EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

WILUNA

1:250 000 SHEET

WESTERN AUSTRALIA

SECOND EDITION

1:250 000 GEOLOGICAL SERIES

SHEET SG 51-9 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

WILUNA

WESTERN AUSTRALIA

SECOND EDITION

SHEET SH 51-9 INTERNATIONAL INDEX

by

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Perth, Western Australia 2001

MINISTER FOR STATE DEVELOPMENT; TOURISM;
SMALL BUSINESS; GOLDFIELDS–ESPERANCE

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Copy editor: D. P. Reddy

REFERENCE
The recommended reference for this publication is:
FARRELL, T. R., 2001, Wiluna, W.A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 28p.

ISSN 0729–3720
National Library of Australia Card Number and
ISBN 0 7307 5683 1

Grid references in this publication refer to the Australian Geodetic Datum 1984 (AGD84)

Printed by Haymarket Bureau, Perth, Western Australia

Copies available from:
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by T. R. Farrell

INTRODUCTION

The WILUNA* 1:250 000 geological sheet (SG 51-9) covers an area in the north Eastern Goldfields Province (Fig. 1) bounded by latitudes 26°00'S and 27°00'S, and longitudes 120°00'E and 121°30'E. The map is named after the town of Wiluna†, in the western part of the sheet area.

Access to WILUNA is via the Kalgoorlie–Meekatharra road, which services the town of Wiluna, or the Wongawol Road, which joins the Gunbarrel Highway at Carnegie on the STANLEY sheet to the northeast. There are also graded roads connecting Wiluna to Sandstone and the Yeelirrie, Barwidgee, Granite Peak, Cunyu, and Jundee homesteads (Fig. 2). Station tracks and numerous mineral exploration grid lines provide good access to most areas underlain by greenstones, but access is difficult to areas underlain by Archaean granitoid rocks or Proterozoic rocks due to the scarcity of tracks.

The sheet area is sparsely populated. The only permanent settlements are the town of Wiluna, small aboriginal communities at Kukabubba and Ngangganawili, mining camps for the Wiluna and Jundee–Nimary gold mines, and the pastoral stations of Lake Way, Lake Violet, and Millrose.

PHYSIOGRAPHY, CLIMATE, AND VEGETATION

WILUNA is typically flat to undulating, ranging in altitude from about 490 m Australian Height Datum (AHD) around Lake Way in the southwest, to more than 600 m in the west. The main physiographic features on WILUNA are the playa lake systems of Lake Way in the southwest and Lake Ward in the north, an unnamed easterly trending saline drainage in the southeast, and dissected plateaus of Proterozoic rocks in the northeast and central-west (Finlayson Range; Fig. 2). Mount Alice West, in the Finlayson Range, is the highest point in the area at 640 m AHD.

Areas underlain by greenstones are characterized by low strike-ridges of resistant rocks, subdued hills with rubbly outcrop and ferruginous debris, and broad valleys covered in sheetwash and alluvium. Areas underlain by granitoid rocks are dominated by extensive sandplains, with scattered outcrops and small breakaways in areas of recent erosion. Proterozoic units in the west and northeast are gently dipping and typically form steep-sided plateau remnants. Prominent scarps in the Finlayson Range, north and west of Wiluna township, have relative reliefs of up to about 50 m.

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* Capitalized names refer to standard 1:250 000 map sheets, unless otherwise indicated.

† Australian Map Grid (AMG) coordinates of localities on WILUNA mentioned in the text are listed in the Appendix.

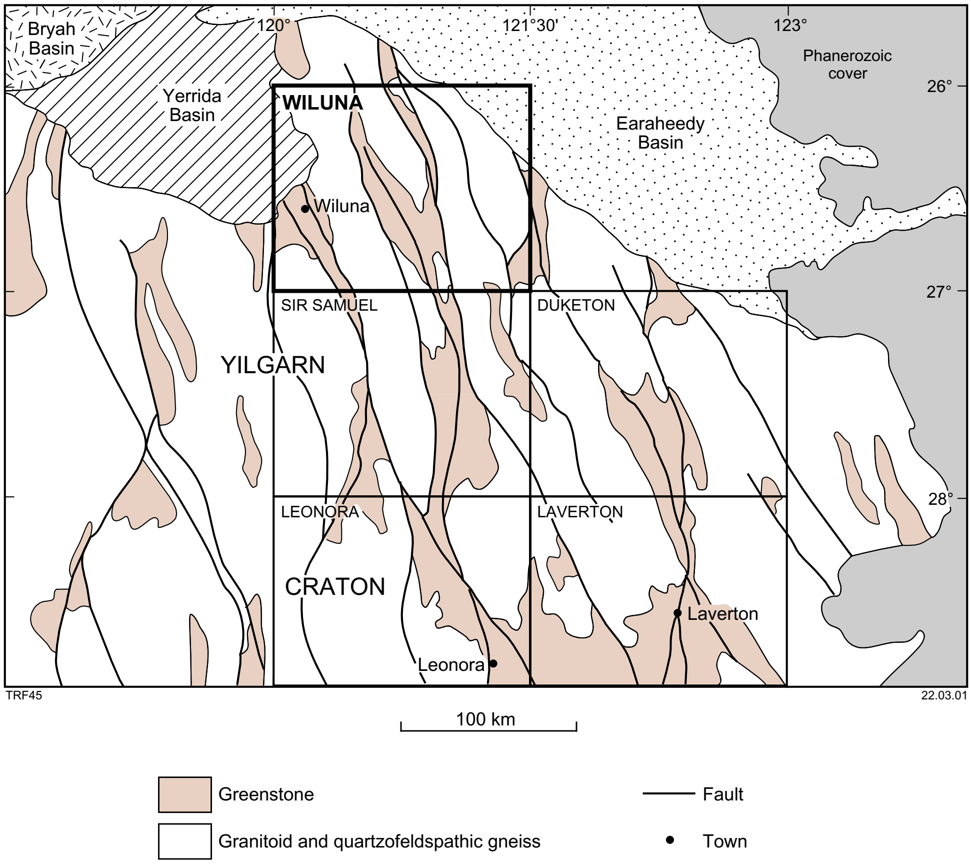

Figure 1. Regional geological setting of WILUNA (modified from Myers and Hocking, 1998)

The climate of the area is semi-arid to arid, with an average annual rainfall of approximately 254 mm*. The rainfall tends to be sporadic and varies markedly from year to year. The summers are hot, with maximum temperatures commonly in excess of 40°C, whereas the winters are cool to mild with occasional frosts and an average maximum temperature in July of 19°C.

Most of Wiluna falls within the Murchison Region of the Eremaean Botanical Province (Beard, 1990), except for the area underlain by Proterozoic rocks in the northeastern corner, which lies in the Gascoyne Region. The following description of the vegetation on WILUNA is mainly from Beard (1990).

The Murchison and Gascoyne Regions are dominated by mulga (*Acacia aneura*) country. Vegetation on areas of alluvium and sheetwash is characterized by low mulga woodland with a variety of small shrubs (mainly *Cassia* and *Eremophila* species), and various grasses and ephemeral herbs. Small trees (including *Eucalyptus camaldolensis* and *Casurina obesa*) grow adjacent to the larger watercourses. The vegetation on areas of outcrop is typified by mulga scrub, with other less abundant *Acacia* species, and a variety of shrubs (including *Eremophila* and *Cassia*). Spinifex (*Triodia basedowii*) grassland, with scattered trees

* Climate data from Commonwealth Bureau of Meteorology website, 2001.

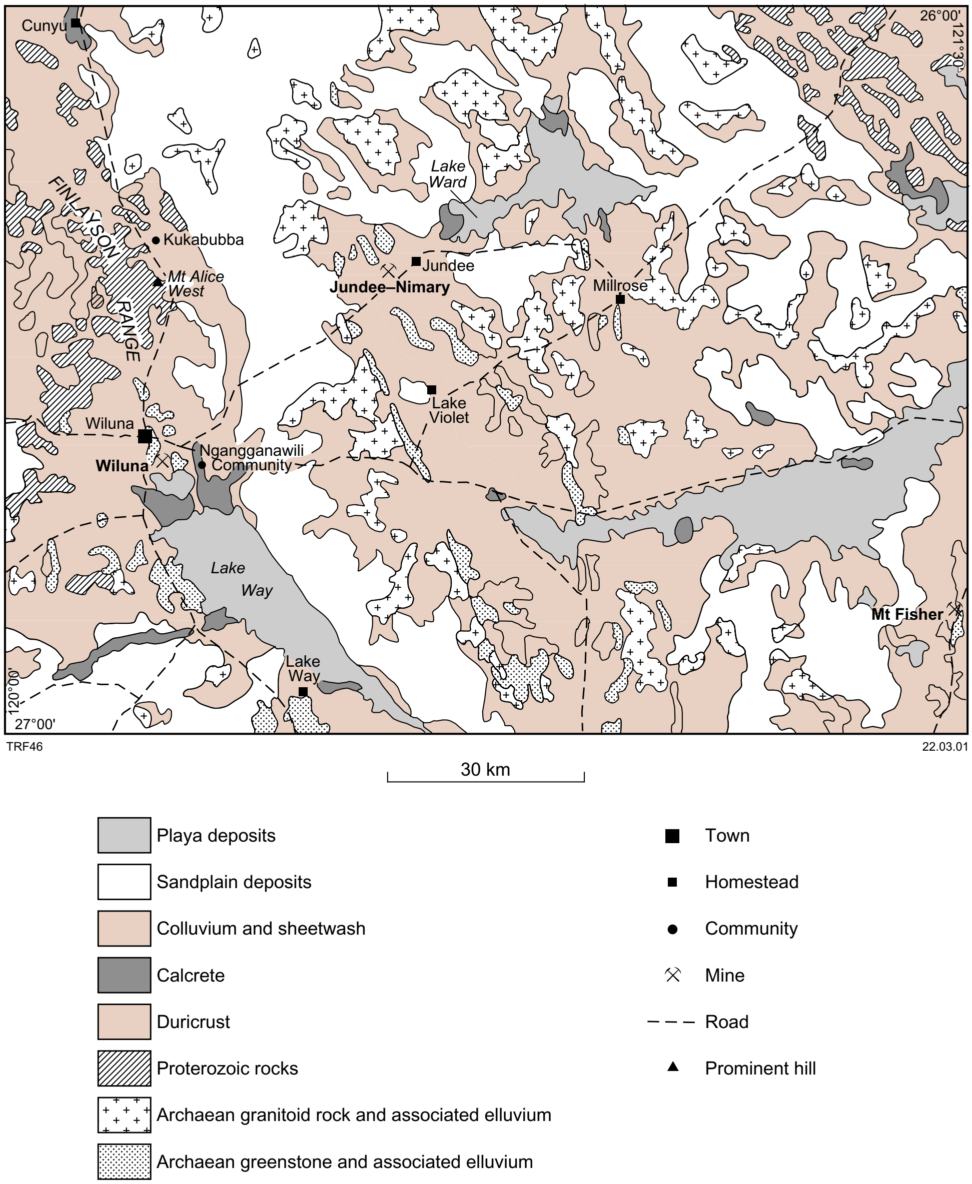

Figure 2. Physiography and simplified Cainozoic geology of WILUNA

(mainly marble gum, *Eucalyptus gongylocarpa*) and small shrubs, is present in areas covered by sandplains. Salt-tolerant plants, including saltbush (*Atriplex* species), bluebush (*Maireana* species), and samphire (*Halosarcia* species), grow in open, low-lying areas around lake systems.

PREVIOUS INVESTIGATIONS

Most of the early work on WILUNA focused on the gold deposits around the town of Wiluna (Blatchford, 1899; Gibson, 1908; Montgomery, 1909; Talbot, 1920; Edwards, 1953).

Sofoulis and Mabbut (1963) presented the first regional geological account of the area, and this was followed by the first edition map and Notes for WILUNA by Elias and Bunting (1981, 1982). Extensive hydrogeological work was also carried out in the area surrounding Wiluna (Ellis, 1954; Chapman, 1962; Morgan, 1962; Brookfield, 1963; Sanders, 1973).

The WILUNA 1:250 000 sheet was remapped at 1:100 000 scale in the 1990s by the Geological Survey of Western Australia (GSWA) and the Australian Geological Survey Organisation (AGSO). Three 1:100 000 maps — LAKE VIOLET (Stewart and Bastrakova, 1997), BALLIMORE (Blake and Whitaker, 1996a), and SANDALWOOD (Blake and Whitaker, 1996b) — were published by AGSO. The remaining three 1:100 000 maps — MILLROSE (Farrell and Wyche, 1997), CUNYU (Adamides et al., 1998), and WILUNA (Langford and Liu, 1997) — were published by GSWA. Descriptions of the geology of the individual 1:100 000 sheets are presented in Stewart (1997), Adamides et al. (1998), Farrell and Wyche (1999), Langford et al. (2000), and Whitaker et al. (2000).

Published works on the mine geology and gold mineralization at Wiluna include McGoldrick (1990), Hagemann et al. (1992), Kent and Hagemann (1996), and Chanter et al. (1998). The geology of the Matilda gold deposits, in the Coles mining centre south of Wiluna, is described by Morgan and El-Raghy (1990). Descriptions of the gold mineralization and geology of the Jundee–Nimary deposits are presented in Phillips et al. (1998a, 1998b) and Byass and MacLean (1998), and the setting of the deposits and controls on mineralization are discussed by Vearncombe (1998, 2000). The geology of the Mount Fisher gold mine, in the southeastern part of WILUNA, is described by Powell et al. (1990).

Nickel mineralization in ultramafic rocks at Honeymoon Well is detailed in Donaldson and Bromley (1981), Gole and Hill (1990), and Gole et al. (1996). Aspects of the geology and volcanology of the ultramafic rocks are also discussed by Hill et al. (1990, 1995).

Ferguson (1998) presented a compilation of the mineral occurrences on WILUNA. Brief descriptions of aspects of the geology, exploration, and mineralization of various small parts of the area, mainly in the greenstone belts, can also be found in open-file statutory mineral exploration reports held in the Department of Minerals and Energy's library in Perth.

NOMENCLATURE

All greenstones on WILUNA have undergone low- to medium-grade metamorphism. However, primary textures are preserved in many cases, and it is commonly possible to identify the parent rock. In view of this, igneous or sedimentary terminology has been used wherever possible. Metamorphic rock names have only been used in areas where the rocks have been extensively recrystallized and the protolith is no longer clear.

The nomenclature of the igneous rocks largely follows the recommendations of the International Union of Geological Sciences (Le Maitre et al., 1989). Komatiite refers to ultramafic rocks with a platy olivine-spinifex texture (cf. Arndt and Nisbet, 1982), and high-Mg basalt refers to mafic volcanic rocks with varioles or relict pyroxene-spinifex texture.

REGIONAL GEOLOGICAL SETTING

WILUNA covers an area of Archaean granite–greenstone terrain on the northeastern margin of the Yilgarn Craton (Fig. 1), and small areas of the Palaeoproterozoic Yerrida (Occhipinti et al., 1997) and Earaheedy Basins (Pirajno, 1999; Fig. 3). The granite–greenstone terrain consists of elongate belts of deformed and metamorphosed volcano-sedimentary rocks, and

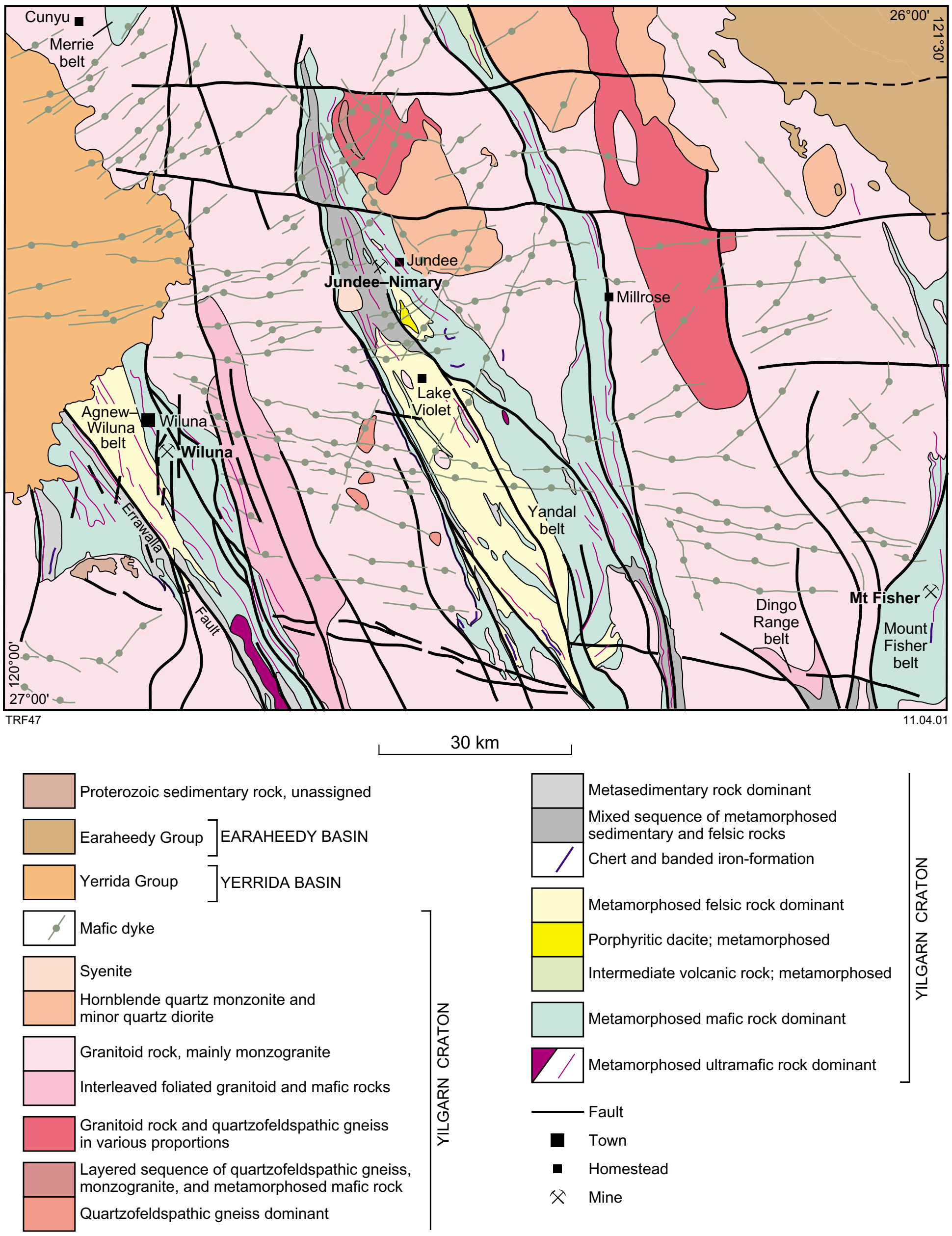

Figure 3. Simplified geological map of WILUNA

large intervening areas of granitoid rock and gneiss, both of which belong to the Eastern Goldfields Province (Gee et al., 1981; Griffin, 1990). The Yerrida Basin contains a c. 2.2 – 1.9 Ga volcano-sedimentary succession that lies unconformably on Yilgarn Craton basement. The Earaheedy Basin succession comprises deformed, c. 1.85 – 1.8 Ga, shallow-marine and fluviodeltaic sedimentary rocks that are unconformable on both the Yilgarn Craton and Yerrida Basin (Pirajno, 1999; Jones et al., 2001).

Table 1. Summary of the geological history of WILUNA

Age (Ma)	*Tectonic event*
c. 2750–2700	Deposition of early greenstone succession in Agnew–Wiluna belt (and other greenstone belts?)
2747 ± 11[(a)]	Intrusion of granitoid precursor to quartzofeldspathic gneiss; northern end of Yandal belt
	D_1 deformation: tight to isoclinal folding in gneisses; foliation in early greenstones
c. 2700–2690	Deposition of greenstones
c. 2685–2655	D_2 deformation: strong foliation parallel to granite–greenstone contact; main phase of granitoid intrusion
c. 2670–2655	Felsic to intermediate volcanism in Yandal belt
2658 ± 2[(a)]	Intrusion of post-D_2 granitoid dyke into gneiss at northern end of Yandal belt
c. 2650–2635[(b)]	Late-stage granitoids; syenite to diorite and low-Ca monzogranite
c. 2640[(b)]	D_3 deformation: north to northwesterly trending shear zones and upright folds
	D_4 deformation: kink folds and crenulations
c. 2400	Intrusion of Palaeoproterozoic mafic dykes
c. 2200–1900	Deposition of Yerrida Group in a rift-related basin
c. 1850–1800	Deposition of Earaheedy Group in a passive-margin setting
?c. 290	Deposition of Paterson Formation

SOURCES: (a) AGSO, OZCRON database
(b) Nelson (1997b, 1998)

The Precambrian rocks are overlain in the east by Phanerozoic sedimentary rocks of the Gunbarrel Basin, (formerly part of the Officer Basin; Hocking, 1994), scattered outliers of which are present in the northeastern corner of WILUNA. Much of the bedrock geology is obscured by Cainozoic regolith.

A summary of the geological history of WILUNA is presented in Table 1.

PRECAMBRIAN GEOLOGY

Greenstone belts in the north Eastern Goldfields Province contain a wide range of rocks, including chert, banded iron-formation (BIF), clastic sedimentary rocks, and ultramafic to felsic volcanic and volcaniclastic rocks (Fig. 3). There are also local areas of conglomerate that postdate the main greenstone sequences, and late felsic to intermediate dykes and plugs. The greenstones were deposited between c. 2750 and c. 2660 Ma (Kent and Hagemann, 1996; Nelson, 1997a,b, 1998), and deformed and metamorphosed at grades ranging from prehnite–pumpellyite to amphibolite facies (Binns et al., 1976).

There are few published studies on the structural geology of the north Eastern Goldfields Province (e.g. Platt et al., 1978; Eisenlohr, 1989; Hammond and Nisbet, 1992; Farrell, 1997; Vearncombe, 1998), and interpretation of the structure has been hampered by the poor exposure in the region. The following summary of the structure is based on work carried out during 1:100 000-scale mapping on the DUKETON, SIR SAMUEL, and WILUNA 1:250 000 sheets.

Four regional Archaean deformation events (D_1–D_4) have been recognized in the north Eastern Goldfields Province (Hammond and Nisbet, 1992; Farrell, 1997; Wyche and Farrell, 2000). Evidence of an early deformation is locally preserved in c. 2750–2700 Ma gneisses adjacent to greenstones (Farrell, 1997), but the nature of this event is unclear. The second deformation coincided with a period of extensive granitoid intrusion at c. 2685–2655 Ma, and was followed by a later phase of granitoid magmatism after c. 2650 Ma, including a suite of alkaline rocks (Smithies and Champion, 1999). The granitoid rocks range in composition from diorite to granite, but monzogranite is by far the most abundant rock type. The third deformation event occurred at c. 2640 Ma within a broadly east–west compressional regime and resulted in the development of major, north to northwesterly trending shear zones and the regional foliation trends. This event was followed by late-stage crenulation and kinking of all earlier structures. Numerous faults and fracture zones cut across all Archaean structures. The faults correspond to prominent aeromagnetic lineaments, and many are intruded by Proterozoic mafic–ultramafic dykes (Hallberg, 1987) or quartz veins.

There are five greenstone belts on WILUNA — the Agnew–Wiluna, Merrie, Yandal, Dingo Range, and Mount Fisher belts (Griffin, 1990; Fig. 3) — as well as small rafts of greenstones within the granitoids. All greenstones in the region are poorly exposed, and much of the interpreted geology is based on data obtained from mineral exploration drilling programs, and regional-scale (400 m line-spacing) aeromagnetic surveys (Fig. 4).

AGNEW–WILUNA GREENSTONE BELT

The Agnew–Wiluna belt (Fig. 3) in the western part of WILUNA contains a metamorphosed sequence of ultramafic, mafic, and felsic volcanic, and sedimentary rocks, as well as younger conglomerate (Jones Creek Conglomerate). Ultramafic rocks host major nickel deposits at Perseverance, Six Mile, and Mount Keith (all on SIR SAMUEL), and Honeymoon Well on WILUNA. Large gold deposits are present at Wiluna and Agnew (on LEONORA).

The section of the Agnew–Wiluna belt exposed on WILUNA can be divided into eastern and western domains separated by the Erawalla Fault (Fig. 3; Hagemann et al., 1992; Langford et al., 2000). Strongly deformed metasedimentary rocks adjacent to the Erawalla Fault may be equivalent to the Jones Creek Conglomerate on SIR SAMUEL (Durney, 1972; Marston and Travis, 1976; Marston, 1978; Liu et al., 1998). In the eastern domain, Hagemann et al. (1992) described a westerly younging stratigraphy around the Wiluna mining centre, and Gole and Hill (1990) described a westerly younging stratigraphy near Honeymoon Well. A correlation between the successions at Wiluna and Honeymoon Well was proposed by Liu et al. (1995). In their stratigraphy, the lowest preserved unit, which consists of basalt and gabbro, is overlain by a unit dominated by basalt, including both high-Mg and tholeiitic basalt. Felsic volcanic and sedimentary rocks, and a regional ultramafic unit (Liu et al., 1995), overlie the basalt. The uppermost unit consists of sedimentary and felsic volcanic rocks.

There is no readily identifiable stratigraphy in the western domain because the mafic-dominated succession is poorly exposed and possibly repeated by folding. However, the

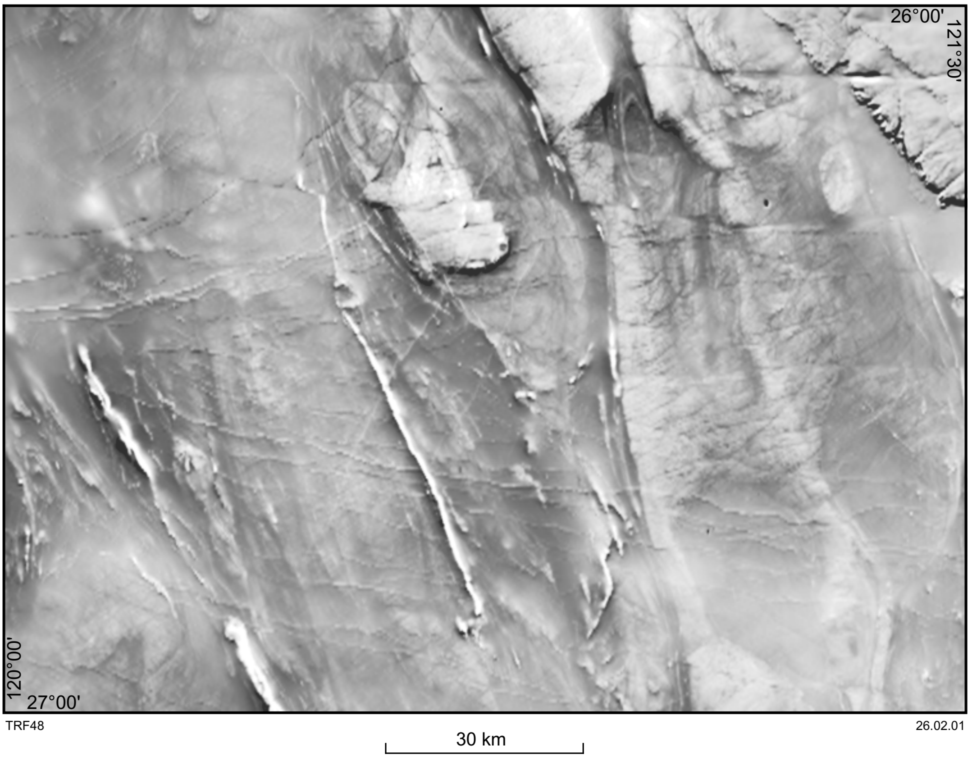

Figure 4. Grey-scale image of total magnetic intensity for WILUNA (400 m line spacing, data from AGSO and GSWA, 1994)

local presence of BIF and the absence of thick ultramafic units suggest that the sequence is not the same as that east of the Erawalla Fault.

The age of the Agnew–Wiluna belt is poorly constrained. The only published sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon date from the northern part is 2749 ± 7 Ma for a microdiorite dyke from the Wiluna mine (Kent and Hagemann, 1996). This age is supported by a SHRIMP U–Pb zircon date of 2720 ± 14 Ma for a felsic volcanic unit from near the Rockys Reward mine on SIR SAMUEL (Nelson, 1997b), and by a conventional U–Pb zircon date of 2795 ± 38 Ma for a granophyric differentiate from a layered gabbro near Yakabindie (on SIR SAMUEL; Cooper and Dong, 1983).

MERRIE GREENSTONE BELT

The southern tip of the Merrie greenstone belt extends onto the northwestern corner of WILUNA, east of Cunyu Homestead. Exposure of this belt is poor, and the only outcrops are of extremely weathered mafic rock. On NABBERU, to the north, the Merrie greenstone belt contains a metamorphosed succession of basalt, subordinate gabbro, and ultramafic rock, and local felsic and sedimentary rocks (Adamides, 2000).

YANDAL GREENSTONE BELT

The Yandal greenstone belt (Fig. 3) in the central part of WILUNA contains a large volume of felsic volcanic and volcaniclastic rocks. Although there are a number of thin komatiite and high-Mg basalt units, the Yandal belt does not have the thick units of ultramafic rock that characterize the Agnew–Wiluna belt, and there is no known economic nickel mineralization.

The Yandal belt contains several major gold deposits (Jundee–Nimary on WILUNA and Bronzewing, Mount McClure, and Darlot on SIR SAMUEL) and numerous smaller deposits, and remains an area of significant gold exploration activity (Phillips et al., 1998a).

Poor exposure and a scarcity of younging indicators hinder determination of a detailed stratigraphy for the part of the Yandal greenstone belt on WILUNA (Fig. 3). In the northern half of the sheet, the belt bifurcates into two arms separated by an extensive area of granitoid rocks and gneiss. Outcrop mapping and examination of numerous mineral exploration drillholes (Stewart and Bastrakova, 1997; Farrell and Wyche, 1999) have allowed the western arm of the belt 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 (the Middle Greenstone Sequence of Phillips et al., 1998a);
- a thick central sequence of felsic volcanic and sedimentary rocks (the Upper Greenstone Sequence of Phillips et al., 1998a);
- a thin western sequence of mafic and ultramafic rocks, and prominent chert and BIF (the Lower Greenstone Sequence of Phillips et al., 1998a).

Pillow lava structures in high-Mg basalt in the mafic–ultramafic-dominated eastern sequence indicate younging to the west. This is supported by sedimentary structures in drillcore from the Jundee gold mine.

There are few published geochronological data from the Yandal greenstone belt. In the southern part of the belt, on SIR SAMUEL, a SHRIMP U–Pb zircon age of 2690 ± 6 Ma was determined for a porphyritic rhyolite from the Spring Well complex, and an age of 2702 ± 5 Ma for porphyritic rhyolite from the Darlot mine (Nelson, 1997b). In the northern part of the belt on WILUNA, a SHRIMP U–Pb zircon age of 2669 ± 10 Ma was obtained for a dacite porphyry from within the central sequence near Camel Bore (Nelson, 1998). Post-mineralization dykes at Jundee and Mount McClure have SHRIMP U–Pb zircon dates of 2668–2656 Ma (Yeats et al., 1999).

DINGO RANGE GREENSTONE BELT

The Dingo Range greenstone belt, which extends onto the southeastern corner of WILUNA (Fig. 3) from SIR SAMUEL, contains a metamorphosed mafic–ultramafic sequence with thin interbeds of chert and BIF, and minor amounts of felsic and clastic sedimentary rocks. Thin units of tremolite–chlorite schist and strongly deformed felsic rock are abundant. The part of the Dingo Range greenstone belt on WILUNA is almost completely obscured by regolith. The age of the Dingo Range greenstone belt is unknown.

MOUNT FISHER GREENSTONE BELT

The Mount Fisher greenstone belt is poorly exposed in the southeastern corner of WILUNA. Little is known about this belt, but it may be related to the Dingo Range greenstone belt. There are sparse weathered outcrops of mafic, ultramafic, and felsic rocks, as well as thin units of chert. The age of the belt is unknown.

ARCHAEAN YILGARN CRATON

Ultramafic rocks (*Au*, *Aup*, *Aus*, *Aut*, *Aux*)

Ultramafic rocks are widely distributed through the Agnew–Wiluna and Yandal greenstone belts on WILUNA. However, in most cases, the rocks are poorly exposed and much of the surface exposure has been affected by deep weathering, resulting in the formation of a distinctive light-brown, siliceous caprock (*Czu*). Ultramafic rocks are typically in thin, laterally extensive units or lenticular bodies.

Ultramafic rocks on WILUNA have been separated into five units: undivided metamorphosed ultramafic rock (*Au*), metamorphosed peridotite (*Aup*), serpentinite (*Aus*), talc–chlorite schist (*Aut*), and metamorphosed pyroxenite (*Aux*). Minor ultramafic rock types not shown separately include tremolite–chlorite schist, talc–carbonate schist, and serpentinized dunite.

Undivided metamorphosed ultramafic rock (*Au*) is used mainly to describe fine-grained, deeply weathered, deformed, and locally altered ultramafic rocks where the original rock type could not be positively identified. Serpentinized peridotite (*Aup*) is a fine- to medium-grained, granular, weakly foliated rock with well-preserved cumulate textures. Olivine crystals are pseudomorphed by serpentine-group minerals. Fine-grained aggregates of magnetite, plus one or more of talc, tremolite, and chlorite, occupy the intercumulus areas, which were probably filled originally by pyroxene and magnetite. A minor associated rock type is serpentinized dunite. Massive serpentinized ultramafic rock (*Aus*), lacking identifiable primary textures, outcrops on the western edge of the Agnew–Wiluna belt near Bridal Well. Metamorphosed pyroxenite (*Aux*) forms a small body within granitoid rocks on the western side of the Yandal belt, south of the Wongawol road.

There are patchy exposures of strongly deformed talc–chlorite(–carbonate) schist (*Aut*) in high-strain zones in all three greenstone belts, particularly near granite–greenstone contacts. The rock is soft, well foliated, typically fine grained, and contains finely intergrown talc and chlorite, as well as minor amounts of carbonate and finely dispersed opaque minerals (probably magnetite).

Fine-grained mafic rocks (*Ab, Aba, Abf, Abg, Abip, Abm, Abs, Aby*)

Metamorphosed mafic rocks are a major component of the greenstone sequences on WILUNA.

Undivided, metamorphosed mafic rock (*Ab*) is common throughout the Agnew–Wiluna, Yandal, and Dingo Range greenstone belts. The unit includes deeply weathered and very fine grained mafic rocks, as well as subordinate interleaved metamorphosed gabbro and thin interbeds of metamorphosed sedimentary rock. It also includes some areas of metamorphosed tholeiitic basalt and plagioclase-phyric basalt that are too small to be shown separately.

Amphibolite (*Aba*) is the dominant mafic rock type in areas of higher metamorphic grade, and is common in greenstone enclaves within granitoid rocks and in the greenstone sequences close to the granite–greenstone contacts. Amphibolite (*Aba*) consists mainly of acicular hornblende and plagioclase, and is typically well foliated with a strong lineation defined by the alignment of hornblende. In the Dingo Range belt, amphibolite is commonly interleaved with metamorphosed gabbro and tremolite schist. Amphibolite (*Aba*) is also a minor component of quartzofeldspathic gneiss (*Anq*), and mixed units containing gneisses (*Angb, Agnq*). In gneisses, the amphibolite is typically fine to medium grained and layered on a scale of 5–30 mm, according to variations in the abundance of dark-green hornblende and plagioclase. The rocks also contain subordinate pale-green clinopyroxene (?diopside) and quartz, plus accessory sphene, epidote, and iron oxides. There are lenses of amphibolite (*Aba*), up to 1 km long and 400 m wide, north of Deadwood Bore on the western edge of WILUNA. These amphibolite bodies are interpreted as metamorphosed gabbro. The weak deformation of the amphibolite lenses, and the presence of fine-grained margins and offshoots into the surrounding strongly deformed granitoid rocks, suggests that they have intruded the granitoids.

Strongly foliated metamorphosed mafic rock (*Abf*) is common along the margins of the Agnew–Wiluna belt in the Coles Find* area. Also common in areas close to the granite–greenstone boundary is a mixed unit of strongly foliated mafic rock with abundant interleaved, deformed granitoid rock (*Abg*).

Metamorphosed porphyritic basaltic andesite (*Abip*) is only encountered in exploration drillholes in the northern part of the Yandal belt near Panakin Bore and in the Jundee area. The rock consists of albitized plagioclase phenocrysts set in a recrystallized matrix of plagioclase and actinolite, with minor chlorite, biotite, and epidote.

Metamorphosed high-Mg basalt (*Abm*) includes basaltic volcanic rocks characterized by pyroxene-spinifex textures or varioles. The best exposure of high-Mg basalt is southeast of the Jundee–Nimary gold mine in the Yandal belt. Here, the rock has abundant varioles and a locally preserved relict pyroxene-spinifex texture, consisting of randomly oriented tremolite–actinolite pseudomorphs of igneous pyroxene set in a fine-grained matrix of tremolite–actinolite, chlorite, epidote, albite, and fine-grained opaque minerals. Locally, the rock contains pillow structures that indicate younging to the west (Farrell and Wyche, 1999). The basalt is spatially associated with metamorphosed fine-grained gabbro.

Fine- to medium-grained, well-foliated, chlorite-rich mafic schist (*Abs*) is restricted to a few small outcrops in the Yandal belt north of Millrose Homestead, although it has also been noted in drillholes in the Jundee area. The origin of this rock is unclear — it may be derived from mafic volcaniclastic rocks, high-Mg basalt, or ultramafic rocks.

Metamorphosed amygdaloidal basalt (*Aby*) is a minor mafic rock type in the Yandal belt. Amygdales are a common feature in the mafic volcanic rocks, but amygdaloidal basalt is rarely in mappable units. The amygdales are up to 15 mm in size, and contain assemblages of pale amphibole, subordinate albite, and minor amounts of epidote and sphene. The host basalt is typically fine grained and consists of quartz, plagioclase, epidote, and actinolite.

Medium- to coarse-grained mafic rocks (*Aog, Aogf, Aogo*)

Medium- to coarse-grained mafic rocks form intrusions or coarser intervals in mafic volcanic successions. Metamorphosed gabbro (*Aog*) is common in all the greenstone belts on WILUNA, and also includes dolerite or microgabbro and areas of basalt with abundant gabbro intrusions. The primary minerals are pseudomorphed by metamorphic assemblages of amphibole, plagioclase, and minor, fine-grained opaque minerals (?ilmenite), and local quartz. The rocks may be intergranular, granular, subophitic, or locally porphyritic. Strongly foliated metamorphosed gabbro (*Aogf*) is typical of areas adjacent to the granite–greenstone contact, such as the Coles Find area.

Metamorphosed olivine gabbro (*Aogo*) is present in a small intrusive body near Twin Tanks Well in the Yandal belt. The rock is fine to medium grained and undeformed, and contains clinopyroxene, plagioclase, a skeletal opaque mineral (?magnetite), and altered, anhedral

* Labelled as Coles mining centre on the 1:250 000 map sheet.

?olivine up to 4 mm in size. The olivine is pseudomorphed by very fine fibrous chlorite, acicular tremolite, and fine-grained, granular epidote.

Felsic volcanic and volcaniclastic rocks (*Af, Afp, Afdp, Afi, Afs, Aft*)

Metamorphosed felsic rocks are common in the Yandal belt near Lake Violet Homestead, and in the northern end of the Agnew–Wiluna belt, but are only a minor component of the Dingo Range belt. In most cases the felsic rocks are poorly exposed and affected by deep weathering.

Undivided metamorphosed felsic volcanic and volcaniclastic rocks (*Af*) are typically kaolinized and silicified. Relict quartz is common in hand specimen and assists in the identification of the rocks. Deeply weathered felsic rocks have only been subdivided where they have a relict porphyritic texture (*Afp*).

Metamorphosed dacite porphyry (*Afdp*) is exposed in fresh, rubbly outcrops south of Camel Bore in the Yandal belt (Farrell and Wyche, 1999). The rock is undeformed and seriate textured to porphyritic. Plagioclase and quartz crystals, up to 16 mm in size, are set in a finer grained groundmass of quartz, plagioclase, and minor biotite, with metamorphic white mica, chlorite, sphene, epidote, ?pumpellyite, and very fine iron oxides. The dacite porphyry contains some scattered, irregular aggregates of chlorite and epidote, and clusters of ?pumpellyite, which may be former amygdales. The rock has a SHRIMP U–Pb zircon date of 2669 ± 10 Ma (Nelson, 1998).

Metamorphosed intermediate rocks (*Afi*) are a minor component of the greenstone sequences in the Yandal belt. They range in composition from basaltic andesite to dacite. These rocks typically contain plagioclase phenocrysts (up to 6 mm), and altered mafic minerals in a fine-grained groundmass of quartz and plagioclase, with small amounts of chlorite and iron oxides, and accessory zircon, apatite, and epidote. These rocks are interpreted to be dykes or shallow-level intrusions.

Strongly deformed felsic schist (*Afs*) is present in areas of higher metamorphic grade along the greenstone margins. The schist is typically well foliated and contains relict, partly recrystallized quartz grains in a foliated matrix of quartz, white mica, and plagioclase. The nature of the protolith is unclear, but is thought to have been a felsic volcanic or volcaniclastic rock.

Felsic tuff (*Aft*) in the Agnew–Wiluna belt includes eutaxitic tuff with euhedral relicts of feldspar pyroclasts up to 1 mm, and ignimbritic tuff with relict feldspar clasts and pumice lapilli up to 5 mm.

Sedimentary rocks (*As, Asc, Asd, Ash, Ass, Ac, Aci*)

Metamorphosed sedimentary rocks on WILUNA can be divided into two broad categories according to their composition and mode of deposition — metamorphosed clastic sedimentary rocks (*As, Asc, Asd, Ash, Ass*) and metamorphosed chemical sedimentary rocks (*Ac, Aci*).

Undivided metamorphosed clastic sedimentary rocks (*As*) are deeply weathered and poorly exposed. They are a minor component of the greenstone sequences on WILUNA, and typically form thin units within volcanic successions, or more extensive units with a significant volcaniclastic component. The sedimentary rocks are typically well foliated and difficult to classify due to deep weathering.

Metamorphosed sandstones (*Ass*) in the Yandal belt are broadly felsic in composition, and contain subrounded to well-rounded clasts of quartz, plagioclase, and felsic rock, in a fine-grained metamorphosed matrix. Metamorphosed polymictic conglomerate (*Asc*) is a minor component of the sedimentary successions in the Yandal belt near Strife Bore. The rock is weathered and contains large (up to 300 mm), well-rounded clasts of massive chert, felsic rock, and BIF in a fine-grained mafic matrix.

Metamorphosed fine-grained sedimentary rocks (*Ash*) include metashale and metasiltstone, and are poorly exposed and deeply weathered. Locally, they are thin bedded and, in fresh drillhole samples, consist of scattered, fine sand-sized clasts of quartz and plagioclase in a very fine grained matrix of metamorphic quartz, albite, white mica, and opaque minerals. Graphite-bearing varieties are present locally. Metamorphosed carbonate-rich sedimentary rocks, dominantly metadolomite (*Asd*), outcrop in one area northwest of Abercromby Well in the Agnew–Wiluna belt.

Metamorphosed chert (*Ac*) forms extensive strike ridges throughout the greenstone sequences, and is a minor but distinctive rock type that can be a useful local stratigraphic marker. There is a range from finely layered chert through to green-grey and brown-grey massive chert. The layering is typically 1 to 30 mm thick, and defined by variations in iron oxide and silica content. Chert units commonly have well-developed mesoscale folding, and some are brecciated or cut by late-stage fractures.

Metamorphosed BIF (*Aci*) is restricted to the western side of the Yandal belt, and the western side of the Agnew–Wiluna belt around Deep Bore. Rhythmic layering in the BIF is typically planar and laterally continuous, and up to 4 mm thick. The layering comprises alternating silica-rich and iron-oxide-rich zones, and is locally magnetite bearing. On the western side of the Yandal belt, the BIF is associated with a metamorphosed succession of ferruginous chert, clastic sedimentary rocks, and ultramafic rock.

Metamorphic rocks (*Alqf*)

Quartz–feldspar schist (*Alqf*) is a strongly foliated felsic rock, probably derived from felsic volcanic or volcaniclastic rocks. The rock is associated with felsic schist, adjacent to the Erawalla Fault, east of Bridal Well.

Quartzofeldspathic gneiss (*Anq, Angb*)

Gneisses underlie large areas on WILUNA, but the rocks are poorly exposed, being covered mainly by sandplain and Cainozoic sheetwash deposits. The quartzofeldspathic gneisses are multiply deformed and intruded by granitoids in many locations, and are older than all dated granitoid rocks. This is illustrated by a SHRIMP U–Pb zircon date of 2747 ± 11 Ma for a gneiss near the northern end of the Yandal belt (AGSO, OZCRON database), and the range of granitoid dates from 2658 to 2648 Ma (Nelson, 1998; AGSO, OZCRON database).

Quartzofeldspathic gneiss is present both as distinct, mappable units (*Anq*) and as a component of mixed units of granitoid rock and gneiss (*Angb, Agnq*, see **Granitoid rocks**). The rock commonly shows a diffuse layering defined by variations in grain size and modal mineralogy, and is multiply deformed. Locally, the gneiss contains two generations of leucosomes and granitic veins. Early leucosomes are thin, rich in quartz, and parallel to a relict S_1 foliation. The leucosomes were folded during the D_2 event, and in high-strain zones they are largely transposed in the S_2 foliation. The first-generation leucosomes are cut by a second generation of thicker, monzogranite leucosomes that are commonly subparallel to the S_2 foliation. Both the host gneiss and the early leucosomes are cut by an undeformed, porphyritic monzogranite dyke that has been dated at 2658 ± 2 Ma (AGSO, OZCRON database).

A north-northwesterly trending belt in the central-northern part of WILUNA, at Amees Bore, contains a layered succession of quartzofeldspathic gneiss and metamorphosed hornblende monzogranite, quartz monzonite, and mafic rock (*Angb*). The exposure is poor, but individual layers appear to be less than 100 m thick. The monzogranite is a hornblende-bearing, fine- to medium-grained, well-foliated rock containing 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 (less than 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 the alignment of thin, plagioclase-rich leucosomes. Epidote alteration of the succession is common and affects all rock types.

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

Many areas of exposed granitoid rock are deeply weathered and have been mapped as undivided granitoid rock (*Ag*) if the primary mineralogy could not be ascertained. In areas where the rocks can be positively identified, biotite monzogranite (*Agm*) is by far the dominant rock type. Minor granitoid rocks types include granodiorite (*Agg*), fine-grained aplitic granitoid (*Aga*), and dykes of diorite to quartz diorite (*Agd*). Hornblende-bearing monzogranite (*Agmh*) and quartz diorite (*Agdq*) are only observed in drillhole samples. A body of syenite (*Ags*) in the Yandal belt, west of Jundee Homestead, is not exposed, but has been identified from exploration drillholes and aeromagnetic images.

Biotite monzogranite (*Agm*) is widespread on WILUNA. The rock is variously deformed and typically fine to medium grained with local, sparsely porphyritic zones. The monzogranite consists of quartz, plagioclase, K-feldspar, small amounts of biotite, opaque minerals, and accessory epidote, allanite, sphene, and zircon. Porphyritic biotite monzogranite (*Agmp*) is present on the edge of the Yandal greenstone belt, near Millrose Homestead, and forms dykes in quartzofeldspathic gneiss east of Amees Bore.

Foliated granitoid rock with interleaved mafic rocks (*Agb*) outcrops along the eastern side of the Agnew–Wiluna greenstone belt near Honeymoon Well. Aeromagnetic images suggest that these rocks extend much farther north, in an area covered extensively by regolith. The mafic rocks typically form discontinuous layers or lenses in the granitoids, along with minor amounts of high-grade metasedimentary rock. Strongly deformed granitoid rock with minor quartzofeldspathic gneiss (*Agf*) outcrops on the edge of the Agnew–Wiluna belt, near Honeymoon Well, and north of Mount Wilkinson. Locally, the rock has biotite-rich schlieren and a diffuse layering.

Over much of WILUNA, granitoid rocks are intimately associated with quartzofeldspathic gneiss and migmatite on a scale too small for the individual rock types to be shown separately. Deep weathering and poor exposure also make it difficult to determine the proportions of each rock type, and so they are mapped as a mixed unit of granitoid rock and gneiss (*Agnq*). Granitoid rocks in this unit commonly have a diffuse layering and abundant biotite-rich schlieren.

There are several large bodies of quartz monzonite (*Agzq*) in the northern part of WILUNA. The quartz monzonite around Lake Ward is known only from mineral exploration drillholes and aeromagnetic data. The rock ranges in composition from monzogranite to quartz diorite and quartz monzonite. The dominant rock type is a weakly deformed, medium-grained quartz monzonite containing equal proportions of plagioclase and K-feldspar, various amounts of hornblende and clinopyroxene, and minor quartz and biotite. The quartz monzonite east of Panakin Bore has been dated at 2664 ± 4 Ma (Nelson, 1999) on NABBERU, just north of WILUNA.

Quartz monzonite is also a component of the layered gneissic sequence near Lignan Well and at Amees Bore (*Angb*), where it appears to be in thin layers (less than 30 m thick). The monzonite in this sequence is a fine- to medium-grained rock containing 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. Monzonite (*Agz*) has also been noted in exploration drillholes in parts of the Yandal belt.

Quartz veins (*q*)

Quartz veins (*q*) are ubiquitous on WILUNA, but in most cases are too small to be shown on the map. Strongly deformed quartz veins are common in the greenstones. These veins are typically subparallel to the regional foliation and boudinaged or folded. A younger set of quartz veins, consisting of interlocking crystals of milky quartz and local iron oxides after ?pyrite, cuts across the regional foliation trends and forms upstanding ridges in areas of poorly exposed granitoid rocks. These veins are typically east to northeasterly trending and parallel to linear magnetic features. Associated with these crosscutting quartz veins is a set of complex veins consisting of multiple generations of quartz veins, and variously brecciated and silicified wallrock.

PALAEOPROTEROZOIC MAFIC DYKES (*Ed*)

Mafic dykes (*Ed*) that cut across the granite–greenstone terrain on WILUNA belong to a suite of Palaeoproterozoic mafic dykes found throughout the Yilgarn Craton (Hallberg, 1987). On WILUNA the dykes range in composition from gabbro to diorite or granophyric gabbro. They rarely outcrop, but are apparent on aeromagnetic images as distinct, linear anomalies (Fig. 4). Easterly trending mafic dykes outcrop between Granite Well and Terry Bore, east of the town of Wiluna.

PALAEOPROTEROZOIC YERRIDA BASIN

Yerrida Group

Palaeoproterozoic sedimentary rocks of the 2.2 – 1.9 Ga Yerrida Group were deposited in the Yerrida Basin, on the western border of WILUNA. The group has been divided into the Windplain and Mooloogool Subgroups (Occhipinti et al., 1997). The lowermost unit, the Windplain Subgroup, consists of sedimentary rocks deposited in fluvial and tidal environments in a continental sag basin (Occhipinti et al., 1997). The Mooloogool Subgroup comprises basal turbidites and conglomerate, overlain by rift-related mafic volcanic and volcaniclastic rocks, evaporites, and chemical sedimentary rocks.

On WILUNA the Windplain Subgroup is represented by the Juderina Formation, a siliciclastic unit with local stromatolitic carbonates and evaporites (Adamides et al., 1999; Langford et al., 2000). The Mooloogool Subgroup is represented by the Killara Formation, which is a succession of subaqueous to subaerial lava flows and mafic sills, with local evaporites and chemical sedimentary rocks (Adamides et al., 1999; Langford et al., 2000).

Windplain Subgroup

Juderina Formation (ⱣYj, ⱣYjf, ⱣYjb)

The Juderina Formation (*ⱣYj*), at the base of the Yerrida Group, is a shallow-water sequence of quartz sandstone with minor siltstone, chert breccia, and conglomerate. Two distinctive subunits, the Finlayson and Bubble Well Members, have been recognized (Occhipinti et al., 1997). The formation outcrops around the margins of the Yerrida Basin, where it typically forms resistant ridges up to 60 m high.

The Finlayson Member (*ⱣYjf*) is a unit of mature quartz sandstone and subordinate quartz siltstone at the base of the Juderina Formation. The dominant rock type is an off-white, silica-cemented quartz sandstone with abundant ripple marks, and local brown diagenetic spots. The sandstone is thin to thick bedded (a few centimetres to 1 m thick), and consists of well-rounded quartz grains (0.2 – 0.5 mm in diameter) and minor detrital zircon, tourmaline, biotite, and rutile.

The Bubble Well Member (*ⱣYjb*; Gee and Grey, 1993) is a unit of chertified carbonate and evaporitic sedimentary rocks near the base of the Juderina Formation that is interpreted as a facies of the Juderina Formation (Adamides et al., 1999). The Bubble Well Member has both well-bedded and chaotic breccia facies. The unit typically consists of layers of chert breccia, chert with a wavy microbial lamination, and chertified stromatolitic dolomite. An outcrop 2 km north of Top Kukabubba Well contains stromatolites of the species *Wilunella glengarrica* (Grey, K., pers. comm. in Adamides et al., 1999).

Johnson Cairn Formation (ⱣYc)

The Johnson Cairn Formation (Occhipinti et al., 1997) is not exposed on WILUNA, but is inferred, from mapping on the GLENGARRY 1:100 000 sheet to the west, to underlie an area on the western edge of WILUNA. In the type area, the formation consists of iron-rich shale and minor carbonate.

Mooloogool Subgroup

Thaduna Formation (ⱣYt)

The Thaduna Formation (Occhipinti et al., 1997; originally named the 'Thaduna Greywacke' by Gee, 1979) is not exposed on WILUNA, but is interpreted to underlie part of the northwestern edge of the sheet. The contact with the underlying Johnson Cairn Formation is inferred to be conformable (Bagas, 1998). The formation consists of lithic sandstone and hematitic shale, and is interpreted as a proximal turbidite sequence (Occhipinti et al., 1997).

Killara Formation (ⱣYk, ⱣYkd, ⱣYkc, ⱣYkb)

The Killara Formation (*ⱣYk*; Occhipinti et al., 1997) consists mainly of dolerite and basalt, with local chertified microbial laminates near the top of the unit and is thought to be the result of continental volcanism related to the rifting of the Yerrida Basin (Occhipinti et al., 1997). The Killara Formation interfingers with rocks of the Juderina and Maraloou Formations along the northeastern margin of the Yerrida Basin.

Dolerite sills belonging to the Killara Formation (*ⱣYkd*) have been preferentially intruded along siltstone layers at three different stratigraphic levels in the Juderina Formation

(Adamides et al., 1999). The dolerite consists of plagioclase, orthopyroxene, clinopyroxene (?augite), and magnetite, and has local interstitial granophyric intergrowths of quartz and feldspar. The rock is microporphyritic in places.

Basalt of the Killara Formation (*ȐYkb*) outcrops in an arcuate belt around the eastern edge of the Yerrida Basin on WILUNA (Adamides et al., 1999). The basalt is fine grained and has intergranular or intersertal textures. Microporphyritic varieties are developed in some areas. Clinopyroxene, plagioclase, and titanomagnetite, along with secondary chlorite, quartz, sphene, and prehnite, are the main constituents. There are thinner layers and cherty interflow sedimentary rocks in the upper parts of the basalt.

The Bartle Member (*ȐYkc*) is a thin, laterally discontinuous unit of chert, tuffaceous rocks, chertified sedimentary rocks, and thin lava flows (Occhipinti et al., 1997; Pirajno and Grey, 1997). Deposition of the unit is interpreted to have occurred in a hot-spring environment (Pirajno and Grey, 1997). The unit consists largely of chert, and attains a maximum thickness of about 10 m. The chert is locally laminated, with cherty siltstone and ironstone in places. Bartle Member cherts locally contain silica pseudomorphs of rhomb-shaped crystals (probably dolomite), globular iron-hydroxide structures, and spherulites of chalcedonic silica (Adamides et al., 1999).

Maraloou Formation (ȐYm)

The Maraloou Formation (Occhipinti et al., 1997) is not exposed on WILUNA, but has been inferred to underlie part of the western edge of the area, based on mapping on the GLENGARRY 1:100 000 sheet. The Maraloou Formation consists of black shale, marl, dolostone, and minor chert.

PALAEOPROTEROZOIC EARAHEEDY BASIN

Earaheedy Group

Palaeoproterozoic rocks of the Earaheedy Group (Hall et al., 1977; Pirajno, 1999) are exposed in the northeastern corner of WILUNA. The four stratigraphically lowest formations in the group are exposed in the sheet area, and the rocks are typically undeformed and dip gently to the northeast. The Earaheedy Group is interpreted to be a passive-margin succession deposited on the northern margin of the Yilgarn Craton at c. 1.85 – 1.8 Ga (Jones et al., 2000).

Yelma Formation (ȐEy)

On WILUNA the Yelma Formation (*ȐEy*) includes sandstone, shale, and minor conglomerate deposited in shallow-marine and locally fluvial environments. The formation is only a few metres thick on WILUNA, but attains a maximum thickness of about 500 m on NABBERU to the north (Hocking et al., 2000; Jones et al., 2000). Carbonate rocks that form part of the formation elsewhere (Hocking et al., 2000) are not present on WILUNA.

Frere Formation (ȐEf)

The Frere Formation (*ȐEf*) consists of granular iron-formation (GIF), ferruginous siltstone, and shale, as well as minor BIF and chert. Granular iron-formation units consist of beds of jasperoidal GIF, 50 to 200 mm thick, with intraclastic breccia and shale interbeds. Individual GIF beds consist of iron oxides, peloids of microplaty hematite, chert, and jasper in a chalcedonic or jasperoidal cement. Hematite is locally replaced by magnetite. The GIF units probably formed on a continental shelf, where ferruginous peloids accreted in wave- and current-agitated, iron-rich, shallow waters (Beukes and Klein, 1992). Interbedded ferruginous shale and siltstone are parallel laminated with minor cross-laminations, and were possibly deposited in a lagoonal environment.

Windidda Formation (ⱣEd)

The Windidda Formation (*ⱣEd*) comprises limestone, shale, and minor jasper and GIF. The formation was probably deposited in a carbonate shelf with coastal lagoons. Recent mapping in the southeastern part of the Earaheedy Basin suggests that the Windidda Formation is a correlative of the upper part of the Frere Formation, rather than an overlying unit (Jones et al., 2000).

Chiall Formation (ⱣEcw)

On WILUNA the Chiall Formation is represented by the Wandiwarra Member (*ⱣEcw*; Hocking et al. 2000), which is a unit of siltstone and shale with subordinate sandstone that outcrops in the northeastern corner of the sheet area.

UNASSIGNED PROTEROZOIC SEDIMENTARY ROCKS (*Ᵽs*)

Proterozoic sedimentary rocks that have not formally been assigned to any stratigraphic unit outcrop at Mount Wilkinson, Mount Lawrence Wells, and near Scorpion Bore, east of Wiluna town. The rocks at Mount Wilkinson and Mount Lawrence Wells consist of chert breccia, quartz-vein breccia, siliceous arenite and conglomerate, cherty mudstone, and silicified carbonates. These rocks are flat lying and undeformed, and partly overlain by silcrete (*Czz*). They were correlated with the 'Finlayson Sandstone' (now the Juderina Formation) by Elias and Bunting (1982), but have not been assigned to any stratigraphic unit in recent 1:100 000-scale mapping.

The unassigned sedimentary rocks east of the town of Wiluna consist of silicified quartz-rich arenite and conglomerate. They are restricted to several easterly trending ridges parallel to large quartz veins in the underlying granitoid rocks. Silicification of the sedimentary rocks is considered to have occurred along fractures related to the formation of the quartz veins (Langford et al., 2000).

STRUCTURE

Four phases of Archaean deformation (D_1–D_4) have been recognized in the north Eastern Goldfields Province (Farrell, 1997; Wyche and Farrell, 2000) from regional 1:100 000-scale mapping carried out by GSWA and AGSO. The recognition of these structures is based on overprinting relationships of outcrop-scale structures, interpretation of magnetic images, and correlation of structures in different parts of the area. All four phases of deformation are recognizable on WILUNA.

First-generation (D_1) structures have largely been overprinted during later events, but relict D_1 fabrics are preserved in gneisses, and possibly in some greenstones. However, it is not clear how the early structures in different parts of the area are related, or even if they are due to the same event. Gneisses northeast of Turnup Bore, in the northwestern part of WILUNA, commonly contain a composite S_1–S_2 fabric with rootless isoclinal folds of S_1

leucosomes. A SHRIMP U–Pb zircon age of 2747 ± 11 Ma (AGSO, OZCRON database) for a gneiss in this area constrains the timing of D_1 to c. 2750 Ma or later.

The second deformation (D_2) coincided with peak metamorphism in the greenstones and craton-wide granitic magmatism. The effects of D_2 are recognized throughout the area, but are most pronounced in high-strain zones in amphibolite-facies rocks adjacent to granite–greenstone contacts. This deformation may be equivalent to the early extension event (D_E) of Hammond and Nisbet (1992).

The characteristic D_2 structure is a steeply dipping foliation (S_2) subparallel to greenstone margins. Layered cherts in the northern end of the Yandal belt contain a strong composite (S_0–S_2) fabric with abundant steeply plunging, tight to isoclinal, intrafolial folds (F_2). The fold axes are typically subparallel to a prominent, steeply plunging, combined intersection – mineral lineation (L_2). Northeast of Turnup Bore, a 2747 ± 11 Ma gneiss contains F_2 folds of S_1 leucosomes. The gneiss is cut by an undeformed monzogranite dyke, parallel to S_2, that has been dated at 2658 ± 2 Ma (AGSO, OZCRON database), indicating that D_2 had ceased by c. 2658 Ma.

The last major penetrative deformation event was largely responsible for shaping the present-day disposition of the greenstone belts. Strong east–west to east-northeast–west-southwest shortening produced large-scale, upright, and shallow to moderately plunging folds, and north to northwesterly trending faults and shear zones (Fig. 3). Outcrop-scale F_3 folds are typically upright and open to tight with shallowly plunging axes that are subparallel to a fine mineral lineation (L_3).

The last recognized Archaean deformation in the region produced outcrop-scale kinks, crenulations, and quartz-filled tension-gash arrays. These features may be related to brittle faults and fractures that form the high-angle conjugate structures described by Vearncombe (1998, 2000).

METAMORPHISM

All greenstones on WILUNA are metamorphosed. The greenstone belts show a distinctive metamorphic zoning from amphibolite facies in areas close to granitoid contacts, to greenschist or prehnite–pumpellyite facies in the central parts of the belts. This type of metamorphic zonation is developed throughout the Eastern Goldfields Province (Binns et al., 1976), and is characteristic of Archaean granite–greenstone terrains worldwide (Condie, 1981; Wilkins, 1997).

In the Agnew–Wiluna belt, the metamorphic conditions range from prehnite–pumpellyite or lower greenschist facies in the centre of the belt (Hagemann et al., 1992) to amphibolite facies in the south, near Coles Find and Honeymoon Well. At Wiluna the typical assemblage in mafic rocks is chlorite–epidote–quartz–plagioclase(–calcite). Hagemann et al. (1992) also reported the presence of pumpellyite in mafic rocks, but this is not diagnostic of prehnite–pumpellyite facies, as pumpellyite is also stable under lower greenschist-facies conditions. The absence of prehnite may be due to the presence of small amounts of CO_2 (indicated by the presence of calcite), which is enough to suppress the formation of prehnite (Bucher and Frey, 1994).

In the Yandal belt, most of the greenstones are metamorphosed to lower greenschist (or prehnite–pumpellyite) facies. Amphibolite-facies rocks are restricted to narrow zones along granite–greenstone contacts. Mafic rocks in the centre of the belt contain the metamorphic assemblage chlorite–albite–epidote–actinolite, which is diagnostic of greenschist facies

(Bucher and Frey, 1994). Felsic rocks contain co-existing white mica – chlorite–albite (–epidote–pumpellyite), which indicates metamorphism at lower greenschist-facies conditions (or lower).

In quartzofeldspathic gneisses, the assemblages are not diagnostic, but the presence of Ca-plagioclase is indicative of amphibolite-facies conditions (or higher). Additionally, the presence of clinopyroxene-bearing amphibolite lenses and localized partial melting suggest upper amphibolite-facies metamorphism and a peak temperature of more than 650–700°C.

PALAEOZOIC GUNBARREL BASIN

PERMIAN PATERSON FORMATION (*Pa*)

Outliers of flat-lying, probable Permian sedimentary rock (*Pa*) are exposed in the northeastern corner of WILUNA. These rocks are interpreted as part of the Paterson Formation on the basis of similarities with Permian rocks to the east (Lowry, 1971). The rocks consist of poorly sorted, medium- to coarse-grained sandstone, pebbly sandstone, and conglomerate.

CAINOZOIC GEOLOGY

Cainozoic regolith deposits, comprising residual indurated material exposed by erosion and younger alluvial, eluvial, eolian, and lacustrine deposits, cover large areas on WILUNA. Individual regolith units have been mapped using field observations, aerial photography, and Landsat TM (Thematic Mapper) images.

The oldest regolith units typically form residual deposits on low hills and in breakaways, and are interpreted as remnants of the Tertiary weathering surface. These units include ferruginous duricrust and ferricrete (*Czl*), silcrete (*Czz*), and silica caprock over ultramafic rocks (*Czu*).

Proximal slope deposits, comprising rock debris, sand, and silt, lie on or adjacent to low hills and on slopes beneath breakaways. They include colluvium (*Czc*), quartz-vein debris (*Czcq*), and ferruginous rock debris and ironstone rubble (*Czf*). The latter unit forms by the degradation of ferruginous duricrust, and is typically developed on low hills, and quartz-vein debris (*Czcq*) is typically associated with large quartz veins. Areas adjacent to outcrops of granitoid rock are commonly covered by deposits of coarse-grained quartz–feldspar sand with various proportions of small fragments of granitoid rock (*Czg*).

Distal parts of the regolith are dominated by sheetwash (*Cza*) and sandplain deposits (*Czs*). Sheetwash deposits (*Cza*) are extensive adjacent to the main drainage systems and on the margins of sandplains. They consist of a thin layer of sand, silt, and clay over weathered rock, and are gradational into sandplain deposits. Areas underlain by granitoid rocks are covered by extensive sandplains (*Czs*) consisting of unconsolidated quartz sand and silt. Ridges of windblown sand are present locally.

The Lake Way drainage system in the southwest and the Lake Carnegie drainage in the east contain a range of ephemeral lake deposits. Playa lakes (*Czp*) contain saline or gypsiferous evaporites, along with minor amounts of sand, silt, and clay. The playas are associated with saline or 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. There are also larger deposits of calcrete (*Czk*) around the margins of the lake deposits.

Younger deposits of unconsolidated to semiconsolidated sandy alluvium and gravel (*Qa*), of probable Quaternary age lie along intermittently active fluvial channels and on adjacent floodplains. 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 that are filled with water after heavy rainfall.

ECONOMIC GEOLOGY

Metallic mineral production from WILUNA is restricted to gold and accessory silver, with recorded production to 30 June 2000 of about 161 882 kg of gold and 315 kg of silver. There are major deposits of nickel on WILUNA, although these have not yet been brought into production.

GOLD

WILUNA lies within the East Murchison Mineral Field, and includes five historic gold mining centres — Wiluna in the southwest (Edwards, 1953; McGoldrick, 1990; Hagemann et al., 1992), and Coles Find (Morgan and El-Raghy, 1990), Kingston, Collavilla, and New England in the south — as well as the disused Mount Fisher mine in the southeast (Powell et al., 1990), and the Jundee–Nimary mining operation in the central part (Byass and MacLean, 1998; Phillips et al., 1998b). Gold was discovered at Wiluna in 1896, and was mined in three main periods (Chanter et al., 1998). Between 1896 and 1924, the gold was extracted from near-surface reefs and relatively shallow workings into the oxidized zone (Gibson, 1908; Montgomery, 1909). Gold production fell when mining progressed below the oxidized zone and refractory, primary sulfide ore was encountered. The second main period of mining occurred in the period 1926–1950, when sulfide flotation techniques were used to treat the sulfide ore. Present-day mining operations commenced in 1984 (Chanter et al., 1998). Gold mineralization at Wiluna is in quartz–carbonate–fuchsite–sulfide veins and breccia zones associated with late northerly to northeasterly trending faults (Hagemann et al., 1992). The mineralization has tentatively been dated at c. 2630 Ma, or later (Kent and Hagemann, 1996).

Gold mineralization was not discovered in the Jundee area until the mid-1980s. The Jundee and Nimary deposits were discovered during drilling programs in 1990 and 1992 respectively (Lewington, 1995; Wright and Herbison, 1995). Opencut mining commenced in 1995, and a total of 48.8 t of gold was produced from the Jundee–Nimary project until 30 June 2000. The geology of the Jundee–Nimary goldfield is described in more detail in Byass and Maclean (1998) and Phillips et al. (1998b). Gold mineralization is in variously oriented quartz–calcite–pyrite veins in late brittle structures (Phillips et al., 1998b), which are cut by undeformed felsic dykes dated at 2656 ± 7 Ma (Yeats et al., 1999).

NICKEL

Nickel mineralization is developed in a thick, poorly exposed ultramafic unit at Honeymoon Well in the southwestern part of WILUNA (Donaldson and Bromley, 1981; Gole et al., 1996). The mineralization is known from extensive drilling and geophysical surveys. Nickel is present as disseminated sulfides in serpentinized olivine-rich cumulates, and as massive sulfides in spinifex-textured komatiite flows (Gole et al., 1996). Deposits have been identified at Hannibals, Harrier, Wedgetail, Corella, and Kingston, all in the southwestern part of WILUNA, with resources (indicated and inferred) of sulfide and laterite mineralization totalling about 370 Mt at average grades of 0.8 – 0.9% Ni (Outokumpu Oyj, 2000). Minor nickel mineralization is also developed in ultramafic rocks elsewhere on WILUNA (Ferguson, 1998).

URANIUM

Uranium (carnotite) mineralization is developed in calcrete along two palaeodrainage systems that discharge into Lake Way in the southwestern part of WILUNA. Three prospects — Hinkler Well, Centipede, and Lake Way — have been identified (Ferguson, 1998). At the Lake Way prospect, carnotite forms coatings on bedding planes of rock fragments in alluvial gravels, and on fractures in calcrete. The prospect contains a measured resource estimated at 3.77 Mt of ore at 0.98 kg/t U_3O_8 (3695 t of contained metal; Ferguson, 1998).

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Appendix

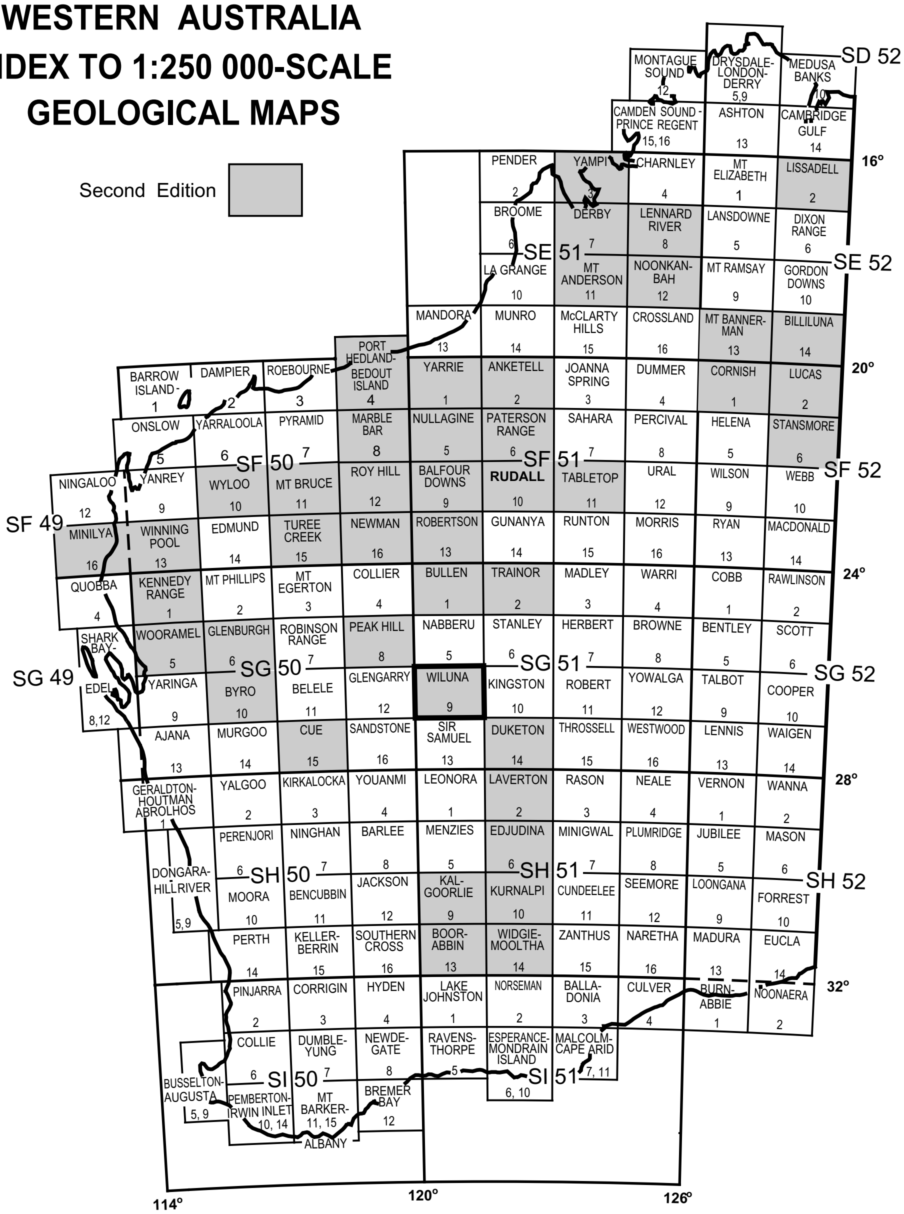
Gazetteer of localities

Locality	*AMG coordinates* *Easting*	*Northing*
Abercromby Well	233000	7027400
Amees Bore	254100	7101900
Bridal Well (abd)	225600	7029300
Camel Bore	264700	7079600
Centipede U prospect	237600	7027400
Corella Ni prospect	240000	7022700
Cunyu Homestead (abd)	211400	7118400
Deadwood Bore	201900	7028200
Deep Bore (abd)	209200	7035900
Granite Well	261900	7046300
Hannibals Ni prospect	239800	7019400
Harrier Ni prospect	241500	7017000
Hinkler Well U prospect	220100	7024000
Honeymoon Well (abd)	243100	7022200
Jundee Homestead	265400	7083100
Jundee–Nimary gold mine	260000	7081000
Kingston Ni prospect	243400	7014700
Kukabubba community	223800	7084600
Lake Violet Homestead	267200	7062400
Lake Ward	271500	7088000
Lake Way Homestead	248300	7016800
Lake Way U prospect	237300	7043900
Lignan Well	293000	7100500
Matilda gold mine	222900	7037600
Millrose Homestead	295700	7078200
Mount Alice West	224700	7079200
Mount Fisher gold mine	349500	7029700
Mount Lawrence Wells	221800	7031900
Mount Wilkinson	218100	7032000
Ngangganawili community	231500	7050500
Panakin Bore	274300	7117000
Scorpion Bore	242000	7057100
Strife Bore (abd)	259000	7073700
Terry Bore	253300	7070200
Top Kukabubba Well	224900	7087600
Turnup Bore	254400	7097600
Twin Tanks Well (abd)	267100	7070300
Wedgetail Ni prospect	237000	7023700
Wiluna gold mine	225000	7051300
Wiluna town	223400	7055500

NOTE: abd: abandoned
Localities are specified by Australian Map Grid (AMG) coordinates, Zone 51, to at least the nearest 100 m

WESTERN AUSTRALIA
INDEX TO 1:250 000-SCALE GEOLOGICAL MAPS

Second Edition



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WILUNA

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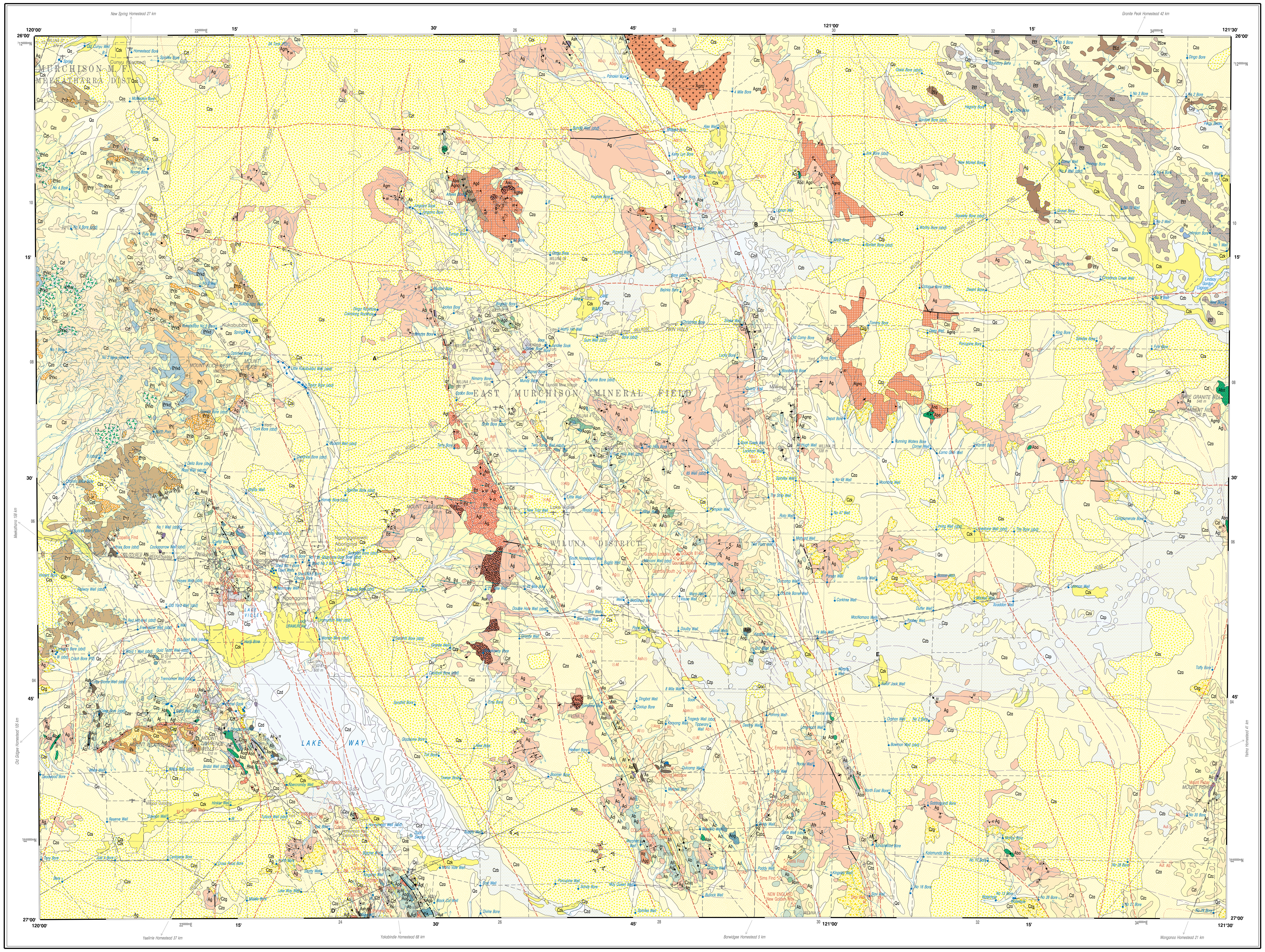
SHEET SG 51-9



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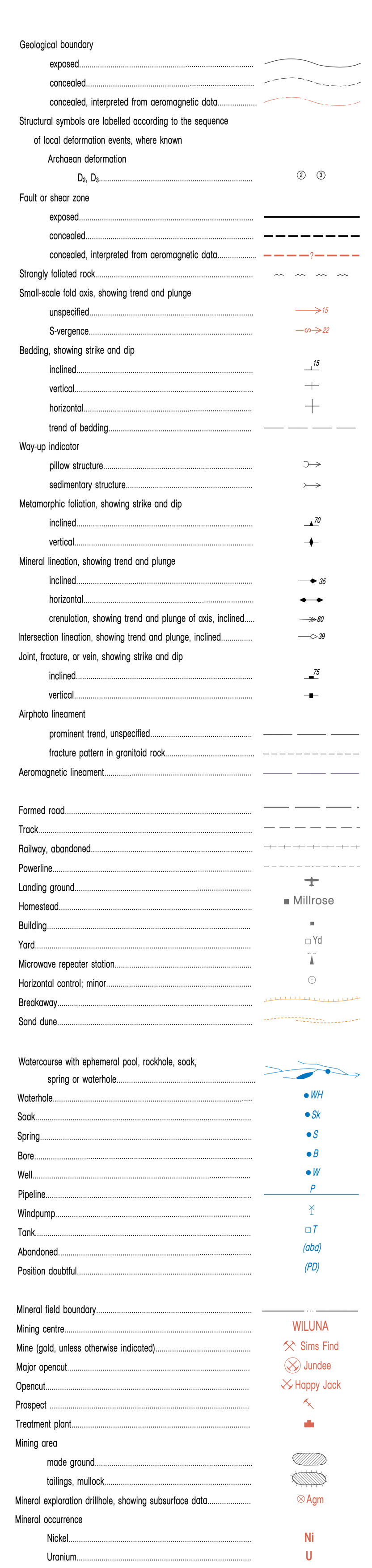

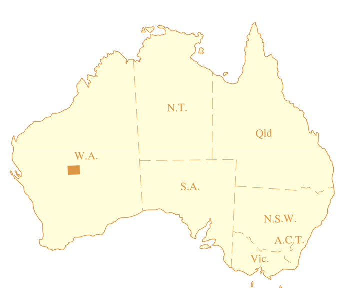

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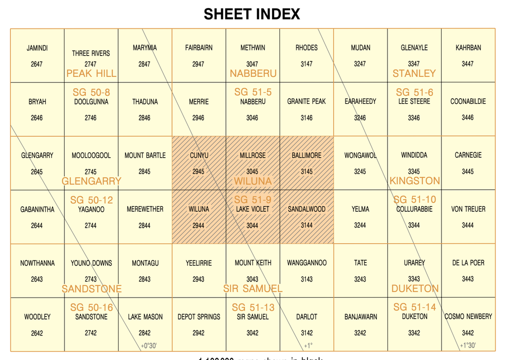

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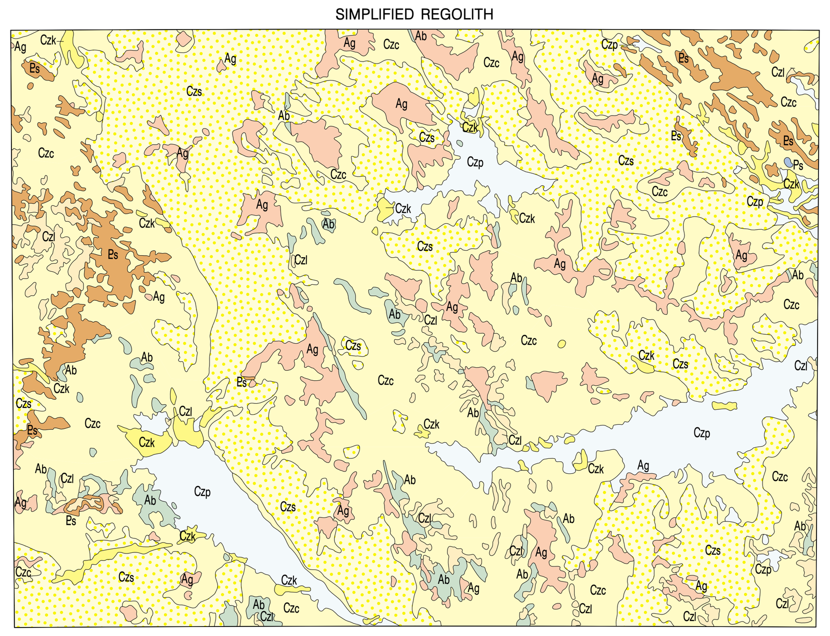

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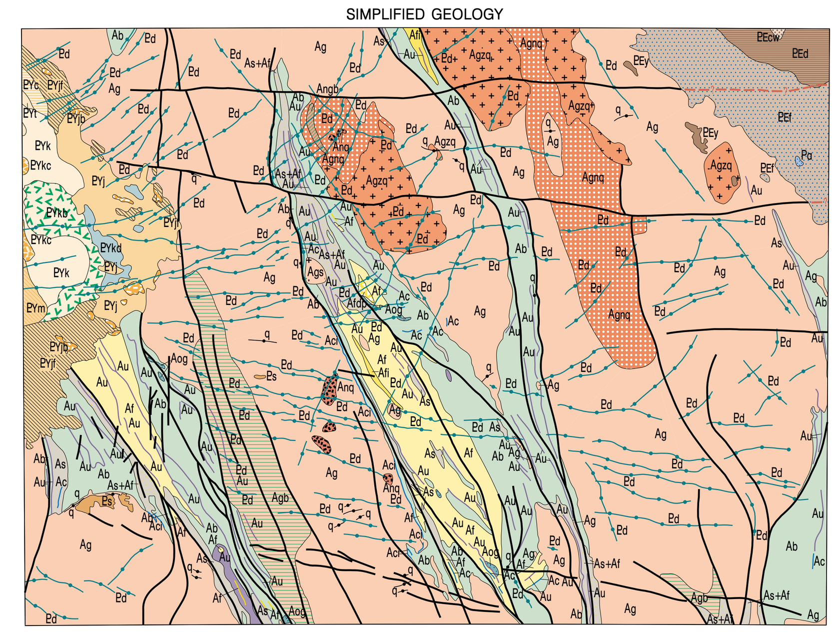
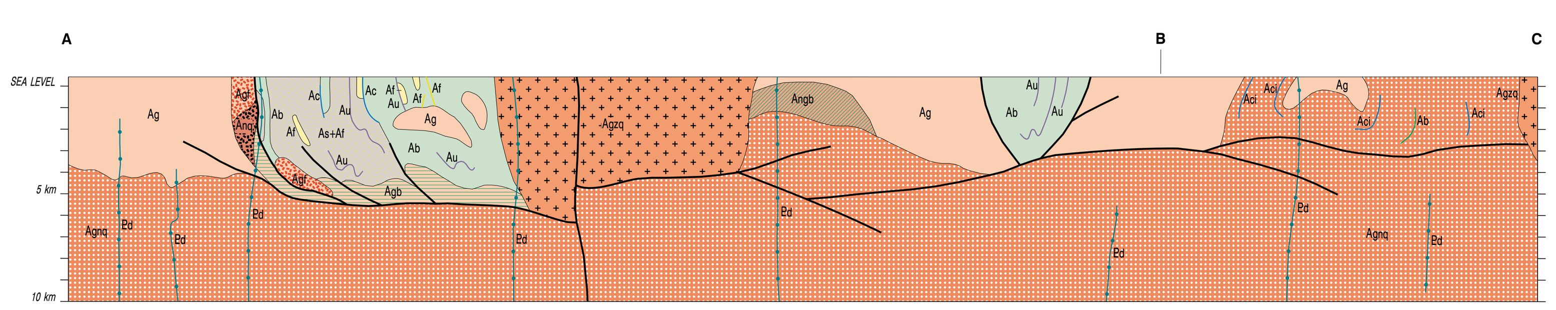
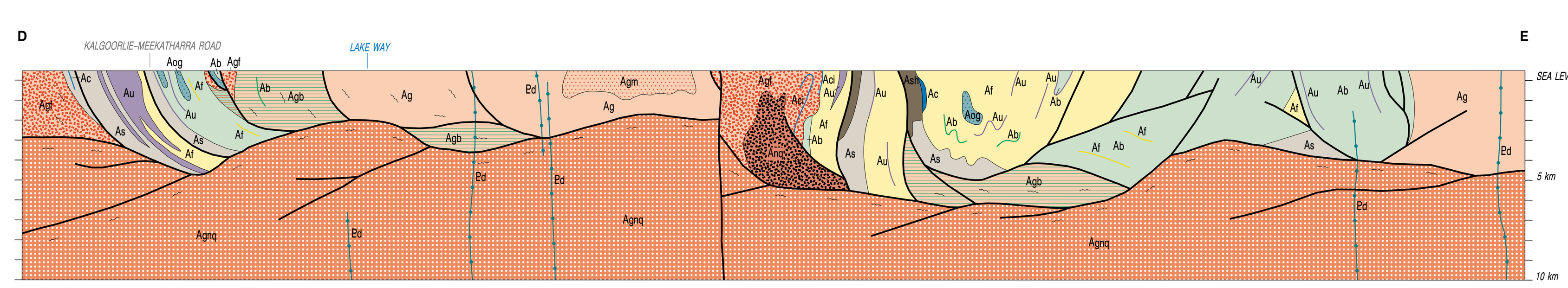


DIAGRAMMATIC SECTIONS

NATURAL SCALE





REFERENCE

PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa Alluvium — clay, silt, sand, and gravel; in channels and on floodplains

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 — sand, silt, clay, gypsum, and carbonate; in low dunes adjacent to playa lakes

Czp Playa deposits — saline and gypsiferous evaporites, clay, and sand in playa lakes

Cza Sheetwash deposits — clay, silt, and sand in extensive fans; commonly ferruginous

Czs Sandplain deposits — unconsolidated sand and minor silt; includes stabilized dunes

Czc Colluvium — silt, sand, and rock debris as slope deposits and proximal sheetwash; includes ironstone fragments

Czcq Quartz vein rubble and debris

Czf Ferruginous rubble — degraded lateritic duricrust, and ferruginous debris

Czg Sand over granitoid rock — quartzofeldspathic sand

Czk Calcrete

Czl Lateritic duricrust

Czu Silica caprock over ultramafic rock

Czz Silcrete

PALAEOZOIC — PERMIAN

Pa **PATERSON FORMATION:** sandstone, pebbly siltstone, and conglomerate

PROTEROZOIC — PALAEOPROTEROZOIC

Ps Conglomerate, quartz-rich sandstone, arkosic sandstone, and microbial laminates; commonly silicified and brecciated

Earaheedy Group (EARAHEEDY BASIN)

PEcw **CHIALL FORMATION** — **Wandiwarra Member:** siltstone and shale, and subordinate sandstone

PEd **WINDIDDA FORMATION:** limestone and shale

PEf **FRERE FORMATION:** granular iron-formation, ferruginous siltstone, and shale; minor banded iron-formation and chert

PEy **YELMA FORMATION:** sandstone, shale, and minor conglomerate

Yerrida Group — Mooloogool Subgroup (YERRIDA BASIN)

PYk **KILLARA FORMATION:** undivided mafic intrusive and extrusive rocks (simplified geology only)

PYkc **Bartle Member:** chertified microbial laminates with barite and anhydrite nodules

PYkd Medium- to coarse-grained dolerite dykes and sills

PYkb Aphyric tholeiitic basalt

Yerrida Group — Windplain Subgroup

PYj **JUDERINA FORMATION:** quartz sandstone; local siltstone, chert breccia, and conglomerate

PYjb **Bubble Well Member:** stromatolitic chert and chert breccia; minor dolomite

PYjf **Finlayson Member:** quartz arenite and subordinate siltstone; planar-bedded or cross-stratified; commonly ripple-marked

Pd Mafic dyke

q Quartz vein

ARCHAEAN

Aup Peridotite; metamorphosed

Aus Serpentinized ultramafic rock

Aut Talc–chlorite(–carbonate) schist

Aux Pyroxenite; metamorphosed

Compiled by T. R. Farrell 1997

Geology after GSWA and AGSO maps (see sheet index)

Edited by N. Tetlaw and G. Loan

Cartography by D. Ladbrook and B. Williams

Topography from the Department of Land Administration Sheet SG 51-9 with modifications from geological field survey

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

This map is also available in digital form

Printed by the Sands Print Group, Western Australia

The recommended reference for this map is:
FARRELL, T. R., 1999, Wiluna, W.A. Sheet SG 51-9 (2nd edition): Western Australia Geological Survey, 1:250000 Geological Series

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

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

NGMA
PRODUCT OF THE NATIONAL GEOSCIENCE MAPPING ACCORD

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:250 000

5000 Metres 0 5 10 15 20 25 30 Kilometres

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

Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 51

WILUNA

SHEET SG 51-9

SECOND EDITION 1999