EXPLANATORY NOTES

Department of
Industry and Resources

LEONORA
1:250 000 SHEET
WESTERN AUSTRALIA
SECOND EDITION

1:250 000 GEOLOGICAL SERIES

SHEET SH 51-1 INTERNATIONAL INDEX

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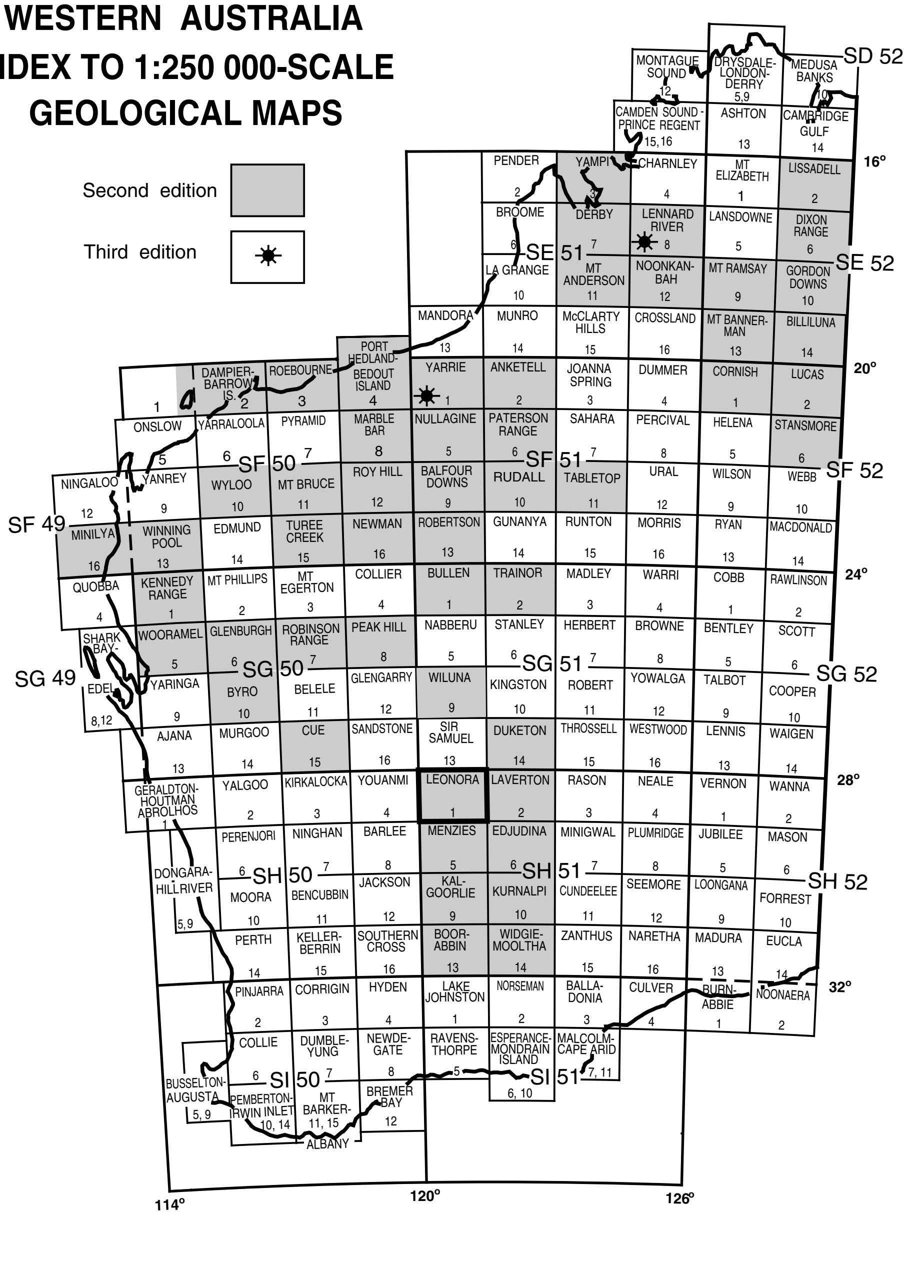

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

LEONORA

WESTERN AUSTRALIA

SECOND EDITION

SHEET SG 51-1 INTERNATIONAL INDEX

by

A. J. STEWART*

* formerly from, and with the support of, Geoscience Australia

Perth, Western Australia 2004

MINISTER FOR STATE DEVELOPMENT

Hon. Clive Brown MLA

DIRECTOR GENERAL,
DEPARTMENT OF INDUSTRY AND RESOURCES

Jim Limerick

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Tim Griffin

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by A. J. Stewart

INTRODUCTION

The LEONORA* 1:250 000 map sheet (SH51-1) is bounded by latitudes 28°00'S and 29°00'S and longitudes 120°00'E and 121°30'E. Of the four gazetted townsites in the sheet, only the pastoral and gold mining centre of Leonora† in the southeast is active. In the north, a hotel operates at Agnew, and the one remaining building at Lawlers is a mining exploration office. The buildings at Gwalia, the former miners' town for the Sons of Gwalia mine 3 km south of Leonora, have been restored as a 'heritage town', and the original hotel at Gwalia is now used as the mine office.

Sealed roads provide access from Kalgoorlie, 235 km south of the sheet area, from Leinster and Wiluna to the north, and from Laverton to the east. Formed roads connect Leonora with Lawlers and Agnew in the north, Munjeroo and Pinnacles in the northwest, Wilbah Outstation in the southwest, Weebo in the northeast, Sturt Meadows in the southeast, Mount Ida (5 km south of the sheet area), and Nambi (17 km east of the sheet area). Pastoral tracks provide good access elsewhere.

PHYSIOGRAPHY, CLIMATE, AND VEGETATION

LEONORA encompasses a region of mainly broad plains and playas with areas of low ridges and hills (Fig. 1). There are three main hilly regions: a large area in the north and east, reaching a maximum height of 557 m above Australian Height Datum (AHD) at both Agnew Bluff and at Mount Clifton; an area in the centre and west reaching 539 m above AHD; and an area in the south reaching 564 m above AHD. These are separated by easterly to south-southeasterly trending playas (350–400 m above AHD), which correspond to the southeast-draining Raeside Palaeoriver (van de Graaff et al., 1977).

Hills and ridges are generally composed of resistant greenstone rock types, especially amphibolite and chert, or laterite caps; Mount Clifton, however, is composed of granite. Broad plains are underlain by granitoid rocks. Breakaways with up to 30 m relief, such as West Terrace in the east, have formed in silcrete-capped, deeply weathered granitoid rocks.

The area has a semi-arid climate. Leonora township has a mean annual rainfall of 227 mm (median 212.5 mm) and a mean of 42 wet days per year, with most rain falling between January and June (Commonwealth Bureau of Meteorology, 2000). Temperatures reach or exceed 40°C between October and April, with December and January the hottest months. Frosts occur in June and July.

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

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

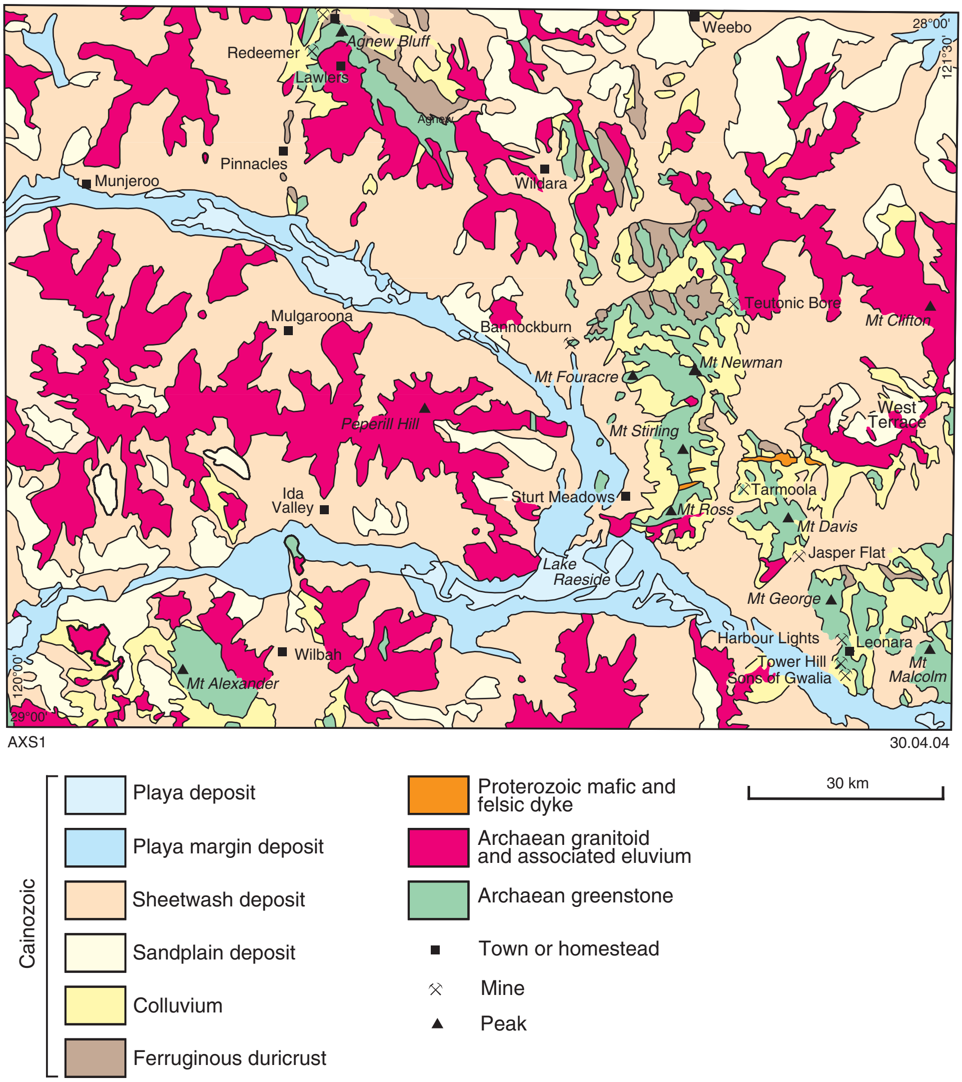

Figure 1. Physiography and Cainozoic geology of LEONORA

LEONORA lies in the Austin Botanical District of Beard (1974, 1990), and consists mainly of low woodland or sparsely vegetated areas with mulga (*Acacia aneura*) growing on Archaean granitoid rocks and associated eluvium, on both proximal and distal Cainozoic colluvium, and on sandplain in the southwest. Elongate areas of mulga, saltbush (*Atriplex*), and samphire (*Arthrocnemum*) grow on most of the gypsum dune country that surrounds and links the salt playas now occupying the palaeodrainage channels; around Lake Raeside, however, the acacia species are *A. ramulosa* and *A. linophylla*. Mulga shrubland, grading to sparse mulga, grows on greenstone and laterite hills in the Lawlers, Mount Newman, Mount Davis, and Mount Alexander areas. Mallee (*Eucalyptus youngiana*) and spinifex (*Triodia basedowii*) grow on sandplain in the north, northeast, and centre.

PREVIOUS INVESTIGATIONS

Reed (1897) made the first geological observations on the sheet area, and Jackson (1904), Gibson (1907), and Maitland (1911) investigated areas where gold had been discovered in the 1890s. Talbot (1912) compiled a regional map of the western half of the area following a ‘flying geological survey’ of parts of the East Murchison and North Coolgardie Goldfields. He delineated greenstone (‘epidiorite’ and amphibolite), ferruginous quartz schist, granite, and quartz reefs, and recorded quartzite in the extreme southwest. Clarke (1925) and Noldart and Bock (1960) produced geological maps and notes on the Leonora area. Young and Tipper (1966) published a solid-geology map of LEONORA based on regional aeromagnetic data (1.6-km line spacing, recorded in 1964), and noted several of the major structural and geological elements of the area, including possible ultramafic rocks in the Lawlers and Mount Clifford mining centre areas, and banded iron-formation (BIF) and ultramafic rocks in the Mount Alexander area. Shelley and Simpson (1972) made the first remote-sensing study in the sheet area, and combined it with 400-m line spacing aeromagnetic data acquired in 1970 to produce a solid-geology map of the Windy Bore – Sergies Well area in the south. Thom and Barnes (1975) produced the first edition of LEONORA, compiled the explanatory notes (Thom and Barnes, 1977), and identified many of the major structural elements of the sheet area, including the Lawlers Anticline and Hangover Syncline, Clifford Fault (now Mount George Shear Zone), Ida Lineament (now Waroonga – Ballard Shear), and Keith–Kilkenny Lineament. Hallberg (1985) published a detailed description of the Leonora–Laverton area accompanied by 16 geological maps at 1:50 000 scale, which included most of the LEONORA 1:100 000 sheet. Bradley et al. (1995) published a geochemical map and notes of LEONORA.

Gold was discovered at Lawlers in 1894, and at Leonora in 1896, when the Sons of Gwalia claim was registered. Summary descriptions of the major gold deposits in the sheet area are given in Ho et al. (1990).

Nickel sulfides were discovered in the area in the 1970s at Marriott prospect (Mount Clifford) and Weebo Bore (Travis, 1975; Donaldson, 1982; Legge, 1975).

Regolith studies began in the 1990s, and Anand (1998), Anand and Smith (1993), Anand and Paine (2002), Anand et al. (1998, 1999a, 1999b), Butt et al. (1998), Davy and Gozzard (1994), Davy et al. (1995), Drury and Hunt (1988), Gozzard and Tapley (1994), Kojan et al. (1996), and Kojan (1997) have reported extensively on the geology and geochemistry of regolith materials and their implications for mineral exploration in the sheet area. Craig and Churchward (1995) produced a regolith-landform map of LEONORA.

The Geological Survey of Western Australia (GSWA) and Geoscience Australia (GA) in conjunction with the Predictive Mineral Discovery Cooperative Research Centre (pmd*CRC) acquired more than 430 km of deep seismic reflection data from south-eastern LEONORA and areas to the east in 2001 (Goleby et al., 2002). Interpretation of the data by Blewett et al. (2002) shows greenstone up to 6 km thick overlying felsic crust, typically with a gently east dipping contact between the two. There is no single ‘detachment’ surface; in many places there appear to be low-angle shears in the crust below the greenstone. The greenstone-base is sheared in some places and intruded by granitoids in others.

Several hundred company reports, which include exploration data and unpublished maps, are available to the public through the GSWA WAMEX database. Several university theses deal with aspects of the geology and mineral deposits in the sheet area (Mazzucchelli, 1965; Leishman, 1969; Donaldson, 1983; Roth, 1988; Skwarnecki, 1990; Winzer, 2001).

The six 1:100 000 geological maps that make up LEONORA — MOUNT ALEXANDER (Duggan et al., 1996a), WILBAH (Duggan et al., 1996b), MUNJEROO (Duggan et al., 1996c), WEEBO (Oversby et al., 1996a), WILDARA (Oversby et al., 1996b), and LEONORA (1:100 000; Stewart and Liu, 2000) — were published by GA (formerly the Australian Geological Survey Organisation — AGSO) as part of the National Geoscience Mapping Accord with GSWA, and were used to compile the second edition of LEONORA. The generalized 'Pre-Cainozoic Geology' sketch beside the 1:250 000 map was compiled from the second edition of LEONORA, together with unpublished interpretations of aeromagnetic data (400 m-line spacing; obtained by AGSO in 1993) by A. J. Stewart, S. F. Liu, and A. J. Whitaker (GA) and unpublished geochemical data on granites supplied by D. C. Champion (GA). Geoscience Australia published a solid-geology map of LEONORA from interpretation of the same aeromagnetic data (Blewett, 2001).

These notes were compiled from GA's OZROX database of field geological observations and petrographic descriptions arising from the 1987–99 geological mapping of the six 1:100 000-scale sheets that make up LEONORA, and from published articles.

NOMENCLATURE

All Archaean rocks on LEONORA have undergone low- to medium-grade metamorphism, but for ease of description the prefix 'meta' is omitted and protolith rock names are used. The IUGS classification (Le Bas and Streckeisen, 1991) is used for igneous rocks, and the five chemical groups of Champion and Sheraton (1997) — high-Ca, low-Ca, high-HFSE*, mafic, and syenitic — is used for granitoids.

Grid references in this report are based on the Geocentric Datum of Australia (GDA94).

PRECAMBRIAN GEOLOGY

REGIONAL SETTING

LEONORA straddles the Barlee and Kalgoorlie† Terranes of the Archaean Yilgarn Craton. The terranes comprise greenstones (volcanic and sedimentary rocks) that were deposited around 2700 m.y. ago (Swager et al., 1992; Swager, 1997; Cassidy et al., 2002), multiply folded, metamorphosed to low or medium grade, intruded by granitoids at about 2680–2660 Ma (Champion and Cassidy, 2002), and subjected to major faulting along northerly to north-northwesterly trends. Swager (1997) described the terranes as contemporaneous volcanic and sedimentary basins, which were deposited in an ensialic rift setting, possibly above a failed spreading ridge, and later brought together. Many other models, however, have been advanced (e.g. Krapez et al., 2000). Chen (1999) summarized several published schemes of structural subdivision used on EDJUDINA, which adjoins LEONORA to the southeast, and erected three subdivisions. His definitions of the Murrin and Malcolm greenstones are used on LEONORA, together with the Agnew, Yandal, Mount Clifford, Mount Ida, and Maynard Hills greenstone belts (Figs 2 and 3). The Murrin and Malcolm greenstones on LEONORA correspond respectively to the Minerie Terrane of Kojan et al. (1996) and Gindalbie Terrane of Swager (1997).

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* high field-strength elements.
† Leonora Terrane of Vanderhor and Witt (1992).

Agnew greenstone belt

The Agnew greenstone belt is located in the northern part of LEONORA (Fig. 2), and extends northward onto SIR SAMUEL. It consists mainly of basalt and ultramafic rocks intruded by extensive sills of gabbro and dolerite; conglomerate and feldspathic sandstone (Jones Creek Conglomerate or, informally, Scotty Creek conglomerate) outcrop on the western side of the belt. The rocks are folded around north-plunging axes, forming the large-scale Lawlers Anticline and Mount White Syncline. Major northerly striking faults bound the belt on the east and west sides. Small mafic granites intrude the belt at Lawlers and Camel Bore, and a large body of granitoid intrudes the southern side of the belt.

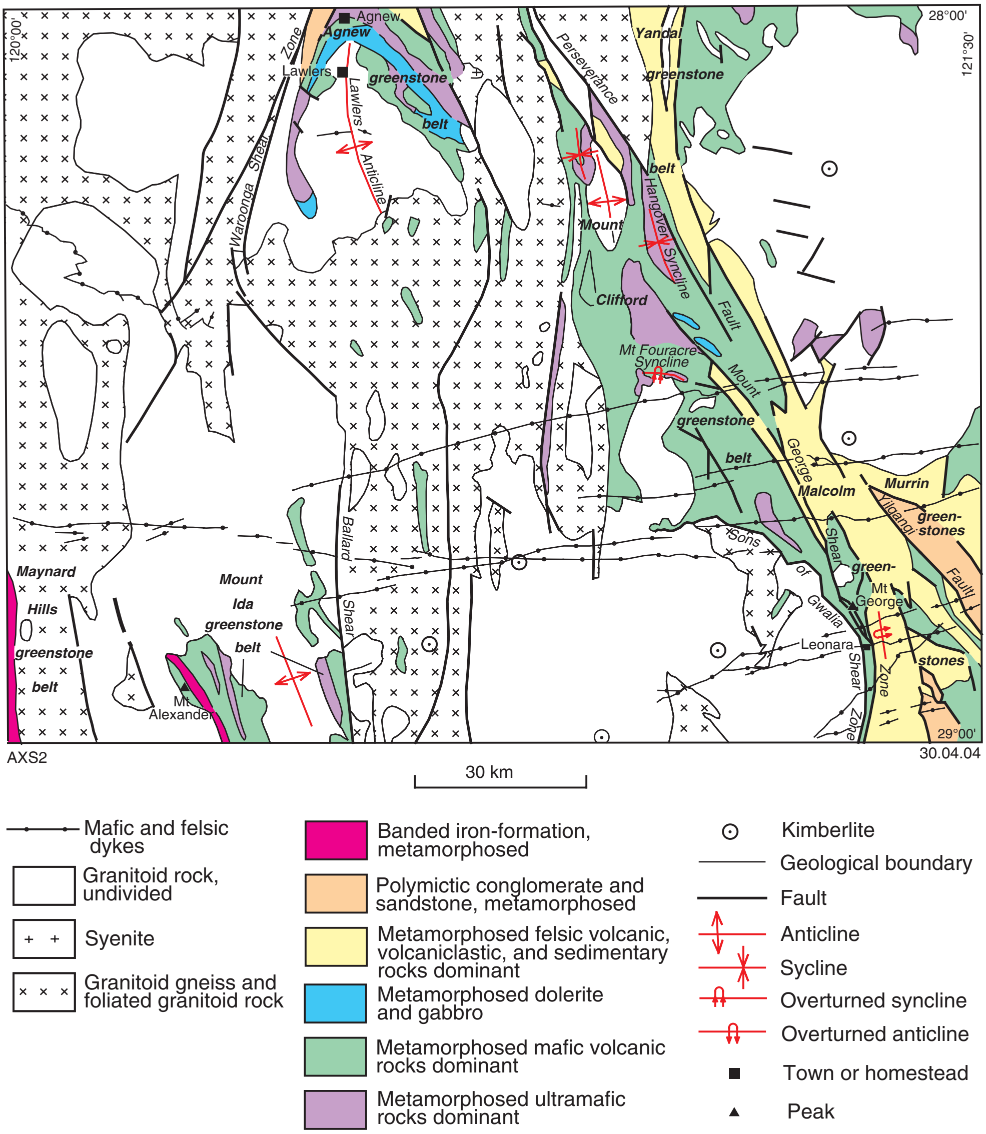

Figure 2. Simplified solid-geology map of LEONORA. Kimberlite localities from Jaques (2001)

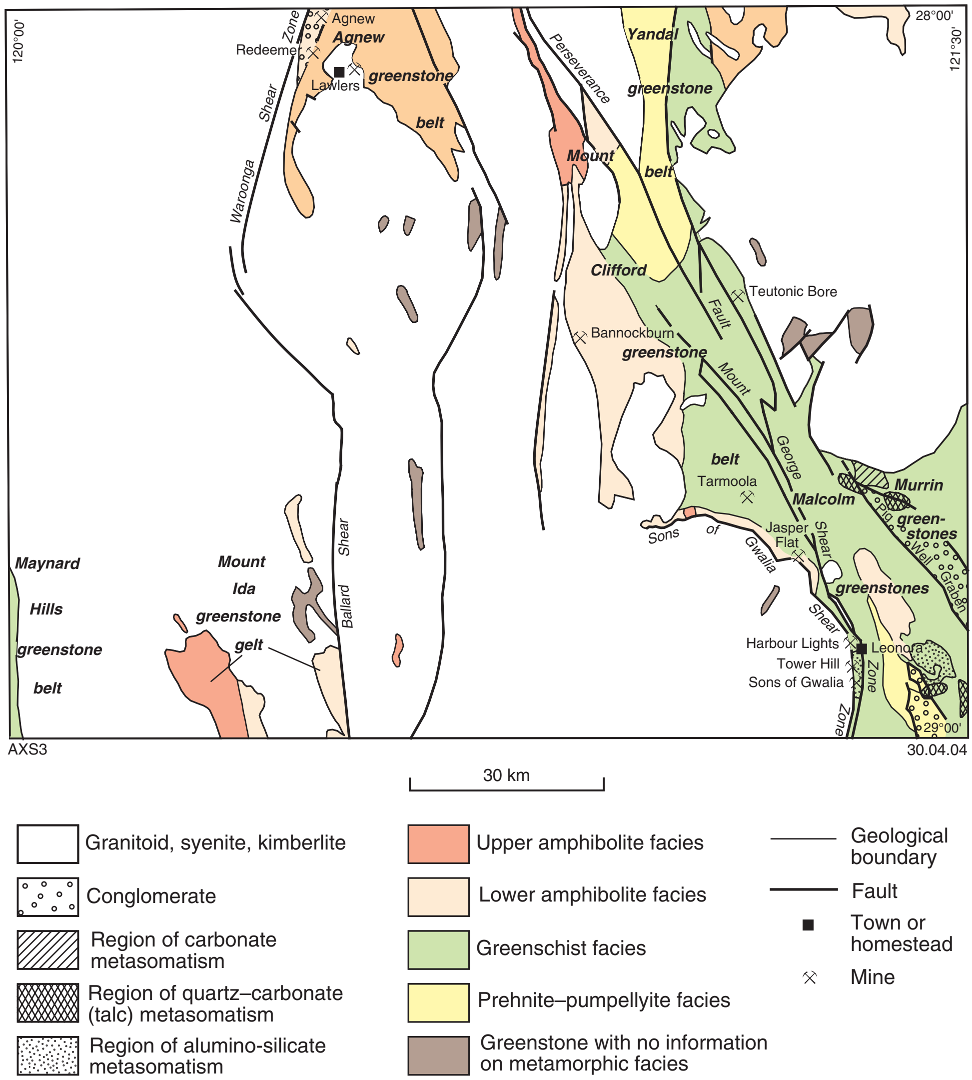

Figure 3. Metamorphic facies map of LEONORA

Mount Clifford greenstone belt

The north-northeasterly trending Mount Clifford greenstone belt crosses the entire LEONORA sheet. In the northern part of the sheet it forms a narrow strip on the western side of the Perseverance Fault, and to the southeast it occupies a narrow strip between the Mount George and Sons of Gwalia Shear Zones. Between these extremes, it widens to about 25 km in the Mount Fouracre area. In the northeast, the Mount Clifford greenstone belt is transitional into the Yandal greenstone belt. The Mount Clifford greenstone belt consists almost entirely of mafic (including both tholeiitic and high-Mg basalts) and ultramafic volcanic rocks (with several nickel prospects), together with fine-grained siliciclastic rocks along the Mount George Shear Zone, and small amounts of felsic volcanic rock (near Haggerty Well), dolerite, and conglomerate (near Mount Newman and Station Creek Pumping Station). There are easterly trending D_1 synclines at Mount Fouracre and probably in the Mount Ross area, and northerly trending D_2 synclines have been mapped near Clifford Bore and at the Wildara mining centre. Several ‘internal’ granitoids (Sofoulis, 1963; Sofoulis and Bock, 1963) intrude the belt, including small mafic granites at the Tarmoola mine*, Mount Stirling, and Victory Corner Well (all in the south of the belt), and small- to medium-size bodies of high-Ca granite at Robbies Well (in the south) and Heather Well (in the north). The Mount Clifford greenstone belt lithologically resembles the Mount Keith – Perseverance greenstone belt on SIR SAMUEL to the north.

Yandal greenstone belt

The Yandal greenstone belt extends into the northeastern part of LEONORA from SIR SAMUEL. Outcrops are few and include basalt near Ford Run Plateau and Seven Mile Well, and felsic volcanic rocks near Ford Run Plateau and 8 km west of Garden Well. There are better exposures on SIR SAMUEL, and these have been described by Westaway and Wyche (1998) and Liu et al. (1998). The belt continues into the Mount Clifford greenstones to the south, and is bordered to the west by foliated granitoid with local layering and mafic lenses. The eastern margin of the belt is problematical. The ‘Pre-Cainozoic Geology’ sketch beside the 1:250 000 map shows greenstone intruded by high-HFSE granite, and, in the south, by several curved, subparallel dykes of moderately magnetic granite (*Ag_m*), some of which correspond with mapped intrusive feldspar porphyry bodies. The LEONORA 1:250 000 scale solid-geology map (Blewett, 2001), however, depicts this region as greenstone continuing to the east for about 10 km beneath granitoid, based on interpretation of aeromagnetic data.

Murrin greenstones

The Murrin greenstones form a small, poorly exposed region east of the Yilgangi Fault in the southeastern part of the sheet area (Fig. 2), and correspond to the Murrin greenstone belt of Griffin (1990). To the north the greenstones are mainly felsic volcanic rocks, basalt, and dolerite, and to the south they comprise conglomerate and sandstone in the northwesterly striking Pig Well Graben. Gravity data indicate that the mafic and felsic greenstones extend north under the granitoids of the West Terrace – Mount Clifton area (see cross section AB below the 1:250 000 map).

Malcolm greenstones

The Malcolm greenstones occupy the area between the Yilgangi Fault and Mount George Shear Zone in the southeastern part of the sheet (Fig. 2), and correspond largely to the Malcolm greenstone belt of Griffin (1990). The greenstones are mainly felsic volcanic rocks, basalt, shale, and dolerite sills; conglomerate in the south is bounded by faults interpreted from magnetic data, and may fill a small graben similar to the Pig Well Graben. The greenstones are deformed by a possible D_1 thrust-fault duplex immediately east of Mount George, and by major north-northwesterly striking D_2 folds (which tipped the D_1 duplex on edge; Witt, W. K., Sons of Gwalia Pty Ltd, 1999, written comm.). Small masses of syenite and granodiorite intrude the greenstones.

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* Subsequently reclassified as high-Ca granite by Champion and Cassidy (2002).

Mount Ida greenstone belt

The Mount Ida greenstone belt in the southwestern part of LEONORA comprises the opposing limbs of the southerly plunging Kurrajong Anticline; these limbs come together on MENZIES to the south. The eastern limb comprises basalt, ultramafic rocks, and gabbro–dolerite sills in the south, together with irregular rafts of greenstone extending for several kilometres to the north. The western limb (Mount Alexander area) includes the boundary between the Kalgoorlie and Barlee Terranes of Swager et al. (1992). The terrane boundary separates mafic and abundant ultramafic rocks with no BIF or quartzite to the east (the Kalgoorlie Terrane) from mafic rocks with abundant BIF and quartzite but few ultramafic rocks to the west (the Barlee Terrane). The boundary, located about 1.5 km northeast of Mount Alexander, is shown by Myers and Hocking (1998) as the Ida Fault, and they interpreted it to continue north from the Mount Alexander area, through granitoids in the western part of LEONORA, to link with the north-northeasterly striking fault in the northwestern part of LEONORA (Fig. 2). There is, however, no expression in the aeromagnetic data of the Ida Fault in this granitoid area (Liu et al., 2000; Blewett, 2001; Whitaker and Bastrakova, 2002), suggesting that the granitoid — the lobate *AgL* body in the 'Pre-Cainozoic Geology' sketch beside the 1:250 000 map — was emplaced after movement on the Ida Fault ceased.

Maynard Hills greenstone belt

The Maynard Hills greenstone belt forms a thin strip in the far southwestern corner of LEONORA, and continues westward onto YOUANMI. The belt consists of quartzite overlain to the west by BIF and basalt, and is bordered to the east by extensive foliated granitoid with local layering and mafic lenses.

ARCHAEAN ROCK TYPES

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

Undivided ultramafic rock (*Au*), peridotite (*Aup*), tremolite schist (*Aur*), serpentinite (*Aus*), talc–chlorite schist (*Aut*), and pyroxenite (*Aux*) form a small proportion of the greenstones on LEONORA, and are most abundant in the north, east, and southwest. In outcrop, peridotite is the most abundant rock type. The rocks generally form concordant layers in the greenstone sequences, and commonly contain magnetite, which causes strong aeromagnetic anomalies.

Undivided ultramafic rock (*Au*) outcrops in the Mount Clifford mining centre and Marshall Pool areas in the east, 2 km north of Schmidt Well and 5 km north of Bannockburn mine in the centre of the sheet, and 8 km southeast of Tarmoola in the southeast. The rock varies from very fine to coarse grained, is massive to moderately schistose, generally serpentinized, and in places silicified; also present are actinolite or tremolite, porphyroblastic talc, chlorite, and opaque grains. Talc and chrysotile are pseudomorphous after olivine near Schmidt Well. Platy spinifex texture is preserved in places, and the rock is scoriaceous at others.

Peridotite (*Aup*) outcrops near Lawlers and Wildara Outstation in the north, in the North Well, Marshall Pool, and Mount Clifford mining centre areas in the central and eastern parts of the sheet, 3 km east of Tarmoola in the southeast, and in the Mount Alexander area in the southwest. The peridotite ranges from fine to very coarse grained, and is composed of: amphibole (including tremolite) after pyroxene; serpentine, talc, and chlorite after olivine; carbonate; magnesite; and quartz. The rock is massive to foliated, generally equigranular, and locally silicified. Alternating fine- and coarse-grained layers outcrop at

LEONORA MGA* 065454. Spinifex texture is preserved southeast of Lawlers, and at MOUNT ALEXANDER MGA 408966.

Tremolite schist (*Aur*) outcrops in the Mount Ross area in the southeast as an elongate body about 200 m thick in amphibolite. The schist is fine to medium grained, and composed chiefly of tremolite needles (60–85%), Mg-chlorite (up to 30%), and zoisite (up to 10%), clinozoisite (up to 25%), or epidote (up to 3%). Other minerals present locally are muscovite (5%) with zoisite, titanite (1–2%), and quartz (up to 3%). The tremolite needles are strongly aligned in the schistosity.

Serpentinite (*Aus*) forms small bodies near the Victory No. 1 mine in the east, and near the Puzzle mine in the southeast. The rock is very fine to medium grained, and composed of serpentine and iron oxide grains. It is massive to foliated, and locally has a saccharoidal texture

Talc–chlorite rock (*Aut*) is abundant in the southeast, where it outcrops near the Harlech mine, forms extensive layers a few metres thick in amphibolite near Mount Ross, and is the main host rock at the Puzzle, Harbour Lights, and Tower Hill mines near Leonora township. It also forms discrete outcrops in the Bannockburn – Slaughter Yard mine area in the central part of the sheet, and outcrops in the Mount Clifford mining centre – Minatichi Well area in the east. It is fine to coarse grained and composed essentially of talc (40%), chlorite (20%), carbonate (30%), and albite (9%), plus small amounts of magnetite, pyrite, biotite, and rare clinochlore (at the Tower Hill mine). It is generally schistose, but locally massive and saccharoidal. The schist at the Tower Hill mine is cut by deformed quartz veins with molybdenite and gold; the molybdenite has given a Re–Os date of about 2755 Ma (Witt et al., 2001), and by inference the talc schist in the Leonora gold camp is older than this age.

Pyroxenite (*Aux*) forms extensive lenses up to 5 km long and 400 m wide in the Lawlers – Camel Bore area in the north. The rock is fine to coarse grained, adcumulate† to porphyritic, foliated, and composed of amphibole, plagioclase (up to 10%), serpentine, and relict pyroxene.

Low- to medium-grade metamorphic rocks (*Alb*, *Ald*, *Alf*, *Alfq*, *Alm*, *Alqb*, *Alqm*)

Low- to medium-grade metamorphosed rocks, with generally unrecognizable protoliths, include clay rock‡ (*Alb*), quartz–andalusite schist (*Ald*), quartz–feldspar schist and quartz–clay rock (*Alf*), schistose clay rock with quartz eyes (*Alfq*), muscovite schist and schistose muscovite–clay rock (*Alm*), quartz–biotite schist (*Alqb*), and quartz–muscovite schist (*Alqm*). These rocks have been mapped only in the east and southeast.

Massive to schistose clay rock (*Alb*) outcrops 2 km southeast of Mount Newman, 7 km east-northeast of Moses Well, on the eastern flank of Mount Leonora, and around the Malcolm Dam Nature Reserve. Many other outcrops are too small to show at 1:250 000 scale. The rock ranges from very fine to (relict) medium or coarse grained, and is composed

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* Localities are specified by the Map Grid Australia (MGA) standard six-figure reference system whereby the six figures (three eastings and three northings) define position to within 100 m on the specified 1:100 000 sheet. The grid references are based on the Geocentric Datum of Australia GDA94.

† Igneous rock formed by accumulation of crystals that settled out from magma by action of gravity; the crystals continued to grow from liquid of the same composition, and are unzoned (Bates and Jackson, 1980).

‡ Indurated clay derived from weathering of feldspar and other minerals.

largely of clay (95% or more), which locally preserves outlines of feldspar laths, phenocrysts, or augen. Quartz (up to 5%) exists as small lobate or cuspate grains, small angular grains, veinlets, or patchy to pervasive very fine grained silica. Accessory minerals include chlorite, iron oxide, and pyrite. The rock is weathered mafic (with preserved basaltic texture) or ultramafic rock at many localities, and weathered felsic rock at others; it also underlies silcrete on poorly sorted sedimentary rocks in the Pig Well Graben (LEONORA MGA 482167).

Quartz–andalusite schist (*Ald*) forms the upper part of the western flank of Mount Leonora, and also outcrops on the southeastern side of the Sons of Gwalia pit. It comprises medium to coarse, ovoid to angular porphyroblasts of andalusite (7–12%) overgrowing a matrix of fine-grained mosaic quartz (80–90%), muscovite films (2–9%), rutile (<1%), and opaque grains (<1%). Joints in the rock are lined with coarse prismatic undeformed kyanite. Miles (1943) recorded kyanite and sillimanite associated with the andalusite. Andalusite schist (too thin to map at 1:250 000 scale) forms a layer up to 200 m wide and 3 km long between gabbro and mafic schist in the area centred on WILDARA MGA 697833.

Quartz–feldspar schist and quartz–clay rock (*Alf*) have been mapped 4 km northeast and 8 km north-northeast of Mount Malcolm. The rocks are very fine to medium grained, schistose or massive, and consist mainly of quartz and clay (which pseudomorphs feldspar augen or clasts) or fine groundmass feldspar. Quartz is present as relict angular grains, broken grains, flattened eyes, wispy aggregates and networks, or as skeletal grains and shards. Iron oxide (some as cubes after pyrite), unweathered feldspar, muscovite, and hematite are minor components. Parent rocks are felsic volcanic or volcaniclastic rocks.

Schistose clay rock with quartz eyes (*Alfq*) with some quartz–feldspar schist outcrops 4 km southeast of Pig Bore. The rocks consist of clear quartz eyes 1–2 mm across in a very fine grained groundmass of kaolin pseudomorphous after feldspar, very fine grained quartz, and iron oxide specks. Schistosity is weak to strong, penetrative in some areas, or confined to zones up to 2 m wide separated by massive rock elsewhere. Parent rocks include silicic volcanic rocks, arkose (LEONORA MGA 481198), and sandy shale (LEONORA MGA 505113).

Muscovite schist and schistose muscovite–clay rock (*Alm*) outcrop 8 km northeast of Leonora township, and 1 km west of Marroon Well in the centre of the sheet. The rock near Leonora is very fine to fine grained, strongly schistose and lineated, and consists of muscovite, quartz, feldspar, and iron oxide. Weathered pebbles (now clay) are present in the rock at LEONORA MGA 387049. The Marroon Well outcrop is a 10 m-thick, coarse-grained lens containing quartz boudins; the schist is composed of quartz (40%; presumably not obvious in outcrop), chlorite (30%), muscovite (10%), plagioclase (10%), biotite (5%), rutile (2%), apatite (2%), and zircon (1%).

Quartz–biotite schist (*Alqb*) forms a single outcrop straddling the Kalgoorlie–Leonora road, 7 km south of Leonora township. The rock is mainly mylonitic schist, but grades northward to weakly foliated porphyritic rhyolite. It consists of small eyes of partly recrystallized quartz and ovoid to broken K-feldspar and oligoclase in a very fine grained groundmass of recrystallized quartz, K-feldspar, plagioclase, oriented biotite and muscovite, chlorite, and opaque grains.

Quartz–muscovite schist (*Alqm*) outcrops on the east side of Leonora township, 3 km south of the township on the Kalgoorlie–Leonora road, 3 km west of the Malcolm Dam Nature Reserve, and 1 km northwest of Mount Davis. It is strongly foliated, and has a moderate to strong stretching lineation. The rock comprises quartz (40–60% total), as small to medium eyes or multicrystalline lenticles, and, in places, augen of sodic plagioclase (including albite), in a very fine grained groundmass of quartz and plagioclase (up to 40%), with anastomosing films and lenticles of muscovite (or fuchsite at LEONORA MGA 379994), and chlorite (up to 5%). Minor components are biotite (up to 2%), pyrite (up to 2%), tourmaline (up to 20% in a few samples), rutile (1%), goethite after pyrite, iron oxide (5–10%), and clay after feldspar. Parent rocks where identifiable are usually felsic igneous rocks. In the Leonora – Mount Malcolm area, hematite (10–20%) pseudomorphs chloritoid tablets.

Fine-grained mafic igneous rocks (*Ab*, *Abam*, *Abb*, *Abba*, *Abc*, *Abd*, *Abf*, *Abg*, *Abm*, *Abp*, *Abs*, *Aby*)

Mafic volcanic rocks, principally basalt, are the most abundant greenstone rock type on LEONORA; high-Mg basalt is abundant in the southeast and near Marshall Well in the centre of the sheet. The basalts have minor laminar interflow sedimentary rocks, particularly in the north and east, and are interlayered at regional scale with units of ultramafic, felsic volcanic, and volcaniclastic rocks, and, in the southeast, clastic sedimentary rock. Dolerite and gabbro bodies are present within the basalts. Where it is unclear whether the rocks are extrusive, intrusive, or pyroclastic, they are mapped as undivided mafic igneous rocks (*Ab*). Pillows are best preserved in high-Mg basalt in the Mount George area in the southeast. The basalts are commonly cleaved or schistose, and lineated. Numerous dykes cut the basalts, including granite, granodiorite, dolerite, porphyry, and diorite; quartz veins are also common.

Undivided mafic igneous rocks (*Ab*) outcrop 3 km northwest of Marshall Well in the centre of LEONORA, and in the southeast there are outcrops 4 km northeast of the Tarmoola mine, 4 km northwest of the Jasper Flat mine, 1.5 km north-northeast of Mount George, 4 km north of Leonora township, in the Sons of Gwalia pit, and 2 km northwest of Pig Bore. The rocks are very fine to fine grained, equigranular to rarely porphyritic, and generally cleaved but locally massive or brecciated. Major constituent minerals are amphibole (largely actinolite) and plagioclase; minor minerals include pyrite, epidote, muscovite, quartz, iron oxide, and clay. Felsic pyroclastic and local volcaniclastic rocks (see below) are exposed on the east side of the ridge of mafic rocks 2 km northwest of Pig Bore. The rocks in the Sons of Gwalia pit include high-Mg basalt, tuff, and interflow sedimentary rocks (Kalnejais, 1987).

Amphibolite (*Abam*) derived from mafic igneous rock outcrops extensively around Mount Stirling in the southeast and near Camel Bore in the north; it also forms numerous thin, elongate layers and lenses up to 6 km long in granitoid in the central and southern parts of the sheet. The rock is commonly very fine to fine grained, but locally medium or coarse grained. It varies from even grained to porphyroblastic, massive to strongly schistose, and is layered in some places (from variation in dark and light mineral proportions). Pillows are preserved at MOUNT ALEXANDER MGA 519178, and variolitic texture is preserved at LEONORA MGA 108230. Patches and veins of partial melt produce migmatitic structure in an amphibolite raft in granite at WILBAH MGA 668014 and at an amphibolite–granite contact at LEONORA MGA 111238. Brecciation and epidote alteration are present locally. The rock is composed essentially of: decussate, fanned, stellate, or aligned amphibole (15–90%) as prisms or granules; granuloblastic or remnant laths of plagioclase (andesine to labradorite, 5–45%; 80% in leuco-amphibolite); mosaic quartz (up to 15%); and titanite (1–5%). Other minerals noted locally include opaque grains (up to 5%), biotite, apatite (<1%), garnet (5%; only in amphibolite lenses in granitoid), pyrite, chalcopyrite, idioblastic augite (9% at LEONORA MGA 087226), and epidote/clinozoisite/zoisite, carbonate, and white mica after plagioclase. The amphibole is blue-green actinolite in greenstone sequences, and green to brown hornblende in bodies enclosed in granitoid. Hornblende blades are locally up to 1.5 cm long. Two occurrences of finely laminated (1–2 mm) amphibolite in the unit at LEONORA MGA 255163 and 061222, the latter with diopside (20%) and quartz (20%), may be metasedimentary.

Basalt (*Abb*) outcrops between Marshall Well and Hill Bore in the central part of LEONORA, in the Mount Alexander area in the southwest, around Lawlers in the north, north and south of Mount Stirling in the east, and 1 km east of Mount George and 15 km east of Leonora township in the southeast. The rock is even grained to locally porphyritic, very fine to fine grained, weakly to strongly cleaved, and in places vesicular or amygdaloidal. It is composed mainly of equant to prismatic, decussate to stellate blue-green actinolite (35–83%), plagioclase (andesine to labradorite; 1–40%) as narrow laths (some with swallow-tail ends), and black to pale-yellow euhedral opaque grains (1–5%). Other minerals present locally include: pyroxene with bow-tie structure; titanite (up to 20%); pyrite; chlorite; hematite; epidote and clinozoisite (up to 40%) after plagioclase; mosaic quartz (<20%) as aggregates, veinlets, and amygdales; carbonate in veinlets and grains; and epidote in and near veinlets.

Aphyric basalt (*Abba*) has been mapped north and east of Wildara Outstation in the north, and 4 km southwest of Teutonic Bore in the east. It is the non-porphyritic equivalent of the basalt (*Abb)* described above.

Carbonated basalt (*Abc*) outcrops in the extreme southeastern corner of the sheet, and is fine to rarely very fine grained, equigranular, massive to moderately foliated, and locally amygdaloidal. Minerals present in all samples range considerably in amount from one sample to the next, and include xenoblastic calcite (up to 80%) pseudomorphous after plagioclase, chlorite (up to 70%) as aggregates or pseudomorphs, plagioclase (up to 20%) as laths or spherulites with cores of calcite(–chlorite), and opaque grains (up to 12%); other minerals present in some samples are quartz (up to 40%), clinozoisite (8–15%), muscovite (up to 50%), iron oxide (up to 3%), epidote (<1%), and pyrite (7% in one sample).

Basalt and dolerite are mapped together as *Abd* where individual units are too small to show at map scale, or where one rock type grades into the other. The unit has been mapped 1 km northeast of Royal Arthur Bore in the east, and 2 km northwest and 3 km west of Mount Davis in the southeast.

Mafic schist (*Abf*) outcrops in the northern part of LEONORA about 5 km southwest and 15 km southeast of Lawlers, and discontinuously from 5 km north of Weebo Bore to near Marshall Pool. In the southeast it outcrops along the western flank of Mount George and near the southeastern edge of the sheet. The schist is fine grained, and consists largely of chlorite (30–55%) or less commonly actinolite (50–60%; some as porphyroblasts), plagioclase (5–15%) as clasts or augen, quartz (12–45%) as aggregates or augen, opaque grains (2–11%), and cloudy brown iron oxide (1–15%). Other minerals present locally are calcite (10–14%), rutile, siderite (up to 15%), porphyroblastic garnet (up to 10%), biotite and muscovite together, ilmenite (up to 5%), and broken tourmaline grains. The schistosity is strong, but lineation, in the form of rodding or crenulation axes, is rare.

Mafic and subordinate felsic rocks (*Abg*) form a single outcrop 10 km northwest of Leonora township on the old Kalgoorlie–Meekatharra road. It comprises fine-grained foliated plagioclase amphibolite interleaved with medium- to coarse-grained foliated granitoid.

High-Mg basalt (*Abm*) is exposed 2 km northeast of Lawlers and at Ponds Well in the northern part of the sheet, near Marshall Well, Minatichi Well, Mount Fouracre, and at the Bannockburn mine and Hill Bore in the central part of the sheet, 2 km east of Mount Stirling and 2 km northwest of Victory Corner Well in the east, and in the Mount Ross, Mount Davis, and Mount George areas in the southeast. It is generally foliated and very fine to fine grained, but locally very coarse grained where relict pyroxene-spinifex texture is preserved. Varioles are common, and reach 2 cm in diameter with concentric compositional zones at LEONORA MGA 154262. Essential constituents are: actinolite (85–99%) as radiating or decussate needles, or as fans, tufts, and rare curved prisms up to 5 cm long in plumose aggregates; and very fine groundmass plagioclase (up to 7%). Accessory minerals include black or cream opaque grains (up to 3%), quartz (up to 2%) as discrete xenoblastic grains, and iron oxide (up to 1%). Relict pyroxene prisms and needles are present in the Mount Ross area. Alteration products include carbonate, very fine grained epidote/clinozoisite (up to 12%), and chlorite. Massive chert or red jasper forms metre-long lenses, tens of metres apart, in high-Mg basalt at several localities in the southeast. Pillows are preserved near the Casino and Forrest mines in the southeast.

Plagioclase-phyric basalt (*Abp*) forms a 100 m-thick layer in basalt, 1 km east of Mount George. The phenocrysts are up to 6 cm across, subhedral to rounded, and form 1–70% of the rock.

Schistose basalt (*Abs*) has been mapped 600 m east of the Tower Hill mine, where it forms exposures a few centimetres high. It is fine to medium grained, equigranular, and composed essentially of actinolite, plagioclase, and opaque grains; chlorite and pyrite are present in some samples. The schistosity arises from planar but non-linear alignment of the actinolite needles.

Vesicular or amygdaloidal basalt (*Aby*) outcrops extensively around the Mount Clifford mining centre and at Clifford Bore in the east, and 4 km east of Marshall Well in the central part of the sheet. Amygdales are sparse (about 1 m apart) to abundant. Sericitic and siliceous alteration have occurred at LEONORA MGA 117437, and the amygdales here are calcite. Shale is commonly interlayered with the basalt northeast of the Mount Clifford mine.

Medium- to coarse-grained mafic igneous rocks (*Aod*, *Aoda*, *Aodp*, *Aog*, *Aoga*, *Aol*)

Dolerite and gabbro, which are distinguished mainly on their difference in grain size, typically form layers, sills, and sheets up to about 700 m thick in basalt sequences, and also in the felsic volcanic rocks 2 km east of Leonora township. They are generally concordant with the country rock, but can be locally discordant (e.g. 1 km southwest of Mount Stirling, 3 km east of Leonora township, and in the extreme southeastern part of the sheet). Platy mineral alignment is common near the Mark Twain mine 6 km north-northeast of Lawlers.

Dolerite (*Aod*) outcrops in all greenstone areas, and is particularly abundant in the Lawlers – Camel Bore area, around the Mount Clifford mining centre, and north and east of Leonora township. Equigranular dolerite (*Aoda*) forms a single outcrop 4 km southeast of Weebo Bore in the north. The rock is fine, medium, and locally coarse grained, usually even grained, but locally plagioclase-phyric. Tremolite–actinolite (45–50%) as oriented short prisms, and plagioclase (35–40%), commonly pseudomorphed by clinozoisite, are present in every sample; other minerals present locally include orthopyroxene (20–25%) partly replaced by chrysotile, titanite (up to 12%), quartz (up to 10%), chlorite (up to 10%), opaque grains (1%), pyrite, and chalcopyrite. Carbonate, sericite, epidote, and silica alteration have affected the rock in places. The rock is generally massive, less commonly foliated, and rarely lineated. Flow banding and amygdales are locally preserved. High-Mg dolerite is associated with high-Mg basalt at LEONORA MGA 250232, 254167, and 255166; at the last locality, talc porphyroblasts are present in the dolerite.

Porphyritic dolerite (*Aodp*) containing plagioclase and ferromagnesian phenocrysts up to 3 cm long has been mapped 3 km north of Mount Stirling in the southeast.

The largest exposures of gabbro (*Aog*) and equigranular gabbro (*Aoga*) are in the Lawlers – Camel Bore area in the north; smaller masses outcrop near Bundarra Homestead in the northeast, 3 km north of Mount Newman in the east, and northeast of Mount Alexander in the southwest. The rock commonly preserves primary textures, despite metamorphism. Grain size is typically coarse, but ranges down to medium and up to very coarse. Gabbro consists essentially of amphibole (about 35%) and plagioclase (up to 60%, enclosing amphibole) locally recrystallized to very fine grained aggregates. Other minerals present are remnant clinopyroxene and olivine, and quartz in pegmatitic patches with plagioclase and locally with prehnite, epidote, chlorite, and retrograde talc. Most gabbro bodies are even grained, but pyroxene phenocrysts and olivine are present in the Mount Alexander area. Gabbro is typically massive, less commonly foliated, and compositional laminae are rare.

Lamprophyre (*Aol*) forms a 1.5 km-long dyke 4 km north of Camel Bore in the north, and is composed of amphibole blades in a quartz-rich groundmass. Other lamprophyre outcrops (too small to show at 1:250 000 scale) are located at WILDARA MGA 547949, LEONORA MGA 109437, 326138, and 221220, and MOUNT ALEXANDER MGA 544949, and elsewhere in the eastern half of LEONORA (Rock et al., 1988).

Felsic volcanic and volcaniclastic rocks (*Af*, *Aff*, *Afp*, *Afpf*, *Afpq*, *Afs*, *Aft*, *Afv*)

Felsic volcanic and volcaniclastic rocks outcrop mainly in the Ossie Well – Teutonic Bore area in the northeastern part of LEONORA, and northeast and east of Leonora township in the southeastern part. Rock types are mainly silicic varieties, and intermediate types are rare. Most exposures are strongly schistose, weathered, and difficult to identify in the field. The group also includes intrusive felsic porphyry. In the southeast, Pidgeon and Wilde (1990) determined conventional U–Pb zircon dates on felsic volcanic rocks of 2735 ± 10 Ma near the Mount Germatong mine, 2697 ± 3 Ma in the Pig Well area, and 2688 ± 4 Ma on felsic rocks hosting the Teutonic Bore base metal deposit in the east. Also at Teutonic Bore, Nelson (1995) obtained a U–Pb SHRIMP date of 2692 ± 4 Ma.

Fine-grained felsic extrusive rocks (*Af*) have been mapped near New Chum Bore and Marshall Well in the north, around Junior and Boudie hills in the east, and in the Dodgers Well mining centre and Mount Malcolm areas of the southeast. They are equigranular to porphyritic, and almost everywhere schistose. Phenocrysts, where present, include anhedral quartz (2 mm across) and subhedral to euhedral feldspar (up to 7 mm across). Rhyolite at Boudie Hill is diffusely banded, and accompanies porphyritic ?intermediate rocks. In the Mount Malcolm area, the rocks are mainly dacite with smaller amounts of ?andesite. The dacite consists of quartz (40%) as partly recrystallized relict phenocrysts and very fine grained groundmass, muscovite (35%) as anastomosing films and decussate aggregates, chlorite (up to 20%) in anastomosing seams, hematite aggregates (up to 8%), and rutile (1%). Other rock types in the southeast include breccia with angular 20-cm clasts (around LEONORA MGA 516008), tuff (LEONORA MGA 419284), and hematite (after ?chloritoid)–muscovite–quartz schist (LEONORA MGA 481026 and 513006).

Foliated felsic volcanic or volcaniclastic rocks (*Aff*) form three small, very fine grained, siliceous outcrops 5 km northeast of the Tarmoola mine in the eastern part of LEONORA.

Intrusive felsic porphyry (*Afp*) forms several irregular bodies up to 3 km across in the northeast between Lehmanns Well and Garden Well; other smaller masses have been mapped near Mount Fouracre in the central part of the sheet, near Horse Rocks Rockhole in the north, and near Pinnacle Well and Mount Davis in the southeast. Phenocrysts make up 3–25% of the rock, and include rounded or irregular quartz (up to 2 mm across) and subhedral feldspar (up to 7 mm across). Rock compositions range from rhyolitic (WEEBO MGA 141672 and 098755) to andesitic (WEEBO MGA 101802, LEONORA MGA 416277).

Felsic porphyry (intrusive or extrusive; *Afpf*) has been mapped 3 km east of the Gambier Lass mine in the southeast, and 3 km east of Mount Fouracre in the east. The rock near Gambier Lass is tonalitic, and comprises euhedral embayed phenocrysts of clear quartz (5–7%), euhedral to subhedral andesine (10–40%), and euhedral brown to green-brown hornblende (2%) in a very fine grained groundmass of quartz (about 45%), plagioclase (20%), and hematite (up to 10%). Calcite, chlorite, and epidote after mafic minerals form 8–14% of the rock.

Quartz-phyric felsic rock (*Afpq*) forms a small body surrounded by basalt and high-Mg basalt at LEONORA MGA 322121.

Quartz–feldspar (or muscovite) schist (*Afs*) forms several outcrops about 5 km northeast of Leonora township. Most of the outcrops consist of embayed quartz eyes (5%) up to 2 mm across, and K-feldspar augen (3%) up to 1 mm long with relict spherulitic texture, in a groundmass of recrystallized mosaic quartz (45%), oriented muscovite flakes (45%), and iron oxide masses (2%). Subsidiary rock types include quartz–andalusite schist at LEONORA MGA 387074, chlorite schist at LEONORA MGA 391076, and banded tuff at LEONORA MGA 393097.

Felsic pyroclastic rocks with local volcaniclastic rocks (*Aft*) outcrop at Ossie Well in the northeast, 7 km southeast of Weebo Bore in the north, and 5 km south of Mount Malcolm in the southeast. The rocks are fine grained, massive or laminated, with angular quartz and feldspar grains up to 1.5 mm in size, muscovite-rich clasts about 2 cm in size, and iron oxide cubes. An exposure (too small to show at 1:250 000 scale) on the eastern side of a ridge of undivided mafic rocks (*Ab*) at LEONORA MGA 448167, 2 km northwest of Pig Bore, comprises clasts (5–20%) of altered volcanic rock (iron oxide(–quartz–plagioclase–chlorite)), iron oxide, chert, quartz, plagioclase, and locally granophyre, in a matrix (80–95%) of quartz and iron oxide, with andesine, chlorite, and introduced carbonate in places.

Felsic volcanic or volcaniclastic rocks (*Afv*), mainly rhyolitic, are exposed as part of a large raft in foliated granitoid 3 km west of Curara Well in the west, and as a layer about 200 m thick between dolerite and gabbro sills 5 km north-northwest of Camel Bore in the north. Other exposures are located 4 km west and 8 km west-southwest of Garden Well in the northeast, 3 km northeast of Pinnacle Well in the southeast, and 7 and 12 km northeast of Leonora township on the Leonora–Nambi road. The layer near Camel Bore is a bedded rhyolitic tuff, whereas the rocks near Garden Well are massive to foliated lavas that are aphyric to porphyritic in ß-quartz and K-feldspar, with some quartz–mica rock fragments up to 5 mm across. The Pinnacle Well outcrop is quartz-phyric clay rock, and the Leonora–Nambi road exposures are chlorite or muscovite schists with relict quartz and plagioclase phenocrysts, together with 1.5-m wide volcanic breccia zones.

Sedimentary rocks (*Ac*, *Aci*, *Acl*, *As*, *Asc*, *Ascb*, *Ascf*, *Ascq*, *Asf*, *Asg*, *Ash*, *AsJC*, *Asq*, *Ass*)

Sedimentary rocks in greenstone sequences on LEONORA include chert, BIF, limestone, conglomerate, sandstone, arkose, shale, and quartzite.

Chert (*Ac*) outcrops at and just north of Mount Newman in the east, in the Mount Malcolm area in the southeast, and is a major component of the ridge-forming metasedimentary rocks that outcrop from Mount Newman through Mount Davis and Mount George to Mount Leonora. Recrystallized chert is very fine to fine and (rarely) medium grained, laminated to thin bedded, planar to wavy bedded, and composed of quartz and small amounts of hematite or goethite, pyrite, and local amphibole, mica, and feldspar. The rock is commonly strongly foliated, but only rarely lineated. Gentle to isoclinal folds are common, and plunges range from shallow to steep, sometimes at a single locality. The contortions have resulted from the marked contrast in rock competency between chert and the adjoining greenstones, and are not representative of regional deformation (Groenewald, P. B., GSWA, 2003, written comm.). In places the chert is faulted, fractured, or brecciated; the timing of brecciation ranges from earlier than folding (shown by folded clasts at LEONORA MGA 509021), to synfolding, to later than folding (LEONORA MGA 166413). Faults are mainly small and extensional, with throws of a few centimetres. Boudinage is fairly common, and affects the most siliceous beds where it is present. In places, chert is interbedded with siltstone and shale. Lenses of carbonate up to 20 cm long are present at LEONORA MGA 106227. Rounded pebbles or cobbles, or angular rip-up clasts of chert are present locally. Chert-pebble conglomerate at LEONORA MGA 108227 has a matrix of actinolite with spinifex texture (plumes, sheafs, and fans). Chert has been affected by hematite alteration at a few localities, and ferruginous chert has a gossan-like appearance at others.

Banded iron-formation (*Aci*) is relatively uncommon on LEONORA. It is abundant at and around Mount Alexander in the southwest, forms small outcrops in foliated granitoid near Chinaman Well in the northwest, and is interbedded with mafic rocks near Robbies Well in the southeast. A small outcrop in the southwestern corner of the sheet is part of extensive iron-formations in the adjoining YOUANMI sheet. Banded iron-formation resembles chert in sedimentary and deformation structures, but laminae are alternately rich and poor in magnetite, resulting in a striped brown, red, black, and white appearance; other minerals present in small amounts include amphibole and pyrite. A gossan-like boxwork after ?pyrite is located at LEONORA MGA 192389.

Limestone (*Acl*) is exposed 4 km west of Mount Newman, and forms a single southeast-striking layer about 100 m wide between dolerite and basalt. The limestone is fine grained, mottled grey, white, and yellow, and deformed by small, gently north plunging folds.

Undivided metasedimentary rock (*As*) outcrops only in the east and southeast, from the Mount Newman area southeastwards through Mount Davis and Mount George to the Mount Leonora area. The rocks are chiefly siltstone and shale, with smaller amounts of phyllite and sandstone containing abundant mafic mineral grains. The rocks are laminated to thin bedded, and locally contain pebbles of chert and vein quartz. Scours, rip-up clasts, and graded bedding face north at LEONORA MGA 092438.

Polymictic conglomerate (*Asc*) has been mapped around the Harriston mine in the southeast, and 10 km southeast of Mount Leonora. It comprises subangular to rounded cobbles and boulders in a very fine to coarse-grained, poorly to well-sorted sandy matrix of quartz, weathered feldspar, iron oxide, opaque grains, and muscovite. Clasts include jasper, granite, quartzite, dolerite, felsic volcanic rock, hematite–quartz rock, vein quartz, arkose, sandstone, mafic rock, chert (with contained folds), microsyenite, claystone, shale, and siltstone. The matrix is commonly schistose, and the clasts flattened and stretched. According to Hallberg (1985), the conglomerate filled a graben (Pig Well Graben of these Explanatory Notes), the detritus being derived from the 'higher-standing margins and deposited near the edges of the graben in alluvial fans'. The Pig Well Graben sequence resembles the Jones Creek Conglomerate in the north of LEONORA and on SIR SAMUEL (Liu et al., 1998; Jagodzinski et al., 1999) in composition, structural setting, and age.

Oligomictic conglomerate with dominantly basaltic clasts (*Ascb*) is exposed at a single outcrop 4 km northwest of Mount George in the southeast. It consists of subrounded to well-rounded pebbles and cobbles of basalt, dolerite, quartz–feldspar porphyry, vein quartz, chert, and high-Mg basalt, in a schistose matrix of silty sandstone with abundant mafic mineral grains. Clasts constitute 5–50% of the rock.

Oligomictic conglomerate with dominantly felsic igneous clasts (*Ascf*) has been mapped only in the southeast around the Artful Dodger mine and 1 km north and west of the Gambier Lass mine. The conglomerate consists of pebbles, cobbles, and boulders, mainly of porphyritic rhyolite, with fewer clasts of feldspathic sandstone, pyritic sandstone, hematite–quartz sandstone, lithic sandstone, and muscovite quartzite in a medium- to very coarse grained sandy matrix of quartz and feldspar pseudomorphed by clay. The conglomerate is foliated and lineated.

Oligomictic conglomerate with dominantly siliceous clasts (*Ascq*) has been mapped 1 km west and 5 km southeast of Mount Newman in the east, and consists of flattened subangular pebbles and cobbles of chert and fine-grained sandstone in a very fine grained matrix of quartz, clay, and iron oxide.

Volcaniclastic conglomerate, sandstone, and tuff (*Asf*) have been mapped 3.5 km south of Mount Newman, where they form a prominent north-dipping ridge striking east from the Iron King mine. The ridge top comprises two resistant strike ridges separated by a recessive interval. The strike ridges are volcaniclastic breccias consisting of clasts of plagioclase-phyric volcanic rock, chert, and chert-grain ferruginous siltstone in a silty matrix of chert grains, iron oxide aggregates, muscovite, and quartz. The recessive interval is made up of: breccia composed of clasts of lithic siltstone, quartz–mica siltstone, felsic volcanic rock, and mica schist in a matrix of microcrystalline quartz, mica, siltstone grains, and iron oxide; and interbeds of siltstone composed of grains of opaline silica, chert, muscovite schist, and an opaque mineral in a matrix of microcrystalline quartz. Fuchsitic siltstone forms 2-cm angular clasts in siltstone at LEONORA MGA 141424; small feldspar grains in this siltstone may be of tuffaceous origin.

Arkose (*Asg*) outcrops around the Flying Pig and Harriston mines in the southeast. It is mainly medium to coarse grained and cobbly, and is rarely fine grained. The arkose is moderately to poorly sorted, massive to foliated, and composed of flattened grains of angular to subrounded quartz (35–60%), feldspar or clay (30–65%), and, locally, biotite (up to 10%). Clasts consist of lutite, quartz-eye–muscovite schist, granite, and microgranite. Bedding is weak to absent.

Shale, slate, phyllite, and claystone (*Ash*) outcrop 2 km southwest of Minatichi Well in the central part of LEONORA, 1 km southeast of Clifford Bore, 4 and 6 km north of Mount Newman and 1 km west of New Well in the east, and at numerous places in the Mount Davis – Mount George – Leonora area in the southeast. The rocks are laminated to thin bedded (except for claystone, which is massive), foliated and (rarely) lineated, and in places crenulated or open to tightly folded. Ripple cross-laminae face west at WEEBO MGA 053642. The rocks are composed essentially of clay, quartz, muscovite, and iron oxide; chlorite is recorded at LEONORA MGA 417042, and chloritoid at LEONORA MGA 376027 and 375049. Iron staining and silicification are common in outcrop.

Granitoid-clast conglomerate and sandstone with some interbedded siltstone (*AsJC*) make up the Jones Creek Conglomerate, which outcrops west and northwest of Lawlers in the north, and forms a raft in granitoid 3 km west of Curara Well in the west. The conglomerate faces west, and is in discordant contact with adjoining greenstone to the east (Durney, 1972).

Most of the conglomerate near Lawlers consists of well-rounded cobbles and boulders of coarse-grained granite in a quartz–feldspar sandy matrix; some mafic-pebble conglomerate with a biotite-rich matrix is also present. Sandstone is composed of quartz, feldspar, and, locally, muscovite. Scours at the base of sandstone beds are evident at MUNJEROO MGA 521985. The rocks are strongly foliated to mylonitic, and fine- to coarse-grained, laminated schist veined with quartz is abundant near Mount Mcauley. The conglomerate contains detrital zircons, which give a maximum depositional age for the conglomerate of 2664 ± 5 Ma (Dunphy et al., 2003)

Quartzite (*Asq*) has been mapped near Mount Alexander and Freshwater Well in the southwest. It is very fine to coarse grained, foliated (parallel or oblique to bedding), and, in places, lineated. Quartz typically makes up 90% or more of the rock; other minerals are muscovite and rutile. Quartzite with andalusite porphyroblasts forms an interbed a few metres thick in andalusite schist on the east side of the summit of Mount Leonora.

Sandstone and/or siltstone (*Ass*) outcrop 5 km west and northwest of Lawlers and 5 km northeast of Wildara Outstation in the north, 4 km east of Mount Fouracre and 6 km southeast of Mount Newman in the east, and 3 km north and 6 km northeast of Leonora township and 5 km west and south of the Harriston mine in the southeast. Sandstone is fine to medium grained and locally pebbly, medium bedded, poorly to moderately well sorted, and composed of subangular to subrounded grains of quartz (70–90%), feldspar or clay (about 10%), very fine muscovite (up to 20%), and iron oxide. Cross-bedding is abundant in the outcrop northwest of Lawlers, and graded bedding in the same area faces west. The rock is commonly foliated and lineated by flattening and elongation of grains. Pebbles consist of felsic porphyry, felsite, chert, vein quartz, amphibolite, and serpentinite; chert-pebble conglomerate is present locally. Siltstone is massive, laminated, or thin bedded, planar bedded, and composed essentially of quartz and clay with iron oxide staining; pyrite moulds are present locally. Sandstone 3 km north of Leonora township contains abundant mafic mineral grains and also carries siliceous pebbles.

Granitoid rocks

Granitoid rocks occupy about 80% of LEONORA. Monzogranite is the most abundant, followed by strongly foliated granitoid and syenogranite; small bodies of diorite, tonalite, granodiorite, and syenite are also present. Large areas of granitoid are concealed by Cainozoic colluvium, sand, or playa deposits. The 'Pre-Cainozoic Geology' sketch beside the 1:250 000-scale map assigns the granitoids to the five chemical groups of Champion and Sheraton (1997) — high-Ca, low-Ca, high-HFSE, mafic, and syenitic groups. Chemical data summarized by Champion and Sheraton (1997) suggest that the granitoid melts were either derived predominantly from the crust, or from the mantle together with a significant crustal component.

Granitoid rock types (Ag, Agb, Agc, Agd, Age, Agf, Agfo, Agg, Agl, Agm, Agmc, Agmf, Agmm, Agmp, Agn, Agq, Ags, Agt, Agtp, Agy)

Undivided granite (*Ag*) underlies extensive areas a few kilometres south of Lawlers and 20 km southeast of Lawlers in the north, around West Terrace in the east, and 2 km south of Mount Ross and around Boiler Well in the southeast. The rock varies from syenogranite to monzogranite to rare granodiorite, is fine to very coarse grained, and equigranular to sparsely porphyritic (1–2% feldspar or quartz phenocrysts). Most of the granitoid has a flattening to mylonitic foliation and stretching lineation; the West Terrace rocks are least deformed. Extensive recrystallization south of Mount Ross has changed a formerly coarse-grained rock to a fine-grained rock. Felsic–mafic (biotitic) or grain-size banding, biotitic schlieren, and xenoliths of greenstone, biotite rock, gneiss, granitoid, and pegmatite are present in places. Cross-cutting veins of aplite, pegmatite, micrograndite, leucogranite, and quartz are common. The typical mineral assemblage is quartz (up to 1.5 cm across), K-feldspar (as subhedra to euhedra up to 5 cm long), plagioclase, and biotite (1–15%); hornblende, garnet, opaque grains, and muscovite are present at some localities. The West Terrace rocks are mainly high-HFSE granite, and the granite around Boiler Well is part of a large high-Ca granite with a strip of granitoid gneiss and moderately to weakly magnetized granite.

Granitoid slices in greenstone (*Agb*) have been mapped only at Chinaman Well in the northwest, where the unit comprises massive biotite granite interlayered with coarse-grained hornfelsed amphibole-bearing BIF.

Coarse-grained granite (*Agc*) forms two small masses: one at Mount Stirling in the east (mafic group of Champion and Sheraton, 1997), and the other 12 km west of Tarmoola Homestead in the southeast. The rock is equigranular to locally porphyritic (phenocrysts include quartz and feldspar), and recrystallized. Greisen is present on the dump at the Mount Stirling mine, and quartz veins are abundant elsewhere in the Mount Stirling body.

Diorite to monzodiorite (*Agd*; high-HFSE group) outcrops in the northeast in the Bundarra Homestead – Garden Well area, at Wilson Creek Well, 3 km north-northeast of Wilson Creek Well, and 9 km northwest of Garden Well. The rock is coarse grained, equigranular, and characterized by randomly oriented feldspar laths (60%) up to 1 cm long in a chlorite-rich groundmass (40%).

Medium-grained granitoid (*Age*) has been mapped only in the southeast, around Robbies Well, 3 km north and 7 km north of Robbies Well, and 5 km southwest of the Jasper Flat mine. The Robbies Well rocks (high-Ca group) are equigranular to seriate, massive to foliated, and recrystallized. Five hundred metres to 1 km south of Robbies Well, the granitoid forms lit-par-lit lenses a few metres thick in mafic rocks of the Mount Ross area. The granitoid 5 km southwest of the Jasper Flat mine ('Auckland monzogranite') has been dated at 2669 ± 7 Ma (Cassidy et al., 2002)

Fine-grained granitoid (*Agf*) has been mapped only in the north in the Wibboo and Haggerty Well areas, around Wildara Outstation, and at No. 2 Well and Heather Well (high-Ca group). It is equigranular, foliated, and in the Heather Well area it is sparsely porphyritic and contains garnet.

Foliated granitoid (*Agfo*) has been mapped only in the southeast, where it outcrops 3 km southwest of the Jasper Flat mine, at the Trump mine, and at the south end of the Tower Hill pit. It is fine, medium, or coarse grained, and equigranular. Biotite ranges in amount from 2 to 15%, and muscovite is also locally present. Foliation ranges from weak to strong, and at the Trump mine the granitoid is also lineated, crenulated, and recrystallized. Quartz–feldspar layering is present at LEONORA MGA 271169.

Granodiorite (*Agg*) outcrops just north of Camel Bore in the north, at Victory Corner Well (mafic group) in the east, and 5 km northwest, 3 km west, and 3 km south of Mount Malcolm in the southeast. The Camel Bore and Victory Corner Well bodies are fine to coarse grained, equigranular to sparsely porphyritic, and massive (Victory Corner Well) to strongly foliated and lineated (Camel Bore). Dark minerals include biotite (10%) and hornblende (up to 10%). Small mafic xenoliths are abundant at Victory Corner Well. The outcrops near Mount Malcolm are porphyritic microgranodiorite, and have phenocrysts of plagioclase, quartz, and, near Sunset Well, K-feldspar. A 50 m-long plug of biotite–hornblende microgranodiorite, too small to show at 1:250 000 scale, intrudes amphibolite at LEONORA MGA 096350, 2.5 km northwest of Mount Stirling.

Leucogranite (*Agl*) has been mapped 3 km west of Lawlers in the north (no other data), and 10 km west-southwest of the Tarmoola mine in the southeast. The leucogranite near Tarmoola is coarse grained, except where partly to wholly recrystallized to fine grain size; it consists of K-feldspar, quartz, and muscovite, and has a strong, gently north dipping flattening foliation and downdip stretching lineation.

Monzogranite (*Agm*) outcrops extensively in the west, northwest, and southwest (all low-Ca group), and in the south (high-Ca group in the Union Jack Well area; no chemical data in the Redling Well area). It is fine, medium, or coarse grained, and equigranular to sparsely feldspar-phyric, with phenocrysts up to 3 cm long (usually K-feldspar, less commonly plagioclase, rarely quartz and biotite) making up about 2% of the rock. The rock is massive to foliated (in some places by flattening of quartz and feldspar, elsewhere by alignment of feldspar phenocrysts and biotite flakes), and in a few places has wispy bands defined by grain-size changes or biotite content. Rare xenoliths of amphibolite or biotite rock range up to 3 m in size. Pegmatite veins are common, but leucogranite, aplite, and quartz are less so. Essential minerals are K-feldspar, plagioclase, quartz, and biotite (2–7%) locally replaced by muscovite. Clots of possible cordierite are present at WILBAH MGA 033215. Aplite contains garnet in the Union Jack Well area in the south. The monzogranite 3 km west of Wildara Outstation has a fine-grained subvolcanic texture with equant plagioclase phenocrysts. Monzogranite at MOUNT ALEXANDER MGA 329392 intrudes gneiss that is possibly derived from the strongly foliated granitoid unit *Agn.* Alteration of monzogranite is uncommon. Monzogranite at and west of Mars Bore in the south has been dated at 2676 ± 7 Ma and 2648 ± 3 Ma (Cassidy et al., 2002), monzogranite near Red Well in the south has been dated at 2664 ± 8 Ma (Cassidy et al., 2002), and monzogranite at Wallaby Nob in the northwest has been dated at 2653 ± 3 Ma (Cassidy et al., 2002). In the Leonora area, deformed monzogranite at the Trump mine has been dated at 2760 ± 10 Ma (Cassidy et al., 2002), and undeformed monzogranite in the west wall of the Tower Hill pit has been dated at 2753 ± 6 Ma (Fletcher et al., 2001). These monzogranites, together with granitic gneiss dated at 2803 ± 8 Ma at Twin Hills to the south in MENZIES (Dunphy et al., 2003), are part of a granitic basement beneath the Eastern Goldfields Granite–Greenstone Terrane (Cassidy et al., 2002).

Several textural variants of monzogranite (all high-Ca group) have been mapped separately in parts of LEONORA. Fine-grained monzogranite (*Agmf*) has been mapped in the north, 10 km west of Wildara Outstation and at Good Friday Bore. Medium-grained monzogranite (*Agmm*) outcrops along the eastern edge of the sheet for several kilometres north and south of Stacks Well. Coarse-grained monzogranite (*Agmc*) forms a single outcrop 16 km north of Stacks Well in the northeast. Porphyritic monzogranite (*Agmp*) outcrops 13 km northwest of Wildara Outstation in the north; K-feldspar phenocrysts up to 2 cm long are aligned in a weak foliation, which also affects pegmatite veins.

Foliated granitoid with local layering and mafic lenses (*Agn*) is very abundant on LEONORA, and outcrops everywhere except in the northeast and east. Much of the granitoid is homogeneous, but in many places it grades into banded gneiss, or contains enclaves of banded gneiss and mafic rocks, and, locally, mafic schlieren. The granitoid ranges from granodiorite through monzogranite to (rare) syenogranite, is fine, medium, or coarse grained, and equigranular to sparsely porphyritic (with up to about 2% of feldspar phenocrysts, and, locally quartz phenocrysts), or seriate. It consists of anhedral quartz (up to 0.5 mm across), K-feldspar (up to 3 cm long), plagioclase, biotite (2–5%), muscovite, titanite, and opaque grains. It is generally strongly foliated and lineated, but locally massive; the fabric arises from alignment of biotite and K-feldspar megacrysts, and from flattening and elongation of quartz and feldspar. The unit is notably heterogeneous in the southwest, where monzogranite contains biotite-rich bands up to 15 cm thick and gneiss enclaves up to 3 m long, and in the west, where granodiorite contains patches and veins of monzogranite. Gneiss is well banded, with bands ranging from 1 mm to 2 m thick but most commonly 3–10 cm thick; the banding arises from differences in grain size, including fine-, medium-, and coarse-grained components, and in dark- and light-mineral proportions. Texture ranges from equigranular to sparsely porphyritic, with up to about 5% phenocrysts. The mineral assemblage is quartz, plagioclase, K-feldspar (locally as phenocrysts up to 13 cm long), biotite, hornblende, and rare muscovite and garnet. Some light layers are composed of quartz alone, or quartz–feldspar, and others are of monzogranite composition. Dark layers contain considerable biotite (up to 50%), or hornblende, the latter grading to amphibolite lenses up to 10 m long. The bands are commonly foliated, the foliation arising from alignment of biotite, hornblende, and K-feldspar phenocrysts, flattening of quartz and feldspar, and felsic segregations. The foliation generally parallels banding, but is oblique to it in some places. A stretching lineation is relatively rare. Locally, bands are isoclinally folded or boudinaged. Migmatite is present in the central part of the sheet (WILDARA MGA 592482, 589497). In addition to the gneiss and amphibolite enclaves, the granitoid also contains lenses and pods of diorite, pyroxenite, metadolerite, metagabbro, and biotite rock. Veins are abundant throughout the unit, and include aplite, pegmatite, leucogranite, microgranite, monzogranite, trondhjemite, diorite, quartz, and plagioclase rock. Some veins are folded, boudinaged, sheared, and foliated; others are massive and crosscut the host-rock foliation. Pegmatite segregations with diffuse margins are relatively rare.

Samples from the central strip of foliated and gneissic granitoid have been dated at 2687 ± 7 Ma (near Peters Bore in the central part of LEONORA), 2675 ± 3 Ma (near Blueys Well in the south), 2670 ± 4 Ma (near Mars Bore in the south), and older than 2652 ± 8 Ma (near New Well in the north; Cassidy et al., 2002). These granitoids contain inherited zircons ranging in age from 2810 to 2800 Ma (Cassidy et al., 2002).

Quartz-rich granitoid (*Agq*) forms a body about 200 m across at LEONORA MGA 208962 in the southeast. It is medium to coarse grained, equigranular to sparsely porphyritic, and is composed of feldspar phenocrysts (about 1%) up to 8 mm long, quartz, and biotite (2%) partly replaced by muscovite and chlorite.

Syenite (*Ags*) has been mapped in the southeast around Pig Bore on the Leonora–Nambi road, 7 km east of Linger and Die Well in the east, and 2 km west of Horse Rocks Rockhole in the north. The Pig Bore rock consists of medium- to coarse-grained euhedral phenocrysts of K-feldspar (15%) in a fine- to very fine grained groundmass of K-feldspar laths (50%) with magmatic flow alignment, oligoclase (28%), and iron oxide rhombs (7%). The rock near Linger and Die Well is coarse grained and contains 10–15% quartz. The syenite near Horse Rocks Rockhole is a stockwork of veins intruding granite at WILDARA MGA 747916, and a syenite–diorite mixture (epidotized) at WILDARA MGA 749901.

Tonalite (*Agt*; mafic group) outcrops around Lawlers in the north, and has commonly been called the Lawlers Tonalite. It is coarse grained, and comprises zoned plagioclase phenocrysts in a groundmass of feldspar, quartz, biotite (10%), and amphibole. Xenoliths are locally abundant, and leucogranite veins cut the tonalite at WILDARA MGA 567905. Fletcher et al. (1998) obtained a U–Pb zircon date of 2666 ± 3 Ma on the tonalite, and 2666 ± 7 Ma on leucogranite and monzogranite dykes cutting the tonalite. Porphyritic tonalite (*Agtp*) forms a small body next to the southern end of the Tower Hill pit in the southeast, and consists of coarse-grained, euhedral to round and embayed phenocrysts of quartz (10%), euhedral to subhedral andesine (20%), and titanite (1%) in a very fine grained groundmass of quartz (25%), andesine (25%), carbonate (10%), iron oxide (5%), chlorite

(3%; as aggregates with carbonate – iron oxide – muscovite–plagioclase — possibly pseudomorphous after hornblende), and rutile euhedra.

Syenogranite ranging to alkali-feldspar granite (*Agy*; high-HFSE group) has been mapped mainly in the east and northeast. It is medium to coarse grained (rarely fine grained), equigranular, massive to weakly foliated and lineated, and consists essentially of pink K-feldspar, quartz, white plagioclase, and biotite (1–2%), with or without muscovite (up to 1%). The syenogranite in the Teutonic Bore area has been dated at 2693 ± 3 Ma (Fletcher et al., 2001), and near Kent Well in the northeast at 2686 ± 7 Ma (Cassidy et al., 2002). Chlorite veins with pyrite euhedra cut the granite at WEEBO MGA 114721.

MINOR INTRUSIONS, BRECCIAS, AND IRONSTONE (*chx*, *d*, *g*, *gg*, *gqx*, *i*, *po*, *q*, *sy*)

Many outcrops of these rocks are too small to show at 1:250 000 scale.

Chert breccia ridges (*chx*) outcrop just to the south of Mount Newman in the eastern part of LEONORA. The rock is massive, and consists of angular clasts, 5–20 cm across, of colourless chert, chalcedony, or jasper in a very fine grained goethite cement. The breccia at LEONORA MGA 119442 encloses masses of yellow clay rock a few square metres in extent.

Dolerite dykes (*d*) intrude tonalite 3 km north of Lawlers and felsic volcanic rocks 1.5 km southeast of Leonora township, and dykes or sills are interlayered with basalt in the Mount Alexander area in the southwest*. The dyke at Lawlers is medium grained, massive, and composed of actinolite and plagioclase.

Granite dykes (*g*) have been mapped 13 km southeast of Lawlers in the north, and 9 km west of the Tarmoola mine in the east; many more are shown on LEONORA (1:100 000). Most are porphyritic micrograniteS, commonly massive, with fine- to coarse-grained phenocrysts in a very fine grained groundmass, and are up to 6 m wide. The dyke west of Tarmoola, however, is a porphyritic granite up to 100 m wide and 1.2 km long. Major minerals present, both as phenocrysts and groundmass, are quartz (generally round, but locally as bipyramidal ß-quartz), K-feldspar, and biotite; plagioclase, chlorite, iron oxide, and pyrite are rare. The dykes grade into microtonalite as the amount of K-feldspar decreases and the amount of plagioclase increases.

Granodiorite and microgranodiorite dykes (*gg*) outcrop 5 km southwest of Mount Newman and 5 km north-northwest of Mount Stirling; numerous others are present around Victory Corner Well. The dykes are 1–25 m wide, massive to foliated (generally only at the margins), and equigranular to porphyritic, with fine- to coarse-grained phenocrysts in a very fine grained groundmass. The mineral assemblage consists of: sparse circular to ovoid phenocrysts or elongate recrystallized mosaic grains of quartz; abundant subhedral to euhedral phenocrysts of sericitized andesine; microcline; and small phenocrysts of biotite; in a groundmass of the same minerals. Prisms and stellate clusters of hornblende are present in some rocks. Small mafic xenoliths are present at some localities. Many of the dykes are actually microdiorites, containing 1–7% quartz.

Goethite–quartz breccia (*gqx*) forms a single body, 1.5 km long and about 120 m wide, located 2.5 km south of Mount Newman. The breccia is massive, dips north at about 75°, and consists of fine- to coarse-grained angular clasts of vein quartz in a cement of hematite

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* The dolerite dyke shown at LEONORA MGA 098350 is a labelling error; it is a diorite dyke.

and goethite. The breccia encloses two elongate masses of ironstone about 200 m long and 500 m apart, and appears to be a fault fill.

Ironstone (*i*) forms several outcrops surrounded by colluvium in the area extending east and south of Mount Newman for about 3 km, and another outcrop is associated with high-Mg basalt 3 km northeast of Mount Stirling. Additional outcrops in the Mount Newman area at LEONORA MGA 130461, 145427, 184399, and 190394 are too small to show at 1:250 000 scale. The rock is very fine grained to (rarely) fine or medium grained, hard, massive, smooth to hackly, porous to compact (in places composed of adjoining centimetre-size patches or anastomosing sheets of alternately porous and compact rock), with an irregular cellular or, less commonly, botryoidal texture. It is composed largely of hematite, with small amounts (a few percent) of quartz as small botryoidal growths and as sparse sedimentary grains at one locality (LEONORA MGA 184399), clay, and goethite replacive after hematite (also at only one locality). Anastomosing veinlets of recrystallized quartz cut the body at LEONORA MGA 133446. The bodies are 3–20 m thick. The ironstone body at LEONORA MGA 130461 cuts across bedding in the shale–chert–sandstone ridge forming Mount Newman itself, and hence appears to have been introduced into a fault. In the body of goethite–quartz breccia (*gqx* — see above), the western body of enclosed ironstone (LEONORA MGA 120441) has a gossan-like appearance and the eastern body (LEONORA MGA 126437) is elongate and strikes obliquely to the trend of the goethite–quartz breccia, so they also appear to be of fault-fill origin. The other ironstone bodies in the area show evidence consistent with replacement of sedimentary rocks, as follows:

- Several elongate ironstone bodies adjoin and strike parallel to chert ridges, for example at LEONORA MGA 154448 and 190392 — the latter preserves the same dip as the neighbouring chert.
- Ironstone at LEONORA MGA 184999 is enclosed in sandstone and contains sedimentary quartz grains.
- Ironstone at LEONORA MGA 130443 is described as 'weathered and ferruginized sedimentary rock' (OZROX Database, Geoscience Australia).

In summary, some of the ironstone bodies appear to have formed by introduction of iron oxide into fault openings, followed by migration of the iron oxide into adjacent sedimentary rocks. Others may be weathered (lateritized) sedimentary rocks.

Porphyry dykes (*po*) are abundant in the Garden Well area in the northeast, where they intrude granitoid, and 8 km west-northwest of Mount Newman, where they intrude basalt. Others are too small to map at 1:250 000 scale. The rocks are granitic, with phenocrysts (20–40% of the rock) of quartz, euhedral to subhedral feldspar aligned parallel to dyke margins, and amphibole (5–10%), in a very fine grained groundmass. A deformed porphyry dyke at the Tower Hill mine has been dated at 2670 ± 5 Ma (Dunphy et al., 2003), and one at the Tarmoola mine at 2667 ± 8 Ma (Fletcher et al., 2001). A quartz porphyry dyke in the eastern part of the Mount Ida greenstone belt has a SHRIMP U–Pb zircon date of 2700 ± 9 Ma (Nelson, 2002).

Quartz veins (*q*) are found throughout LEONORA. The largest vein strikes northerly over a distance of 47 km from Arlidges Well in the south to Peters Bore in the centre of the sheet area, and marks the Ballard Shear. Quartz veins are also abundant in the Depot Spring – Skippy Bore area in the west and southwest, and near Five Mile Well in the northwest. The veins are normally coarse grained, but fine or medium grained where recrystallized, such as along the Ballard Shear, where the quartz is faulted and fractured, and foliated on the western side of the vein at WILBAH MGA 573986. Accessory minerals in the veins are magnetite and pyrite.

Syenite dykes (*sy*) have been mapped 3 km north-northwest of Boiler Well in the southeast, and others, too small to show at 1:250 000 scale, outcrop at LEONORA MGA 452174 (2.5 km northwest of Pig Bore) and LEONORA MGA 478139 (2 km southeast of Pig Bore). The Boiler Well dyke is exposed for 1.5 km and coincides with a major, easterly striking linear magnetic anomaly typical of Proterozoic dykes in the Yilgarn Craton. The anomaly extends for 35 km east of Boiler Well, and coincides with an easterly striking tonalite dyke at LEONORA MGA 447060. The rock near Boiler Well is fine to medium grained and equigranular; the other dykes are about 1 m wide and a few tens of metres long, and are porphyritic microsyenites. They consist of subhedral to euhedral, randomly oriented to aligned, 1-cm K-feldspar phenocrysts, making up to 35% of the rock, in a fine- or very fine grained groundmass of K-feldspar, with small amounts of mica, plagioclase (up to 5%), and opaque grains. Brown garnet is present in the Boiler Well rock. None of the dykes are foliated.

FELSIC AND MAFIC DYKES (*Ędi*, *Ędy*)

Felsic and mafic dykes on LEONORA are members of a widespread swarm of basic, ultrabasic, intermediate, and silicic dykes that intruded the Yilgarn Craton in the late Archaean (Nelson, 1998, p. 41–47) or early Proterozoic (Fletcher et al., 1987), or both.

Felsic rocks (*Ędi*) make up much of the King of the Hills dyke, which outcrops for 60 km from 2 km east of Sturt Meadows in the southeastern part of LEONORA to 2 km southwest of East Terrace on LAVERTON; aeromagnetic data indicate that the dyke continues for at least another 11 km to the east and 10 km to the west. The dyke is massive, compound, and heterogeneous, and contains abundant felsic xenoliths. It comprises felsic rocks bordered by mafic rocks in the western half (west of Linger and Die Well) and mafic rocks in the eastern half. The felsic rocks range from diorite through tonalite and monzogranite to syenite; they are equigranular and fine or medium grained, or coarsely feldspar-phyric with a fine- to very fine grained groundmass. The mineral assemblage is essentially anhedral K-feldspar, laths of plagioclase (andesine), and quartz* as sparse grains, resorbed phenocrysts, or as thin randomly oriented plates mantled by micrographic intergrowth of quartz and K-feldspar. Other minerals, not present everywhere, are clinopyroxene (up to 5%), green or blue-green amphibole needles (up to 7%), biotite, opaque grains, titanite (up to 5%), iron oxide, epidote, chlorite, muscovite, and calcite. Xenoliths range from 40 cm across to single xenocrysts, are angular and commonly concave (indicating magmatic corrosion), equant to elongate, and are composed of vein quartz, granite, and aplite.

Mafic dykes (*Ędy*) are numerous in the southern half of LEONORA, and are also present in the View Hill area in the west, 2 km north of White Cloud Well in the northwest, and 10 km south of Lawlers in the north. Most exposures are massive and equigranular, with grain size ranging from very fine to coarse. They consist essentially of: plagioclase (labradorite to sodic bytownite; 50–65%); clinopyroxene (5–30%); a feldspathic mesostasis (15–20%) comprising laths or microcrystalline aggregates of plagioclase(–opaque grains–calcite); iron oxide (3–5%; probably magnetite); and pseudomorphous chlorite (3–8%) and calcite (1–2%) after ferromagnesian grains. Minerals present in some samples include round to subhedral olivine (up to 15%) altered to serpentine along cracks, biotite (1%), and chalcopyrite. Part of the King of the Hills dyke at LEONORA MGA 120276 is a breccia, and comprises clasts of microdolerite and orthopyroxene-phyric basalt in a groundmass of clinopyroxene, orthopyroxene, plagioclase, and opaque grains.

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* It is possible that all the quartz in these rocks is xenocrystic; if so, the 'tonalite' and 'monzogranite' variants would be of contamination origin.

STRUCTURE

MAJOR FAULTS

The major faults on Leonora are: the northerly trending Waroonga Shear Zone and Ballard Shear (mistakenly labelled Ida Lineament on the cross section below the 1:250 000-scale map); the north-northwesterly striking Perseverance Fault, Mount George Shear Zone, and Yilgangi Fault; and the arcuate Sons of Gwalia Shear Zone (Fig. 2). Swager (1997) and Etheridge et al. (2001) suggested that the north-northwesterly striking faults began as normal faults that shaped and bounded greenstone sequences during east–west extension. Blewett et al. (2002) suggested that they began as transfer structures that accommodated north–south extension, and were later reactivated and inverted.

The steeply dipping Waroonga Shear Zone has been traced for some 4 km on the ground in the Five Mile Well area west of Agnew, and a prominent aeromagnetic lineament continues south and then southeast from there into the northwestern part of the Wilbah 1:100 000 sheet (Liu et al., 2000; Blewett, 2001; Whitaker and Bastrakova, 2002). Platt et al. (1978) showed that the Waroonga Shear Zone underwent dextral strike-slip during D_2. The near-vertical Ballard Shear is represented by major north-striking quartz veins in the northwestern and southwestern parts of Wilbah (1:100 000), and continues south onto Menzies on the eastern side of the Mount Ida greenstone belt. Major movement on the Ballard Shear may have been sinistral strike-slip during D_3, followed by dextral movement late in D_4 (Rattenbury, 1999). Gravity and magnetic modelling by Blewett et al. (2002) indicate that the Waroonga Shear Zone is listric, with a steep west dip at the surface and a flat dip at about 10 km depth, and that it transects the Ballard Shear, which dips steeply east to about 15 km depth.

The Perseverance Fault has been mapped for some 5 km on the ground in the northern part of Wildara (1:100 000) and continues to the southeast as a distinct aeromagnetic lineament to the Mount Clifford mining centre. The fault continues north onto Sir Samuel and Wiluna. Evidence from Mount Keith (1:100 000) shows that D_3 strike-slip movements near the fault were dextral in some areas and sinistral in others (Jagodzinski et al., 1999).

The Mount George Shear Zone is a several-hundred-metre thickness of cleaved, fine-grained clastic sedimentary rocks, chert, and small amounts of conglomerate, and is more strongly deformed than mafic volcanic rocks on either side. It is an en echelon continuation of the Perseverance Fault, and the two together form the eastern boundary of the Kalgoorlie Terrane of Kojan et al. (1996). Williams et al. (1989) regarded the Mount George Shear Zone as a major tectonic break, and presented evidence (asymmetric quartz fabrics and cleavage-bedding intersections) for D_3 sinistral shear followed by dextral movement along the shear zone. Passchier (1990) disagreed, and concluded that the Mount George Shear Zone is a D_1 shear zone and terrane boundary, with a ‘major component of east-directed normal movement’ (extension), and was folded and reactivated in D_2 when it became the eastern limb of a D_2 antiform. Blewett et al. (2002) interpreted the Mount George Shear Zone as listric, dipping moderately to gently east, and flattening at about 17 km depth (or possibly continuing to the Moho at about 40 km — Goleby, 2002).

The Sons of Gwalia Shear Zone is the moderately dipping arcuate fault in the southeastern part of Leonora that forms the southern margin of the Mount Clifford greenstone belt. It dips to the east in the Leonora area, to the northeast in the Jasper Flat mine area, and to the north-northwest in the Mount Ross area. Sense of shear is extensional — top-to-east, northeast, or north in those areas, respectively (Skwarnecki, 1987; Passchier, 1994; Williams, 1998). A SHRIMP U–Pb zircon date of 2760 ± 3 Ma on foliated granite in the shear zone at the Trump mine, and one of 2753 ± 6 Ma on massive monzogranite at the

Tower Hill mine, show that the Sons of Gwalia Shear Zone formed at about 2755 Ma (Witt et al., 2002).

Keith–Kilkenny Fault Zone and Keith–Kilkenny High-Strain Zone

I. R. Williams (1974) recognized the Keith–Kilkenny Lineament for some 500 km in the Yilgarn Craton, and Hallberg (1985) introduced the broader concept of the Keith–Kilkenny Tectonic Zone on LEONORA, LAVERTON, and EDJUDINA. Subsequently, P. R. Williams (1998) defined the Keith–Kilkenny High-Strain Zone on LEONORA (1:100 000) as the north-northwesterly striking zone, 5–7 km wide, bound on the west by a major geological break at the eastern foot of the Mount George ridge and on the east by the Kilkenny Fault, parallel to, but about 5 km west of, the western bounding fault of the Pig Well Graben. P. R. Williams' Kilkenny Fault is not visible on the 400-m line spacing aeromagnetic data obtained by AGSO (now Geoscience Australia) in 1993; on the contrary, if it were present, it would continue through, instead of truncating, well-defined trends in the magnetic data. The western margin of the Keith–Kilkenny High-Strain Zone south of Leonora township is similarly unsupported by the magnetic data. The Keith–Kilkenny Fault Zone defined by Chen (1998, 1999) on EDJUDINA continues onto LAVERTON and LEONORA as the Yilgangi Fault and Pig Well Graben, and bears no relation to the Keith–Kilkenny High-Strain Zone of Williams (1998) — the two zones are offset along the LEONORA–LAVERTON join by about 12 km. The Yilgangi Fault on LEONORA terminates northwards in the Pinnacle Well area, and the Keith–Kilkenny Fault Zone continues from there to the north-northwest in an en echelon fashion as the Perseverance Fault. Blewett et al. (2002) interpreted the Keith–Kilkenny Fault Zone as dipping 35–40°E and relatively planar compared to the listric faults described above.

DEFORMATION SEQUENCE

Swager (1997) tabulated a deformation sequence for the Eastern Goldfields, which involved four episodes of shortening, preceded and separated by two discrete episodes of extension (Hammond and Nisbet, 1992; Williams, 1993; Passchier, 1994). Witt et al. (2002) recognized deformed greenstone and granitoid at the Leonora gold camp as part of an older, basement complex. Using these schemes as a basis, the deformation history of LEONORA is shown in Table 1.

D_{E1} structures on LEONORA are recognized only in the southeast, and have been described and studied in detail by Skwarnecki (1987; designated therein as D_1), Williams et al. (1989; D_1), VanderHor and Witt (1992; D_1), Williams and Currie (1993; D_1), Passchier (1992, 1994; D_1), Williams (1998; D_e), and Witt et al. (2002; D_E). The largest of these structures is the Sons of Gwalia Shear Zone, located along the arcuate granite–greenstone contact that outcrops from the Sons of Gwalia mine to the Mount Ross area. The shear zone dips moderately steeply east at the mine, and has an east-side-down sense of shear. In the Gold Blocks mine area, the zone dips northeast and has northeast-side-down movement; in the Jasper Flat mine area the dip is gently north with north-side-down movement; and in the Mount Ross area, the zone dips north-northwest and has north-side-down movement. The overall radial movement of greenstone off the underlying granitoid implies a rising core complex (Williams and Currie, 1993) or massive intrusion of granitoids (Passchier, 1994). Dating in the Leonora gold camp by Cassidy et al. (2002) and Fletcher et al. (2001) shows that the Sons of Gwalia Shear Zone formed at about 2755 Ma (Witt et al., 2002). The shearing formed amphibole-bearing millimetre-scale banding in greenstones at the camp.

D_{1a} and D_{1b} structures (summarized from Witt et al., 2002) are known only at the Leonora gold camp in the greenstones deformed by the Sons of Gwalia Shear Zone. D_{1a} produced a

Table 1. Regional deformation history of LEONORA

Age (Ma)	*Event*	*Regional deformation history and structures*	*Examples on LEONORA*
<2760[a], >2755[b]			Granitoid emplacement into greenstone at Leonora gold camp (Gwalia domain[b])
~2755[b]	D_{E1}	Extension: low- to moderate-angle shearing	Sons of Gwalia Shear Zone
	D_{1a}[b]	Shortening, east–west directed[b]	Foliation, recumbent folds in greenstone at Leonora gold camp
	D_{1b}[b]	Shortening, north–south directed[b]	Transposition of foliation, intersection lineation at Leonora gold camp
<2675[d]	D_1[c]	Shortening: north–south directed; tight to isoclinal inclined folds	Mount Fouracre Syncline, north-dipping foliation at Agnew Bluff and Mount Newman, Mount Malcolm Shear Zone? S_1 in tonalite at Lawlers
	D_{E2}	Extension: grabens in southeast and north	Grabens at Pig Well and Moses Well; trough with Jones Creek Conglomerate at Agnew; Yilgangi Fault
<2670[e]	D_2	Shortening: east–west directed; upright northerly to north-northwesterly trending major folds and steep foliation; strike-slip faulting begins	Lawlers Anticline, Hangover Syncline, Waroonga Shear Zone
<2665[f], >2653[g]	D_3, D_4	Continued shortening: east- or southeast-directed; strike-slip faults	Ida Fault, Waroonga Shear Zone, Perseverance Fault, Mount George Shear Zone, Ballard Shear

SOURCE: (a) Cassidy et al. (2002)
(b) Witt et al. (2002)
(c) Swager (1997)
(d) Age of felsic volcanic rocks cut by S_1 (Swager, 1997)
(e) Age of foliated granite in Mars Bore area (Cassidy et al., 2002)
(f) Overall age of granites affected by D_3 (Blewett et al., 2002)
(g) Age of massive monzogranite at Wallaby Knob (Cassidy et al., 2002)

foliation 'isoclinally folded with greenstone layering', and D_{1b} produced a 'layer-parallel foliation which is axial-plane to tight to isoclinal folds'. The gold at the Leonora camp was introduced during D_{1a} (Witt et al., 2002). D_{1b} may be equivalent to D_1 of Swager (1997).

D_1 structures on LEONORA are rare. The large isoclinal, east-trending fold at Mount Fouracre has a steep, north-dipping foliation parallel to its axial plane, and so the fold is assigned to D_1. The fold has commonly been regarded as an antiformal anticline, but sedimentary facings in shale and sandstone of the north-dipping southern limb (LEONORA MGA 094440) are upright, indicating that the fold is a syncline, and a plot of poles to bedding around the fold (Stewart, A. J., 2003, unpublished data) yields a fold axis plunging 23° to 073°, which indicates a synform. Other examples are the top-side-north Mount Malcolm Shear Zone in the southeast (Williams et al., 1989; Passchier, 1994), and possibly a gently north dipping foliation cut by steep S_2 cleavage at Mount Newman (Passchier, 1994). At Agnew Bluff in the north of the sheet, interlayered mafic sills and volcanic rocks display a north-dipping, layer-parallel S_1 foliation, which is represented by axial-planar to isoclinal intrafolial folds in sedimentary rocks (Platt, 1980). The layered rocks are folded into a north-plunging D_2 anticline accompanied by a moderate to steep axial-plane S_2 foliation. Tonalite at Lawlers, about 5 km south of Agnew Bluff, intrudes the layered rocks, and has a gently north dipping foliation, which was assigned to S_1 by Platt et al. (1978). Eisenlohr (1987) disagreed, stating that the tonalite foliation is not deformed by any S_2 foliation, although Platt et al. (1978, fig. 14) showed S_1 in tonalite crenulated by S_2, and that tonalite S_1 was confined to the contact or roof zone of the tonalite. If S_1 in the tonalite is the regional S_1, D_1 must be younger than the c. 2666 Ma age of the tonalite (Fletcher et al., 1998).

D_{E2} structures are represented by the conglomerate- and sandstone-filled troughs and grabens at Pig Well and Moses Well in the southeast, and 3 km west of Agnew in the northwest. The clastic rocks are deformed by the regional north-northwesterly striking S_2 foliation, and so are pre- or early-D_2.

The main D_2 deformation formed several north-northwesterly trending upright major anticlines and synclines accompanied by a steep penetrative axial-plane S_2 foliation. The largest is the Lawlers Anticline in the north, plunging north at about 45°. Smaller D_2 folds include the Hangover Syncline and the syncline at Wildara mining centre in the northeast, and the tight to isoclinal overturned anticline near Braemore in the southeast. The two areas of Mount Ida greenstone belt in the southwest are the opposite limbs of a major south-southeasterly plunging anticline. The Waroonga Shear Zone was initiated at this time.

D_3 and D_4 deformation on LEONORA involved chiefly strike-slip movements on major faults and lineaments. Most movements were sinistral (e.g. Mount George Shear Zone, Perseverance Fault) but dextral movement took place along the Waroonga Shear Zone and Ballard Shear.

METAMORPHISM

Figure 3 is a map of metamorphic facies on LEONORA compiled from Hallberg (1985) in the southeastern part of the sheet, from Ahmat (1986) along the southwestern edge, and from Binns et al. (1976) elsewhere. Regional metamorphic facies ranges from prehnite–pumpellyite, through greenschist, to amphibolite. In the prehnite–pumpellyite facies, original rock textures are well preserved, and penetrative deformation is weak to absent (static style of Binns et al., 1976). The amphibolite facies is relatively more strongly deformed, and metamorphism was dynamic in style (Binns et al., 1976). Metamorphism took place during and after D_2–D_3 deformation (Ahmat, 1986).

The prehnite–pumpellyite facies occupies a large, north-trending, elongate area in the Yandal greenstone belt in the northeast, and a smaller area in the southeast (Fig. 3).

Greenschist-facies rocks are the most extensive in the area, and make up most of the Mount Clifford, Yandal, and Malcolm greenstone belts in the eastern part of the sheet (Binns et al., 1976), and the Maynard Hills greenstone belt in the southwest (Ahmat, 1986). In the southeast, extensive metasomatic carbonate, quartz–carbonate, and quartz–andalusite–chloritoid were introduced into several areas in the greenschist facies (Fig. 3; Hallberg, 1985).

Amphibolite-facies rocks are most abundant in the northern and southwestern parts of LEONORA, where they form moderately elongate areas — the Agnew and Mount Ida greenstone belts — in or near granitoid masses. Binns et al. (1976) depicted the greenstones of the Mount Ida belt as upper amphibolite facies in the west, and lower amphibolite facies in the east — the boundary foreshadowing the western boundary of the Kalgoorlie Terrane of Swager et al. (1992). Small areas of partial melt in amphibolite indicate upper amphibolite facies at WILBAH MGA 668014 and LEONORA MGA 111238.

CAINOZOIC GEOLOGY

Cainozoic sedimentary rocks cover large parts of LEONORA. Two branches of a major palaeochannel — the southeast-draining Raeside Palaeoriver (van de Graaff et al., 1977) — cross the sheet from west to east, and are now filled with playa-lake and associated deposits. They are the descendants of a Mesozoic to Cainozoic southeast-directed drainage system (van de Graaff et al., 1977).

Deposits formed in place are:

- Silcrete (*Czz*) and silcrete or silicified kaolinized granitoid (*Czzg*) as horizontal cappings and breakaways over kaolinized granitoid in the east (West Terrace area). Silcrete is about 2 m thick, massive, poorly sorted, and consists of fine to coarse, angular quartz grains in a very fine grained cement of silica and a small amount of iron oxide. Vein quartz pebbles are abundant in places (LEONORA MGA 458176 and 480166), and these rocks appear to be silcreted colluvial gravel.
- Yellow-brown silcrete (‘silica cap rock’; *Czu*) on ultramafic rock in the Fairyland mine and Marshall Pool prospect areas in the north, around the Mount Clifford mining centre in the east, and near Kurrajong and the Jasper Flat mine area in the southeast. Grain size ranges from very fine to medium, and relict foliation and lineation are commonly preserved.
- Calcrete (*Czk*) in the northwest and northeast corners of the sheet area.

Transported deposits include:

- Proximal colluvial deposits, which are: unsorted gravel (*Czc*) mantling hills and rises of greenstone and, to a lesser extent, granitoid, composed of angular to subrounded boulders (nearest the source), cobbles, and pebbles (farthest from source), mainly of vein quartz and ironstone with smaller amounts of chert and basalt, in a sandy loam matrix; ironstone pebble and cobble gravel (*Czf*) derived from laterite; aprons of colluvial quartz–feldspar sand and gravel (*Czg*) with some ground-level exposures of granitoid; talus (*Czi*) derived from BIF in the far southwest; and quartz talus (*Czq*) adjacent to quartz veins.
- Distal lithified colluvium (*Cza*) composed of sand, silt, clay, and sparse pebbles, forming plains that extend for up to 15 km from granite and greenstone exposures. A creek-bank section at Little Peters Well in the east exposes 0.8 m of yellow, clay-rich silty and sandy mudstone with 5-cm thick gravel layers, overlain with a low-angle unconformity by 0.2 m of red-brown porous gravel containing angular pebbles of quartz, ferricrete, and chert. Flat-lying feldspathic sandstone (*Ts*) in the Bottle Well – Cork Well area in the north is 3–4 m thick, medium grained, medium to thick bedded, well sorted, porous, with subrounded to well-rounded grains; it may be an old colluvial deposit.
- Alluvial gravel, sand, silt, and clay (*Qa*) in channels formed by streams flowing from granitoid and greenstone areas out onto the surrounding plains. Claypans (*Qac*) have formed at several places in the southeast; the largest are along Station Creek.

- Sheets of sand (*Czs*) with dunes in some places occupy much of the flat country between granitoid outcrops, and were formed by eolian reworking of the colluvial plains (*Cza*; cf. Mabbutt, 1977, p. 215).

- Lacustrine deposits fill the palaeochannels in the northwest, centre, and southern half of the sheet area. The deposits include: extensive red-brown quartz and white gypsum dunes (*Czd*) forming most of the palaeochannel fill; playa-lake evaporites, sand, and clay (*Czp*) within the *Czd* areas; clay flats with subordinate quartz sand dunes (*Czb*) in the southeast; and a small area of silt, sand, and gravel with halophyte plant cover (*Czh*) near Cutmore Well in the southeast. Small playas away from the palaeochannels have formed in the Rainbow Well area in the northeast.

Lateritic duricrust (*Czl*), or ferruginous duricrust of Anand and Paine (2002), is a mixture of transported and residual deposits. The duricrust forms breakaways, mesas, and rises on greenstone, particularly in the north and east, and is generally about 1 m thick, but ranges up to 3 m in thickness. There are four varieties:

1. Residual pisolitic lateritic duricrust (Anand and Paine, 2002) is composed of millimetre- to centimetre-size single or coalesced pisoliths of iron oxides/hydroxides, with cuspate, clay-lined vugs between the pisoliths. Cutans, which are yellow bleached rinds on the pisoliths, are common.

2. Pisolitic-nodular ferricrete (Anand and Paine, 2002) is composed of clasts in the form of single or coalesced pisoliths (as in pisolitic lateritic duricrust), fragments of saprolite with coatings of concentrically layered iron oxides/hydroxides, angular fragments of broken pisoliths, and lumps and balls of structureless aphanitic black iron oxide (with cutans), in a matrix or cement of red or brown iron oxide with rare angular quartz grains, or of pisolitic to colloform goethite; irregular to cuspate, clay-lined vugs are common. It is formed by transport and cementation. It commonly overlies the pisolitic lateritic duricrust, but at the Victory No. 1 mine, pisolitic-nodular ferricrete is underlain and overlain by pisolitic lateritic duricrust (Davy and Gozzard, 1994, fig. 39). Subvariants of pisolitic-nodular ferricrete comprise:

    - clasts of hard, black iron oxide, claystone, and clay – iron oxide – quartz grain aggregates cemented by black iron oxide/hydroxide with quartz-lined vugs;

    - clasts and pisoliths of black aphanitic iron oxide in a pisolitic to colloform iron oxide/hydroxide cement.

3. Conglomeratic ferricrete (Anand and Paine, 2002) is rarely exposed. It is up to 0.5 m thick, and consists of unsorted angular quartz grains and granules together with chert pebbles in a porous matrix or cement of friable iron oxides/hydroxides or clay. The conglomerate underlies the pisolitic lateritic duricrust.

4. Vermiform lateritic duricrust (Anand and Paine, 2002) underlies conglomeratic ferricrete, and is composed of hard, dark brown to black iron oxide penetrated by irregular tubes 0.5–1 cm in diameter filled with clay and fine quartz grains. The walls of the tubes are bleached yellow, and some tubes are lined with quartz.

ECONOMIC GEOLOGY

LEONORA includes parts of the East Murchison, North Coolgardie, and Mount Margaret Goldfields. Gold is the most important commodity in the area, and has been mined from about 200 deposits, most of it from the world-class deposit at Sons of Gwalia.

Other commodities in the area include nickel, copper, lead, zinc, silver, uranium, and chrysoprase. Table 2 summarizes production statistics for the major mineral deposits in the area.

GOLD AND SILVER

Gold production to December 1998 was 266 t (Table 2). Thom and Barnes (1977) recorded 5.916 t of silver to 1973, and Teutonic Bore produced 255.5 t of silver to 1985 (Table 2). Where relevant, the major gold deposits are grouped into camps following Hagemann and Cassidy (2001), and are briefly described in order of production or resource (with source references after the titles).

Table 2. Mineral commodity statistics for LEONORA from the Geoscience Australia OZMIN database

Name	*Map sheet (1:100 000)*	*Locality (MGA)*[a]	*Status*	*Production (t)*	*To date*	*Remaining resources*[b] *(t)*	*Grade (g/t)*[c]
Gold							
Agnew[d]	WILDARA	546994	Operating	49.344	Dec 1998	17 800 000	4.36
Bannockburn	WILDARA	937502	Historic	8.594	Dec 1997	7 445 000	2.50
Harbour Lights	LEONORA	364048	Historic	12.348	1996	527 200	8.77
Jasper Hill	LEONORA	265176	Deposit	–	1989	1 400 000	2.50
Lawlers[e]	WILDARA	582916	Operating	22.630	Dec 1998	4 285 300	4.32
Raeside[f]	LEONORA	453991	Deposit	–	–	4 114 000	1.48
Redeemer	MUNJEROO	528933	Operating	24.181	Jun 1996	na	–
Sons of Gwalia	LEONORA	375000	Operating	123.244	Dec 1998	16 870 000	2.28
Tarmoola	LEONORA	205271	Operating	19.177	Dec 1998	57 724 000	1.58
Thunderbox[g]	WILDARA	042800	Operating	0.018	Nov 2002	11 000 000	2.5
Tower Hill	LEONORA	364022	Historic	6.597	Jun 1992	1 715 000	2.12
Nickel							
Weebo Bore	WILDARA	859952	Deposit	–	–	12 000 000	0.70%
Copper							
Teutonic Bore	WEEBO	186561	Historic	55 200	1985	620 000	3.33%
Lead							
Teutonic Bore	WEEBO	186561	Historic	–	–	2 510 000	0.80%
Zinc							
Teutonic Bore	WEEBO	186561	Historic	175 000	1985	620 000	11.27%
Silver							
Teutonic Bore	WEEBO	186561	Historic	255.5	1985	620 000	108.00
Uranium							
Lake Raeside	WILBAH	705136	Deposit	–	–	6 800 000	0.03%

NOTES:
(a) Localities are specified by the Map Grid Australia (MGA) standard six-figure reference system whereby the six figures (three eastings and three northings) define position to within 100 m on the specified 1:100 000 sheet
(b) At date noted in 'To date' column
(c) Except where otherwise indicated. Refers to remaining resources
(d) Emu
(e) Great Eastern
(f) Michaelangelo, Krang, Forgotten Four
(g) Company announcement to Australian Stock Exchange by Dalrymple Resources NL <www.dalrymple.com.au>
na: not available

Leonora Gold Camp

Sons of Gwalia (Kalnejais, 1990; Skwarnecki, 1990; Ho et al., 1990; Coates, 1993)

The Sons of Gwalia* deposit was discovered in 1896. It is located about 200 m west of the dextral Mount George Shear Zone in the east-side-down extensional Sons of Gwalia Shear Zone. The deposit is in a sequence of ultramafic rocks, high-Mg basalt with pillows, minor dolerite and interflow sedimentary rocks, and quartz–muscovite schist (after felsic volcanic rocks). Mineralization is associated with sulfides in sheared and altered basalt (mylonitic chlorite–muscovite schist) adjoining isoclinally folded and foliation-parallel quartz–carbonate veins. Alteration took place after greenschist-facies metamorphism, and introduced CO_2 and K, forming chlorite–sericite(–fuchsite–biotite–albite) schist and the quartz–carbonate veins. Pyrite is the most abundant sulfide, and is accompanied by traces of chalcopyrite, arsenopyrite, pyrrhotite, gersdorffite, and galena; scheelite is also common. The gold is free, attached to sulfides or as blebs in pyrite. Mineralization was contemporaneous with extensional D_{E1} shearing along the lower and upper contacts of the basalt unit, and the lodes were subsequently folded and then dextrally sheared along the Mount George Shear Zone.

Harbour Lights (Dudley et al., 1990; Skwarnecki, 1988)

The Harbour Lights deposit was discovered in 1896, about the same time as Sons of Gwalia 5 km to the south. The deposit is in an east-facing sequence of amphibolite (local and discontinuous), overlain by sheared komatiite (talc-chlorite schist) and high-Mg basalt with thin slate horizons. The sequence is intruded to the west by granitoid. Metamorphic facies in the greenstones is mid- to upper greenschist, with widespread retrogression along shear zones. Gold is present in east-side-down (extensional) shear zones with a steep stretching lineation in altered high-Mg basalt and talc–chlorite schist. Alteration of the schist produced chlorite–biotite–quartz–ankerite–magnesite or fuchsite–chlorite–quartz–ankerite; alteration of the basalt formed chlorite–albite–quartz–calcite–ankerite. The gold forms as inclusions in and around grains of arsenopyrite (pseudomorphous after pyrite) in the altered rocks, and rarely as isolated grains in pyrite and quartz–carbonate veinlets. The ore forms as shoots, some with a steep plunge parallel to the steep lineation, others with a shallow plunge. Deformation and alteration were contemporaneous, and post-dated peak metamorphism. Arsenopyrite layers are folded by, and hence pre-date, northerly trending upright folds (D_2), but arsenopyrite grains are undeformed, and so mineralization occurred late in the alteration. Vearncombe (1992) showed that the gold mineralization was related to D_1 quartz veins oriented parallel to the northeasterly to easterly dipping D_1 cleavage, and confirmed that both veins and cleavage were deformed by steeply dipping D_2 extensional shear bands.

Tower Hill (Schiller and Hanna, 1990; Witt, 2001)

The Tower Hill leases were taken up early in 1897. The deposit is located in east-dipping ultramafic schist next to and within 100 m of monzogranite, in the east-side-down extensional Sons of Gwalia Shear Zone. The schist is composed of chlorite, talc, carbonate, biotite, muscovite, and fuchsite in different proportions from place to place; in composition it is a pyroxenite with high concentrations of K, CO_2, and H_2O. The monzogranite is altered next to the ultramafic rock, and contains patchy gold. Subparallel bifurcating quartz veins in the ultramafic schist strike north-northwest, dip 45°E, and form a system 600 × 150 m in extent. The veins are parallel to schistosity, and consist of quartz, minor carbonate and

* Gwalia — the old name for Wales, whence came many of the early miners at the mine.

silicate minerals, gold, pyrite, chalcopyrite, molybdenite, bismuth/bismuthinite, and trace amounts of other sulfides. The host ultramafic rock contains no gold. The lodes formed at a granite–ultramafic boundary because of shear movements during metamorphism, accompanied by metasomatic alteration of the ultramafic rock. Witt (2001) noted that the quartz veins are localized along thin units of felsic schist, representing deformed monzogranite and felsic porphyry, which provided sites of contrasting competence for vein formation. He also thought that the veins were formed early in D_2 (the regional upright folding), and were subsequently deformed during syntectonic solid-state emplacement of the monzogranite. However, the molybdenite in the veins has given a Re–Os date of about 2755 Ma, which pre-dates the greenstone sequence and its D_1–D_3 deformation sequence in the Eastern Goldfields Granite–Greenstone Terrane by about 100 m.y., and the ultramafic host rocks are inferred to be even older (Witt et al., 2001, 2002).

Agnew–Lawlers Gold Camp

Agnew (Emu) (Aoukar and Whelan, 1990)

The Emu deposit (named after East Murchison United, the first operator) was discovered in 1895. Gold is present in three west-dipping lodes — one at and two below a sheared contact between arkosic metasedimentary rocks and underlying conglomerate composed of ultramafic volcanic rock clasts in an ultramafic mineral matrix. The zone of shearing is about 100 m wide and hosts the lodes, which are zones of hydrothermal alteration wherein pyrite, arsenopyrite, and auriferous quartz were deposited. Randomly oriented actinolite adjoining the lodes overprints amphibolite-facies wallrocks, indicating that mineralization post-dated peak metamorphism. Shear-zone fabrics control the geometry of the lodes, and it seems that the hydrothermal fluid flowed through an actively propagating shear system and precipitated quartz, sulfides, and gold in permeable ultramafic rocks. Arsenic and gold vary sympathetically in the regolith above the deposit (Mazzucchelli and James, 1980).

Redeemer (Broome et al., 1998)

Redeemer was discovered in 1985 from a 4.1-ppm Au soil anomaly. The deposit is in steeply east dipping, overturned mafic conglomerate of the Jones Creek Conglomerate. Mineralization forms as lenses close to the eastern and western contacts of the conglomerate; the lenses are joined by cross-lodes along anastomosing shear zones that dip steeply east. The lode has a pervasive north-striking foliation, and a younger northwest-striking foliation; the main lode plunges parallel to the resulting intersection lineation. Gold mineralization is marked by biotite–amphibole enrichment, sulfides, silica, carbonate, and magnetite. Native gold forms interstitial grains in coarse actinolite or biotite, and is accompanied by tellurobismuthite (Bi_2Te_3), joseite [$Bi_3Te(Se, S)$], arsenopyrite, chalcopyrite, molybdenite, and scheelite. The deposit is mesozonal (T = ~520°C), but mineralogically atypical, possibly caused by unusual fluid–wallrock interaction that destabilized gold-bisulfide ions, forming native gold and sulfur and leading to amphibole ± biotite + CO_2 instead of quartz–carbonate precipitation.

Lawlers (Great Eastern) (Cassidy, 1988; Stokes et al., 1990)

The Great Eastern mine opened in 1896. It is associated with an easterly striking sinistral shear zone 2–3 km long in the core of the Lawlers Anticline; the shear zone is subsidiary to the dextral northerly striking Waroonga Shear on the west side of the Lawlers Anticline. Host rocks are: subhorizontally foliated diorite variably altered to biotite–muscovite schist; mafic xenoliths and rafts in the diorite; and leucogranite and felsic porphyry dykes. Auriferous quartz forms veins in sinistral shear zones striking 240–290° and dipping steeply north to vertical, and also forms planar and sigmoidal veins in tension gashes formed by later, relatively more brittle, normal vertical movements. Highest gold grades are located where the shear zones 'are less discrete and form multiple small intersecting shears' (Stokes et al., 1990). Hydrothermal alteration of wallrock is widest at these places, and took place in three stages. The first was pervasive alteration, where biotite formed chlorite(–epidote–titanite), and plagioclase formed clinozoisite/epidote and sericite. This was followed by two stages of mineralization and alteration in zones (up to 100 m wide on each side) symmetrically arranged around shears: the first of these formed new biotite, quartz, epidote and patchy carbonate, and the second formed chlorite (from the new biotite), sericite, and hematite. Mikucki et al. (1994) showed that the two episodes of mineralization corresponded to two different mineralizing fluids. The first was relatively hot (T = 380°C), high in CO_2, reduced, magmatic or metamorphic in origin, and deposited gold and pyrite in the shears. The second was cooler (T = 300°C), low in CO_2, oxidized, subsurface-derived, and deposited gold and telluride in the tension gashes. Fletcher et al. (1998) dated the first episode of mineralization at 2646 ± 25 Ma, and the second at 2592 ± 9 Ma (both by SHRIMP U–Pb on titanite).

Ungrouped mines and deposits

Tarmoola (Fairclough and Brown, 1998)

Tarmoola was discovered in 1897, as King of the Hills, and was renamed Tarmoola in 1990. The deposit is hosted in silica-altered basalt, ultramafic rocks, and minor metasedimentary rocks intruded by granodiorite. Two separate studies of the deposit arrived at significantly different conclusions. According to Fairclough and Brown (1998), the deposit is located in the closure of a gently north plunging D_2 antiform, which formed a strain shadow and preserves segments of gently dipping D_1 faults and the D_{E1} Sons of Gwalia Shear Zone. Gold is largely shear-zone hosted, and was deposited in subvertical brittle D_2 shear zones in the granodiorite, in the Sons of Gwalia Shear Zone, and in the steeply southeast dipping, D_2-faulted granodiorite–greenstone boundary. Gold is present in two main areas. In the northeast it is in en echelon quartz–carbonate veins (with pyrite, chalcopyrite, galena, sphalerite ± stibnite) in north-dipping (D_1) and east-dipping (D_2) reverse faults, and in a later set of subvertical contractional faults in the granodiorite. In the southwest, gold is present in stockwork veins (quartz–carbonate with pyrite, sphalerite, a trace of arsenopyrite, but no chalcopyrite) in two subvertical northwest-striking corridors in the granodiorite, and in brecciated ultramafic rocks along the eastern flank of the granodiorite. Greenstone around the veins is intensely silicified and carbonated. Mineralization occurred in two stages: the first took place during D_1 thrusting along the irregular roof zone and northern edge of the granodiorite, and involved a low-temperature ($<$190°C), low-salinity, chloride-rich fluid; and the second took place during D_2 folding and faulting and involved high-temperature (c. 290°C), high-CO_2, moderate-salinity fluid that precipitated gold into east-dipping reverse faults in greenstone and vein stockworks in the granodiorite.

In a later study, Duuring et al. (2001) did not recognize D_1 faults nor the D_{E1} Sons of Gwalia Shear Zone at Tarmoola, and regarded the auriferous vein assemblages as sourced from a single fluid that precipitated gold and sulfides during D_3 northwest-directed shortening.

Bannockburn (Pratt and Jankowski, 1993)

The Bannockburn gold mine, which dates from about 1900, is situated in an upward-facing sequence of high-Mg basalt, felsic volcanic and volcaniclastic rocks and shale, and komatiite, intruded by dykes of micrograndiorite and lamprophyre. Both sequence and dykes are folded into a major north-northwesterly trending syncline and smaller anticlines, cut by easterly striking undeformed dolerite dykes. Metamorphic facies is upper greenschist. An S_1 cleavage is subparallel to bedding, and is cut by a steeply dipping S_2 axial-plane cleavage; a lineation formed by the S_1–S_2 intersection plunges gently north. The lodes are stratiform envelopes, 2–15 m thick, around veined and altered high-Mg basalt, felsic volcanic rock, and rare shale, and generally mimic the main syncline, although locally they crosscut the sequence. The altered volcanic rocks constituting the lodes are quartz–carbonate–arsenopyrite–chlorite–biotite assemblages with accessory pyrrhotite, pyrite, marcasite, galena, and sphalerite, and are cut by veins of carbonate(–quartz), quartz, quartz–pyrrhotite, and alkali feldspar. Alteration is controlled by breccia zones and brittle shear zones in the felsic volcanic and basaltic rocks, by bedding-parallel shearing in the felsic rocks, and by shear zones parallel to S_1. The gold is present as free grains in the quartz–carbonate veins, and the highest-grade shoots plunge north, parallel to the lineation.

Thunderbox (Bennet and Buck, 2000)

Thunderbox was discovered in 1999, and production began in November 2002. The deposit was found by RAB drilling through Cainozoic cover sediments, and is located at the southern end of the Yandal greenstone belt, where major shear zones converge with the Perseverance Fault. The deposit is hosted in a tonalitic to dioritic porphyry intrusion located in the immediate hangingwall of a major, steeply west dipping shear zone. The footwall rocks are a sequence of weakly deformed quartz to lithic wacke and epiclastic rocks. The hangingwall rocks comprise the mineralized porphyry followed to the west by chlorite-altered and carbonate-veined metabasalt, which includes another interval of dioritic porphyry near the top of the sequence. The metabasalt is strongly deformed, with brittle to ductile structures, whereas the porphyries are weakly deformed in a mainly brittle fashion. The shear zone separating the two sequences is filled with deformed ultramafic rock, which acted as a glide plane. A banded mixed rock of interlayered altered dacite and basalt with porphyry-hosted mineralization forms lenses and fringes around the main mineralized porphyry; it probably formed by tectonic transposition of various rock types, and is itself modestly mineralized. The main porphyry body has been strongly altered, forming annealed quartz (silica flooding), albite, ankerite–dolomite, and about 5% sulfides. Carbonate ranges from pervasive to vein fillings. Sulfides are pyrite, pyrrhotite, arsenopyrite (which is associated with ankerite), and small amounts of galena, chalcopyrite, and sphalerite. The sulfides are distributed along foliation surfaces, form deformed laminae, and exist as coarse grains. Gold forms exsolved blebs in and around arsenopyrite grains. Gold grades are high in arsenopyrite- and ankerite-rich regions, and low in pyrite- and/or dolomite-rich regions. Pre-, syn-, and post-deformation sulfides indicate several episodes of mineralization. In summary, the mineralization is hosted in a large overthrust slab with a stock of porphyry in the hangingwall. The porphyry was deformed in a largely brittle fashion, pervasively altered and mineralized by fluid infiltration through fractures, and subsequently annealed. Mineralization began fairly early in the deformation history of the district.

COPPER, LEAD, AND ZINC

Teutonic Bore (Greig, 1984; Hallberg and Thompson, 1985)

The Teutonic Bore massive sulfide deposit was discovered in 1976, and was mined from 1980 to 1984. The deposit lies near the base of a tholeiitic basalt sequence, about 100 m above a rhyolite volcanic pile. It comprises a single lens of bedded fine-grained sulfide, and an underlying body of crosscutting stringer mineralization. Sulfide minerals include sphalerite, pyrite, chalcopyrite, and galena, together with minor arsenopyrite and argentiferous tetrahedrite; cassiterite is also present. Weathering formed an 85 m-thick leached oxide layer overlying a thin erratic chalcocite supergene enriched layer. The ratio

Cu/Zn decreases away from the centre of the ore body. Alteration is strong in the stringer-mineralization body, and formed a central Fe–Mg carbonate zone, a zone of chlorite–silica alteration below the massive sulfides, and an outer sericite halo. The deposit is of volcano-exhalative origin — submarine discharge on the flank of a rhyolite dome, with the sulfides accumulating in a topographic depression (fault-controlled, according to Hallberg and Thompson, 1985) above a feeder zone of alteration and stringer mineralization. Hallberg and Thompson (1985) noted that the same felsic–mafic contact has minor base metal mineralization and carbonate–sericite–quartz alteration for 10 km along strike from the Teutonic Bore deposit, and that granite 2 km northeast of the mine is veined by pyrite and base metal sulfides; they concluded that the base metal mineralization was related to felsic magmatism in the region. Nickel (1984) studied weathering of the orebody, and identified more than 30 secondary minerals in the top 70–85 m, including native Cu and Ag, and the lead–aluminium phosphate, plumbogummite. The fine grain size of the primary sulfides produced a gossan without boxworks (except for pyrite), but the presence of the orebody was indicated by cassiterite, plumbogummite, and anomalous amounts of Pb, Sn, Sb, and As in the gossan, and by sulfide inclusions in quartz. Fritz and Sheehan (1983) studied various geophysical signatures of the orebody, and found that electrical resistivity was by far the most sensitive detection method, the sulfides being about a thousand times more conductive than the host rocks. Another resource of similar massive sulfides, the Jaguar deposit, was discovered in 2002, 4 km south of Teutonic Bore. The Jaguar deposit has a strike length of 200 m, and maximum grades of 4.28% Cu, 16.05% Zn, 0.76% Pb, and 173 g/t Ag over 7.7 m at a vertical depth of 450 m (Mining Australia, 2002).

NICKEL

Waterloo deposit (Dalrymple Resources NL, 2002a)

The Waterloo deposit is located about 6 km north of the Thunderbox gold mine, and was discovered by drilling in 2001. Nickel sulfide mineralization has been delineated over a strike length of 500 m and to a depth of about 150 m. The deposit is truncated along the western side by a strike-parallel, west-side-down vertical fault, implying that further mineralization may exist at depth to the west of the fault. The best intersection is 7.35 m with 10.07% Ni. Copper (up to 0.81% Cu) and platinum-group elements, which grade up to 4.38 g/t PGE over 2.16 m and 3.09 g/t over 4.02 m, are also present.

Amorac deposit (Dalrymple Resources NL, 2002b)

The Amorac deposit is located close to the Waterloo deposit, and was discovered by drilling in 2002. Massive and stringer nickel sulfides are present over a strike extent of 250 m and a dip extent of 100–150 m within a vertical depth range of 90–180 m from the surface. The sulfides are controlled and hosted by sheared siliceous sedimentary rocks with minor associated ultramafic lenses. Mineralization pinches and swells, and intersections grade up to 6% Ni over 6 m. The deposit is separate, distinct, and unrelated to the Waterloo deposit.

Mount Clifford deposit (Marriott prospect) (Travis, 1975; Donaldson, 1982)

The Marriott prospect is in a thick upward-facing sequence of moderately north dipping ultramafic rocks, which overlie a thin layer of chloritic metasedimentary rock above tholeiitic pillow basalt of the Mount Fouracre area. The ultramafic sequence begins with about 1000 m of serpentinized dunite with a chilled base; this is overlain by 150 m of gabbro, and this by 100–140 m of serpentinized spinifex-textured peridotite flows with nickel sulfide lenses and several horizons of albite-rich metasedimentary rock. This is followed by 30 m of volcanic breccia (ultramafic clasts in a matrix of albite and pyrite), and then by more than 1000 m of altered ultramafic flows. Blebs, disseminations, flecks, and stringers of nickel sulfide are concentrated in three main zones in the serpentinized peridotite, each associated with individual flow units about 5 m thick. The main ore mineral is millerite, with minor heazlewoodite, other nickel sulfides, and rare native nickel and copper. Maximum grade is 2.2% Ni over 17 m.

Weebo Bore prospect (Legge, 1975)

The Weebo Bore prospect is situated in serpentinized dunite, which intruded a sequence of amphibolite and metasedimentary, ultramafic, and volcanic rocks. The dunite is a lens, 80 × 300 m, and includes rafts and xenoliths of amphibolite along its western margin. Nickel mineralization coincides with the dunite, and is oxidized to secondary iron oxides with sulfide boxworks to a depth of 45 m. Sulfides are present below 45 m, zoned as follows: 45–70 m, violarite (plus minor pyrite, pentlandite, and pyrrhotite); 70–135 m, pyrrhotite and pentlandite (plus minor violarite, millerite, and pyrite); and 135–280 m, pyrite (plus minor linneaite, pentlandite, millerite, and chalcopyrite). The deposit formed when a crystal mush of dunite with immiscible iron-sulfide and nickel-sulfide fluids filled a sigmoidal opening that formed by sinistral movement along a fault located 1 km east of the prospect.

URANIUM (Butt et al., 1977)

Three uranium deposits are located in playa-lake sediments at the western end of Lake Raeside. Carnotite has been precipitated in clay, calcrete, and opaline silica in the top 5 m of sediments. Maximum grade is 500 ppm U in the top 15 cm. Enriched areas range up to 2000 × 500 m (siliceous rock), and 3 × 2 km (calcrete), and contain up to an estimated 6.7×10^6 t at 0.025% equivalent U_3O_8. The uranium is derived from the extensive granitoid exposures in the area. Increasing salinity of the evaporating lake water led to the release of U from carbonate complexes, which in turn allowed the concentration of uranyl ions to increase and eventually precipitate as carnotite.

DIAMOND

Several kimberlites have been identified on LEONORA (Joyce, 1997; Shee et al., 1999; Jaques, 2001), and are shown in Figure 2. They have been dated at 2060–2020 Ma (Graham et al., 2001), but information on their diamond potential is not available.

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Appendix

Gazetteer of localities

Locality	*MGA coordinates* *Easting*	*Northing*
Agnew	256000	6899100
Agnew Bluff	257600	6897400
Agnew (Emu) mine	254600	6899400
Amorac deposit*	301900	6884700
Arlidges Well	258500	6796500
Artful Dodger mine	352000	6817000
Bannockburn mine	293700	6850200
Blueys Well	261600	6806600
Boiler Well	318400	6798000
Bottle Well	265000	6872000
Boudie Hill	318700	6856900
Braemore Homestead	337900	6807300
Bundarra Homestead	321200	6865700
Camel Bore	275400	6877600
Casino mine	332800	6810500
Chinaman Well	241900	6898000
Clifford Bore	306900	6862600
Cork Well	261800	6877200
Curara Well	244200	6857500
Cutmore Well	306200	6817900
Depot Spring	222600	6831500
Dodgers Well mining centre	338000	6829000
Fairyland mine	269300	6891400
Five Mile Well	249200	6895200
Flying Pig mine	350800	6815600
Ford Run Plateau	308000	6878000
Forrest mine	351000	6806400
Freshwater Well	209900	6789300
Gambier Lass mine	349900	6818900
Garden Well	317100	6867900
Gold Blocks mine	333400	6809200
Good Friday Bore	274400	6895400
Haggerty Well	286200	6888800
Harbour Lights mine	336400	6804800
Harlech mine	325400	6819900
Harriston mine	352000	6813500
Heather Well	300300	6870000
Hill Bore	298300	6826700
Horse Rocks Rockhole	277600	6889600
Iron King mine	312900	6842500
Jaguar deposit*	319500	6852200
Jasper Flat mine	328500	6817500
Junior Hill	316000	6861400
Kurrajong	316000	6822400
Lake Raeside	293000	6814400
Lawlers	256600	6890700
Lawlers (Great Eastern) mine	258200	6891600
Lehmanns Well	307000	6886000
Leonora township	337200	6803800
Linger and Die Well	335900	6831900
Little Peters Well	320200	6841600
Malcolm Dam Nature Reserve	348600	6805000
Mark Twain mine	260500	6895800
Marriott prospect	303300	6851200
Marroon Well	260200	6848700
Mars Bore	262100	6801000
Marshall Pool	298300	6865000
Marshall Pool prospect	302500	6866300
Marshall Well	297000	6862000
Minatichi Well	301500	6853200
Moses Well	345200	6796200
Mount Alexander	234000	6797200
Mount Clifford mine	310000	6850000
Mount Clifford mining centre	307000	6849000
Mount Clifton	349100	6856400
Mount Davis	327700	6823300
Mount Fouracre	302600	6844800
Mount George	334100	6810900
Mount Germatong mine	342000	6807600
Mount Leonora	338000	6801300
Mount Malcolm	349700	6803300
Mount Mcauley	251800	6890000
Mount Newman	313100	6846000
Mount Ross	309400	6823400
Mount Stirling	311500	6833300
Mount Stirling mine	311300	6834300
Munjeroo Homestead	218300	6871900
New Chum Bore	302000	6898800
New Well	321300	6834600
North Well	292200	6856500
No. 2 Well	285000	6868600
Ossie Well	306000	6875000
Peters Bore	258900	6842600
Pig Bore	346700	6815400
Pinnacles Homestead	248600	6878200
Pinnacle Well	340700	6826300
Ponds Well	293600	6870000
Puzzle mine	322600	6823600
Rainbow Well	320000	6875600
Red Well	280500	6817400
Redeemer mine	252800	6893300
Redling Well	293400	6795700
Robbies Well	310200	6826000
Royal Arthur Bore	315500	6853600
Schmidt Well	287400	6834700
Sergies Well	263400	6812500
Seven Mile Well	318100	6898800
Skippy Bore	214600	6820700
Slaughter Yard mine	294000	6863700
Sons of Gwalia mine	337500	6800000
Stacks Well	351100	6861200
Station Creek	338000	6817400
Station Creek Pumping Station	334000	6815400
Sturt Meadows Homestead	301700	6825900
Sunset Well	347900	6806800
Tarmoola Homestead	319200	6821400
Tarmoola mine	320500	6827100
Teutonic Bore	320000	6857000
Teutonic Bore mine	318600	6856100
Thunderbox mine	304200	6880000
Tower Hill mine	336400	6802200
Trump mine	334200	6808000
Union Jack Well	285700	6821600
Victory Corner Well	313600	6841400
Victory No. 1 mine	309100	6844700
View Hill	218300	6854600
Wallaby Nob	221800	6880200
Waterloo deposit*	301300	6885400
Weebo Bore	283000	6895700
Weebo Bore prospect	285900	6895200
Weebo Homestead	311100	6900600
West Terrace	345700	6837800
White Cloud Well	231500	6888700
Wibboo	296000	6899200
Wilbah Outstation	249500	6800700
Wildara mining centre	292000	6877000
Wildara Outstation	289000	6876400
Wilson Creek Well	313000	6862500
Windy Bore	267700	6795800

NOTE: * Not shown on the 1:250 000 map

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STEWART

LEONORA, WESTERN AUSTRALIA, SECOND EDITION

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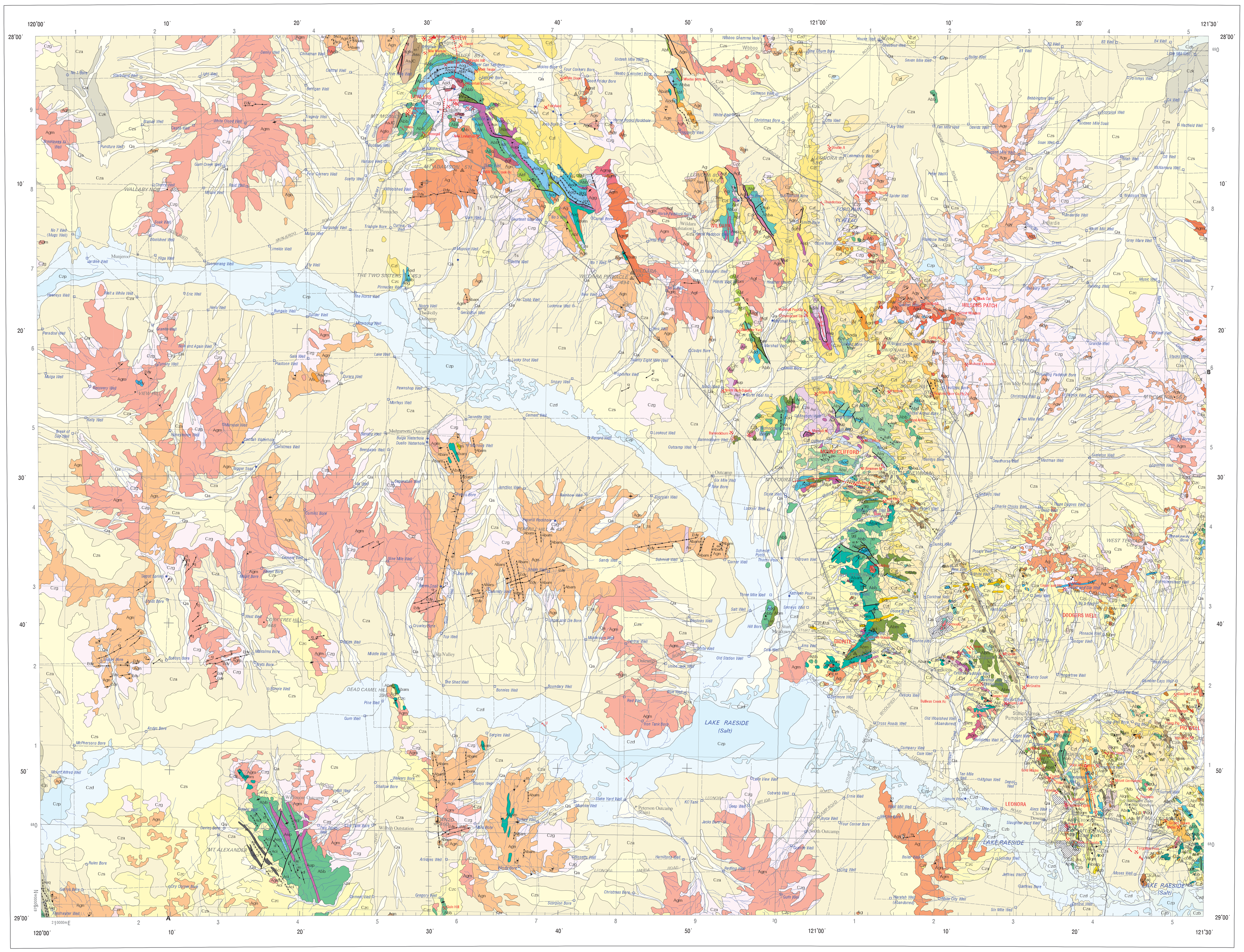


CAINOZOIC

Qa — Clay, silt, sand and gravel in and near active stream channels; alluvial
Qac — Clay in claypans

Cza — Clay, silt and sand; pebbly in places; colluvial, distal
Czb — Clay and dune sand, adjacent to playas (clay dominant)
Czc — Gravel, talus, sand; colluvial, proximal
Czcl — Sandy colluvium with limonitic pisoliths on low plateaus on weathered granitoid
Czd — Quartz and gypsum dunes with minor silt and clay adjacent to playas (dunes dominant)
Czf — Pebbly colluvium and alluvium derived from laterite
Czg — Colluvial sand and gravel derived from quartzofeldspathic rock
Czh — Silt, sand and gravel in halophyte flats adjacent to playas
Czi — Detritus and talus, derived from banded iron-formation
Czk — Calcrete
Czl — Lateritic duricrust, massive and rubbly
Czp — Evaporites, sand and clay in playas
Czq — Talus and quartz-rich detritus derived from quartz veins
Czs — Sand plain
Czu — Silcrete on or derived from ultramafic rock
Czz — Silcrete over granitoid
Czzg — Silcrete and/or kaolinised granite

Ts — Sand and gravel

PROTEROZOIC

Ꝑdi — Felsic dyke
Ꝑdy — Mafic dyke

ARCHAEAN

chx — Chert breccia, commonly cemented by goethite
d — Dolerite
g — Granite
gg — Granodiorite
gqx — Goethite-quartz breccia
i — Ironstone
po — Porphyry
q — Quartz, quartzolite
sy — Syenite

Ag — Granite, undivided
Agb — Foliated granitoid rock with mafic lenses; local gneissic banding
Agc — Coarse-grained granitoid, undivided
Agd — Diorite to monzodiorite
Age — Medium-grained granitoid, undivided
Agf — Fine-grained granitoid, undivided
Agfo — Foliated granitoid
Agg — Granodiorite
Agl — Leucogranite and microgranite
Agm — Biotite monzogranite
Agmc — Coarse-grained biotite monzogranite
Agmf — Fine-grained biotite monzogranite
Agmm — Biotite monzogranite, medium-grained
Agmp — Porphyritic monzogranite
Agn — Strongly foliated granitoid with local weak and/or incipient layering (banding) +/- mafic lenses
Agq — Quartz-rich granitoids
Ags — Syenite to alkali-feldspar syenite
Agt — Tonalite
Agtp — Porphyritic tonalite
Agy — Syenogranite to alkali-feldspar granite

Ac — Chert and banded chert; metamorphosed
Aci — Banded iron-formation; metamorphosed
Acl — Limestone; metamorphosed
As — Metasedimentary rock, undivided
Asc — Polymictic conglomerate; metamorphosed
Ascb — Oligomictic conglomerate; dominantly basaltic clasts
Ascf — Oligomictic conglomerate with dominantly felsic igneous clasts; metamorphosed
Ascq — Oligomictic conglomerate with dominantly quartzitic or chert clasts; metamorphosed
Asf — Volcaniclastic conglomerate, sandstone and tuff
Asg — Arkose
Ash — Shale and/or slate and/or phyllite and/or claystone and/or siltstone; metamorphosed
AsJC — Jones Creek Conglomerate: conglomerate and sandstone; granitoid clasts and matrix dominate; metamorphosed
Asq — Quartzite, quartz metasiltstone
Ass — Sandstone and/or siltstone, metamorphosed

Af — Metamorphosed felsic extrusive rocks, fine-grained
Aff — Metamorphosed foliated felsic volcanic or volcaniclastic rocks
Afp — Metamorphosed intrusive felsic porphyry
Afpf — Metamorphosed felsic porphyry
Afpq — Metamorphosed quartz-phyric felsic rock
Afs — Quartz-feldspar schist and/or quartz-muscovite schist derived from felsic volcanic rock
Aft — Metamorphosed felsic pyroclastic +/- volcaniclastic rocks
Afv — Metamorphosed felsic volcanic or volcaniclastic rocks

Aod — Metadolerite +/- metabasalt +/- metagabbro
Aoda — Dolerite, equigranular
Aodp — Dolerite, porphyritic
Aog — Metagabbro, undivided; massive, equigranular or porphyritic
Aoga — Gabbro, equigranular
Aol — Lamprophyre

Ab — Metamorphosed fine-grained mafic igneous rocks, undivided
Abam — Amphibolite derived from mafic igneous rock
Abb — Metabasalt +/- metadolerite
Abba — Metabasalt, aphyric
Abc — Carbonated metabasalt
Abd — Metabasalt and metadolerite
Abf — Mafic schist, low-grade
Abg — Mafic and subordinate felsic volcanic rocks intercalated with minor foliated granitoid rock; metamorphosed; gneissic banding locally developed
Abm — High-magnesium metabasalt with spinifex texture
Abp — Metabasalt +/- metadolerite, porphyritic
Abs — Schistose metabasalt
Aby — Metabasalt, vesicular or amygdaloidal

Alb — Clay rock, massive to schistose, quartz absent or minor
Ald — Quartz-andalusite schist +/- feldspar
Alf — Quartz-feldspar schist +/- muscovite, schistose to massive quartz-clay rock +/- muscovite
Alfq — Schistose clay rock with quartz eyes
Alm — Muscovite schist +/- feldspar; schistose muscovite-clay rock
Alqb — Quartz-biotite schist +/- feldspar +/- muscovite
Alqm — Quartz-muscovite schist +/- feldspar

Au — Metamorphosed ultramafic rock, undivided or unassigned
Aup — Peridotite; metamorphosed
Aur — Tremolite schist
Aus — Serpentinite, serpentine-talc rock
Aut — Talc-chlorite schist, chlorite-talc schist
Aux — Pyroxenite; metamorphosed

Geological boundary
Marker bed
Fault, position accurate
Thrust-fault. Triangle on older rocks
Dyke or vein
Anticline
Syncline
Overturned anticline
Overturned syncline

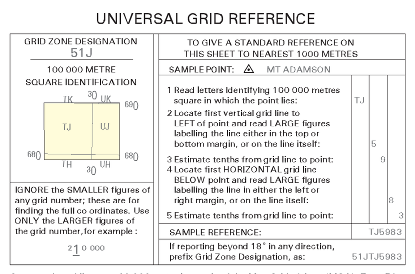
Where position of boundaries, faults, and folds is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted and faults are shown as short dashes.

Strike and dip of strata
Strike and dip of strata. Dot indicates proved direction of facing
Strata, facing not known
Trend-line
Strike and dip of foliation
Vertical foliation
Strike and dip of cleavage
Vertical cleavage
Plunge of bedding-cleavage intersection
Plunge of crenulation
Plunge of mineral elongation
Strike and dip of platy alignment
DIORITE — Mining centre
Mine; may be abandoned
Prospect
Minor open cut or quarry
Major open cut or quarry
Treatment plant

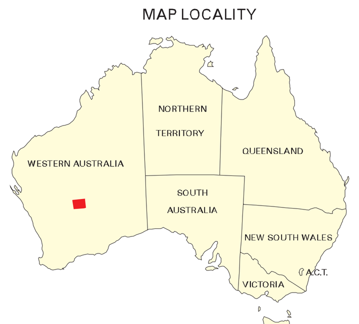
All unlabelled mines are gold.
Cu-Copper, Gs-Gemstone, Ni-Nickel, Pb-Lead, Rc-Crushed rock aggregate, U-Uranium, Zn-Zinc

Highway
Secondary road
Minor road
Vehicle track
Railway
Landing ground
Building
Clover Downs — Homestead
Agnew — Town
River or creek
Waterhole
Bore
Well
Water tank
Tailings
Made ground

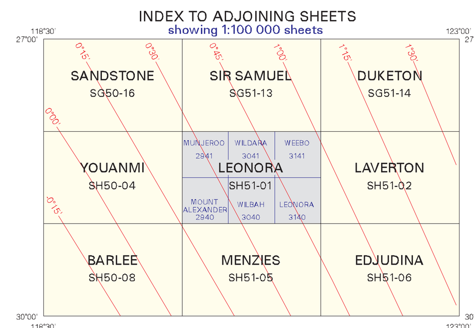
UNIVERSAL GRID REFERENCE



MAP LOCALITY



INDEX TO ADJOINING SHEETS

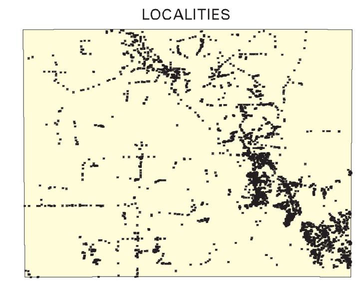


SCALE 1:250 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
Horizontal Datum: GDA94 MGA Zone 51

Horizontal coordinates on this map are based on the earth-centred GEOCENTRIC DATUM OF AUSTRALIA (GDA). For all practical purposes GDA and WGS84 are equivalent. GDA and AGD (Australian Geodetic Datum) coordinates vary by approximately 200 metres in a north-easterly direction. GDA on the web: www.anzlic.org.au/icsm/gda/index.htm

FIELD OBSERVATION LOCALITIES



DIGITAL DATA

Map data are stored digitally in topologically structured ARC/INFO version 8.0.2 export format. This format may be suitable for transfer to other digital systems. Detailed site data are stored in AGSO's OZROX Database. Map information can be purchased from AGSO as hardcopy plots and as digital datasets.
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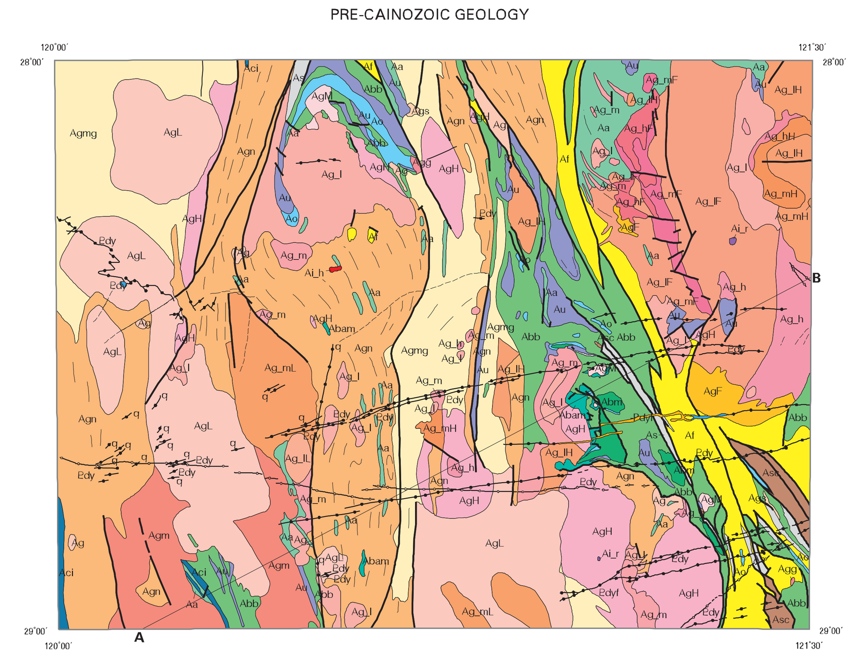
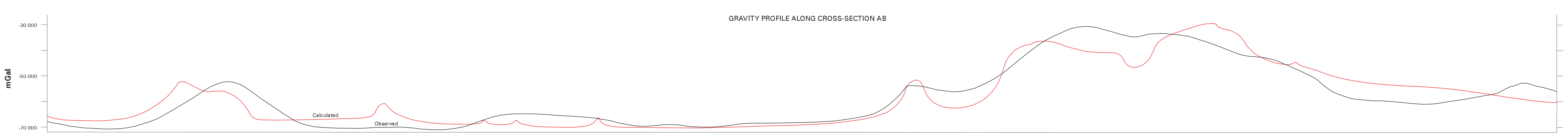
PRE-CAINOZOIC GEOLOGY



Geology by A.J.Stewart, S.F.Liu, A.J.Whitaker and D.C.Champion 1999-2000

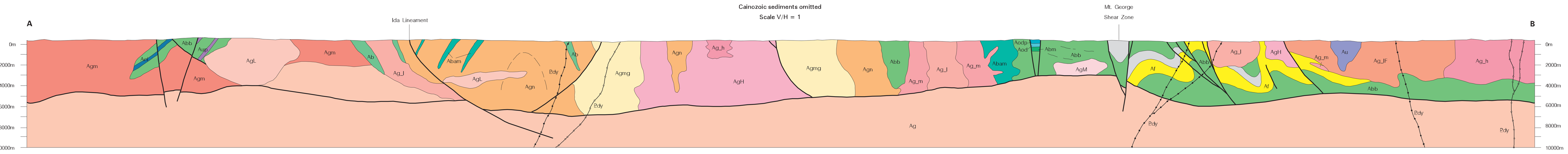
Geological boundary
Fault, position accurate
Normally magnetised dyke or vein
Remanently magnetised dyke or vein
Trend-line, linear feature of unknown origin
Fracture/Joint
Lineament

GRAVITY PROFILE ALONG CROSS-SECTION AB



INTERPRETATIVE SECTION

Cainozoic sediments omitted
Scale V:H = 1



Geology 1987-1992, by M.B.Duggan, B.S.Oversby and P.R.Williams, AGSO - Geoscience Australia
1998-1999 by A.J.Stewart, S.F.Liu, AGSO
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Mining Centre locations supplied by GSWA, Perth, WA

Cross-section by A.J.Stewart and D.C.Champion based on original concept by Goleby, B.R., Rattenbury, M.S., Swager, C.P., Drummond, B.J., Williams, P.R., Sheraton, J.W., & Heinrich, C.A.,1993. Archaean crustal structure from seismic reflection profiling, Eastern Goldfields, Western Australia. AGSO Record 1993/15,fig.8.1.
Gravity profile computed by B.Bell, AGSO, 2001

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Stewart, A.J. (Compiler), 2001
Leonora Second Edition (1:250 000 scale geological map)
AGSO - Geoscience Australia, Canberra
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SECOND EDITION

SUBJECT TO REVISION

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