biotite-rich clots with a leucocratic halo that give the rock a spotted appearance

Figure 5. Layered quartzofeldspathic gneiss (AMG 552029). Darker layers are richer in biotite and poorer in quartz and plagioclase. Pencil is 145 mm in length

(Fig. 6). In a few cases, the leucocratic patches appear to be restricted to certain layers, suggesting a host-rock compositional control.

Quartzofeldspathic gneiss is cut by several generations of leucosomes. The gneiss typically contains an early set of thin, quartz-rich leucosomes that are parallel to the earliest recognizable fabric (S_1, see **Structural geology**). These leucosomes are deformed to different degrees. In a few places they are gently folded and overprinted by a weak, second-generation fabric (S_2), whereas in others, they are tightly folded and boudinaged in S_2. Ptygmatic folds and isoclinal fold hooks of early leucosomes can be seen in the most highly deformed gneisses. A second generation of irregular, vein- or pod-like pegmatite leucosomes of various sizes cut across the first generation leucosomes (Fig. 7) and, in a few outcrops, form an interconnected network. They contain relatively coarse grained quartz and feldspars (up to about 15 mm), and are interpreted to be former melt patches. Less commonly, the gneiss contains irregular biotite monzogranite leucosomes and aplite veins that are deformed and have a fabric parallel to S_2 in the host rock.

Quartzofeldspathic gneiss consists of quartz, plagioclase, and K-feldspar, with subordinate biotite, and accessory apatite, zircon, sphene, epidote, and opaque minerals (?ilmenite). In a few places the gneiss contains perthitic K-feldspar, suggesting upper amphibolite-facies (or possibly higher grade) metamorphism. Biotite-rich clots in the 'flecky' gneiss dominantly contain green–brown biotite, irregular grains of an opaque mineral (?magnetite), and quartz, along with accessory epidote and zircon. The gneisses also show some evidence of lower grade metamorphism and deformation; for example, quartz is strained and partly recrystallized to finer grained aggregates, and K-feldspar and biotite are partially replaced by finer grained microcline and chlorite respectively.

A north-northwesterly trending belt (*Angb*), in the northwestern part of MILLROSE near Amees Bore, contains a layered sequence of quartzofeldspathic gneiss, hornblende monzogranite, quartz monzonite, and mafic rock. The exposure is poor, but individual layers appear to be less than 100 m thick. The monzogranite is fine to medium grained and well foliated, with abundant hornblende and sparse clots of hornblende up to 10 mm in diameter. There appears to be a gradation from hornblende monzogranite to hornblende-bearing quartz monzonite (*Agzq*, see **Granitoid rocks**). Numerous, thin layers (<5 m thick) of mafic rock are also present. The main mafic rock type is a foliated and lineated amphibolite (*Aba*, see **Mafic rocks**) with a crude layering defined by variations in plagioclase content, and by the alignment of thin, plagioclase-rich leucosomes. Epidote alteration of the sequence is common and affects all rock types.

Quartz–K-feldspar gneiss (*Anqk*) is a distinctive, but minor, rock type in the southwestern corner of MILLROSE (AMG 575670). The relationship to the host granitoid

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Figure 6. Biotite-rich clots in flecky gneiss (AMG 592986). The clots contain coarse, green–brown biotite, and lesser amounts of quartz, and ?magnetite, and typically have a leucocratic halo. Coin is 23 mm in diameter

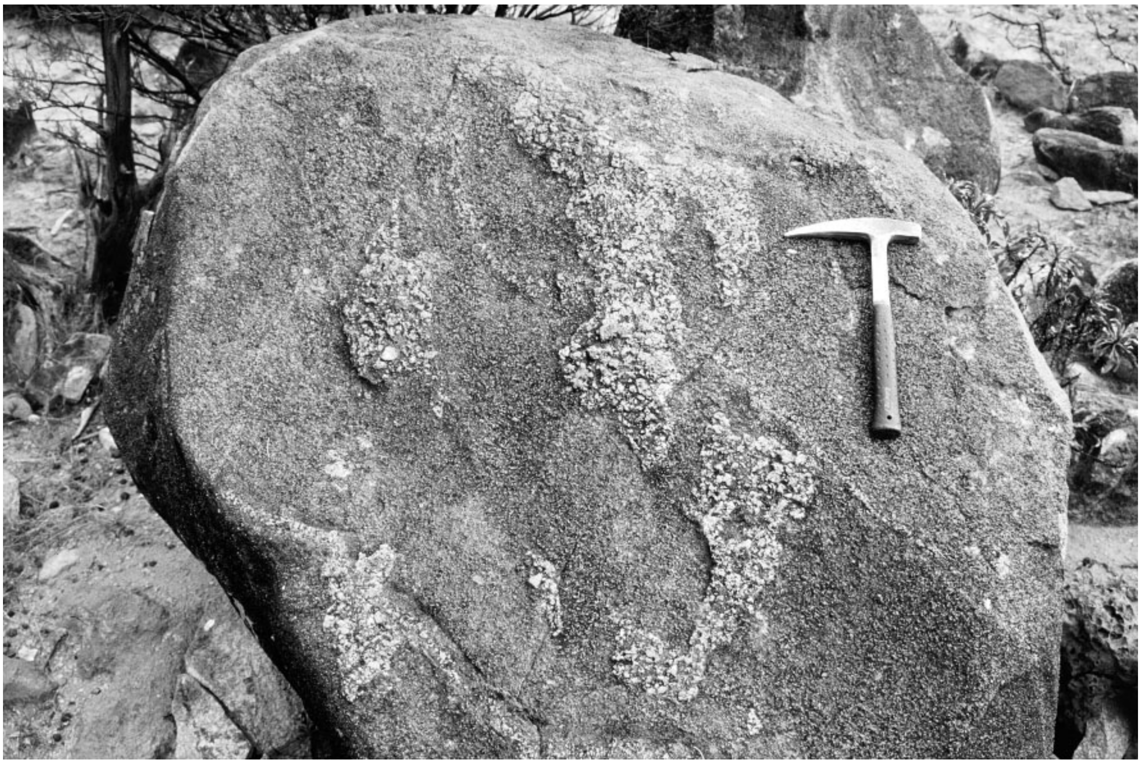

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Figure 7. Pod-like pegmatitic leucosomes in quartzofeldspathic gneiss (AMG 587001); predominantly granodiorite in composition

rocks is uncertain, but it may be a thick layer in a poorly exposed, layered gneiss. The unit consists mainly of fine-grained granoblastic quartz, K-feldspar, and plagioclase, with scattered large grains up to 1.8 mm of quartz and K-feldspar, and accessory opaque minerals (iron oxides) and white mica.

Greenstones

Ultramafic rocks (Au, Aut, Aur, Auc, Auk, Aup)

Ultramafic rocks are widely distributed through the northern part of the Yandal greenstone belt, and many linear features on aeromagnetic images (Fig. 4) correspond to ultramafic rocks. However, ultramafic rocks are poorly exposed on MILLROSE and much of the surface exposure has been affected by deep weathering, resulting in the formation of a distinctive brown, siliceous caprock (*Czu*). Consequently, most of the petrographic information on the ultramafic rocks is from examination of drillhole samples. A few rocks have possible relict orthocumulate textures, suggesting that they were originally peridotite, but in most cases, deformation and metamorphism have overprinted the primary textures. Where the rocks are weathered and fine grained or where petrographic information is not available, they have been mapped as undivided ultramafic rocks (*Au*).

Many ultramafic rocks are metamorphosed to fine-grained, talc–chlorite schist (*Aut*). These rocks are typically well foliated and contain finely intergrown talc and chlorite, with small amounts of carbonate and equant, fine-grained ?magnetite. In a few schists, vague, relict igneous textures are still recognizable due to the concentration of fine-grained opaque minerals (?magnetite) along former grain boundaries. There are patchy outcrops of talc–chlorite schist about 2.5 km northeast of Terry Bore (AMG 548722) in the Jundee domain, and about 1.2 km east-southeast of Snake Well (AMG 903858) in the Millrose domain.

Tremolite schist (*Aur*) is a common, although minor, rock type on MILLROSE. The rock is typically well foliated and contains aligned, acicular tremolite–actinolite, up to 1.5 mm in length. Common accessory minerals are chlorite, epidote, and iron oxides (probably magnetite). In a few cases these rocks have a vague compositional layering (?igneous layering) defined by variations in the abundance of tremolite–actinolite. Tremolite schist is interpreted to be the result of metamorphism of an ultramafic or high-Mg basalt precursor.

Talc–carbonate schist (*Auc*) is a minor ultramafic rock type that has only been identified in drillholes. The rock is weakly foliated and contains various proportions of talc, carbonate, chlorite, and iron oxides. The carbonate forms small, fine-grained aggregates (up to 0.8 mm in length) that appear to pseudomorph a prismatic igneous mineral (?pyroxene). Carbonate is also present in irregular, coarse-grained patches and thin seams aligned parallel to the foliation.

In the Jundee domain, altered komatiite (*Auk*) was observed in one drillhole in the northern part of Rose Hills, about 3 km south of Ronnie Bore (AMG 693750). The rock has a platy olivine-spinifex texture pseudomorphed by carbonate and talc. In the Millrose domain, fresh samples from a closely spaced line of drillholes, about 1.3 km east-northeast of George Bore (AMG 815051), include tremolite–chlorite rocks with a well-preserved, relict, platy olivine-spinifex texture. Talc–serpentine rock, from the same line of drillholes, has a relict orthocumulate texture delineated by very fine grained iron oxides (?magnetite), and is probably a metamorphosed peridotite (*Aup*).

Mafic rocks (Ab, Abv, Abm, Abml, Abe, Aoge, Aby, Abp, Abf, Abs, Aba, Ao, Aog, Aogf, Aogo)

Mafic rocks are the most common rock types in the greenstones on MILLROSE. A wide range of mafic rocks is present, although a few of them have only been identified from exploration drillholes. Much of the surface exposure is deeply weathered and, therefore, unless the mafic rocks are sufficiently fresh or coarse grained (or both) to allow reliable identification, they have been mapped as metamorphosed, fine-grained, undivided mafic rock (*Ab*). This category includes associated metagabbro that could not be distinguished at map scale. In fresh exposures, a volcanic protolith is commonly indicated by the presence of pillow fragments or relict volcanic textures and, in these cases, the rocks have been mapped as metabasalt (*Abv*).

Metamorphosed high-Mg basalt (*Abm*) outcrops at several localities in the Jundee domain, and has been identified mainly on the basis of textural criteria, such as varioles or pyroxene spinifex, which are characteristic of high-Mg basalt (Arndt and Nisbet, 1982). The rock is heterogeneous and commonly shows subtle variations in grain size and texture; for example, spinifex and granular textures may be present within the one specimen. Metagabbro is also a common, subordinate rock type. There are fresh exposures of metamorphosed high-Mg basalt near Bogada Bore (e.g. AMG 603866).

Fine-grained metamorphosed high-Mg basalt (*Abm*) commonly contains a relict pyroxene-spinifex texture (Fig. 8) in which randomly oriented, skeletal, acicular pyroxene crystals have been pseudomorphed by tremolite–actinolite, with or without albite and sphene. These rocks may also contain albite(–epidote–chlorite) pseudomorphs of needle-like plagioclase crystals. The plagioclase pseudomorphs reach up to about 1.2 mm in length, whereas those of pyroxene are commonly coarser, reaching up to about 4 mm. The groundmass typically comprises microcrystalline, lamellar or feathery intergrowths (<5 μm thick) of chlorite and albite, or tremolite–actinolite and albite, after ?devitrified glass. Quartz and carbonates are minor alteration minerals in the groundmass. Locally, the groundmass may also be occupied by turbid, brownish-green aggregates too fine to be resolved optically.

A local variant, not shown separately on the map, is metamorphosed, fine-grained, pyroxene-spinifex textured, olivine-phyric basalt. Pseudomorphs of olivine phenocrysts reach up to 0.3 mm in diameter and are typically skeletal, although euhedral olivine shapes are

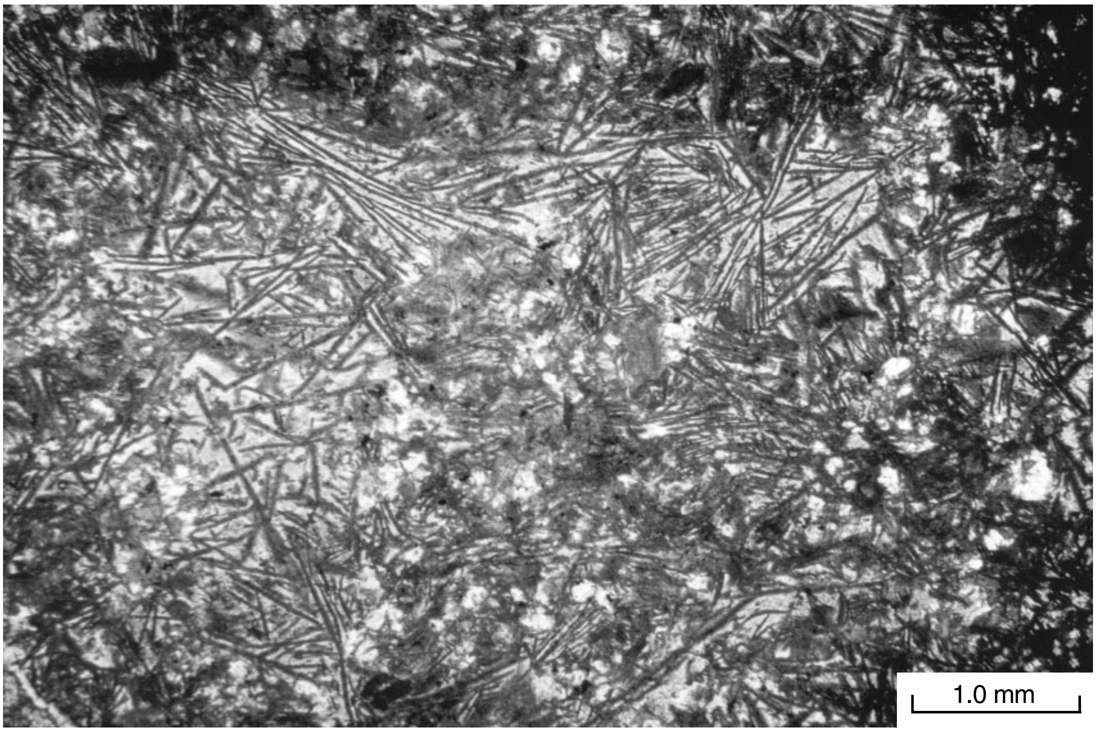

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Figure 8. Relict pyroxene-spinifex texture in metamorphosed high-Mg basalt (AMG 583880; GSWA 137120). Pyroxene is replaced by tremolite–actinolite, and interstitial areas are occupied mainly by albite and quartz. Plane polarized light

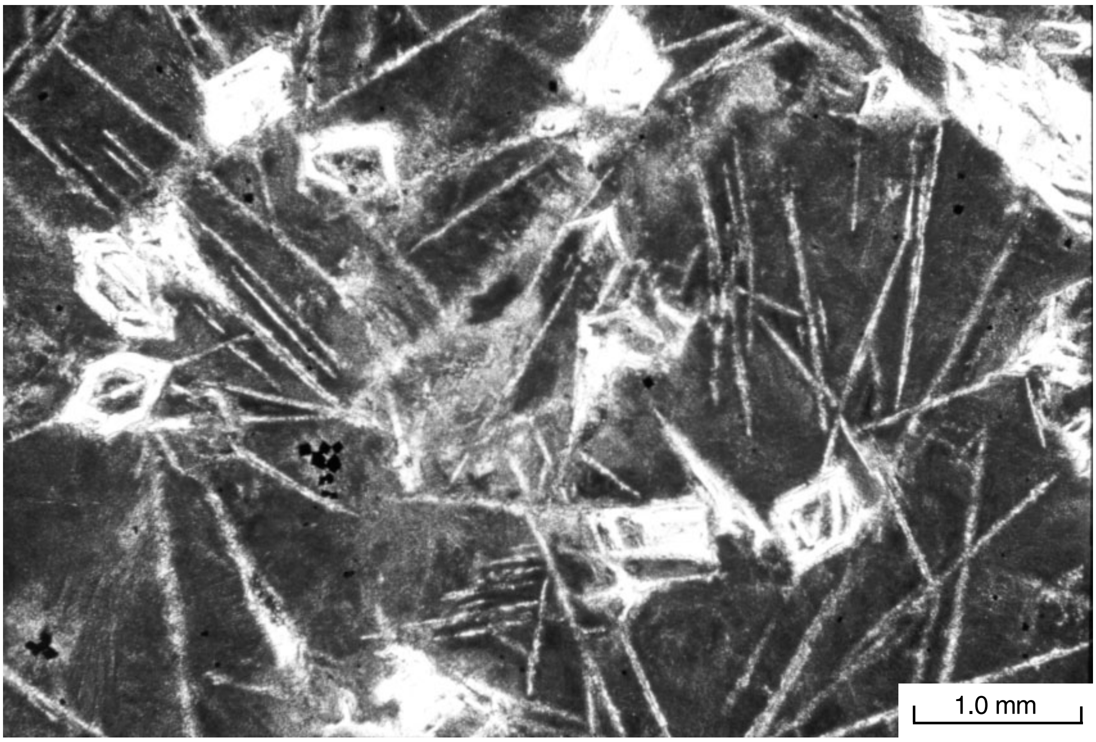

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Figure 9. Relict skeletal olivine and acicular pyroxene in a metamorphosed high-Mg basalt (AMG 712693; GSWA 121575). Olivine and pyroxene are replaced by chlorite and albite. Interstitial area is probably devitrified glass, now occupied by extremely fine intergrowths of chlorite and albite, with or without tremolite–actinolite

also preserved (Fig. 9). The olivine is completely replaced by chlorite and extr emely fine opaque minerals or by quartz(–albite), depending on the type of alteration. Pyroxene is typically replaced by chlorite and albite, and rare plagioclase laths by albite.

Varioles are present in most exposures of high-Mg basalt (*Abm*), but are best developed in fine-grained rocks (Fig. 10). The varioles are diffuse, rounded, pale-coloured patches (up to about 7 mm in diameter), with similar mineralogy to the rest of the rock, but a greater abundance of extremely fine epidote or sphene, or both. Varioles may also contain fan-like or radiating aggregates of finely intergrown chlorite and albite with disseminated sphene.

Metamorphosed, pillowed, high-Mg basalt (*Abml*) is well exposed in the Rose Hills area. Here, the rocks are relatively fresh and undeformed, and contain well-preserved igneous textures, including abundant varioles and local pyroxene-spinifex textures. Fragments of pillows and pieces of possible lava tubes (up to 150 mm in diameter) are common. Complete pillow structures are preserved in places (e.g. AMG 682740; Fig. 11). Many of the pillows have a variole-poor outer rind and a variole-rich centre, where individual varioles coalesce into large, irregular pale patches (Fig. 10).

Epidote-rich alteration of the mafic rocks is common throughout MILLROSE, but only in a few areas is it extensive enough to be shown separately on the map. Metamorphosed gabbro, basalt, and mafic fragmental rocks with conspicuous epidote-rich alteration (*Abe*) outcrop about 7 km northwest of Jundee Homestead (AMG 588865). The proportion of epidote varies depending on the degree of alteration — in highly altered rocks, epidote is by far the most abundant mineral. Other alteration minerals include leucoxene and a fine-grained opaque mineral (?hematite). Epidote-rich metagabbro (*Aoge*) is exposed near 2 Hills Well (AMG 732695) in the southern part of MILLROSE.

A distinctive, fine-grained metabasalt with abundant amygdales (*Aby*) outcrops 5 km northwest of Jundee Homestead (AMG 602857). The amygdales are irregular, have cuspate boundaries, and reach up to 15 mm in diameter (Fig. 12). They are rich in pale amphibole, and have lesser amounts of albite and fine-grained epidote, and minor sphene. Larger amygdales also have a core of coarse-grained, xenoblastic quartz. Amygdales are also common in other areas, but sporadically distributed and not present in clearly mappable units.

Plagioclase-phyric metabasalt (*Abp*) is a minor variant that is only shown in drillholes. Plagioclase phenocrysts are common in a few mafic rocks, but do not form readily mappable units. Fresh plagioclase-phyric metabasalt has only been identified in drillhole samples. The rock has a spinifex-like texture defined by randomly oriented fine plagioclase laths in a very fine grained, metamorphosed matrix of intergrown chlorite, tremolite–actinolite, albite, and abundant disseminated opaque minerals, as well as scattered patches of fine-grained epidote. Plagioclase also forms sparse, prismatic, subhedral to euhedral phenocrysts up to 0.5 mm in length.

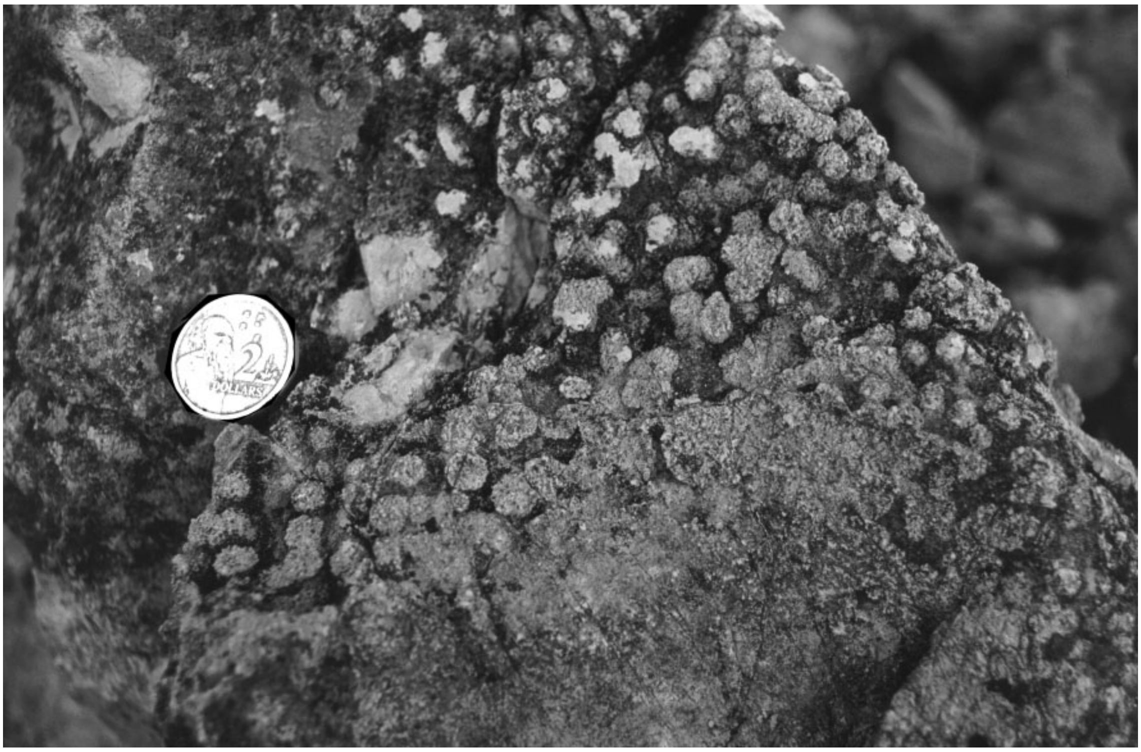

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Figure 10. Relict varioles in metamorphosed, pillowed high-Mg basalt (AMG 682740). Varioles increase in abundance towards the centre of the pillow (at the bottom of photograph). Coin is 20 mm in diameter

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Figure 11. Pillow structures in metamorphosed high-Mg basalt in the Rose Hills area (AMG 682739). Pillows young upwards in photograph

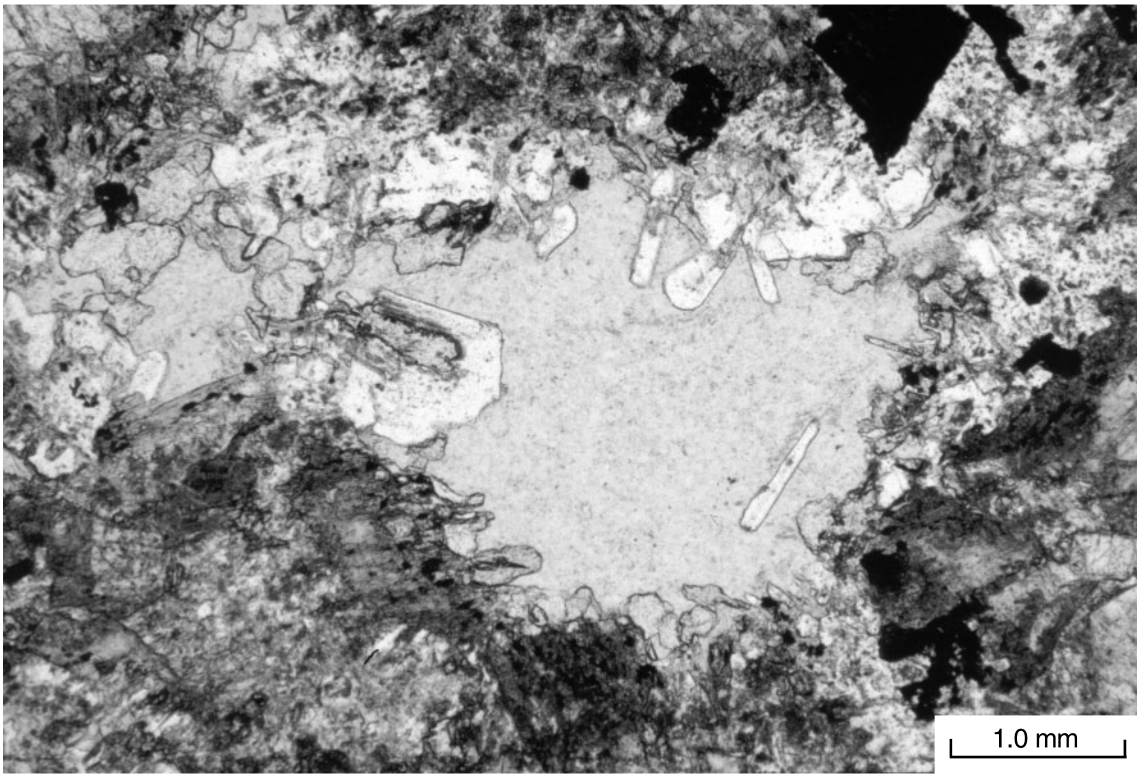

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Figure 12. Relict amygdale in a metamorphosed basalt (AMG 696733; GSWA 121524). Amygdale has albite (subhedral, off-white) and epidote (medium-grey) around the margins, and chlorite in the centre. Plane polarized light

Strongly foliated mafic rock (*Abf*) is typically found in areas of higher strain close to granite–greenstone contacts. The rock has been identified in numerous drillholes in the Millrose domain, and in drillholes along the southwestern and southeastern margins of the Jundee domain. Foliated rocks along the western margin of the Jundee domain typically contain abundant lepidoblastic bluish-green amphibole (after pyroxene), subordinate plagioclase, and fine-grained accessory epidote, sphene, and opaque minerals. In places, these rocks have pyroxene spinifex-like textures partly overprinted by deformation, and are possibly metamorphosed high-Mg basalt. Patches of quartz(–epidote) in a few rocks may be recrystallized amygdales.

Fine- to medium-grained, strongly foliated schists containing metamorphic assemblages of chlorite, with or without tremolite–actinolite, have been mapped as mafic schist (*Abs*). The origin of these rocks is uncertain: they may be derived from mafic volcaniclastic sedimentary rocks, hydrothermally altered high-Mg basalt, or ultramafic rock.

Amphibolite (*Aba*) is a minor component of quartzofeldspathic gneiss (*Anq*) and mixed units containing gneisses (*Angb, Agnq*), northeast of Lignan Well (AMG 960049) and northeast of Turnup Bore (e.g. AMG 545018). The amphibolite is typically layered on a scale of 5–30 mm according to variations in the abundance of dark-green hornblende and plagioclase (Fig. 13). The rocks are fine to coarse grained with a granoblastic texture. They contain subordinate pale-green clinopyroxene (?diopside) and quartz, as well as accessory sphene, epidote, and iron oxides. Local epidote-rich zones are due to late alteration.

Deeply weathered, medium- to coarse-grained mafic rocks (*Ao*) are shown where primary textures are not well preserved and the identification of the protolith is uncertain.

There are several patchy exposures of metagabbro (*Aog*) in the Rose Hills area. A northwesterly trending gabbro unit, just south of Twin Tanks Well (AMG 672701), is fine to medium grained and weakly deformed, with various proportions of mafic minerals (Fig. 14). The unit is mostly equigranular, but slightly porphyritic in a few sections. This gabbro is either a small intrusion or a thicker section of a basalt flow. A medium-grained, intergranular-textured gabbro near the southern margin of the sheet (AMG 716681) may also be an intrusion because it appears to be lens shaped, up to 300–400 m thick, and about 1.2 km long.

Deformed metagabbro (*Aogf*), with a strong foliation enclosing porphyroclasts of pyroxene (now pseudomorphed by metamorphic amphibole), has been identified in drillhole samples in the northern part of the Jundee domain (e.g. AMG 509085).

A small outcrop of ?olivine gabbro (*Aogo*) is present in the Rose Hills (AMG 690725). The rock is fine to medium grained, undeformed, and contains clinopyroxene, plagioclase, possible olivine (now altered),

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Figure 13. Layered amphibolite within a mixed unit of quartzofeldspathic gneiss and granitoid rocks (*Agnq*), northeast of Lignan Well (AMG 960049). Amphibolite has a steeply plunging F_2 fold

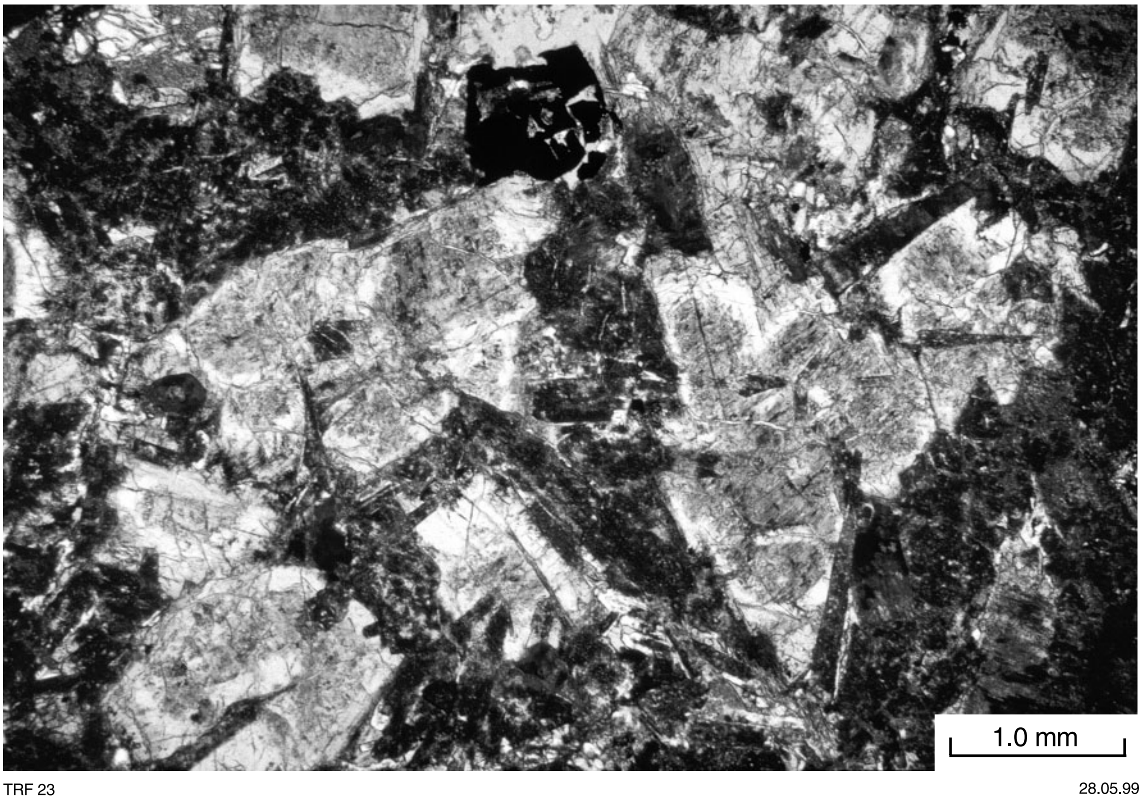

Figure 14. Relict intergranular texture in metagabbro (AMG 725693; GSWA 121565). Plagioclase is replaced by albite and very fine epidote and tremolite–actinolite (dark areas). Clinopyroxene is largely unaltered. Skeletal leucoxene after ?ilmenite in top centre of photograph. Plane polarized light

and skeletal opaque minerals. The ?olivine is present as large (up to 4 mm), anhedral grains now replaced by metamorphic assemblages comprising very fine grained, fibrous chlorite, acicular tremolite–actinolite, and small aggregates of granular epidote. Patchy alteration of plagioclase to aggregates of chlorite, epidote, and sphene is widespread, but the clinopyroxene is typically unaltered.

Intermediate rocks (Afi, Abi, Abip, Afip, Abie)

Intermediate rocks are common on MILLROSE. They are mostly known from exploration drillholes, and appear to be most abundant in the eastern zone of the Jundee domain and northern part of the Millrose domain. They have been subdivided into unspecified intermediate volcanic rock (*Afi*), and basaltic andesite to andesite (*Abi*) for more mafic varieties, but there appears to be a complete range of compositions from basalt to dacite. Further subdivision of the rock types is based on whether they are coarsely porphyritic (*Abip, Afip*) or have strong epidote alteration (*Abie*).

There is a distinctive intermediate rock in the Jundee area (e.g. AMG 593828) with large pinkish-brown plagioclase phenocrysts in a brownish-green groundmass (*Afip*). This rock is weakly deformed and shows various degrees of alteration. The distinctive colour of the plagioclase phenocrysts is due, at least in part, to incipient clay alteration. The rock contains subhedral to euhedral phenocrysts of plagioclase (up to 6 mm) and altered mafic minerals (up to 3 mm; Fig. 15) in a fine-grained, granular-textured groundmass of quartz and plagioclase, with small amounts of chlorite, iron oxides, and accessory zircon, apatite, and epidote. The mafic phenocrysts have been almost completely replaced by epidote, chlorite, or tremolite–actinolite. In a few rocks, the former mafic phenocrysts have relict cores of clinopyroxene, but in others, they have amphibole crystal shapes and trails of fine-grained opaque minerals mimicking the amphibole cleavage. These rocks are interpreted to be andesite to dacite lava flows or shallow-level intrusions, possibly thin sills or dykes.

Intermediate rock types in the northern part of the Millrose domain, north of Panakin Bore, have been identified mainly from drillhole samples. Where they outcrop, adjacent to the granite–greenstone contact (e.g. AMG 737221), they are strongly deformed and have undergone extensive epidote-rich alteration. Fresh drillhole samples are recrystallized and weakly to moderately deformed. They are typically fine to very fine grained, and composed principally of plagioclase and amphibole, with secondary chlorite, biotite, and epidote. The mineralogy of the rocks suggests an original composition in the andesite to basaltic andesite (*Abi*) range. Albitized plagioclase phenocrysts up to 2 mm are preserved in a few specimens (*Abip*).

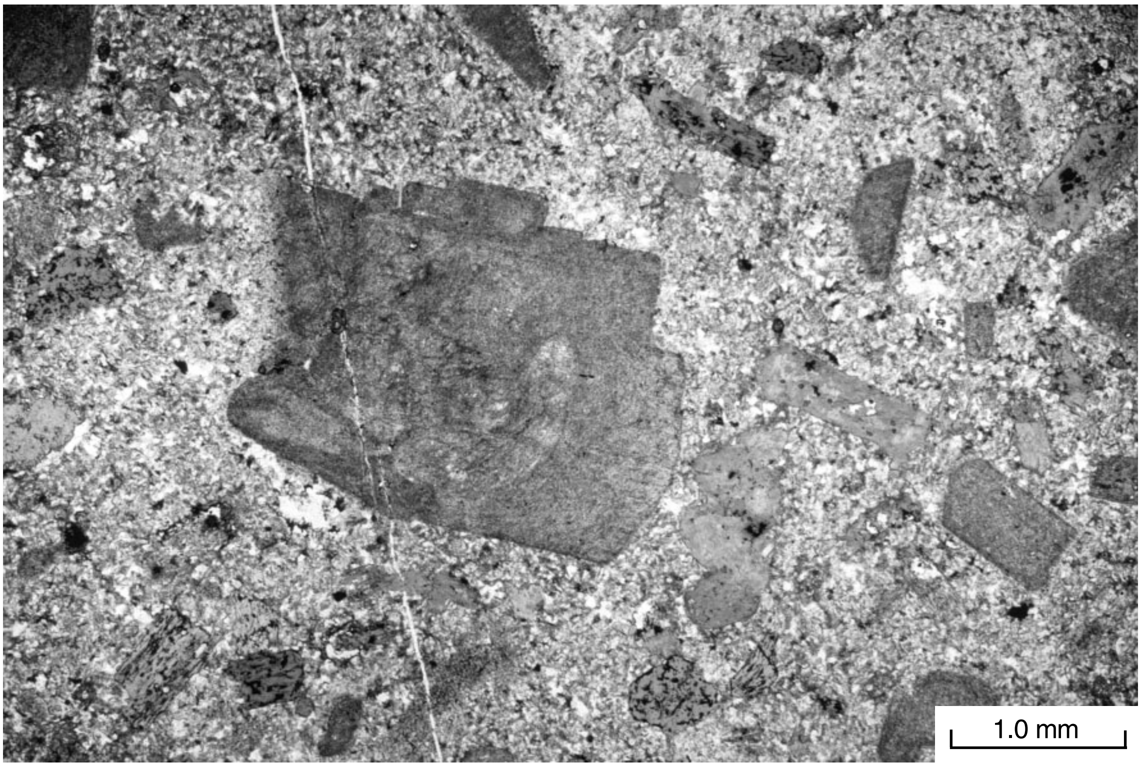

Figure 15. Metamorphosed coarsely porphyritic intermediate volcanic–subvolcanic rock (AMG 593828; GSWA 121564). Plagioclase phenocrysts (centre of photograph) are replaced by albite and fine white mica, and mafic phenocrysts by chlorite and opaque minerals. The groundmass contains quartz (white), albite, chlorite, and fine opaque minerals. Plane polarized light

Felsic rocks (Af, Afp, Afdp, Afd, Afs)

Felsic rocks on MILLROSE are typically weathered and very poorly exposed. Not all rock types outcrop and much of the information on the mineralogy has been obtained from the examination of drillhole samples. Deeply weathered varieties have not been subdivided (*Af*), except where they show evidence of a relict porphyritic texture (*Afp*).

Felsic rocks (*Af*) in the central part of the Jundee domain have not been subdivided due to the difficulty in identifying primary rock types in deeply weathered, rubbly outcrops. The sequences in this area are dominated by metasedimentary rocks and metamorphosed felsic volcanic and volcaniclastic rocks. There are weathered exposures east and northeast of Strife Bore (e.g. AMG 602738), and southeast of Bendys Bore (AMG 532827). The rocks near Bendys Bore contain relict quartz grains up to 1.3 mm in diameter, in addition to possible altered feldspar grains and lithic clasts of various sizes, in a well-foliated, fine matrix of quartz, white mica, and albite with small amounts of opaque minerals. They are probably metamorphosed felsic volcaniclastic rocks.

A distinctive dacite porphyry (*Afdp)* outcrops in an area 9 km south of Jundee Homestead. The porphyry is undeformed, but shows evidence of partial metamorphic recrystallization. The texture varies from inequigranular through to quartz and plagioclase phyric (Fig. 16). The plagioclase phenocrysts reach up to 5 mm in length, and are typically subhedral. They are completely altered to albite, and subordinate fine-grained white mica, chlorite, epidote, and ?kaolinite. Quartz phenocrysts are commonly rounded and embayed (Fig. 16). The groundmass is finer grained and consists of a partly recrystallized, inequigranular mosaic of quartz and plagioclase, with minor amounts of relict biotite, and metamorphic white mica, chlorite, sphene, epidote, ?pumpellyite, and very fine grained iron oxides. The rock contains either a few irregular aggregates of chlorite and epidote, or rosettes of pumpellyite that may be former amygdales, or both. The presence of possible amygdales, coupled with the fine-grained, granular texture of the matrix, suggests that it is a shallow-level intrusive rock. SHRIMP U–Pb dating of zircons from this rock indicates a crystallization age of 2669 ± 10 Ma (Nelson, 1998). Nonporphyritic varieties of the metadacite (*Afd*) have been observed in drillhole samples, but do not outcrop.

Felsic schist (*Afs*) outcrops on the eastern side of a prominent quartz vein about 4 km south of Millrose Homestead (AMG 957744). This strongly deformed rock contains flattened, recrystallized quartz crystals, up to 4 mm across, in a very fine grained matrix of quartz, altered feldspar, and white mica. Felsic schist has also been identified in drillholes near the western margin of MILLROSE, close to Amees Bore (e.g. AMG 516983).

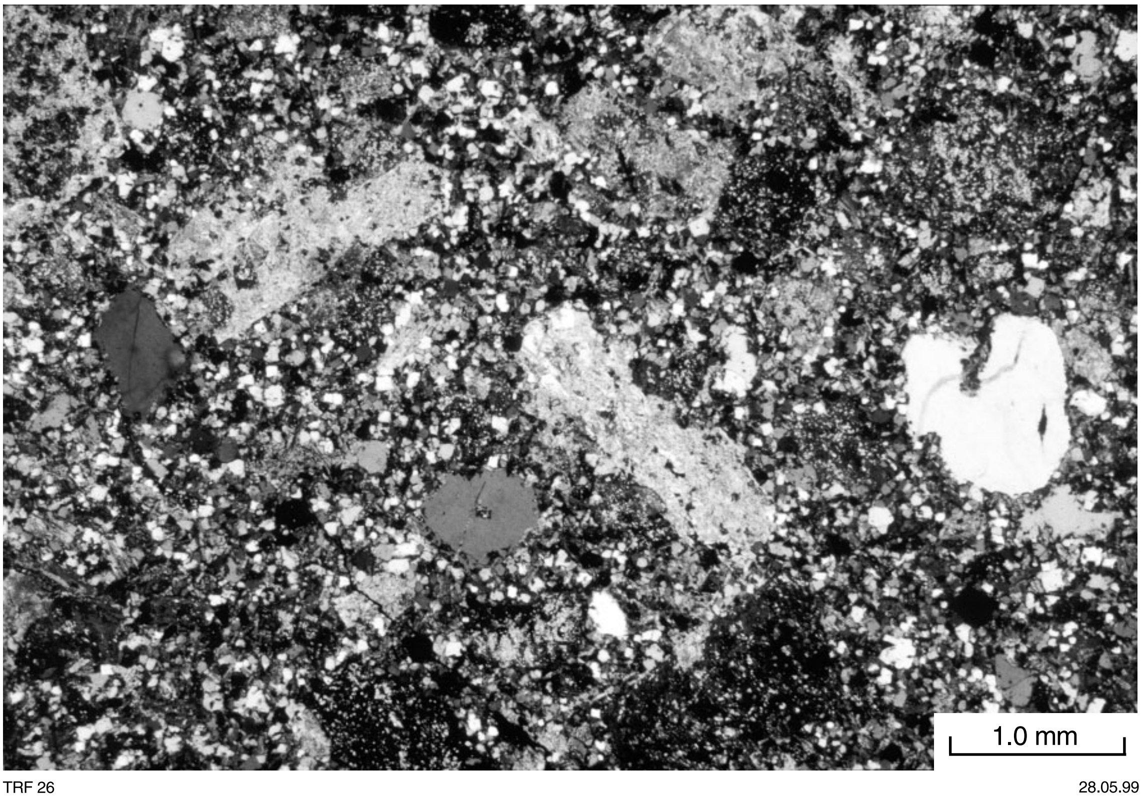

Figure 16. Metamorphosed porphyritic dacite, containing embayed quartz and partly recrystallized plagioclase phenocrysts (AMG 643733; GSWA 121533). Groundmass contains fine-grained quartz, albite, chlorite, sphene, epidote, and ?pumpellyite. Plane polarized light

Sedimentary rocks (As, Ac, Aci, Asc, Ash, Ashg, Ass)

Metasedimentary rocks are widely distributed on MILLROSE, and are the dominant rock type in the central part of the Jundee domain. Apart from chert and BIF, the metasedimentary rocks are deeply weathered and poorly exposed and, therefore, mainly shown as undivided metasedimentary rock (*As*). Much of the information on their mineralogy is derived from examination of drillhole samples.

Metamorphosed chert (*Ac*) is a minor, but distinctive, rock type that typically forms narrow, resistant ridges and can be a useful local stratigraphic marker. Chert varieties range from finely layered, ferruginous chert to greenish-grey and brown-grey, massive chert. Iron-oxide content varies, but most cherts are ferruginous to some degree.

Metamorphosed banded iron-formation (*Aci*) is mainly restricted to the western margin of the Jundee domain. There are isolated occurrences of BIF in other areas (e.g. 3 km southwest of Twin Tanks Well, AMG 691681), but these are limited in extent. Rhythmic layering in the BIF is typically planar and continuous, 0.2 – 4.0 mm thick, and comprises alternating silica-rich and iron-oxide-rich zones. The BIF is magnetite bearing in a few locations (e.g. AMG 580673). In the southwestern part of MILLROSE, it forms thin layers and lenses in a narrow zone containing both chert and BIF, along with clastic sedimentary rocks. Along strike, the BIF commonly grades into finely layered chert with thinner, more irregularly spaced iron-oxide-rich layers.

Metamorphosed BIF has been identified in the Millrose domain in one drillhole about 1.5 km south of Old Camp Bore (AMG 951832). In northeastern MILLROSE, there are thin units of BIF within a sequence of quartzofeldspathic and mafic gneisses about 5 km northeast of Lignan Well (AMG 958045) on the western side of a broad, domal feature visible on aeromagnetic images (Fig. 4).

Metamorphosed polymictic conglomerate (*Asc*) is a minor rock type at several locations. Rubbly exposures of matrix-supported conglomerate are present 2 km northeast of Strife Bore (AMG 607751). The conglomerate contains large clasts of massive, dark-grey chert, felsic rock, and brick-red, finely layered BIF in a fine-grained mafic matrix. The clasts are well rounded and reach up to 300 mm in diameter.

Small exposures of weathered, fine-grained, typically well foliated metasedimentary rock (*Ash*) are present in parts of MILLROSE. In fresh drillhole samples, these rocks contain scattered clasts of relict quartz and plagioclase, up to 0.2 mm across, in a very fine grained, foliated matrix of albite, quartz, white mica, and opaque minerals. Patchy carbonate alteration and carbonate veins are present locally. Bedding is not preserved in most outcrops, probably due to strong deformation and weathering. Alternatively, these rocks may have been deposited as thick, relatively massive beds of silt or mud. A finely laminated metasedimentary rock is present in one outcrop 3 km north of O'Keefe Well (AMG 629736). Dark-grey, graphitic varieties of fine-grained metasedimentary rocks (*Ashg*) have only been observed in drillhole samples. A very weathered outcrop (*Ash*) near the central-northern boundary of MILLROSE (AMG 668212) contains strongly deformed, fine-grained metasedimentary rock with porphyroblasts of andalusite and ?cordierite. The rock is probably a higher grade equivalent of the fine-grained metasedimentary rocks in the southern part of the area.

Metasandstone (*Ass*) outcrops near the southern boundary of MILLROSE, and is typically medium to coarse grained and feldspathic, with subordinate quartz. The rock contains subrounded to well-rounded clasts that reach up to 10 mm in diameter in local conglomeratic layers. Fresh samples of similar rocks from exploration drillholes in the Jundee area contain clasts (up to 2.0 mm across) of plagioclase, quartz, and felsic volcanic rock in a silty matrix. The matrix is recrystallized and typically contains fine-grained, metamorphic white mica, chlorite, albite, quartz, and very fine grained sphene and opaque minerals. Localized, patchy carbonate alteration is also present.

Granitoid rocks (*Ag, Agf, Agmh, Agm, Agz, Aggp, Agnq, Agdq, Aga, Agd, Agmp, Agzq, Ags*)

In most outcrops on MILLROSE, granitoid rocks are deeply weathered and their mineralogical compositions uncertain; therefore, they have mainly been shown as undivided granitoid rocks (*Ag*).

A range of granitoid rock types is present in the southwestern part of MILLROSE, but due to poor exposure and strong deformation, they have been mapped collectively as strongly foliated granitoid rock with minor quartzofeldspathic gneiss (*Agf*). Biotite monzogranite is the predominant rock type, but there is a wide variation in mineralogy locally. Leucocratic granitoid is present in places, and muscovite is conspicuous in others. Minor rock types include mica schist, quartzofeldspathic gneiss, and quartz–K-feldspar gneiss (*Anqk*). Layered rocks comprising alternating zones rich in mica (mainly muscovite) and feldspar outcrop in a few localities.

The granitoid rocks occupying the central part of MILLROSE are typically more mafic in character than those in the southwest. The dominant rock type is a moderately to strongly foliated, fine- to medium-grained hornblende monzogranite (*Agmh*). Subordinate biotite monzogranite (*Agm*) has been identified in drillholes. Minor rock types include monzonite (*Agz*) and porphyritic granodiorite (*Aggp*), both of which have been noted in drillholes along the eastern side of the Jundee domain.

Areas of weathered outcrop with an intimate mixture of granitoid rocks and quartzofeldspathic gneiss are shown as a mixed unit (*Agnq*). This unit has been used to characterize weathered quartzofeldspathic rocks northeast of Turnup Bore and northeast of Lignan Well.

In the area northeast of Turnup Bore, fine- to medium-grained, moderately to strongly foliated granitoid rocks are intimately associated with quartzofeldspathic gneiss (*Agnq*). Foliated, metamorphosed mafic rock (*Ab*) is a minor, but important, rock type in this area, and forms thin, discontinuous layers, the largest of which have been shown separately on the map. A less abundant, but distinctive, component of this sequence is metamorphosed quartz diorite to quartz monzodiorite (*Agdq*). This is a fine- to medium-grained, granoblastic rock containing plagioclase, clinopyroxene, and hornblende, with subordinate K-feldspar and a small amount of quartz (Fig. 17). This rock contains numerous thin, irregular plagioclase-rich leucosomes, which may be former patches of melt. The origin of this rock type is unclear, but it is possible that it represents a metamorphosed and deformed diorite dyke.

A weathered, mixed unit of granitoid rocks and quartzofeldspathic gneiss (*Agnq*) in eastern MILLROSE is similar in character to that on the western side, but is mainly too weathered to determine primary mineralogy and composition. Rare, fresh exposures are present in a creek section about 5 km northeast of Lignan Well (AMG 969047), where foliated hornblende monzogranite, quartz diorite, and layered quartzofeldspathic gneiss are associated with thin units of BIF and layered amphibolite. These outcrops are on the western side of a large dome that is evident on aeromagnetic images (Fig. 4). On the eastern side of the dome, quartzofeldspathic rocks are typically completely weathered, but a strong gneissic fabric is preserved locally (Fig. 18). The only fresh rocks exposed on the eastern side of the dome are scattered outcrops of weakly to moderately foliated, medium-grained, equigranular monzonite (*Agz*). One of these outcrops, about 8 km northeast of Lignan Well (AMG 985071), forms a linear unit that can be traced along strike for several hundred metres. This rock has a high magnetic susceptibility and appears to correspond to a prominent feature on aeromagnetic images (Fig. 4).

Undivided granitoid rocks (*Ag*) in the centre of the dome on the eastern side of MILLROSE were intruded by sheets of weakly foliated, quartz-phyric granitoid rock (*Aga*). The sheets are up to about 5 m thick, and a few have a weakly developed layering on a scale of 0.2 – 0.5 m.

Quartz diorite (*Agdq*) also outcrops within greenstones of the Jundee domain, about 5 km northwest of Jundee (AMG 603857). Here, it contains individual phenocrysts of plagioclase and hornblende, as well as large hornblende aggregates, in a fine-grained matrix of quartz, plagioclase, hornblende, opaque minerals, and micrographic quartz–K-feldspar intergrowths. Further northwest (AMG 592869), there are a few exposures of a rock tentatively identified as diorite (*Agd*). This is a porphyritic rock containing phenocrysts of plagioclase and pale-green amphibole in a felty, seriate-textured groundmass of fine-grained epidote, plagioclase, acicular amphibole, and opaque minerals. A few of the amphibole phenocrysts have relict cores of clinopyroxene. These

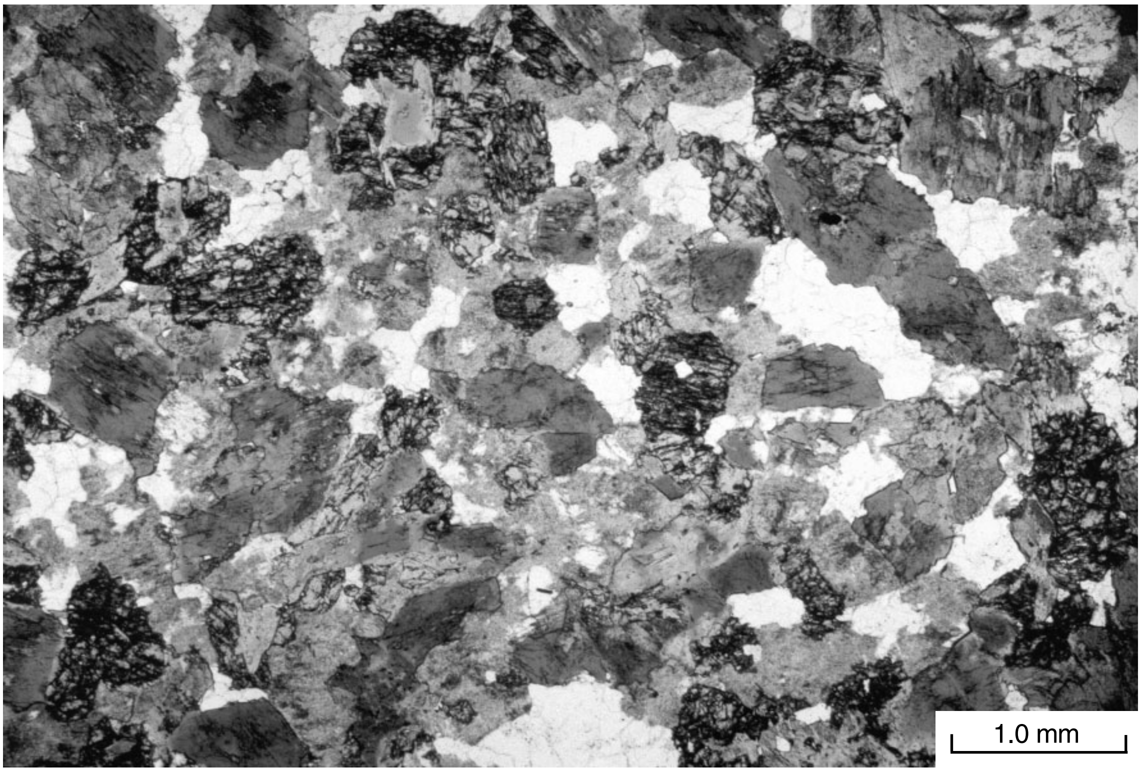

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Figure 17. Metamorphosed quartz monzodiorite, containing abundant clinopyroxene, hornblende, plagioclase, and quartz (AMG 549031; GSWA 137123). Plane polarized light

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Figure 18. Gneissic layering in very weathered quartzofeldspathic rock, northeast of Lignan Well (AMG 989088)

rocks are presented on the map as diorite, but could also be described as shallow-level andesite–dacite intrusions.

Well-exposed, northwesterly trending dykes of inequigranular to porphyritic biotite monzogranite (*Agmp;* Fig. 19) intruded quartzofeldspathic gneisses about 7 km northeast of Turnup Bore (AMG 590027). The dykes are K-feldspar phyric and reach up to about 10 m in thickness. They are essentially undeformed and contain subequal amounts of plagioclase and K-feldspar, abundant quartz and biotite, and minor amounts of subhedral green hornblende (up to 1.5 mm across) and euhedral, zoned sphene (up to 2 mm across). The K-feldspar is present as strained, subhedral crystals reaching up to 6.5 mm in diameter, and commonly shows microcline twinning and partial replacement by myrmekite along grain boundaries. The biotite is ragged (up to 1.5 mm across), partially chloritized, and commonly associated with clusters of opaque minerals, sphene, and epidote. The dykes contain abundant, rounded enclaves of a finer grained, more mafic biotite monzogranite up to about 0.5 m in diameter (Fig. 20). The enclaves are fine to medium grained, sparsely plagioclase phyric (up to 5.5 mm across), and have essentially the same mineralogy as the host dykes, except for a higher proportion of mafic minerals (dominantly biotite).

In the northeastern part of MILLROSE, relatively fresh outcrops of quartz monzonite (*Agzq*) are exposed over a wide area between Panakin and 4 Mile Bores. There are sparse outcrops east and northeast of 4 Mile Bore, but the full extent of the unit is indicated by a prominent high on aeromagnetic images (Fig. 4). Another area with locally fresh outcrops of quartz monzonite lies about 4 km west of Quartz Bore, adjacent to a prominent easterly trending quartz vein. The quartz monzonite is medium to coarse grained, with a quartz content less than about 15 vol.%. The rock typically contains abundant dark-green, strongly pleochroic hornblende, but there is also minor biotite, along with accessory sphene and iron oxides. In outcrop, the quartz monzonite is massive to weakly foliated. The foliation, defined by the alignment of hornblende and small mafic enclaves, may be, in part, a flow foliation. However, in thin section, quartz grains are clearly strained, indicating that the rock has been deformed.

A large mass of quartz monzonite in the central part of MILLROSE, around Lake Ward (Fig. 3), is known only from mineral exploration drillholes. The extent of the unit is indicated by a distinct high on aeromagnetic images (Fig. 4). The unit ranges in composition from monzogranite (*Agm, Agmh*) to quartz diorite (*Agdq*), and quartz monzonite (*Agzq*). The dominant rock type is a weakly deformed, medium-grained, quartz monzonite. The rock has been mapped as undivided monzonite (*Agz*) where there is no macroscopically visible quartz, and petrographic data are not available. The monzonite contains K-feldspar and plagioclase (up to 5 mm in diameter) in roughly equal proportions, and various amounts of hornblende and clinopyroxene. Quartz and brown biotite are minor constituents (up to a maximum

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Figure 19. Porphyritic biotite monzogranite dyke containing abundant K-feldspar phenocrysts (AMG 590027). Coin is 24 mm in diameter

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Figure 20. Mafic enclave in porphyritic biotite monzogranite dyke (AMG 590027). The enclave contains sparse plagioclase phenocrysts

of about 5 vol.% each). The biotite is typically subhedral, and strongly pleochroic, with grains up to 2.2 mm long, and is commonly present in aggregates with hornblende and clinopyroxene. In a few drillholes, the quartz monzonite is cut by numerous fractures with epidote alteration. Microscopically, the fracture zones comprise angular fragments of plagioclase and hornblende in a fine-grained matrix of granular epidote, with minor sphene and opaque minerals. A common feature of these rocks is the strong intracrystalline strain in feldspar. The K-feldspar typically shows undulose extinction, kinking, and microcline twinning, probably resulting from deformation associated with the fracturing.

Quartz monzonite (*Agzq*) is also a component of the layered gneissic sequence north of Turnup Bore, where it appears to be in thin layers (<30 m thick). The monzonite in this sequence is fine to medium grained and contains K-feldspar, plagioclase, various amounts of quartz (5–20 vol.%), and minor sphene and myrmekite (after K-feldspar). Accessory minerals include iron oxides, apatite, epidote, and rare zircon. In contrast to the large bodies of quartz monzonite, the monzonite in the layered sequence does not contain clinopyroxene or biotite.

A small body of syenite (*Ags*; wrongly labelled as syenogranite on the map) in the southwestern corner of MILLROSE, adjacent to the western edge of the Jundee domain (AMG 534756; Fig. 3), is a prominent feature on aeromagnetic images, but does not outcrop. The main rock type is a fractured and partly recrystallized, coarse-grained, massive syenite to quartz syenite. The syenite contains large grains of pink K-feldspar, up to 10 mm across, with numerous healed fractures.

Felsic veins and dykes (*a, p, q*)

Leucocratic, fine-grained aplite dykes (*a*) are common in the southern part of MILLROSE between 2 Hills Bore and 65 Well. A few of the dykes have a vague compositional layering and are locally porphyritic. They are typically less deformed and finer grained than the host monzogranite. Most individual dykes are less than about 0.3 m thick, and appear to be in swarms. The dykes are not shown on the map, except where they form larger outcrops (AMG 739743). They may be related to the weathered, fine-grained granitoid sheets (*Aga*) northeast of Lignan Well.

Small pegmatite bodies (*p*), typically near granite–greenstone contacts, are usually too small to be shown on the map face. One small outcrop of weathered, deformed pegmatite, on the northwestern side of the domal feature in eastern MILLROSE (AMG 961086), coincides with an aerial photograph lineament and an aeromagnetic lineament.

Quartz veins (*q*) are common throughout MILLROSE. They are present in all rock types and typically cut across the main structural trends. The major types of quartz veins include deformed quartz veins parallel to the regional foliation; simple, relatively massive, milky quartz veins commonly associated with fracture zones; and complex quartz veins that show evidence for repeated fracturing and veining.

Complex quartz veins commonly consist of multiple sets of crosscutting milky quartz veins, fragments of altered wallrock, and various amounts of iron oxides. The constituent veins are from about 1 to 220 mm thick, and have a range of orientations, usually at a high angle to the overall trend of the host vein complex. With increasing density of veining, the rock grades into a vein network, with the space between the veins commonly occupied by iron oxides after ?pyrite. These complex veins are typically parallel to a set of northeasterly trending aeromagnetic lineaments (see **Late brittle structures**).

A large, prominent quartz vein in the centre of the sheet area, west of Quartz Bore, coincides with a major easterly trending aeromagnetic feature (Fig. 4) that probably represents a late fracture (see **Late brittle structures**).

Mafic and ultramafic dykes (*Edy*)

The only rocks of probable Proterozoic age on MILLROSE are mafic (and ?ultramafic) dykes related to major crosscutting lineaments on aeromagnetic images (Figs 3 and 4). These rocks are interpreted to be Proterozoic in age by analogy with similar rocks elsewhere in the Eastern Goldfields Province (Hallberg, 1987). The only known exposure of a mafic dyke on MILLROSE is just south of the prominent quartz vein in the centre of the sheet area (AMG 785992). The rock is fresh and massive, comprises fine-grained plagioclase and clinopyroxene in a glassy groundmass, intruded weathered granitoid rock, and is coincident with a northeasterly trending aeromagnetic lineament.

Greenstone stratigraphy

Poor exposure and a scarcity of younging indicators make it difficult to describe a detailed stratigraphy for the Yandal greenstone belt on MILLROSE. The Jundee domain contains a broad range of rock types in a belt, up to about 16 km wide, that occupies the southwestern part of the sheet area. The Millrose domain contains a very poorly exposed and deeply weathered sequence of mafic, ultramafic, andesitic, and sedimentary rocks in a narrow belt, less than about 7 km wide. This belt extends in a broad arc from the southeastern corner to the central-northern part of the sheet area (Fig. 3). All greenstones have been metamorphosed to low to medium grade.

Outcrop mapping and examination of numerous mineral exploration drillholes have allowed the Jundee domain to be divided into three main lithological packages: an eastern sequence dominated by mafic and ultramafic rocks, with locally abundant felsic volcanic and subvolcanic rocks; a thick central sequence of felsic and sedimentary rocks; and a thin western sequence of mafic rocks, chert, and BIF (Fig. 3).

The eastern sequence of the Jundee domain contains basalt, ultramafic rock, and minor chert and gabbro. The relationships between individual rock types are not clear, but the sequence appears to consist mainly of basalt, with numerous thin layers of ultramafic rock. Relict pillow structures in a prominent outcrop of high-Mg basalt (AMG 682740) and graded bedding in diamond drillcore samples of sedimentary rocks from the Jundee mine indicate that the sequence youngs to the west. Upper (western) parts of the sequence contain locally abundant felsic to intermediate volcanic and subvolcanic rocks. An extensive area of felsic rocks about 3 km northeast of O'Keefe Well (AMG 638731) may be a former felsic volcanic centre. The upper boundary of this sequence is not exposed.

Sedimentary rocks dominate the central part of the Jundee domain. Felsic rocks are locally abundant, and mafic, intermediate, and ultramafic rocks are a minor component. The sequence also contains a few chert layers, mainly in the east. The relationship between this central unit and rocks further to the west is not known due to the almost complete absence of outcrop.

The westernmost part of the Jundee domain is characterized by deformed mafic rocks and a distinctive unit of BIF and associated ultramafic rocks. Way-up indicators were not observed in this unit and, therefore, both its younging direction and relationship with the remainder of the Jundee domain are unclear.

Fresh rocks are only rarely exposed within the Millrose domain on MILLROSE, and mineral exploration drilling is much less abundant and very patchy compared with the Jundee domain. The rocks are also strongly deformed, making it difficult to determine the protoliths of the greenstones.

The most complete section across the Millrose domain lies south of the Millrose Homestead where patchy, weathered outcrop and mineral exploration drillholes indicate a sequence dominated by mafic volcanic and volcaniclastic rocks, with subordinate shale, siltstone, and ultramafic rocks, and minor felsic rocks. The ultramafic rocks appear to be most abundant along the strongly deformed eastern margin of the domain where they correspond to linear features on aeromagnetic images (Fig. 4).

North of Millrose Homestead, deeply weathered rocks on the western side of the belt south of Snake Well and exploration drillholes south of Old Camp Bore indicate that the sequence is similar to that in the south. In this section, silica caprock (*Czu*) on the western side of the belt suggests that thin units of ultramafic rock are distributed throughout the sequence. The presence of BIF in a drillhole 1.5 km south of Old Camp Bore (AMG 951832) suggests that a few of the linear magnetic features on aeromagnetic images (Fig. 4) may be due to BIF units.

Further north, outcrop is sparse, but limited data from exploration drilling suggest that the same sequence continues at least as far as Mistake Bore. There are few data from north of Mistake Bore, but exploration drilling in the area north of Panakin Bore indicates a sequence of basic to intermediate composition containing thin layers of ultramafic rocks.

Structural geology

Archaean rocks on MILLROSE have been metamorphosed and multiply deformed. Four phases of deformation (D_1–D_4) have been identified on the basis of overprinting relationships, and the consistent style and orientation of each set of structures. In addition, there are ?Proterozoic, regional-scale zones of brittle deformation that cut across all major rock units.

The quartzofeldspathic gneisses show evidence of three phases of deformation (D_1–D_3), and are the oldest known rocks in the area. The greenstones also show evidence of three deformation events (D_2–D_4), the first two of which are correlated with D_2–D_3 in the gneisses. Granitoid rocks show evidence of having intruded the gneisses during or after D_2, and many granitoid rocks contain only one generation of structures (D_3).

Structure of the gneisses

The interpretation of the deformation history of the gneisses is based largely upon an examination of structures in the area northeast of Turnup Bore, in central-western MILLROSE. Gneisses in this area lie in the hinge zone of a large-scale (wavelength ~8 km), gentle asymmetric F_3 fold. Structures in granitoid rocks and gneisses in the large domal structure east of Lignan Well, on the eastern side of MILLROSE, are poorly preserved. The few small areas of well-preserved outcrop (e.g. AMG 960049) show similar structural relationships to those observed near Turnup Bore.

The earliest recognizable structure in the gneisses is a strong, upright, layer-parallel foliation (S_1) that has been folded into a northwest to west-northwest orientation. The S_1 foliation is defined mainly by the preferred alignment of biotite and thin, quartz-rich leucosomes. The S_1 fabric is deformed into small (outcrop-scale) F_2 folds (Fig. 13), and also appears to be folded on a larger scale (with a wavelength of about 200 m) because it shows across-strike reversals in vergence relationships with S_2. A coarse, easterly plunging lineation (L_1), defined by the alignment of biotite-rich clots, is present locally.

The D_1 structures are overprinted to different degrees by structures attributed to D_2, depending on host rock type. Layered and mica-rich gneisses, in particular, tend to be more highly deformed than homogeneous varieties of gneiss. The S_2 foliation is upright and west-northwesterly to north-northwesterly trending. In low-strain areas, S_1 is gently folded about F_2 axes. In contrast, in high-strain areas, S_1 is tightly to isoclinally folded and largely transposed into S_2 (Fig. 21), making it difficult to distinguish the two fabrics. In high-strain zones, S_1-parallel leucosomes are commonly boudinaged in S_2. The F_2 folds are typically upright, open to tight, with rounded profiles and moderate to steep plunges to the west.

The third deformation event (D_3) was heterogeneous, and its effects are not apparent in all the gneisses exposed near Turnup Bore. The characteristic structure is a planar foliation (S_3) in both quartzofeldspathic gneisses and granitoid rocks. The S_3 foliation is variably developed, typically increasing in intensity near the granite–greenstone contact. The S_3 foliation is only patchily developed within quartzofeldspathic gneisses. In places, the gneisses contain a strong S_2 foliation, whereas nearby granitoid rock has a northerly trending S_3 fabric. Where S_3 is well developed in quartzofeldspathic gneisses, existing S_1–S_2 fabrics and the layering are transposed into S_3 by dissection of the layers into individual fragments that are rotated into S_3 and flattened. A subhorizontal mineral lineation (L_3) is present in deformed granitoid rocks at the margins of the area.

Structure of the greenstones

The principal structure in the greenstones is a regional, upright, north to northwesterly trending foliation. This fabric is strongly developed in the Millrose domain and along the margins of the Jundee domain. However, in most of the central part of the Jundee domain, the strain is low and the rocks have only a weakly developed fabric. The age of this foliation is not clear, but is interpreted to be S_3 because it has a similar trend to S_3 in the gneisses. In addition, it shows a consistent trend throughout MILLROSE and there is no evidence of refolding, suggesting that it is related to the last major deformation event (D_3). The regional foliation is axial-planar to a large, open to gentle fold (F_3) in the greenstone sequence near the southern boundary of MILLROSE (Fig. 3). There are also small folds in metamorphosed chert units in the central part of the Jundee domain, but these have various orientations and, in isolation, their relative position in the deformation sequence cannot be determined.

The best-developed structures in greenstones are in higher strain zones along the western margin of the Jundee domain. Units of metamorphosed, laminated chert and BIF in this area have a prominent planar layering that is parallel to a strong foliation, with rare intrafolial tight to isoclinal folds (S_0–S_2; Fig. 22). The foliation is interpreted to be S_2 because it is deformed into shallow-plunging, asymmetric folds (F_3), with axes subparallel to the L_3 mineral lineation in deformed granitoid rocks. At this location, S_2 and S_3 are probably parallel because S_2 is broadly parallel to the axial plane of the F_3 folds. However, at the northern end of the Jundee domain (AMG 513077), where the granite–greenstone contact swings around to the west, S_2 is easterly trending and cut at a high angle by S_3, producing a prominent 'pencil cleavage' due to the intersection of the two foliations. This suggests that S_2 may have developed parallel to the granite–greenstone contact.

Metamorphosed cherts on the western side of the Jundee domain typically show two or more overprinting lineations on S_0–S_2 surfaces (Fig. 23). The earliest

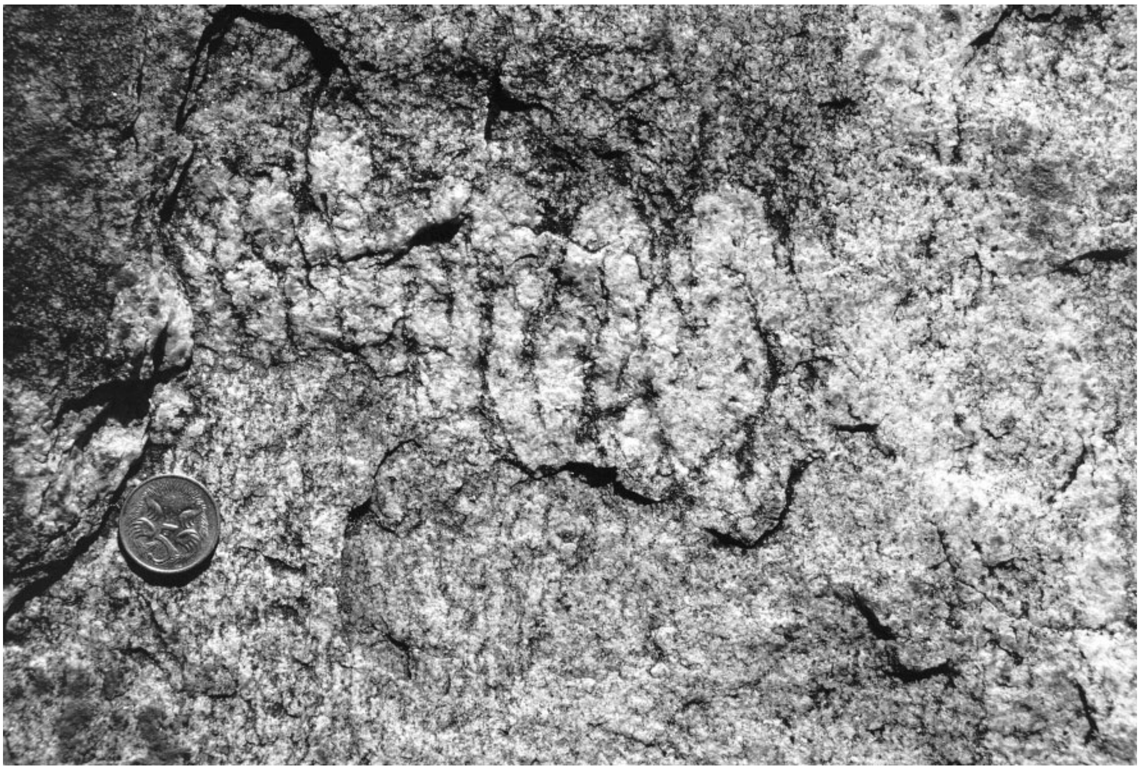

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Figure 21. Ptygmatic F_2 fold of an S_1-parallel leucosome in a quartzofeldspathic gneiss (AMG 577018). The fold has a strong composite axial-planar S_1–S_2 fabric. Coin is 18 mm in diameter

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Figure 22 Steeply plunging isoclinal fold (F_2) in metamorphosed layered chert (AMG 575682). Plan view of a horizontal surface

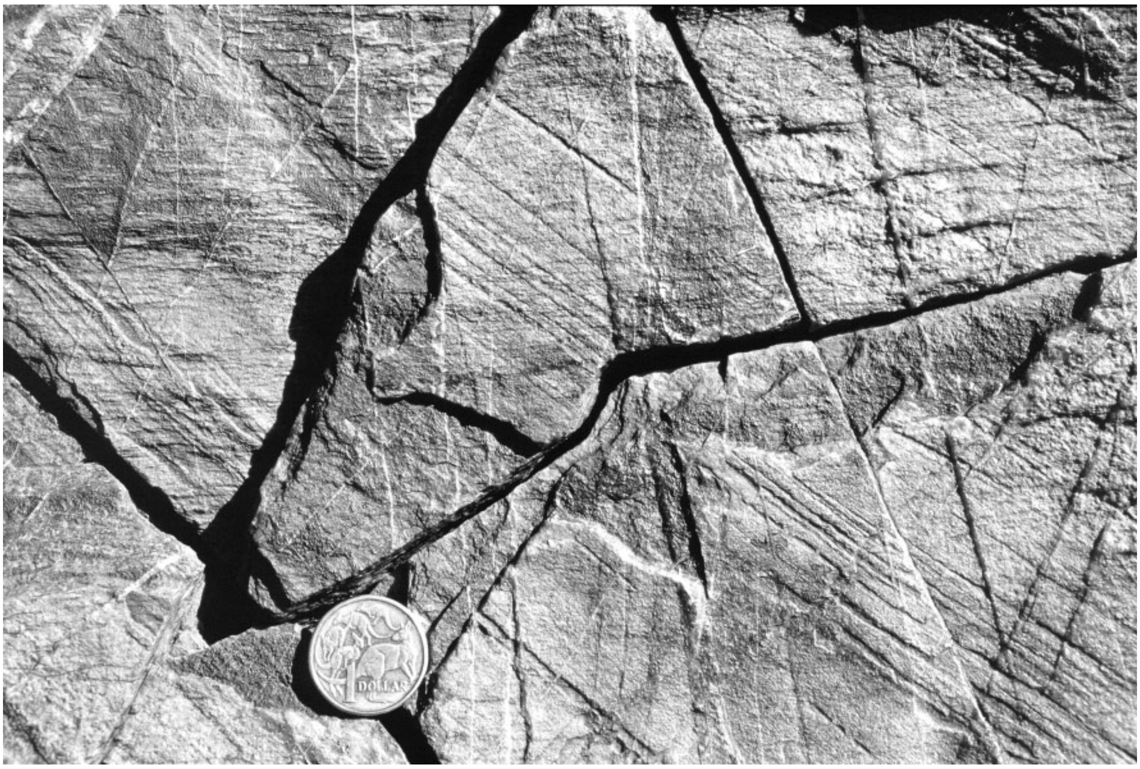

Figure 23 Overprinting lineations in a metamorphosed layered chert (AMG 520826). A moderately pitching lineation (L_2), due to the intersection of S_0 and S_2, is overprinted by a subhorizontal crenulation lineation (L_3). Side view of a steeply dipping S_2 foliation surface. Coin is 24 mm in diameter

lineation is a prominent combined intersection – mineral elongation lineation (L_2, due to the intersection of S_0 and S_2; Fig. 23) that has a moderate to steep northward plunge. This early lineation is locally overprinted by a fine, subhorizontal crenulation lineation (L_3; Fig. 23) that is parallel to the axes of outcrop-scale, upright asymmetric folds (F_3). The crenulation lineation (L_3) is subparallel to a shallow L_3 mineral lineation in strongly deformed granitoids nearby, and is similar in orientation to D_3 structures in the gneisses. The first two lineations are overprinted in a few locations by a later lineation (L_4) resulting from small-scale kink bands, which commonly have an axial-plane quartz-vein or fracture.

The eastern boundary of the Millrose domain is very strongly deformed, and rarely well exposed. Asymmetric quartz porphyroclasts and S–C fabrics in felsic schist 4 km south of Millrose Homestead (AMG 957744) are suggestive of sinistral shear. However, a strongly deformed, porphyritic monzogranite on the eastern side of the contact has symmetric plagioclase porphyroclasts and does not give a clear sense of movement, suggesting that there was a very strong component of flattening. This eastern boundary is probably the northern extension of the Ninnis Fault on DARLOT (Westaway and Wyche, 1998). The western contact of the Millrose domain is poorly exposed, but a locally developed, strong, steeply plunging mineral lineation in weathered rocks near the granite–greenstone contact close to Snake Well is similar to L_2 on the western side of the Jundee domain.

Structure of the granitoid rocks

Granitoid rocks on MILLROSE show various degrees of deformation, but the highest strain is typically along granite–greenstone contacts. A well-developed foliation (S_3) and a strong, shallow-plunging mineral lineation (L_3) are present in deformed granitoids along the margins of both greenstone domains. The mineral lineation is defined by the alignment of biotite, quartz, and quartzofeldspathic aggregates.

The timing of granitoid emplacement is not clear, but an undeformed monzogranite dyke 7 km northeast of Turnup Bore (see **Granitoid rocks**) has intruded parallel to S_2 in a quartzofeldspathic gneiss (Fig. 24). This dyke has a U–Pb zircon age of 2658 ± 2 Ma (AGSO, unpublished data), indicating that D_2 occurred at c. 2660 Ma or earlier.

Late brittle structures

Numerous prominent aeromagnetic lineaments cut across all Archaean structures and rock associations on MILLROSE (Figs 3 and 4). There are two main sets of lineaments: a northeasterly to east-northeasterly trending set that shows apparent dextral offsets of up to about 1 km, and a later, easterly trending set with displacements of up to about 2.5 km. A few of these lineaments coincide with Proterozoic mafic dykes (see **Mafic and ultramafic**

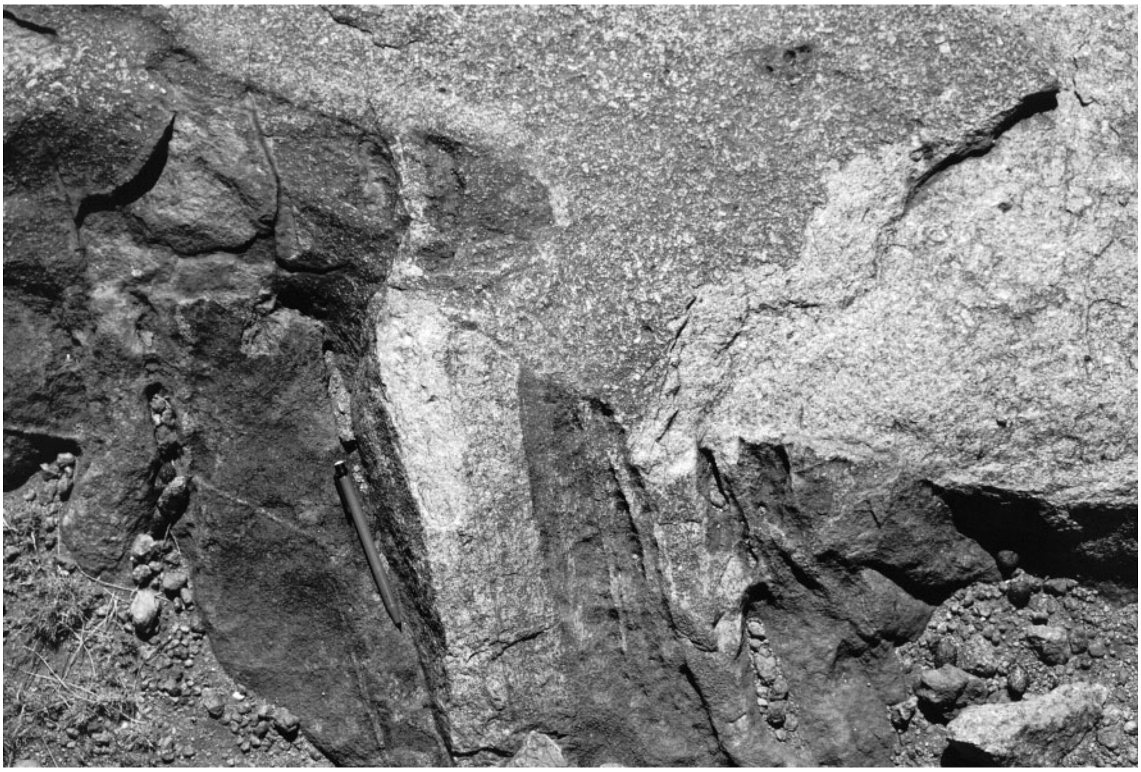

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Figure 24. Contact between porphyritic monzogranite dyke and layered quartzofeldspathic gneiss (AMG 590027). There is a foliation parallel to the layering in the gneiss (S_1), and a weakly developed foliation (S_2) parallel to the contact. Plan view of a horizontal surface. Pencil is 145 mm in length

dykes) or quartz veins (e.g. AMG 790998; see **Felsic veins and dykes**). The northeasterly trending set is also parallel to complex quartz veins in the southern part of the Jundee domain. These lineaments are interpreted to be fault or fracture zones infilled by quartz veins (?latest Archaean) or mafic dykes (Proterozoic).

Metamorphism

Most of the greenstones on MILLROSE have been metamorphosed to lower greenschist facies, with amphibolite-facies rocks restricted to narrow zones along granite–greenstone contacts. In contrast, gneisses have been metamorphosed to a higher grade — probably to upper amphibolite facies — and show evidence of partial melting. There is no evidence for overprinting by retrograde fabrics in the greenstones, and it is uncertain whether they have undergone separate metamorphic events in D_2 and D_3, or if there was a single metamorphic event.

Mafic igneous rocks in the central part of the Jundee domain are partly recrystallized, and typically contain a metamorphic assemblage that includes chlorite, albite, epidote, and tremolite–actinolite, which is diagnostic of greenschist facies (Bucher and Frey, 1994). Felsic volcanic rocks also contain a similar assemblage, with the addition of white mica and pumpellyite. The presence of pumpellyite indicates lower greenschist-facies conditions (or lower), at a maximum temperature of about 300°C (Bucher and Frey, 1994). The deeply weathered nature of rocks in the Millrose domain precludes a complete determination of the metamorphic grade, but samples from drillholes suggest that conditions were similar to those in the Jundee domain.

The gneisses have been metamorphosed at high grade, probably upper amphibolite facies. Mafic and quartzofeldspathic gneisses both contain thin, foliation-parallel, quartz–plagioclase leucosomes (up to 10 mm thick), as well as larger, pod-like leucosomes (up to 160 mm in width; Fig. 7), which form an interconnected network in places. These leucosomes are interpreted to be former melts, and indicate a peak temperature greater than about 650°C (Bucher and Frey, 1994). A high metamorphic grade is also indicated by the presence of abundant clinopyroxene in mafic gneiss and amphibolite, and relict perthite lamellae within K-feldspar in quartzo-feldspathic gneiss.

Cainozoic geology

Much of MILLROSE is mantled by Cainozoic regolith deposits. They consist of residual, indurated deposits exposed by erosion, and a range of younger alluvial, eluvial, eolian, and lacustrine deposits. Individual regolith units have been mapped using field observations complemented by aerial photograph and Landsat TM image interpretation.

The oldest regolith units typically form residual deposits on low hills and in breakaways. They include lateritic duricrust (*Czl*), massive ironstone (*Czli*), ferruginous rock debris and degraded duricrust (*Czf*), silcrete (*Czz*), and silica caprock over ultramafic rocks (*Czu*). The massive ironstone units (*Czli*) are typically thin, ridge-forming units that may be deeply weathered relics of original sedimentary rocks.

Proximal slope deposits, comprising rock debris, sand, and silt, lie on or adjacent to low hills and below breakaways. They have been mapped as colluvium (*Czc*). or quartz-vein debris (*Czcq*) if they are dominated by quartz fragments. The latter units are restricted to areas adjacent to large quartz veins.

More distal parts of the regolith are dominated by sheetwash (*Cza*) and sandplain deposits (*Czs*). Sheetwash deposits (*Cza*) are by far the most extensive regolith unit in areas of MILLROSE underlain by greenstone. They consist of a thin layer of sand, silt, and clay over saprolite, and are gradational into sandplain deposits. Areas underlain by granitoid rocks are covered mainly by extensive sandplains consisting of unconsolidated quartz sand and silt. Ridges of wind-blown sand are present locally.

The Lake Ward drainage, in central MILLROSE, contains a range of ephemeral lake deposits. Playa lakes (*Czp*) contain saline and gypsiferous evaporites, along with minor amounts of sand, silt, and clay. The playas are associated with saline and gypsiferous dune deposits (*Czd*) that contain low, crescent-shaped dunes formed by wind action during dry periods. Extensive, low-lying areas containing hummocky deposits (*Czb*) of sand, silt, and clay, with small interspersed playas, claypans, and patchy deposits of calcrete, surround the gypsiferous dune deposits. Larger deposits of calcrete (*Czk*) are present in areas around the margins of the lake deposits.

Younger deposits of unconsolidated to semi-consolidated sandy alluvium and gravel (*Qa*), of probable Quaternary age, lie along intermittently active fluvial channels and on adjacent flood plains. These deposits grade laterally into sheetwash, and may have undergone some degree of eolian reworking. Lake and sheetwash deposits may also contain small claypans (*Qac*), consisting of thin deposits of silt and clay in shallow depressions.

Economic geology

The first significant gold production on MILLROSE began in early 1995 with the mining of the Jundee and Nimary deposits in the southwestern part of MILLROSE. The only evidence of previous mining activity are a few shallow workings near 2 Hills Well (AMG 730695), but no production records have been found.

Gold mineralization was discovered in the Jundee area in the mid-1980s (Lewington, 1995; Wright and Herbison, 1995), and the Nimary and Jundee deposits were discovered during drilling programs in 1990 and 1992 respectively. Descriptions of the geology of the Jundee and Nimary deposits are presented in Byass and Maclean (1998) and Phillips et al. (1998a). The setting of the deposits and controls on mineralization are discussed by Vearncombe (1998). The deposits lie within a sequence of metamorphosed basalt, fine-grained gabbro, subordinate porphyritic felsic rocks, and minor sedimentary rocks. The gold mineralization is in quartz–carbonate – white mica – pyrite–arsenopyrite(–chlorite) alteration zones in late brittle structures (Lewington, 1995; Wright and Herbison, 1995). In places, the mineralization is related to Proterozoic mafic dykes (Phillips et al., 1998a), and appears to post-date much of the regional ductile (D_1–D_3) deformation.

Production for the Jundee mine up to and including 1997–98 was 6.391 Mt of ore at an average recovered grade of 2.80 g/t gold for 17 859 kg of gold. The total production to 1997–98 for the Nimary mine was 1.889 Mt of ore at an average recovered grade of 4.4 g/t gold for 8319 kg of gold.

The Jundee and Nimary operations have been combined and are operated by Great Central Mines Limited. The combined production for the Jundee–Nimary project for 1998–99 was 2.996 Mt of ore yielding 11 549 kg of gold at an average recovered grade of 3.85 g/t of gold. Total production from the Jundee–Nimary project from 1995 to June 1999 was 37 727 kg of gold, making it the fourth-largest operating mine in Western Australia. The Jundee–Nimary project has resources containing about 210 t (6.76 Moz) of gold, contained within measured and indicated resources totalling 30.49 Mt and averaging 4.32 g/t of gold, and inferred resources of 10.59 Mt averaging 7.43 g/t of gold (Great Central Mines Limited, 1998).

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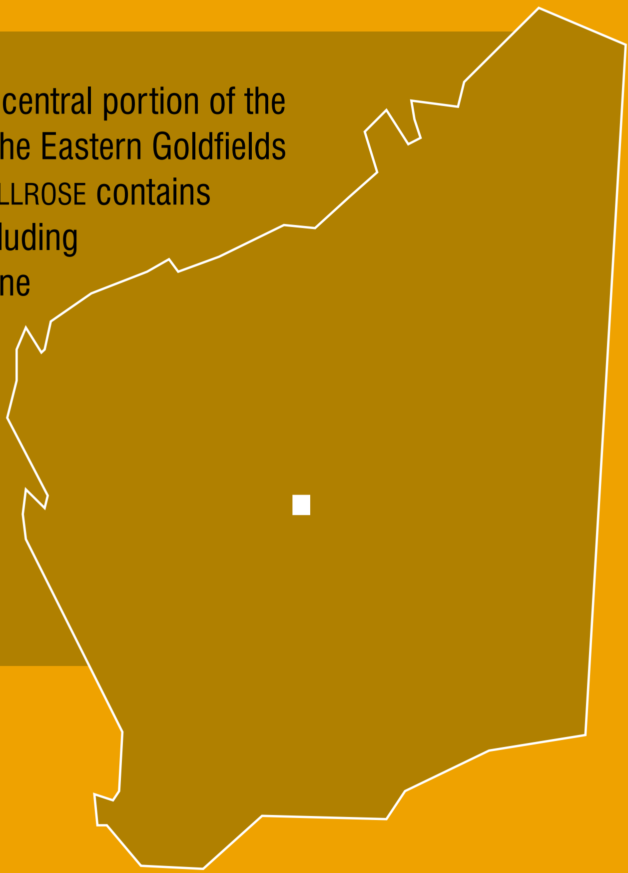
Appendix

Gazetteer of localities

Locality	*AMG coordinate*
Amees Bore	541019
Bendys Bore	506844
Bogada Bore	608881
4 Mile Bore	874156
George Bore	803044
Jundee Homestead	645831
Jundee–Nimary goldfield	600810
Lake Ward	715880
Lignan Well	930005
Millrose Homestead	957782
Mistake Bore	789103
O'Keefe Well	622702
Old Camp Bore	950845
Panakin Bore	743170
Quartz Bore	818985
Ronnie Bore	695789
Rose Hills	710740
Snake Well	891862
Strife Bore	590736
65 Well	852677
Terry Bore	533702
Turnup Bore	544976
Twin Tanks Well	671703
2 Hills Bore	768706
2 Hills Well	730695

NOTE: Localities are specified by the Australian Map Grid (AMG) standard six-figure reference system whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on this sheet, to within 100 m.

The MILLROSE 1:100 000 sheet covers the north-central portion of the WILUNA 1:250 000 sheet in the northern part of the Eastern Goldfields Province, within the Archaean Yilgarn Craton. MILLROSE contains a poorly exposed granite–greenstone terrain, including much of the northern end of the Yandal greenstone belt. These Explanatory Notes describe the Precambrian rock types, and the metamorphic and structural history of the granite–greenstone terrain. Other aspects of the geology that are considered in these Notes include the extensive Cainozoic regolith cover, and the regional setting of the Jundee–Nimary goldfield.



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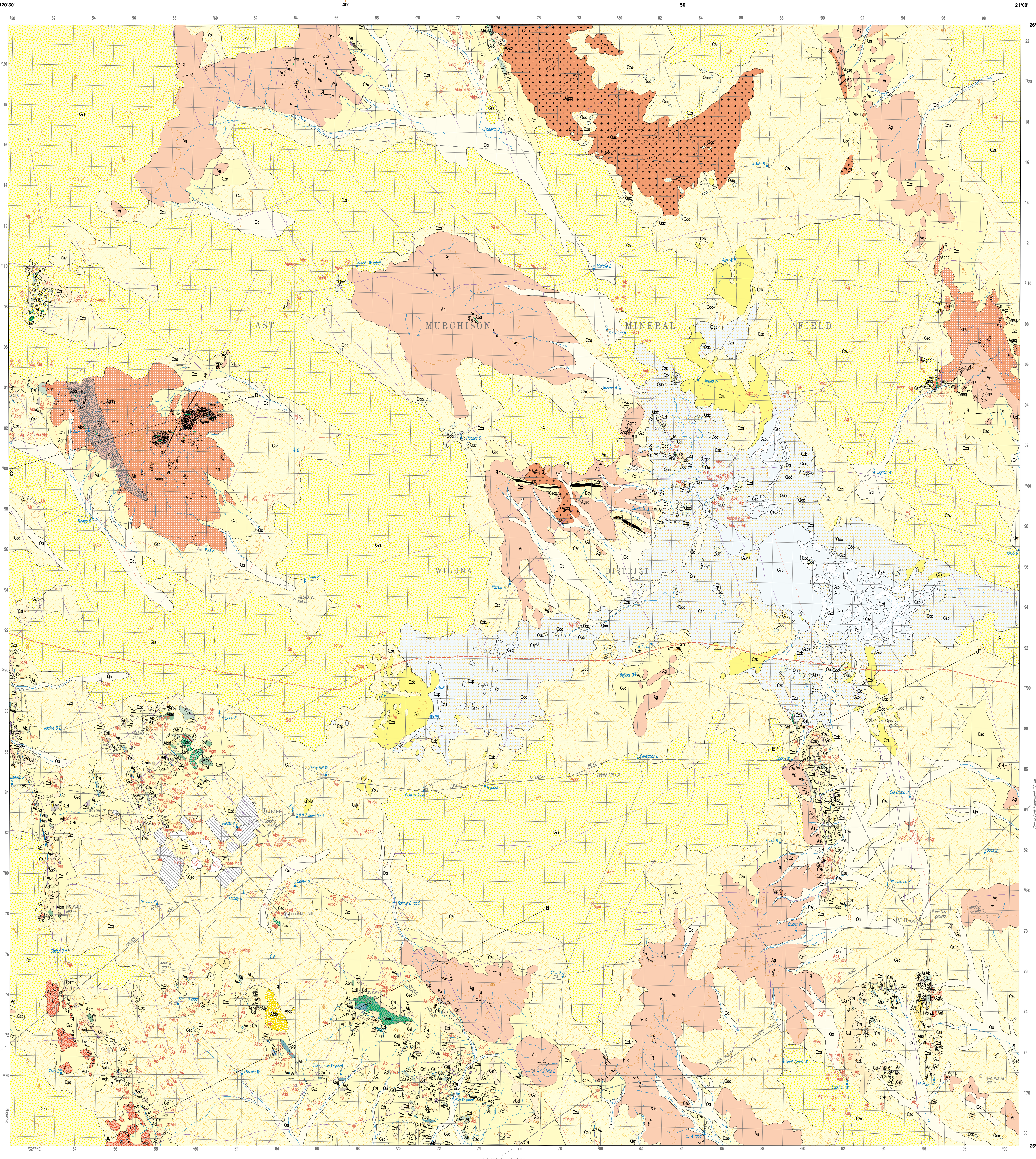
MILLROSE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



QUATERNARY

Qa Alluvium—clay, silt, sand, and gravel in channels and flood plains
Qac Clay and silt in claypans

CAINOZOIC

Czb Ephemeral lake and dune deposits—clay, silt, and sand in drainage basins adjacent to playa lakes
Czd Dune deposits—saline and gypsiferous evaporites, clay, silt, and sand in playa lakes
Czp Playa deposits—saline and gypsiferous evaporites in playa lakes
Cza Sheetwash deposits—clay, silt, and sand in extensive sheetwash fans
Czs Sandplain deposits—unconsolidated sand, minor silt; includes stabilized dunes
Czc Colluvium—sand, silt, and rock debris as scree and proximal sheetwash
Czcq Quartz vein debris
Czf Ferruginous rubble and colluvium—degraded lateritic duricrust

Czk Calcrete
Czl Lateritic deposits—lateritic duricrust
Czli Massive ironstone
Czu Silica caprock over ultramafic rock
Czz Silcrete

PROTEROZOIC

Ꞓdy Mafic dyke

Veins and dykes: a - aplite, p - pegmatite, q - quartz

ARCHAEAN

Ags Syenogranite (subsurface only)
Agz Monzonite, undivided
Agzq Quartz monzonite

Ag Granitoid rock, undivided
Aga Fine-grained granitoid rock; deeply weathered
Agd Diorite
Agdq Quartz diorite and quartz monzodiorite
Agf Foliated granitoid rock and minor quartzofeldspathic gneiss
Aggp Granodiorite; porphyritic (subsurface only)
Agm Biotite monzogranite (subsurface only)
Agmh Hornblende monzogranite (subsurface only)
Agmp Biotite monzogranite; coarsely porphyritic

Agnq Granitoid rock and quartzofeldspathic gneiss

Anc Calc-silicate gneiss (subsurface only)
Angb Interlayered quartzofeldspathic gneiss, monzonite and metamorphosed mafic rock
Anq Quartzofeldspathic gneiss
Anqk Quartz-K-feldspar gneiss

As Metamorphosed clastic sedimentary rocks, undivided
Asc Polymictic conglomerate; metamorphosed
Ash Shale and siltstone; metamorphosed
Ashg Graphitic shale and siltstone; metamorphosed (subsurface only)
Ass Sandstone with minor siltstone; metamorphosed
Ac Chert and layered chert; metamorphosed
Aci Banded iron-formation; metamorphosed

Af Metamorphosed felsic rock, undivided
Afd Metadacite (subsurface only)
Afdp Porphyritic dacite; metamorphosed
Afi Intermediate volcanic rock; metamorphosed (subsurface only)
Afip Porphyritic intermediate volcanic rock; metamorphosed (subsurface only)
Afp Porphyritic felsic rock; metamorphosed
Afs Felsic schist

Ao Metamorphosed medium- to coarse-grained mafic rock, undivided
Aog Metagabbro
Aoge Epidotized metagabbro
Aogf Foliated metagabbro (subsurface only)
Aogo Olivine gabbro; metamorphosed

Ab Metamorphosed fine-grained mafic rock, undivided
Aba Amphibolite
Abe Epidotized metabasalt
Abf Foliated and metamorphosed mafic rock
Abi Basaltic andesite; metamorphosed
Abie Basaltic andesite and andesite; foliated and epidotized; metamorphosed
Abip Plagioclase-phyric basaltic andesite and andesite; metamorphosed (subsurface only)
Abm High-Mg basalt; commonly with pyroxene-spinifex and variolitic texture; metamorphosed
Abml Pillowed high-Mg basalt; variolitic texture and local pyroxene-spinifex texture; metamorphosed
Abp Plagioclase-phyric basalt; metamorphosed (subsurface only)
Abs Mafic schist; chlorite-rich schist, probably after basaltic volcaniclastic rocks
Abv Metabasalt
Aby Amygdaloidal basalt; metamorphosed

Au Metamorphosed ultramafic rock, undivided
Auc Talc-carbonate schist (subsurface only)
Auk Komatiite; relict olivine-spinifex texture; metamorphosed (subsurface only)
Aup Peridotite; serpentinized (subsurface only)
Aur Tremolite schist; probably after ultramafic rock or komatiitic basalt (subsurface only)
Aut Talc-chlorite schist

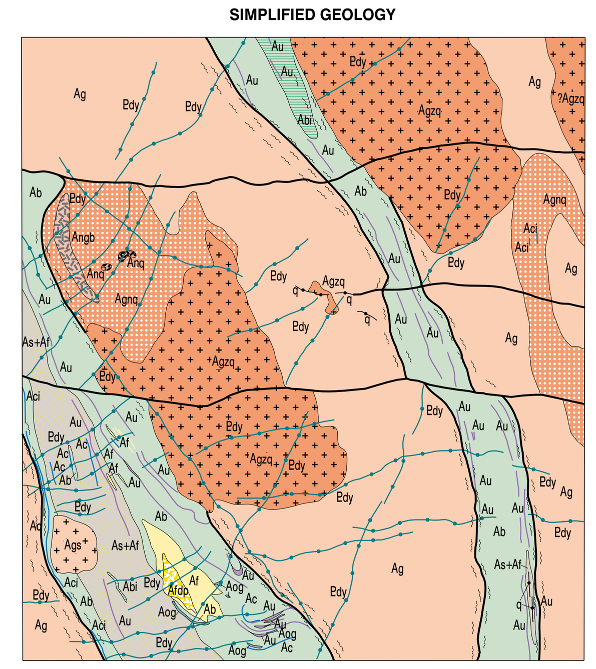
Geological boundary
exposed
concealed, interpreted from aeromagnetic data
Structural symbols are numbered according to the sequence of deformation events, where known
Local deformation events
Fault
exposed
concealed, interpreted from aeromagnetic data
strongly foliated rock
Minor folds, showing trend and plunge of fold axis
symmetric
asymmetric
Bedding, showing strike and dip
inclined
Igneous layering, showing strike and dip
inclined
vertical
Way-up indicator
pillow structure
Metamorphic foliation, showing strike and dip
inclined
vertical
Mineral lineation, showing trend and plunge direction
inclined
horizontal
Bedding–cleavage intersection lineation, showing trend and plunge
inclined
Axis of crenulation, showing trend and plunge direction
inclined
Air-photo lineaments
structural trend
fracture pattern in granitoid rock
Aeromagnetic lineament

Road, unsealed
Track
Fence, generally with track
Homestead
Building
Yard
Microwave repeater station
Horizontal control, minor
Breakaway
Sand dune
Contour line, 20 metre interval

Watercourse, ephemeral
Bore
Well
Windpump
Abandoned

Mineral field boundary
Major opencut (gold, unless otherwise indicated)
Quarry
Prospect
Treatment plant
Mining area
opencut
tailings, mullock
made ground
Mineral exploration hole, showing subsurface data
Mineral occurrence

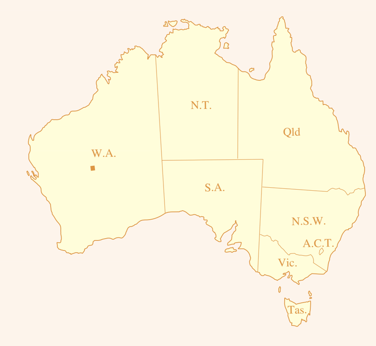
SIMPLIFIED GEOLOGY



Ꞓdy Proterozoic mafic dyke
q Quartz vein
Ags Syenite
Agzq Quartz monzonite and minor quartz diorite
Ag Granitoid rock, undivided; mainly monzogranite
Agnq Granitoid rock and quartzofeldspathic gneiss
Angb Interlayered quartzofeldspathic gneiss, monzonite and metamorphosed mafic rock
Anq Quartzofeldspathic gneiss
As+Af Mixed sequence of metamorphosed sedimentary and felsic rocks
Ac Chert and layered chert, metamorphosed
Aci Banded iron-formation, metamorphosed
Af Metamorphosed felsic volcanic rock dominant
Afdp Metamorphosed porphyritic dacite
Aog Metagabbro
Ab Metamorphosed mafic rock dominant
Abi Metamorphosed basaltic andesite and andesite
Au Metamorphosed ultramafic rock, undivided

YILGARN CRATON

SCALE 1:500 000



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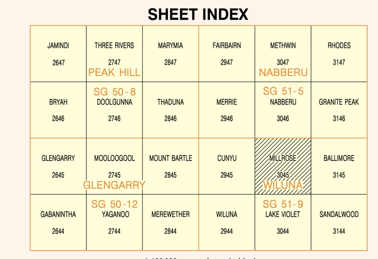
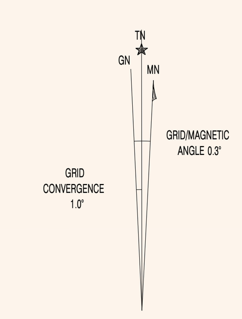
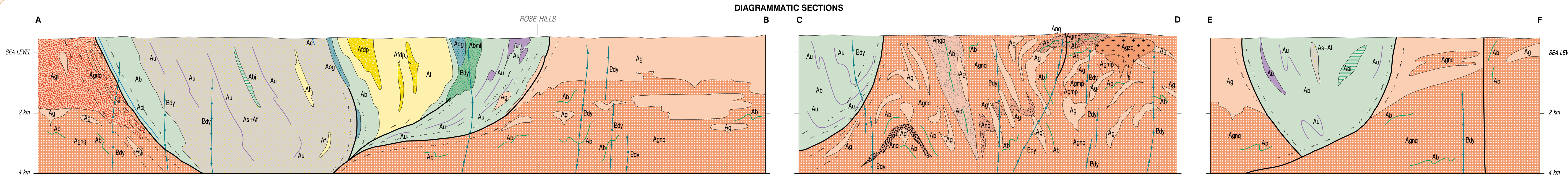


1:100 000 maps shown in black
1:250 000 maps shown in brown



True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1997 and moves easterly by about 0.1° in 6 years

DIAGRAMMATIC SECTIONS



DEPARTMENT OF MINERALS AND ENERGY
L. C. RANFORD, ACTING DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PIETRO GUJ, DIRECTOR

SCALE 1:100 000

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

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

Geology by T. R. Farrell and S. Wyche 1994

Edited by L. Taylor, C. Strong and G. Loan

Cartography by E. Green, C. Brien, C. Bartlett and K. Greenberg

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MILLROSE

SHEET 3045 FIRST EDITION 1997

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