EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

LAVERTON
1:250 000 SHEET
WESTERN AUSTRALIA

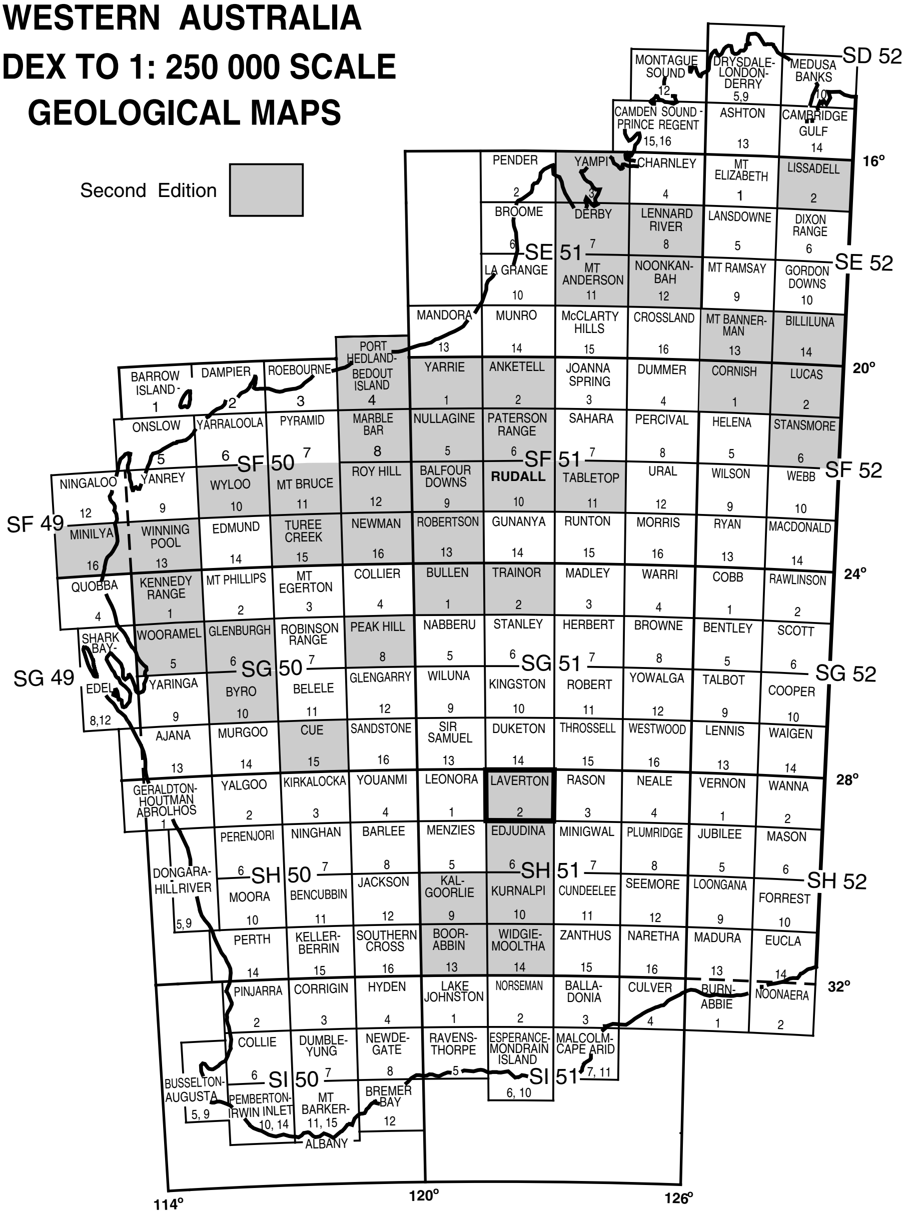
SECOND EDITION

SHEET SH 51-2 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DEPARTMENT OF MINERALS AND ENERGY

WESTERN AUSTRALIA
INDEX TO 1: 250 000 SCALE
GEOLOGICAL MAPS

Second Edition



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

LAVERTON

WESTERN AUSTRALIA

SECOND EDITION

SHEET SH 51-2 INTERNATIONAL INDEX

by

A. J. STEWART*

* Australian Geological Survey Organisation

Perth, Western Australia 2001

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

The Hon. Clive Brown MLA

DIRECTOR GENERAL

L. C. Ranford

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Tim Griffin

Copy editor: C. D'Ercole

REFERENCE
The recommended reference for this publication is:
STEWART, A. J., 2001, Laverton, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 34p.

ISSN 0729-3720
National Library of Australia Card Number and
ISBN 0 7307 5669 6

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

Printed by Optima Press, Perth, Western Australia

Copies available from:
Information Centre
Department of Minerals and Energy
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
Telephone: (08) 9222 3459 Facsimile: (08) 9222 3444
www.dme.wa.gov.au

CONTENTS

APPENDICES

FIGURES

TABLES

Explanatory Notes on the Laverton 1:250 000 Geological Sheet, Western Australia (Second Edition)

by A. J. Stewart

INTRODUCTION

The LAVERTON* 1:250 000 map sheet (SH 51-2) is bounded by latitudes 28°00'S and 29°00'S and longitudes 121°30'E and 123°00'E. The town of Laverton, near the centre of the sheet area, is a pastoral and mining centre (chiefly gold and nickel).

The sealed Leonora–Laverton road provides access from the Kalgoorlie–Wiluna road west of the sheet area. The formed Warburton Range road connects Laverton† with Warburton to the northeast. Other formed roads connect Laverton with gold mines at Granny Smith and Sunrise Dam (8 km south of the sheet area) to the south, with Mount Dennis to the southeast, White Cliffs to the east, Laverton Downs and Bandya (35 km north of the sheet area) to the north, and Nambi and Melrose (25 km northwest of the sheet area) to the northwest. A network of pastoral tracks provides good access elsewhere.

PHYSIOGRAPHY, CLIMATE, AND VEGETATION

LAVERTON (1:250 000) has a landscape of mainly broad plains and playas with areas of low ridges and hills. There are two main hilly areas: a large area in the east reaching a maximum height of 565 m above Australian Height Datum (AHD), and a smaller area in the southwest about 460 m AHD. These are separated by a broad, south-southeasterly trending low area (400–430 m AHD) of playas (Fig. 1), which corresponds to the Carey Palaeoriver (van de Graaff et al., 1977). Other similar palaeochannels are located in the southwestern corner of the LAVERTON 1:250 000 sheet (Raeside Palaeoriver) and in the northeast (unnamed). The palaeorivers drain to the southeast and may have been localized by Cainozoic block faulting, the rivers flowing along the low ground between uplifted fault blocks.

Hills and ridges are commonly composed of resistant greenstone rock types, especially chert or banded iron-formation (BIF), or laterite caps. Broad plains are underlain by granitoid. Breakaways in the east, such as the Shay Cart Range, are 15–30 m high (Gibson, 1906) and have formed in silcrete, which caps deeply weathered granitoid.

The area has a semi-arid climate. Laverton has a mean annual rainfall of 225.7 mm (median 202.5 mm), and a mean of 41.1 wet days per year, with most rain falling between February and July‡. Temperatures reach or exceed 40°C between October and April, with January the hottest month, and frosts occur from May to August.

---

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

† Coordinates of localities mentioned in text are shown in Appendix 1.

‡ Climate data from Commonwealth Bureau of Meteorology Website, 2000.

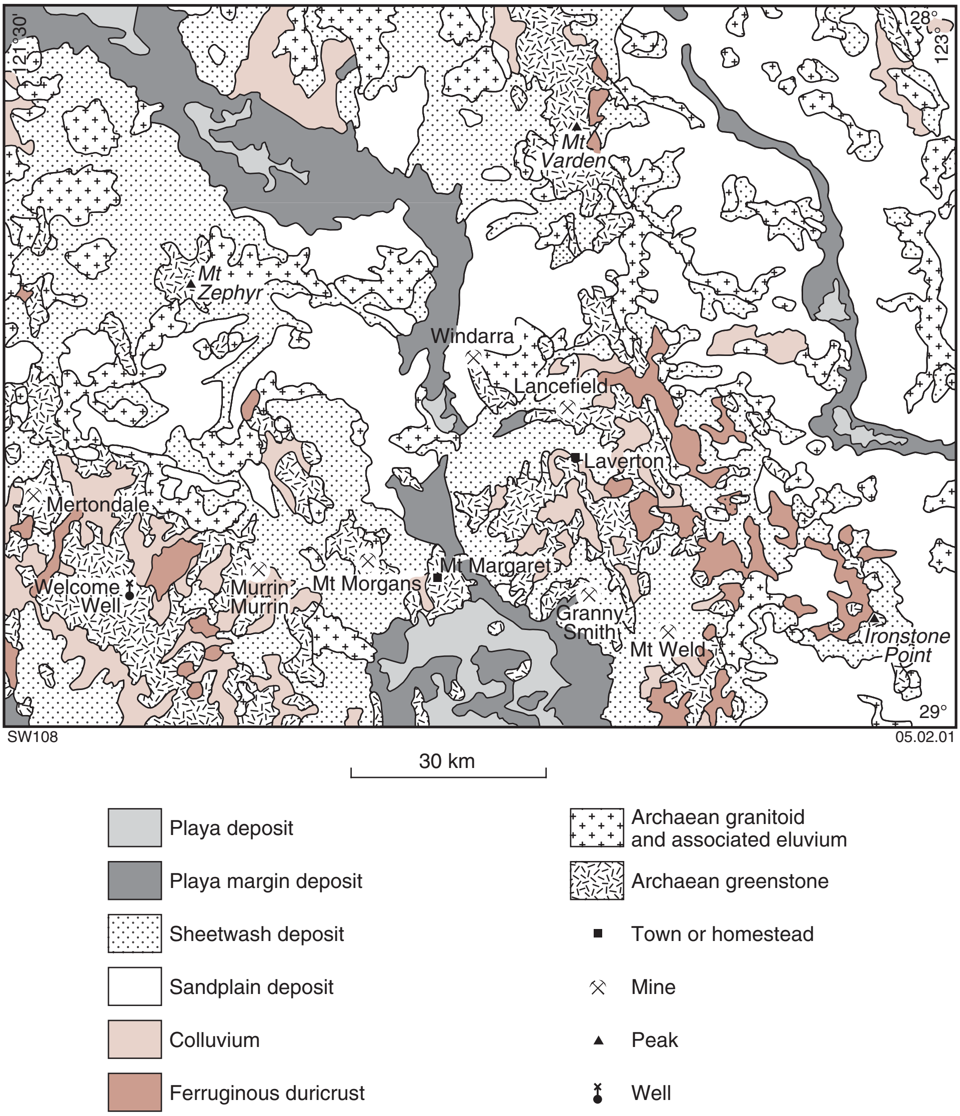


Figure 1. Physiography and Cainozoic geology of LAVERTON (1:250 000)

The western two-thirds of LAVERTON (1:250 000) lie in the Austin Botanical District of Beard (1974, 1990), and consist typically of low woodland with mulga (*Acacia aneura*) growing on Archaean bedrock, Cainozoic laterite, and on both proximal and distal Cainozoic colluvium. Elongate areas of mulga and saltbush (*Atriplex, Kochia,* and *Bassia*) grow on the gypsum dune country that surrounds and links the salt playas now occupying the palaeodrainage channels. Smaller areas of mallee (*Eucalyptus youngiana*) and spinifex (*Triodia basedowii*) form discrete patches on sandplains around the mulga–saltbush areas, and in the western part of LAVERTON (1:250 000). There is an area of mulga on stony greenstone hills in the southwest.

The eastern third of LAVERTON (1:250 000) is in the Helms Botanical District of the Great Victoria Desert (Beard, 1974, 1990), and consists largely of marble gum (*E. gongylocarpa*), mallee, and spinifex on sandplain. Within this area, smaller, irregular elongate areas of mulga low-woodland grow on laterite rises and low hills of bedrock. A sinuous strip of mulga and saltbush follows the gypsiferous dunes and small playas in the northeast and east of the sheet area.

PREVIOUS INVESTIGATIONS

Talbot and Clarke (1917) made the first geological observations on LAVERTON (1:250 000), and Clarke (1925) compiled the first regional map of the area. Tipper and Gerdes (1971) published a solid geology map of LAVERTON (1:250 000) based on regional aeromagnetic data (1.6 km line spacing, recorded in 1966), and noted several of the major structural and geological elements of the area, including the Margaret Anticline, the layered mafic intrusion at Diorite Hill, the large anomaly over the Mount Weld carbonatite, and the major easterly and southeasterly striking mafic dykes. Gower and Vogwill (1975) produced the first edition of the LAVERTON 1:250 000 sheet; Gower (1976) compiled the Explanatory Notes and referenced much of the work previous to that date. He identified many of the major structural elements of the sheet area, including the Benalla, Corkscrew, and Margaret Anticlines, the Kilkenny Syncline, and the north-northwesterly striking Keith–Kilkenny, Celia, and Laverton tectonic lineaments. He suggested that the lineaments might have acted from early in the Archaean, because they controlled the distribution of greenstones and, indirectly, major granitoid masses. Hallberg (1985) published a detailed description of the Leonora–Laverton area accompanied by 16 geological maps at 1:50 000 scale, which included the southern half of LAVERTON (1:250 000).

Gold was discovered in the area in the 1890s. Hallberg (1985) gave a detailed account of the gold deposits in the area.

Nickel was discovered at Mount Windarra* in 1969 (Robinson et al., 1973) and South Windarra in 1971. Reddell and Schmulian (1990) gave a general descriptive account of the deposits. Fazakerley and Monti (1998) described the lateritic nickel deposit at Murrin Murrin.

The Mount Weld carbonatite was discovered in 1967 (Duncan, 1988), and Duncan and Willett (1990) gave a general description of the carbonatite and its associated rare earth and phosphate deposits.

More than 500 company reports, which include exploration data and unpublished maps, are available to the public through the Geological Survey of Western Australia's (GSWA) Western Australian mineral exploration open-file database (WAMEX). Several university honours theses have been written on aspects of geology, geophysics, and geochemistry of gold, nickel, and base metal deposits in the sheet area (Chenoweth, 1969; Williams, 1969; Davidson, 1970; Drew, 1971; Jacobson, 1971; Watchman, 1971; Drake, 1972; Leahy, 1973; Van Klinken, 1974; Santul, 1975; Falconer, 1983; Hayward, 1983; Poll, 1987; Roth, 1988; Gillman, 1989).

The six 1:100 000 geological maps that make up LAVERTON (1:250 000) — NAMBI (Jagodzinski et al., 1996), MOUNT VARDEN (Rattenbury et al., 1997), MCMILLAN (Duggan,

* The name of the Mount Windarra nickel mine is commonly (including these Explanatory Notes) shortened to Windarra.

1995), MINERIE (Williams et al., 1997a), LAVERTON (Williams et al., 1997b), and BURTVILLE (Duggan et al., 1997) — were published by the Australian Geological Survey Organisation (AGSO) as part of the National Geoscience Mapping Accord (NGMA) with the GSWA, and were used to compile the second edition of the LAVERTON 1:250 000 sheet (see index on map). The generalized solid geology map (Fig. 2) was compiled from the second edition of LAVERTON (1:250 000), together with unpublished interpretations of aeromagnetic data (400 m line spacing; obtained by AGSO in 1993) by A. J. Stewart and A. J. Whitaker (AGSO), unpublished geochemical data on granites supplied by D. C. Champion (AGSO), and various published articles (Hallberg, 1985; Chen, 1998; Newton et al., 1998).

These Explanatory Notes were compiled from AGSO's Field Geology Database (OZROX) of field geological observations and petrographic descriptions arising from the 1989–95 geological mapping of the six 1:100 000-scale sheets that make up LAVERTON (1:250 000), and from the references cited herein.

NOMENCLATURE

All Archaean rocks on LAVERTON (1:250 000) have undergone low- to medium-grade metamorphism, but for ease of description in most cases the prefix 'meta' is omitted and protolith rock names are used. The Internation Union of Geological Sciences (IUGS) classification (Le Bas and Streckeisen, 1991) is used for igneous rocks.

PRECAMBRIAN GEOLOGY

REGIONAL GEOLOGICAL SETTING

LAVERTON (1:250 000) lies within the Eastern Goldfields Province of Gee et al. (1981), the easternmost subdivision of the Archaean Yilgarn Craton. The Eastern Goldfields Province comprises volcanic and sedimentary rocks (greenstones) that were deposited around 2700 Ma ago (Swager et al., 1992; Swager, 1997), multiply folded, metamorphosed to low or medium grade, extensively intruded by granitoids at about 2680–2660 Ma, and subjected to major faulting along northerly to north-northwesterly trends. Swager (1997) divided the greenstones in the Kalgoorlie–Edjudina area into terranes separated by major faults or granitoids. He regarded the terranes as contemporaneous volcanic and sedimentary basins that were deposited in an ensialic rift setting, possibly above a failed spreading ridge, and later brought together. The Kurnalpi, Edjudina, and Linden Terranes of Swager (1997) could be extended onto LAVERTON (1:250 000), where the Kurnalpi Terrane would comprise the greenstones west of the Celia Lineament (Fig. 2), and the Linden Terrane the greenstones east of the Laverton Fault (Fig. 2). The greenstones between the Celia Lineament and Laverton Fault would then form a separate (?Margaret) terrane. Chen (1999) summarized several published schemes of structural subdivision used on EDJUDINA (1:250 000), which adjoins LAVERTON (1:250 000) to the south, and suggested three subdivisions partly corresponding to elements of the previous ones. His subdivisions — the Malcolm, Murrin, and Laverton greenstones — are used on LAVERTON (1:250 000), together with the Cosmo Newbery greenstones.

Malcolm greenstones

On LAVERTON (1:250 000), the Malcolm greenstones occupy a small area southwest of the Yilgangi Fault in the southwest (Fig. 2), and correspond to the Malcolm greenstone belt of Griffin (1990). The rocks are mainly basalt, gabbro–dolerite, and mafic schist.

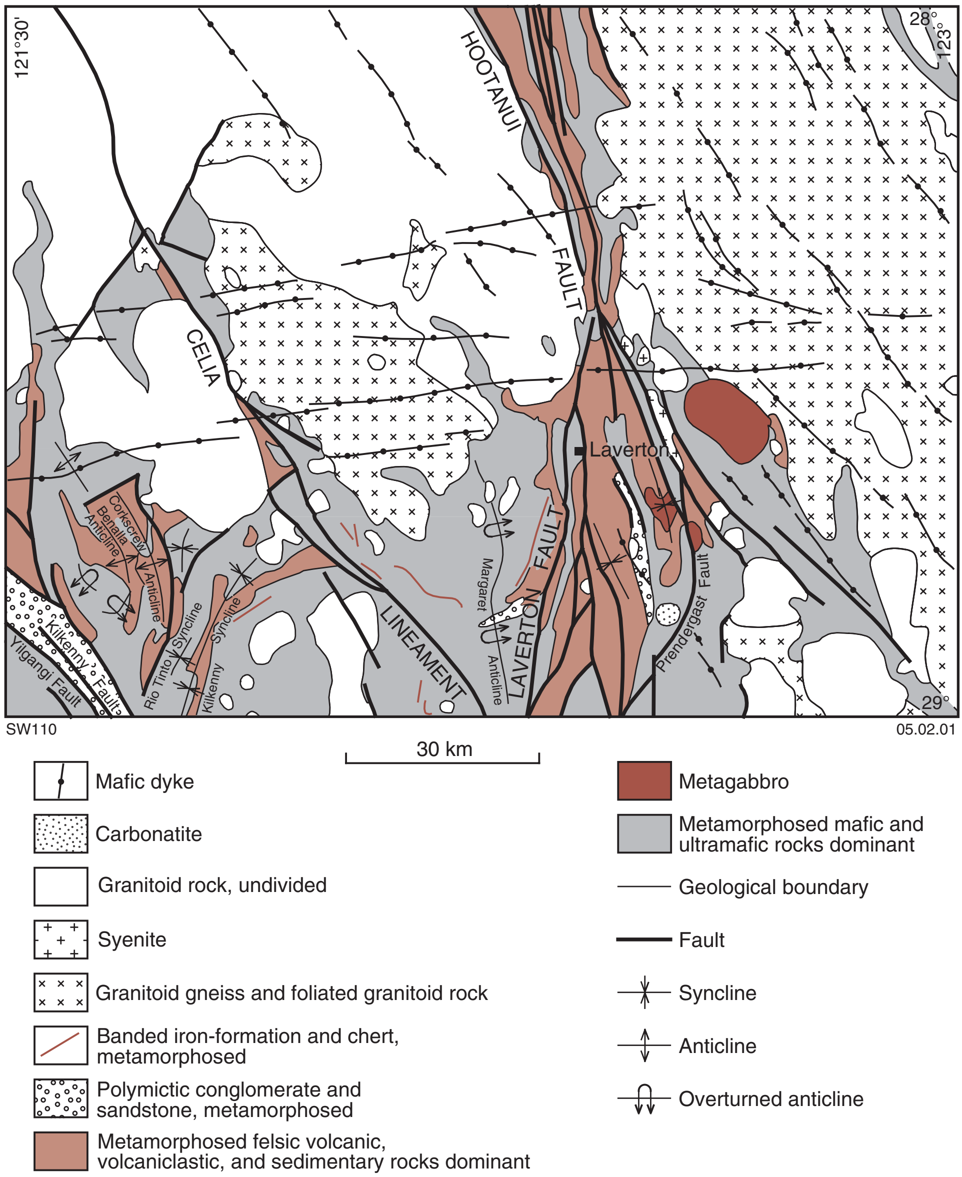


Figure 2. Simplified solid geology map of LAVERTON (1:250 000)

Murrin greenstones

The Murrin greenstones are located between the Yilgangi Fault and Celia Lineament (Fig. 2), and correspond to the Murrin greenstone belt of Griffin (1990). The area is typified by basalt, sandstone, siltstone, felsic volcanic rocks, dolerite, peridotite, and volcaniclastic rocks that have been deformed by large-scale D_1 and D_2 folds, and D_3 faults (see **Structure**), and intruded by several small to large, ovoid to elongate granitoid plutons.

In the central part of LAVERTON (1:250 000), the stratigraphically lowest rocks are extensive felsic volcanic rocks that form large volcanic edifices (Kauri Well and Manger Bore areas). They are overlain and flanked by volcaniclastic rocks — the Welcome Well Complex — derived from the felsic volcanic rocks. Giles and Hallberg (1982) included all the volcanic and volcaniclastic rocks together in their Welcome Well volcanic complex. The volcaniclastic rocks interfinger with, and are overlain by, a thick sequence of basalt interbedded with sandstone and siltstone. Numerous thick, extensive units of dolerite and peridotite formed within the sequence, and there is a peridotite body in the upper part of the andesite volcanic pile. D_1 and D_2 folds form interference structures in the Welcome Well – Cardinia Hill area (Stewart, 1998). The metamorphic facies is mainly prehnite–pumpellyite (Hallberg, 1985).

In the southeast (Mount Kowtah), the sequence comprises mainly basalt and dolerite, and is metamorphosed to greenschist facies. To the northwest (north of Mertondale), basalt and sandstone outcrop between granitoid bodies, and are metamorphosed to amphibolite facies.

In the southwest, the Pig Well Graben (Pig Well domain of Williams, 1998; Fig. 2) is filled with conglomerate and feldspathic sandstone.

Laverton greenstones

The Laverton greenstones are the most extensive greenstones on LAVERTON (1:250 000), and are bounded to the west by the Celia Lineament, and to the northeast and northwest by granitoids (Fig. 2). The greenstones are characterized by basalt and high-Mg basalt, layered dolerite and gabbro intrusions, amphibolite, sandstone and siltstone, chert, felsic volcanic rocks, conglomerate, and rare ultramafic rocks that have been deformed by large-scale D_2 folds and faults, regionally metamorphosed to greenschist facies, and intruded by numerous small granitoid intrusions.

Basalt, high-Mg basalt, ultramafic rocks, and dolerite sills outcrop west, north, and southeast of the Laverton greenstones. In the west, these rocks form the core of a large anticline (the Margaret Anticline), and so form the structurally lowest part of the sequence in this area. On the eastern limb of the anticline, they are overlain by abundant sandstone, siltstone, and felsic volcanic rocks in a northerly trending fold and fault belt, which is possibly a synclinorium. A fault-bounded, northerly trending trough filled with conglomerate, similar to the Pig Well Graben, lies between the Ida H mine and Mount Weld carbonatite (Fig. 2). The sandstone and siltstone continue north and join with similar rocks on DUKETON (1:250 000).

Gower (1976) recorded a westerly facing, northerly striking angular unconformity beneath the conglomerate from Mount Barnicoat (east of Laverton) south to Hacks Well. The unconformity is synclinally folded, and its corresponding easterly facing ‘limb’ was shown extending from the Laverton township to the Granny Smith mine. Hallberg (1985) recorded two northerly striking angular unconformities within the greenstone sequence at, and 4 km west of, Laverton. None of these unconformities were seen in the 1989–93 AGSO survey. The unconformities are largely concealed beneath Cainozoic cover, but according to Hallberg (1985, fig. 7) they are exposed around Mount Jumbo (LAVERTON AMG 395225* and LAVERTON AMG 420220).

* Localities are specified by the Australian Map Grid (AMG) standard six-figure reference system whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on the specified 1:100 000 sheet, to within 100 m.

A layered mafic intrusion, 9 × 14 km in extent, is located at the northeastern margin of the Laverton greenstones. Only its noritic northeastern margin is exposed, near Diorite Hill, but it is prominent on aeromagnetic images. Ten kilometres to the southwest, a smaller gabbro body is exposed along the Merolia road.

The small 'internal' granitoid intrusions include high-Ca, low-Ca, and mafic granites (Champion and Sheraton, 1997), and foliated syenite east and southeast of Laverton Downs.

Cosmo Newbery greenstones

The Cosmo Newbery greenstones occupy a small area in the northeastern corner of the LAVERTON 1:250 000 sheet, and consist of basalt and tremolite schist intruded by gabbro and granite dykes.

ARCHAEAN ROCK TYPES

Weathered Archaean rock (*Aw*)

Weathered Archaean rock of unknown protolith outcrops on the northwestern shore of Lake Carey. The rock adjoins basalt, subordinate gabbro, and metasedimentary rock, and is probably their weathered counterpart.

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

Undivided ultramafic rock (*Au*), komatiite (*Auk*), peridotite (*Aup*), tremolite schist (*Aur*), serpentinite (*Aus*), talc–chlorite schist (*Aut*), and pyroxenite (*Aux*) form a small proportion of the Murrin and Laverton greenstones on LAVERTON (1:250 000), and are most abundant in the southwest. In outcrop, peridotite is the most abundant rock type and komatiite the least. The rocks commonly form concordant lenses or sheets in the greenstone sequences, and carry up to 10% magnetite, which produces strong anomalies on aeromagnetic images.

Undivided ultramafic rock (*Au*) outcrops near Gibson Well in the north, 5 km north of Laverton Downs Homestead in the central area, near Minerie Hill in the southwest, and on the shores of Lake Carey in the south. The rock is commonly schistose, and ferruginous and siliceous where weathered; it may include foliated serpentinite.

Komatiite (*Auk)*, characterized by platy olivine-spinifex texture, forms small outcrops 8 km north-northwest of Mount Varden and 1–3 km north of Laverton Downs in the Laverton greenstones.

Peridotite (*Aup*) is most abundant in the Murrin greenstones where it outcrops in the southwest around the Murrin Murrin mine, and near Macey Hill, Mount Korong, Mount Phoenix, and Homestead Well. In the Laverton greenstones, peridotite is located south of Windarra, around Red Flag Well, and around Doris Well in the north. The peridotite is fine, medium, or coarse grained, and composed of green or blue-green amphibole after pyroxene, serpentine minerals (mainly antigorite) after olivine, plagioclase, magnetite (or hematite), and small amounts of magnesite and chalcedony. It is commonly massive and homogeneous, but pyroxene-phyric, flow banded, or layered in places. Schistose varieties contain abundant chlorite(–talc).

Tremolite schist (*Aur*) outcrops in the Laverton greenstones in the southeast as elongate bodies up to about 1 km thick in basalt at Ironstone Point, as a smaller body at Mallock

Well, and in the northeast at Two Mile Well. The schist is fine to medium grained, and composed chiefly of tremolite or actinolite needles or blades up to 10 mm long. The needles are randomly oriented in the schistosity plane at some localities, or aligned in a lineation at others.

Serpentinite (*Aus*) forms elongate bodies several kilometres in extent, and is exposed in the Laverton greenstones at Jubilee Hill and 10 km east of Laverton Downs. The rock is fine grained and composed of serpentine (20–90%), opaque minerals, actinolite, relict olivine, chlorite, epidote, plagioclase, hornblende, magnesite, and chalcedony. It is even grained to weakly blastoporphyritic, massive to foliated and lineated, and in places grades into talc schist or chlorite–magnetite schist. The unit is derived from peridotite, dunite, or komatiite.

Talc–chlorite schist (*Aut*) forms elongate strips up to 500 m wide at Mount Morgans in the southwest, in the South Pinnacle – Swincer Well area in the north, and 1.5 km east of Mallock Well in the southeast, all in the Laverton greenstones. It is very fine to medium grained and composed of talc, magnetite euhedra up to 2 mm across, chlorite, and rare tremolite. The schist at Mount Morgans includes interbedded chert, and elsewhere is closely associated with silica caprock (*Czu*).

Pyroxenite (*Aux*) is exposed near Admiral Hill and Weebo Well in the central part of LAVERTON (1:250 000), 2 km north of Mount Margaret in the south, and 4 km north-northeast of Rotorua Well in the southeast, all in the Laverton greenstones. The largest exposures are 1–2 km east of Admiral Hill, where they form a bifurcating layer 5 km long and 250 m thick in felsic volcanic rocks. A thin layer is present along the contact of gabbro and peridotite (MINERIE AMG 940160) at the Murrin Murrin mine. The rock is medium to coarse grained, even grained to porphyritic, massive, and composed of bastitic serpentine after pyroxene.

Low- to medium-grade metamorphic rocks (*Ala*, *Alax*, *Alf*, *Alqm*, *Ang*)

This group denotes metamorphosed rocks whose protoliths are unrecognizable, and includes amphibolite (*Ala*), amphibolite with minor porphyry, aplite, and schist (*Alax*), quartz–feldspar schist and quartz–clay rock (*Alf*), quartz–muscovite schist (*Alqm*), and quartzofeldspathic gneiss with mafic bands (*Ang*).

Amphibolite (*Ala*) exposures are widespread in the Murrin and Laverton greenstones on the LAVERTON 1:250 000 sheet; for example, in the northwest near Mount Zephyr and Roman Well, the west near Geyer Well, the north at Freshwater Bore, 5 km north of Mount Korong in the southwest, and in the centre near Windarra and Goose Hill. The unit forms elongate bodies several kilometres long in, or next to, granite at all these places except at Goose Hill, where it forms a 5 × 10 km body intruded by several masses of felsic porphyry. The amphibolite is typically fine to medium grained (rarely coarse grained), and massive or foliated and lineated (grain orientation). It is composed of green amphibole (30–75%) as blades, needles, or rare porphyroblasts, plagioclase (10–30%, commonly altered), opaque minerals (10–20%), epidote (5–40% as porphyroblasts), and quartz (0–40% as aggregates or in the groundmass). Small amounts of titanite, relict pyroxene, tremolite, and carbonate are present in some samples. The amphibolite 3 km southeast of Fleming Bore (LAVERTON AMG 146302) has been serpentinized and is now serpentine, chlorite, talc, and muscovite. In places, amphibolite is interlayered with ?volcanic feldspar–quartz porphyry (MOUNT VARDEN AMG 399753) and pyritic black shale (LAVERTON AMG 317240). Felsic dykes (granite and porphyry) commonly intrude the amphibolite.

Amphibolite, with minor porphyry, aplite, and felsic schist (*Alax*), outcrops 5 km northwest of Mount Korong in the Laverton greenstones, and at Mount Kowtah in the Murrin greenstones, both in the southwestern part of LAVERTON (1:250 000). Both areas are flanked by mafic or ultramafic meta-igneous rocks, and probably represent sequences of mafic and felsic volcanic rocks that have been deformed and metamorphosed, and then intruded by felsic dykes.

Quartz–feldspar schist and quartz–clay rock (*Alf*) in the northern part of the Laverton greenstones (MOUNT VARDEN AMG 400680), 3 km west of Corktree Well, consist of 1–2 mm quartz grains in kaolinized schist, and may be clastic or volcaniclastic in origin.

Quartz–muscovite(–feldspar) schist (*Alqm*) is exposed in the Murrin greenstones in the west near Winston Well and 3 km east of Mertondale mine. The rock is typically fine grained (in places very fine or medium grained), and consists essentially of muscovite, quartz (in places as eyes up to 3 mm in size), and, in some samples, feldspar (or clay). Texture is schistose to phyllitic (rarely massive), with or without a crenulation lineation.

Quartzofeldspathic gneiss with mafic bands (*Ang*) outcrops in three areas between the David Well – Lent Well area in the west. The largest area measures 6 × 3 km. The rock comprises bands of granitic biotite gneiss, foliated granite, and rare hornblende gneiss. Banding is 1–10 cm thick, and arises from differences in grain size (ranging from very fine to coarse) and biotite content — about 2% in light layers, 20% in dark layers. It is commonly migmatitic, and in places nebulitic, with thin folded layers or early veins. Mafic enclaves and amphibolitized mafic dykes are present at some localities. Other crosscutting veins include leucocratic quartz-poor or quartz-rich veins, epidote veins, and granite dykes. Minerals present are quartz, K-feldspar, plagioclase, biotite, hornblende (only in mafic bands), allanite, magnetite, and titanite. The gneissosity is readily apparent in all outcrops, but lineation (stretched quartz) is rare.

Fine-grained mafic igneous rocks (*Ab*, *Abb*, *Abf*, *Abhp*, *Abm*, *Abp*, *Aby*)

Mafic volcanic rocks, principally massive to pillowed basalt and amygdaloidal basalt, are the most abundant greenstone rock type on LAVERTON (1:250 000); high-Mg basalt is abundant near Mount Margaret and Macey Hill. The basalts commonly contain chert or BIF interbeds and laminar interflow sedimentary rocks, and are interlayered at regional scale with units of ultramafic, felsic volcanic and volcaniclastic rocks, and clastic sedimentary rock. Sheets and lenses of dolerite and gabbro are intercalated with the basalts, and some of the dolerites may be slowly cooled parts of basalt flows, particularly in the Mount Varden area. Where it is unclear whether the rocks are extrusive, intrusive, or pyroclastic, they are mapped as undivided, fine-grained mafic igneous rocks (*Ab*). Pillows are best preserved in the southwest between Cement Tank Well and Pub Well, and 3 km west of Pub Well (Gower, 1976), but have been noted at many other places. The basalt is commonly amygdaloidal, and is cleaved or schistose, and lineated; small-scale sinistral shear zones 3 m wide are present around Hillside Well (LAVERTON AMG 396113). Numerous dykes cut the basalt, including porphyry, quartz, and gabbro (NAMBI AMG 818603), and quartz and epidote veins are also common. Metamorphically banded basalt outcrops about 4 km southeast of Swincer Well (MOUNT VARDEN AMG 407758).

Basalt (*Abb*) outcrops in all four greenstone areas and is typically even grained, very fine to fine grained (but in places medium and coarse grained), and composed of blue-green actinolite (20–50%), plagioclase (10–30%), and opaque minerals (5–10%; some have been identified as ilmenite). Other minerals present locally include: green hornblende (60–75%)

instead of actinolite, epidote (5–50%) after plagioclase, hematite (10%), quartz (5–10%), carbonate (5%), and titanite (5%). The unit includes some thin layers of high-Mg basalt.

Mafic schist (*Abf*) outcrops in the Laverton greenstones north and south of Mount Barnicoat, 7 km southeast of Windarra, between Mount Margaret and Mount Morgans, northwest of Mount Korong, and at Camel Hump; in the Malcolm greenstones at Mount Stewart; and in the Murrin greenstones at Mount Korong and 5 km east of Federation Well. The schist is fine to medium grained, and consists of chlorite, actinolite, feldspar, minor quartz, and, in some samples, calcite. The schistosity is strong and arises from the parallel alignment of chlorite flakes and actinolite needles; linear alignment is rarely recorded.

Pyroxene hornfels (*Abhp*) has been mapped at Eighteen Mile Well in the Laverton greenstones, where it is black, fine grained, poikiloblastic, and composed of pink hypersthene (30%), acicular actinolite (30%), simply twinned plagioclase (30%), and opaque minerals (10%). The rock has been hornfelsed by norite to the north.

High-Mg basalt (*Abm*) is exposed 5 km south-southeast of Mount Varden and east of Mount Margaret Mission in the Laverton greenstones, and at Federation Well and around Macey Hill in the Murrin greenstones. These rocks are commonly near or adjacent to ultramafic rock, particularly the extensive peridotite near Macey Hill. High-Mg basalt is characterized by relict pyroxene-spinifex or variolitic textures and 8–17% MgO (OZROX database). Essential constituents are actinolite (20–70%), plagioclase (10–20%), and opaque minerals (10%). Other minerals noted in some samples are quartz (5–30%), biotite (5–10%), carbonate (10%), epidote (10%), chlorite (20%), tremolite (20%), and antigorite (50%).

Plagioclase-phyric basalt (*Abp*) is located 7 km east of Macey Hill in the Murrin greenstones, where it continues onto the EDJUDINA 1:250 000 sheet (Chen, 1999). The phenocrysts are up to 2 cm across and concentrated in 5–10 m-size patches.

Vesicular or amygdaloidal basalt (*Aby*) outcrops mainly in the Murrin greenstones in the Cement Tank Well area, to a lesser extent in the Laverton greenstones 4 km north of Mount Morgans, and at Mallock Well and Golden Ring Well in the southeast. Actinolite and plagioclase form small phenocrysts, and quartz is abundant (20%) in groundmass and amygdales. The basalt around Cement Tank Well is underlain, overlain, and interbedded with thick units of sandstone, the whole forming a steeply easterly dipping, upright sequence about 3300 m thick. Basaltic tuff and hyaloclastite breccia are present 3.8 km west of Mailman peak (MINERIE AMG 740000).

Medium- to coarse-grained mafic igneous rocks (*Aod*, *Aodp*, *Aog*, *Aogl*, *Aogp*, *Aon*)

Dolerite and gabbro commonly form layers, sills, and sheets up 1000 m thick in basalt sequences, and are also present in felsic volcanic sequences in the Cardinia Hill area in the southwest, and at Mount Clarke in the north. They are commonly concordant with the country rock, but can be locally discordant (e.g. 1–2 km west of Welcome Well). Platy mineral alignment is common in the Benalla Hill and Mount Redcastle areas in the southwest.

Dolerite (*Aod*) outcrops extensively throughout LAVERTON (1:250 000) in all greenstone areas except Cosmo Newbery, and is particularly abundant in the southwestern, northern, and central part of the sheet area. The rock is fine to medium grained, commonly even grained, and composed chiefly of actinolite (40–50%) commonly in clots, plagioclase (30–40%), quartz (up to 10%), and opaque minerals (2–10%). Secondary minerals include epidote, chlorite, and carbonate. The rock is massive to weakly or strongly foliated and lineated (due to the alignment of amphibole and plagioclase grains). Ophitic texture is preserved locally. At some localities, dolerite is interlayered with basalt, or sedimentary rocks, or felsic volcanic rock (e.g. MINERIE AMG 760089). Elsewhere, it contains enclaves of sedimentary and ultramafic rocks.

Porphyritic dolerite (*Aodp*) containing plagioclase phenocrysts is present in the Murrin greenstones in the southwest, where it forms large lenses and crosscutting intrusions between Cardinia Hill and Welcome Well. One kilometre west of Welcome Well, the plagioclase phenocrysts are up to 6 cm long (Gower, 1976).

The largest exposures of gabbro (*Aog*) are in the Macey Hill – Toomey Hill – Mount Redcastle area of the Murrin greenstones, along the Merolia road, on the western shore of Lake Carey, and at Mount East in the Laverton greenstones. The rock is typically coarse grained, but ranges from medium to very coarse grained. The gabbro consists of light-green actinolite or dark-green hornblende (10–50%) after pyroxene, plagioclase (20–40%), quartz (10–15%), chlorite (5–20%), and opaque minerals (commonly magnetite; 5–10%). Relict clinopyroxene is present in many samples. The gabbro also contains orthopyroxene (15–30%), zoisite (10–20%), titanite (5–10%), epidote (5–10%), and biotite (10%). Saussuritized gabbro (BURTVILLE AMG 570250) contains abundant clinozoisite, garnet, sericite, and ilmenite, and serpentinized gabbro (BURTVILLE AMG 610140) contains serpentine, a feldspathoid, and numerous, brown clasts of mafic volcanic rock. Most gabbros are even grained, but plagioclase-, amphibole-, and pyroxene-phyric varieties have formed in a few places. The rock is massive to weakly foliated. A vein of gabbroic pegmatite intrudes gabbro 5 km southwest of Corner Well (BURTVILLE AMG 560230). Gabbro associated with peridotite at Murrin Murrin has been metasomatized, and is composed of diopside, hydrogrossular, vesuvianite, chlorite, and opaque minerals (Gower, 1976); according to Miles (1950), Ca was added and Mg, Si, and alkalis were removed.

The gabbro dipping at about 65° east-southeast, 2 km southwest of Macey Hill (MINERIE AMG 770920), has an upper zone of leucogabbro and resembles the Kilkenny Gabbro (Jaques, 1976), which outcrops 2 km to the southeast and about 1500 m stratigraphically higher on EDJUDINA (1:250 000).

Plagioclase-rich leucogabbro (*Aogl*) outcrops on the western shore of Lake Carey in the Murrin greenstones. Porphyritic gabbro (*Aogp*) has been mapped separately 4 km southwest of Mount Zephry (NAMBI AMG 782567).

Norite (*Aon*) has been mapped only in the Laverton greenstones in the east, near Diorite Hill, where it is part of a layered intrusion some 8 × 12 km in extent (from aeromagnetic data interpretation). The unit is black, coarse grained, subtly layered, and composed of ortho- and clinopyroxene (together 50%), plagioclase (40%), and magnetite (10%).

Felsic volcanic and volcaniclastic rocks (*Af*, *Afd*, *Afi*, *Afia*, *Afif*, *Afih*, *Afis*, *Afp*, *Afs*, *Aft*, *Afv*)

Felsic volcanic and volcaniclastic rocks outcrop extensively in the Murrin greenstones in the southwestern part of LAVERTON (1:250 000), especially in the Welcome Well and Randwick Hill areas. They are less abundant in the Laverton greenstones in the south near Brewery and Hillside wells and Mount Jumbo; in the centre at Admiral Hill, near Mount Barnicoat, at Lawson Well, and several other places southwest of Laverton township; north of Laverton Downs; and around the Mount Clarke area in the north. Rock types include silicic varieties, mainly dacite to rhyodacite, and intermediate types; for example, andesite. Most exposures are difficult to identify in the field, and have been called simply felsic volcanic and volcaniclastic rocks or intermediate extrusive rocks. The group also includes intrusive felsic porphyry. The felsic volcanic and volcaniclastic rocks in the Welcome Well – Manger Bore – Kauri Well area were grouped as the Welcome Well Complex by Hallberg (1985), but the AGSO 1989–93 survey restricted the term Welcome Well Complex to the volcaniclastic rocks around Welcome Well only. Pidgeon and Wilde (1990) determined conventional U–Pb dates of 2735 ± 10 Ma and 2697 ± 3 Ma on zircons from felsic volcanic rocks in the Mount Germatong mine and Pig Well area on LEONORA (1:250 000), 3–10 km west of LAVERTON (1:250 000).

Fine-grained, felsic extrusive rocks (*Af*) have been mapped in the Murrin greenstones (Christmas Well, No. 10 Well, 3 km south of Minerie Hill, and Bernie Bore), in the Laverton greenstones at several localities within about 15 km of Laverton, and 2 km northwest and 4 km east of Mount Weld. They are characteristically equigranular, but porphyritic in a few places, and consist essentially of quartz, feldspar, and biotite. Phenocrysts, where present, are anhedral quartz 2–6 mm across, subhedral feldspar up to 8 mm, biotite 1–3 mm long, and rare subhedral to euhedral hornblende up to 6 mm long. The rocks are typically massive, but foliated in a few places, and lineated in even fewer.

Rocks of dacitic to rhyodacitic composition (*Afd*) form a small outcrop surrounded by amphibolite in the northwest (NAMBI AMG 593665).

Undivided, intermediate extrusive rocks (*Afi*) outcrop on LAVERTON (1:250 000) north of the Laverton greenstones at Mount Amy, 5 km north-northeast of Mount Amy, and 6 km southeast of Camel Hump. Their schistose equivalent (A*fis*) has been mapped immediately west of Mount Clarke, and comprises metavolcanic schist, tuff, sandstone, and rare basalt. The schist is fine to very fine grained, and composed essentially of quartz and sericite; chlorite is present in places, and quartz forms 2 mm eyes locally (MOUNT VARDEN AMG 367932). Foliation and lineation are strong, and the rock is crenulated east of Kirkpatrick Well (MOUNT VARDEN AMG 367932). Basalt included in the unit (e.g. at MOUNT VARDEN AMG 357971) is amygdaloidal.

Andesite (*Afia*) outcrops in the Murrin greenstones in the southwest in the Kauri Well – Corkscrew Well area, in the Laverton greenstones at Lawson Well, and at a locality 7 km southwest of the Laverton township. In the Kauri Well – Corkscrew Well area, clinopyroxene–plagioclase-phyric andesite forms flows, agglomerate, tuff with andesite clasts, and intercalated mud flows, the whole making up a volcanic centre (Giles and Hallberg, 1982). Hallberg (1985) assigned the intermediate rocks in the Kauri Well – Corkscrew Well area to the Welcome Well Complex. Amygdales are present locally (MINERIE AMG 705226). At Lawson Well, rock types include porphyritic and amygdaloidal andesite, agglomerate with clasts up to 0.5 m long, feldspar-phyric, crystal-lithic tuff, hornblende- and feldspar-phyric tuff, interbedded tuff and agglomerate (20 m interbeds), and breccia composed of fine-grained, angular volcanic fragments. Andesite southwest of Laverton is porphyritic and strongly cleaved. The andesites are composed of phenocrysts of hornblende, plagioclase, clinopyroxene (rare), quartz (rare), and biotite clots in a fine- to medium-grained groundmass. Calcite fills vugs in glassy, welded crystal tuff at Lawson Well (LAVERTON AMG 484249).

Hornblende(–plagioclase)-phyric intermediate lava (*Afih*) and its foliated variant (*Afif*) outcrop in the Murrin greenstones 4–5 km west of Minerie Hill, and in the Laverton greenstones around Lawson Well and immediately north of Laverton Downs. At Lawson Well, the assemblage comprises porphyritic andesite, with lesser dacite, rhyolite, agglomerate and brecciated flows, volcanic breccia, volcaniclastic conglomerate, and tuff. Biotite–hornblende–feldspar-phyric dacite is abundant 2 km west of Lawson Well (LAVERTON AMG 464259). Rhyolite is quartz-phyric, fragmental, and vesicular (LAVERTON

AMG 490220). Feldspar-phyric vesicular tuff is present in the same area. The tuff contains 10% relict pyroxene grains partly altered to chlorite, and 10% serpentine (LAVERTON AMG 464215). The volcanic rocks 5 km west of Minerie Hill have been contact metamorphosed to hornblende-hornfels facies and contain relict amygdales. Andesitic schist and mylonite are also present locally. North of Laverton Downs, intermediate lavas are sericitized.

Intrusive felsic porphyry (*Afp*) is widespread on the LAVERTON 1:250 000 sheet. The largest intrusions are between Goose Hill and Mount Ajax in the Laverton greenstones, and between Mount Redcastle and Mount Murrin Murrin in the Murrin greenstones. Phenocrysts include rounded or irregular quartz (up to 6 mm long; 5–30%), subhedral plagioclase (up to 6 mm long; 5–40%), orthoclase (up to 1 cm long; 35–50%), clots or flakes of biotite (1–2 mm long; 1–15%), and rare hornblende (up to 8 mm long; 5–10%). The groundmass is very fine to fine grained and composed of quartz, feldspar, and biotite. Other minerals include magnetite, fluorite, apatite, hematite, unidentified opaque minerals, and tourmaline. Secondary minerals include muscovite after feldspar, interstitial calcite, and chlorite. Pyrite is present locally (e.g. at LAVERTON AMG 260240 and LAVERTON AMG 330270). Chloritic, micaceous xenoliths are present 4 km east of Ida Hill Well (LAVERTON AMG 510210).

Quartz–feldspar (or muscovite) schist (*Afs*) outcrops in the Laverton greenstones at Admiral Hill and 3 km northeast of Laverton Downs, and in the Murrin greenstones 3 km southwest of Mount Morgans. The Admiral Hill rocks are on strike with, and so may be deformed and metamorphic equivalents of, pyroclastic rocks 5 km east of Mount Barnicoat.

Felsic pyroclastic and volcaniclastic rocks (*Aft*) on LAVERTON (1:250 000) are exposed mainly in the Murrin greenstones in the southwest, where they form numerous beds up to 500 m thick interlayered with basalt in the Cardinia Bore – Windy Bore – Welcome Well area; they also outcrop at Mount Korong and 10 km west of Mount Morgans. In the Laverton greenstones, a large north-northwesterly striking body has been mapped 5 km east of Mount Barnicoat, and smaller outcrops are present east and south of Mount Weld. The rocks are fine- to coarse-grained, laminated tuffs and composed of quartz (20–80%) as angular grains, clasts, and in the groundmass, groundmass feldspar (10–40%), hematite (5–10%), and felsic volcanic clasts (15–60%). Other minerals present, but not in all samples, are groundmass plagioclase (20%), chlorite (10–20%) after mafic grains, muscovite (10–20%) as very small flakes, biotite (10%), and epidote (10%). Quartz crystals (bipyramidal to 2 mm) are abundant (BURTVILLE AMG 550290). The pyroclastic rocks 5 km east of Mount Barnicoat are well laminated and schistose, with feldspar grains concentrated in laminae.

Felsic volcanic or volcaniclastic rocks (*Afv*) are exposed in the Murrin greenstones at Manger Bore and Cardinia Bore; and in the Laverton greenstones at several localities around Mount Clarke and 12 km southeast of Mount Weld. Near Manger Bore, the rock is a fine-grained, eutaxitic crystal tuff (welded pyroclastic flow deposit), which is flow banded, vesicular, and has hornblende and feldspar crystals (MINERIE AMG 710200).

Sedimentary rocks (*Ac*, *Aci*, *Acl*, *As*, *Asc*, *Ascb*, *Asfv*, *AsfW*, *Ash*, *Ass*)

Sedimentary rocks on LAVERTON (1:250 000) are grouped into those of chemical origin — chert, BIF, and limestone; and those of clastic origin — conglomerate, sandstone, and shale.

Chert (*Ac*) is widespread on LAVERTON (1:250 000), and forms resistant strike-ridges up to several kilometres long within the greenstones. Chert is very fine to (rarely) fine grained, laminated to very thin bedded, and composed of quartz and small amounts of magnetite, hematite (after magnetite), pyrite, and locally amphibole (MOUNT VARDEN AMG 443658).

The rock is commonly foliated, but rarely lineated. Open to isoclinal folds are common, and in places the chert is faulted, fractured, or brecciated. Easterly facing sedimentary scours are preserved locally (e.g. at LAVERTON AMG 347181). Chert may be interbedded with phyllite and shale.

Banded iron-formation (*Aci*) also forms resistant strike-ridges and is abundant in the Murrin greenstones and southern part of the Laverton greenstones, but absent from the northern and eastern part of the Laverton greenstones. The BIF resembles chert in sedimentary and deformation structures, but the laminae are alternately rich and poor in iron oxide, resulting in a brown, red, or black and white striped appearance. The pale laminae are composed of 80% quartz and 20% magnetite, and the dark laminae of 40% quartz and 60% magnetite; hematite has replaced magnetite in places. Bedding laminae are commonly planar, but locally wavy (e.g. at LAVERTON AMG 375337). Sedimentary scours face west near Mount Weld Homestead. The iron formation is interbedded with clastic sedimentary rocks — feldspathic sandstone, slate, or phyllite — in several places.

Limestone (*Acl*) is exposed 7 km west of Mount Ajax, where it forms a single, northerly striking, elongate layer about 150 m wide between gabbro and porphyry.

Undivided metasedimentary rock (*As*) includes a range of rock types, some of which may form in the same outcrop, and are commonly weathered. This unit has been mapped in the Laverton greenstones in the south near Mount Weld Homestead, at Harold Well, 3 km west of the Granny Smith mine, and 9 km northeast and 8 km southeast of Mount Varden. In the Murrin greenstones, undivided metasedimentary rocks have been shown in the southwest near Christmas Well, Bernie Bore, Garden Well, and in the west on the Leonora–Nambi road. At Bernie Bore, the rocks include hornfels and laminated metasiltstone. Cleaved and schistose quartz siltstone and BIF float are exposed at Garden Well. The exposures on the Leonora–Nambi road are very fine grained quartz–feldspar–sericite schist. The rocks in the Mount Varden area are interbedded, fine-, very fine, or medium-grained, moderately well bedded, silicified sandstone.

Polymictic conglomerate (*Asc*) has been mapped in the Laverton greenstones near Mount Weld, at Bore No. 8, 3 km southwest of Mount Amy, 5 km north of Laverton Downs, and 1 km west of Barnicoat Well. It is also abundant at Butcher Well and Allan Well in the southwest. The conglomerate comprises angular to rounded cobbles and boulders up to 2 m in size, in a fine- to coarse-grained sandy matrix of quartz, feldspar (some of which is plagioclase), and iron oxide grains. Most clasts are quartzite or granite. The rock is typically massive, but horizontally planar medium-bedded in places. Graded bedding and scours face west near Mount Weld (LAVERTON AMG 511177); the rock here has numerous moulds after pyrite. Rip-up clasts are present locally (e.g. at LAVERTON AMG 509227). The conglomerate is commonly foliated, and the clasts flattened and stretched. According to Hallberg (1985), the conglomerate in the southwest filled a graben (Pig Well Graben of these Explanatory Notes), with the detritus being derived from higher-standing margins and deposited near the edges of the graben in alluvial fans. The conglomerates north and southeast of Laverton may be of similar origin. Conglomerate above the unconformities at, and 4 km west of, Laverton (see **Laverton greenstones**) is composed mostly of locally derived mafic clasts and, according to Hallberg (1985), may have been deposited in channels and depressions in the underlying basalt. The granitoid and quartz-pebble conglomerates on LAVERTON (1:250 000) resemble the Jones Creek Conglomerate on SIR SAMUEL (Liu et al., 1998) in composition and structural setting.

Oligomictic conglomerate (*Ascb*) is exposed in the Laverton greenstones near Mount Zephyr in the west. The conglomerate consists of flattened and aligned, subrounded cobbles and boulders, mainly of quartz–feldspar composition, in a grey mafic matrix.

Undivided sedimentary (non-volcanic) and volcanic rocks (*Asfv*) on LAVERTON (1:250 000) have been mapped only in the southern part of the Laverton greenstones at Brook Tank, 3 km east of Mount Weld Homestead, and 9 km west of Granny Smith mine. At Brook Tank, the rocks are an assemblage of agglomerate (with pale felsic clasts) and crystal-lithic tuff, feldspathic sandstone with chlorite clasts, BIF, and feldspar-phyric xenolithic porphyry with relict augite phenocrysts partly altered to chlorite and quartz. The tuff contains abundant pale felsic clasts, and cross-bedding and graded bedding in the tuff are westerly facing. East of Mount Weld Homestead, the exposures are mainly feldspathic volcanic breccia. West of Granny Smith mine, the assemblage comprises silicified arkosic sandstone, mafic schist, schistose conglomerate (with clasts of porphyry), chert, jaspilite, quartz-rich slate, and rhyolitic agglomerate.

Volcaniclastic conglomerate, sandstone, and tuff (*AsfW*) make up the Welcome Well Complex in the Welcome Well and Murrin Murrin areas of the Murrin greenstones. Around Welcome Well, the rocks consist of conglomerate with felsic volcanic clasts, sandstone, and siltstone. Sandstone is fine, medium, or coarse grained, poorly to moderately well sorted, and composed of quartz, subangular feldspar, and carbonate represented by rhomboid moulds. Siltstone is thinly bedded and also has rhomboid holes. To the northwest in the Windy Bore – Cudi Bore area, the assemblage comprises fine-grained feldspathic sandstone, planar-bedded conglomerate, andesite agglomerate, and clinopyroxene–plagioclase-phyric andesite–dacite. In the Murrin Murrin area, the Welcome Well rocks include volcaniclastic, siliciclastic, and volcanic rocks, and overlie peridotite lavas (Fazakerley and Monti, 1998). The following rock types are present in the Murrin Murrin area (from the OZROX database): tuffaceous breccia with volcanic clasts; weakly banded to well-bedded, dacitic feldspar-phyric tuff with angular volcanic or sedimentary clasts up to 5 cm long; massive agglomerate with very fine grained clasts of quartz–feldspar porphyry; coarse-grained sandstone composed of quartz and angular feldspar; very thinly bedded, poorly sorted sandstone; laminated to very thinly bedded, silty shale; faintly laminated, clayey siltstone; vesicular feldspar-phyric lava (silicified and very fine grained); and rhyolite breccia.

Giles and Hallberg (1982) and Hallberg (1985) placed these rocks in the upper part of the Welcome Well Complex, and interpreted them as an alluvial fan derived from the andesitic volcanic centre of the Kauri Well – Corkscrew Well area.

Shale, slate, phyllite, and claystone (*Ash*) are common in the Laverton greenstones in the north at Mount Clarke and Mount Amy, in the southeast 10 km east of Mount Weld and 4 km north-northwest of Rotorua Well, at several places within 4–5 km north and south of Laverton, 4 km east of Granny Smith mine, near Eight Foot Well on the Leonora–Laverton road, and 5 km north-northwest of Mount Morgans. A single outcrop in the Murrin greenstones is located 4 km west-northwest of Macey Hill. The rocks are very fine to fine grained, laminated to very thinly bedded, cleaved or foliated, commonly lineated, and in places crenulated, boudinaged, or open to isoclinally folded. Shale is composed of clay and quartz; pyrite and carbonate are common. Quartz eyes and broken plagioclase grains are rare. Phyllite is composed of mica (90–95%) and quartz (5–10%); pyrite cubes are common and magnetite euhedra rare. Claystone and slate are commonly silicified. The rocks are commonly interlayered with each other, and in places are interlayered with fine-grained sandstone and BIF.

Sandstone with minor siltstone (*Ass*) are abundant in the Laverton greenstones around Laverton and south from there to Lake Carey; between Admiral Hill and Mount Crawford just north of Laverton; and in the Camel Hump – Mount Clarke – Murphy peak area in the north. They are also abundant in the Murrin greenstones near and around Cardinia Hill, Mailman peak, Mount Murrin Murrin, and Mount Korong, at a locality 2 km west of

Maurice Bore, and along the Erlistoun–Nambi road. Sandstone at, and northwest of, Butcher Well is in the Pig Well Graben. The sandstone is typically fine grained, but ranges from very fine (rarely) to coarse grained. The unit is composed of quartz, angular feldspar, and a small amount of muscovite or biotite. Sorting is moderate to poor, and bedding thin to (rarely) medium or thick. Cross-bedding is common, and includes low-angle, planar cross-bedding and ripple cross-laminae. The sandstone contains some conglomerate (LAVERTON AMG 483301), and also carbonate patches 30 cm across (MOUNT VARDEN AMG 394913). Siltstone is composed of quartz and feldspar or clay, with rare pyrite cubes. Bedding is very thin to laminated. Both sandstone and siltstone are commonly cleaved but rarely lineated, and tightly folded in places (e.g. MINERIE AMG 937352, MOUNT VARDEN AMG 294962, MOUNT VARDEN AMG 329979, LAVERTON AMG 439177). Graded bedding faces northwest near Mount Weld (LAVERTON AMG 495217).

Granitoid rocks

Granitoid rocks occupy about 60% of the LAVERTON 1:250 000 sheet. Monzogranite is by far the most abundant variety, but small bodies of granodiorite, syenite, and tonalite outcrop near Laverton. Large areas of granitoid are covered by Cainozoic sand, colluvium, or playa-lake sediments. These Explanatory Notes use the five chemical groups of Champion and Sheraton (1997) — high-Ca, low-Ca, high field strength elements (HFSE), mafic, and syenitic groups. The chemical data summarized by Champion and Sheraton (1997) suggest that, although derived predominantly from the crust, there may have been a mantle contribution to some of the granitoid melts.

Granitoid rock types (Ag, Agd, Agg, Agm, Agmc, Agmf, Agmm, Agmp, Agn, Agp, Ags, Agt)

Monzogranite, granodiorite, and tonalite (described together) are commonly medium grained, but range from fine to coarse grained. The major constituent minerals include anhedral quartz (5–40%), commonly with undulose extinction; anhedral perthitic microcline (8–60%); anhedral to subhedral plagioclase (10–60%) with multiple twinning and muscovite inclusions, typically antiperthitic and sericitized, with oscillatory to normal zoning in some samples; and yellow to brown or brown-green biotite (4–20%), which is commonly chloritic.

Other primary minerals that may be present include: green or blue-green amphibole (0–15%), which is anhedral to euhedral, up to 3 cm across, and chloritic; orthopyroxene (5–10%; e.g. at MOUNT VARDEN AMG 306475 and MOUNT VARDEN AMG 482745); and accessory amounts of hematite, opaque minerals, rutile, zircon, titanite, apatite, pyrite, allanite, garnet, and fluorite. Secondary minerals include epidote after biotite, plagioclase, or titanite; muscovite after plagioclase and biotite; chlorite after biotite and hornblende; hematite after mafic grains; and carbonate, mainly in plagioclase.

The granitoids are even grained to sparsely porphyritic or seriate. Phenocrysts are mainly microcline and are up to 10 cm across; rare quartz phenocrysts are up to 5 cm across. Weak gneissic or migmatitic centimetre-scale banding defined by changes in mineral proportions is present in about 10% of the rock. Elsewhere, granitoid is commonly foliated due to the flattening of quartz and feldspar and alignment of biotite. A stretching lineation is less common. The rock is mylonitic in places and boudinaged (e.g. at MINERIE AMG 750262). In places, the granitoids contain metre-size patches of pegmatite, biotite-rich schlieren, and xenoliths of biotite-rich rock, gneiss, amphibolite, or granite. Veins and dykes of quartz, pegmatite, aplite, and porphyry, and more rarely granite, lamprophyre, epidote, or chlorite cut the granitoids.

Alteration has affected the granitoids at many places on LAVERTON (1:250 000), and details are provided in Appendix 2.

Unassigned granitoid (*Ag*) has been mapped in the centre of LAVERTON (1:250 000) along the Erlistoun–Nambi road and south of Spinifex Well, and in the north at Pumping Station Well, Mistletoe Bore, and 10 km southeast of Mount Varden. The unit is commonly pink, less commonly grey or white, and fine to medium grained. The outcrops in the north are low Ca, and those in the centre are high Ca (Champion and Sheraton, 1997).

Diorite (*Agd*; mafic group of Champion and Sheraton, 1997) forms a small body 1 km north of Woolshed Well in the northwest (NAMBI AMG 656699). It is fresh, coarse grained, composed of plagioclase and hornblende, and locally epidotized.

Granodiorite (*Agg*; mafic group of Champion and Sheraton, 1997) forms a small body that intrudes sandstone at the Granny Smith mine, and also outcrops 2 km south-southeast of Minerie Hill, at the margin of a large area of monzogranite. The body near Minerie Hill is medium to coarse grained, equigranular, foliated, and contains both biotite and hornblende.

Monzogranite (*Agm*) on LAVERTON (1:250 000) includes a high-Ca group in the northwest, west, southwest, and the Beasley Well – Windarra area, a low-Ca group in the northeast and immediately northeast of Laverton Downs, and a HFSE group in the south (Mount Kowtah area). The unit is grey, or varicoloured pink, white, grey, and black, medium grained (*Agmm*), but includes fine- (*Agmf*) and coarse-grained (*Agmc*) varieties, and is commonly porphyritic.

Layered and foliated granitoid (*Agn*) is abundant on LAVERTON (1:250 000), particularly in the northeast, east, and southeast. In these areas, it is a mixture of medium to very coarse grained, migmatitic banded gneiss and foliated granite. Banding in the gneiss is about 10 cm thick, and results from grain-size and mineral-abundance changes. The banding ranges from wispy streaks and nebulitic stringers to clear layering, and from planar to intricately folded. The mafic mineral is typically biotite, and less commonly hornblende. The granite component is foliated, and foliation and lineation in both gneiss and granite arise from flattening and stretching of quartz and feldspar grains. Pegmatite veins are deformed within the gneiss and granite. The unit is less extensive in the centre and west, and outcrops at Mount Zephyr, North Well, Steve Well, Windarra, Woodline Well, and Smith Well. In these areas, it is commonly a weakly to strongly foliated and lineated granite, with enclaves and layers of schist, and mafic and ultramafic rock. The granite is mylonitic in the Smith Well and Mount Zephyr areas. Foliated granite includes high-Ca granite in the southeast, low-Ca granite in the northeast (Darby Well), and mafic granite in the southeast (east of Russell Well).

Porphyritic granitoid (*Agp*, *Agmp*) on LAVERTON (1:250 000) forms small bodies in the north at Murphy peak and Nulerie Waterhole, and 7 km southeast of Ironstone Point in the southeast.

Five masses of syenite (*Ags*; syenitic group of Champion and Sheraton, 1997) have been mapped on the LAVERTON 1:250 000 sheet. The largest trends north-northwest in the Mount McKenna area. Two irregular, elongate bodies have been mapped 5 and 7 km southeast of Laverton Downs, and are on strike with the Mount McKenna body. Two small stocks outcrop in the same general area (MOUNT VARDEN AMG 438545 and LAVERTON AMG 490425). Syenite is typically pink to brown, locally grey, medium to coarse grained, and even grained to porphyritic to seriate. Unlike most syenite in the Eastern Goldfields, the syenite on LAVERTON (1:250 000) is foliated in many places by the flattening of feldspar and quartz, and a stretching lineation is common. The syenite comprises 12% quartz, 20%

plagioclase, 8% biotite, and 25% amphibole (blue-green to green). Orthopyroxene forms relict cores in amphibole (e.g. at BURTVILLE AMG 574306). Syenite may contain up to 10% fluorite (e.g. at MOUNT VARDEN AMG 500492) and disseminated pyrite (e.g. at BURTVILLE AMG 543385).

Tonalite (*Agt*) forms small elongate bodies (mafic group of Champion and Sheraton, 1997) separated by sandstone and dolerite 5 km north of Mount Weld Homestead, and also forms a stock 3 km north of the Lancefield mine (high-Ca group). The tonalite is grey, blue, or white, fine to medium grained, even grained to porphyritic to seriate, massive to locally foliated, and contains up to 30% mafic minerals (biotite and hornblende). Round to rectangular mafic xenoliths are common.

Granitoids with unusual compositions (*Ags*, *Agt*) are mostly present as 'internal' bodies in the Laverton greenstones.

MINOR INTRUSIONS (*d*, *g*, *gb*, *gr*, *lp*, *p*, *po*, *q*, *sy*)

Many of the minor intrusions shown on the 1:100 000 map sheets that make up LAVERTON (1:250 000) are not shown on the 1:250 000 sheet.

Dolerite sheets and dykes (*d*) of presumed Archaean age intrude greenstones in the west, southwest, and centre of LAVERTON (1:250 000). Some are concordant with layering in the greenstones, others are moderately to highly discordant. Granite dykes (*g*) have been mapped in the northwest, where they form a parallel swarm in basalt and amphibolite 2 km southwest of Clifton Well and a randomly oriented swarm in monzogranite 7 km west of Victor Well, and in the northeast on the Warburton Range road at the northern margin of the sheet. Concordant gabbro sheets (*gb*) intrude greenstones in the northeast, west, and southwest, but are uncommon. Greisenized dykes (*gr*) are rare, and intrude mafic greenstones at or near their contacts with granitoid.

Lamprophyre dykes (*lp*) have been recognized only in the southwest and south, and strike northeast or southeast. They have a range of compositions. Sample 93964128 (BURTVILLE AMG 527081) has 35% opaque minerals, 30% carbonate, 10% biotite, 10% amphibole, 10% hematite, and 5% chlorite. Sample 91964929 (LAVERTON AMG 209105) has 40% amphibole, 30% epidote, 20% albite, 10% chlorite, and less than 1% carbonate. Sample 90963137 (LAVERTON AMG 316203) has 30% amphibole, 30% quartz, 15% orthopyroxene, 10% feldspar, 10% chlorite, and 5% olivine.

Only two occurrences of pegmatite (*p*) have been mapped on the LAVERTON 1:250 000 sheet (MINERIE AMG 923370 and NAMBI AMG 960970). Porphyry (*po*) is common in the west, southwest, and centre, but absent elsewhere, and forms swarms of discordant, parallel to divergent dykes hosted in mafic igneous rocks. Quartz veins (*q*) are found throughout the sheet area, and are equally distributed in greenstone, granite, and near granite–greenstone contacts. Many form a conjugate set striking 340–345° and 075°, and another approximately conjugate set strikes 310° and 030–050°. Accessory minerals in the veins are muscovite, tourmaline, and pyrite. Syenite (*sy*) dykes are known only in the Mount Margaret area (e.g. LAVERTON AMG 212130).

MAFIC DYKES (*Ᵽdy*)

Mafic dykes (*Ᵽdy*) cut greenstone and granitoid on LAVERTON (1:250 000; Fig. 2), and are members of a widespread swarm of mafic, ultramafic, and intermediate dykes that intruded the Yilgarn Craton in the early Proterozoic (Fletcher et al., 1987) or possibly late Archaean

(Nelson, 1998). The dykes are poorly exposed, but readily identified as pronounced linear anomalies on aeromagnetic images. Exposed dykes strike east-northeast, are massive ophitic dolerite, and consist of clinopyroxene, plagioclase zoned from labradorite to andesine, iron oxides, secondary amphibole and apatite, and, in some samples, interstitial quartz (Gower, 1976). North-northwesterly striking magnetic lineaments are also attributed to mafic dykes (Fig. 2), and Gower (1976) reported exposures of ?dolerite with this orientation east of Hanns Camp and similarly oriented saussuritized anorthositic gabbro southwest of Cosmo Newbery (just off the LAVERTON 1:250 000 sheet in the northeast). The ?dolerite was not located in the 1993 mapping, and the anorthositic gabbro is mapped as (*gb*) and described in **Minor intrusions**. The unusual King of the Hills dyke, which contains numerous quartz and granitoid xenoliths, is exposed beside the Leonora–Nambi road (MINERIE AMG 580370).

The Mount Weld Carbonatite is a subsurface carbonatite intrusion 3 km in diameter, located 30 km south-southeast of the Laverton township. It is concealed below Cainozoic colluvium and was discovered by drilling of a prominent aeromagnetic anomaly in 1967. The carbonatite comprises a primary calcitic core with subordinate dolomite, apatite, and biotite, and many accessory minerals bearing Nb, Ta, Y, and lanthanide elements (Duncan and Willett, 1990). A 500 m-wide, fenitized annulus surrounds the core, and consists of alkali-metasomatized basalt — now K-rich micaceous rock (glimmerite) — veined by carbonate. The carbonatite has been dated at c. 2.05 Ga (Nelson et al., 1988).

STRUCTURE

NORTH-NORTHWESTERLY STRIKING FAULTS

The major faults and lineaments on LAVERTON (1:250 000), including the Celia Lineament, Yilgangi Fault, and the Laverton–Hootanui Fault, are three of many north-northwesterly striking, regional-scale faults and shear zones that cut the Yilgarn Craton for hundreds of kilometres. Activity on these faults may have begun early in the tectonic history of the Eastern Goldfields, as they appear to have controlled greenstone-basin size, shape, and location, from their inception through felsic and mafic volcanism and intrusion, sedimentation, deformation, and dismemberment, to mineralization (Gower, 1976; Hallberg, 1985; Swager et al., 1995). They are possibly strongly modified successors to initial extensional faults that controlled the original greenstone basins (Swager, 1997).

The Mount Celia Fault Zone on EDJUDINA (1:250 000) is 8–18 km wide and bounded by the Claypan Fault to the west, and the Safari Fault to the east (Chen, 1999). On regional-scale aeromagnetic images (derived from 400 m-spaced data acquired by AGSO in 1993), the Claypan Fault cannot be traced beyond 7 km north of the southern boundary of LAVERTON (1:250 000). Farther north, the fault zone is represented by the continuation of the Safari Fault, and is referred to here as the Celia Lineament (after Gower, 1976; Fig. 2). The Celia Lineament continues northwest for about 95 km to the Mount Zephyr area. Northwest of Mount Zephyr, aeromagnetic images suggest that the lineament forms a boundary between granite to the west and granitic gneiss to the east.

The Keith–Kilkenny Fault Zone extends for over 300 km and, in areas of poor outcrop, is seen as a clear lineament on aeromagnetic images. On LEONORA (1:250 000) and LAVERTON (1:250 000), it coincides with the Yilgangi Fault and Pig Well Graben (conglomerate and arkosic sandstone). On EDJUDINA (1:250 000), polymictic conglomerate and greywacke fill a continuation of the same graben that crosses the entire sheet area (Chen, 1999).

DEFORMATION SEQUENCE

Swager (1997) summarized a sequence of deformation events in the Eastern Goldfields, and tabulated four episodes of shortening preceded and separated by episodes of extension that have been proposed by various workers in the region. The earliest proposed extensional episode stems from work on the LEONORA and LAVERTON 1:250 000 sheets by Hammond and Nisbet (1992), Williams (1993), Williams and Whitaker (1993), and Passchier (1994), but has not been recognized in the Kalgoorlie area (Swager, 1997). The deformation history of LAVERTON (1:250 000) is shown in Table 1.

D_{E1} structures on LAVERTON (1:250 000) have been described by Williams and Whitaker (1993) from the granite–greenstone contact between Windarra and South Windarra. They regarded the granitoid intrusion here as a smooth and concordant, gently dipping dome with no evidence of stoping or diapiric piercement. In the Goose Hill area, foliation (called S_1 by them) in greenstone dips gently south, and asymmetric pressure shadows around quartz phenocrysts in porphyry dykes intruding the greenstone indicate top-to-north movement. West of Goose Hill, S_1 is folded into upright, gently plunging F_2 folds parasitic on the Margaret Anticline, and a persistent crenulation cleavage (S_2) in the greenstone parallels the axial surface of the anticline. Two distinct foliations (S_1 and S_2) are present in the granites north of Goose Hill. Williams and Whitaker (1993) concluded that major, broadly north–south regional extension took place after greenstone deposition. They further concluded that extension resulted in emplacement of gneiss domes and granitic complexes as metamorphic core complexes.

D_1 structures on LAVERTON (1:250 000) have been mentioned by Williams and Whitaker (1993) in the Mount Margaret area, where they reported intense D_1 isoclinal folds, mylonite, and shear zones in the Keith–Kilkenny and Mount Celia Fault Zones, overprinted or crenulated by regional, upright D_2 folds. They interpreted the zones as originally low-dipping, regional D_1 shear zones, with much of their early movement history obscured by

Table 1. Regional deformation history of LAVERTON (1:250 000)

Event	*Regional deformation history*	*Examples on LAVERTON (1:250 000)*
D_{E1}	Extension: low-angle shearing on granite–greenstone contacts; north–south movement (top to north)	Windarra – Goose Hill area (Williams and Whitaker, 1993)
D_1	Shortening: tight to isoclinal, reclined to recumbent folds, bedding-parallel foliation, and shear zones; some upright folds	Mount Margaret area (Williams and Whitaker, 1993); Kilkenny Syncline and recumbent fold in Welcome Well area (Stewart, 1998)
D_{E2}	Extension: trough or graben in southwest	Yilgangi Fault, Pig Well Graben
D_2	Shortening (east-southeast – west-southwest directed): upright to overturned, north-northwesterly trending major folds and steep foliation	Mount Margaret, Benalla, and Corkscrew Anticlines; north–south folds in Welcome Well area
D_3	Continued shortening (east–west or east-southeast – west-northwest directed): strike-slip faults	Celia Lineament, Laverton–Hootanui Fault

late strike-slip movement. However, several observations cast doubt on Williams and Whitaker's conclusions. Firstly, the straightness of the Keith–Kilkenny and Mount Celia Fault Zones negates their origin as originally low-dipping D_1 surfaces. If this were so, they should have been deformed by the regional D_2 folding. Their straightness suggests that they are largely D_2–D_3, steeply dipping fault zones, possibly with fault horses retaining D_1 structures preserved in places along them. Secondly, the Mount Celia Fault Zone is a single fault on LAVERTON (1:250 000), some 8 km from, and so unrelated to, isoclinal D_1 folds at Mount Margaret.

In the southwestern part of LAVERTON (1:250 000), Stewart (1998) noted that the Kilkenny Syncline is cut at a large angle by strong, northwesterly striking cleavage, interpreted as S_2. If this is so, the Kilkenny Syncline is a D_1 fold. He also suggested that the digitate outcrop pattern of the volcaniclastic rocks of the Welcome Well Complex can be explained by folding of a D_1 recumbent anticline by southerly plunging D_2 anticlines and synclines.

Conglomerate and arkosic sandstone in the Pig Well Graben in the southwest of LAVERTON (1:250 000) are deformed by a north-northwesterly striking foliation, interpreted as S_2. Hence, the graben must have formed before or during early D_2 deformation. The sedimentary rocks are analogous to the Merougil Conglomerate in the Kalgoorlie area (Swager, 1997) in timing and structural setting.

The main D_2 deformation produced large anticlines and synclines on LAVERTON (1:250 000). The largest D_2 fold is the Margaret Anticline in the Laverton greenstones (Fig. 2). It has an inverted western limb, and a stereographic plot of poles to bedding from both limbs of the anticline (A. J. Stewart, unpublished data) shows that it plunges east at 60° towards 104°, and is virtually a reclined fold. In the southwest, the Benalla and Corkscrew Anticlines plunge south and interfere with the interpreted D_1 recumbent anticline at Welcome Well.

D_3 deformation on the LAVERTON 1:250 000 sheet involved mainly strike-slip, and possibly reverse, movement on the major faults and lineaments. The numerous northerly striking faults and splays in the Laverton – Mount Weld area may have been initiated at this time. The faults bounding the Pig Well Graben may have been reactivated.

Chen (1998) proposed the existence of a large-scale antidilational jog between the Celia Lineament and Hootanui Fault on LAVERTON (1:250 000), and ascribed the north to north-northeasterly trending folds and faults inside the jog, that is, in the Laverton – Mount Weld area, to local compression during D_3 strike-slip faulting along the Celia Lineament and Hootanui Fault. Similarly oriented folds and faults in the southwestern part of LAVERTON (1:250 000) — the Kilkenny and Rio Tinto Synclines and Benalla and Corkscrew Anticlines — were similarly ascribed to local D_3 compression during sinistral strike-slip along the Keith–Kilkenny Fault Zone.

Hallberg (1985) recognized that movement on major northerly striking faults through Mertondale and Laverton occurred after major D_3 strike-slip faulting — the Mertondale Fault cuts the Pig Well Graben, and the Laverton Fault (called the Crawford Fault by Hallberg, 1985) offsets Proterozoic mafic dykes.

METAMORPHISM

Figure 3 is a map of metamorphic facies compiled from Binns et al. (1976) in the northern half of LAVERTON (1:250 000), and from Hallberg (1985) in the southern half. Regional metamorphic facies ranges from prehnite–pumpellyite through greenschist to amphibolite. In the prehnite–pumpellyite facies, original rock textures are well preserved, and penetrative

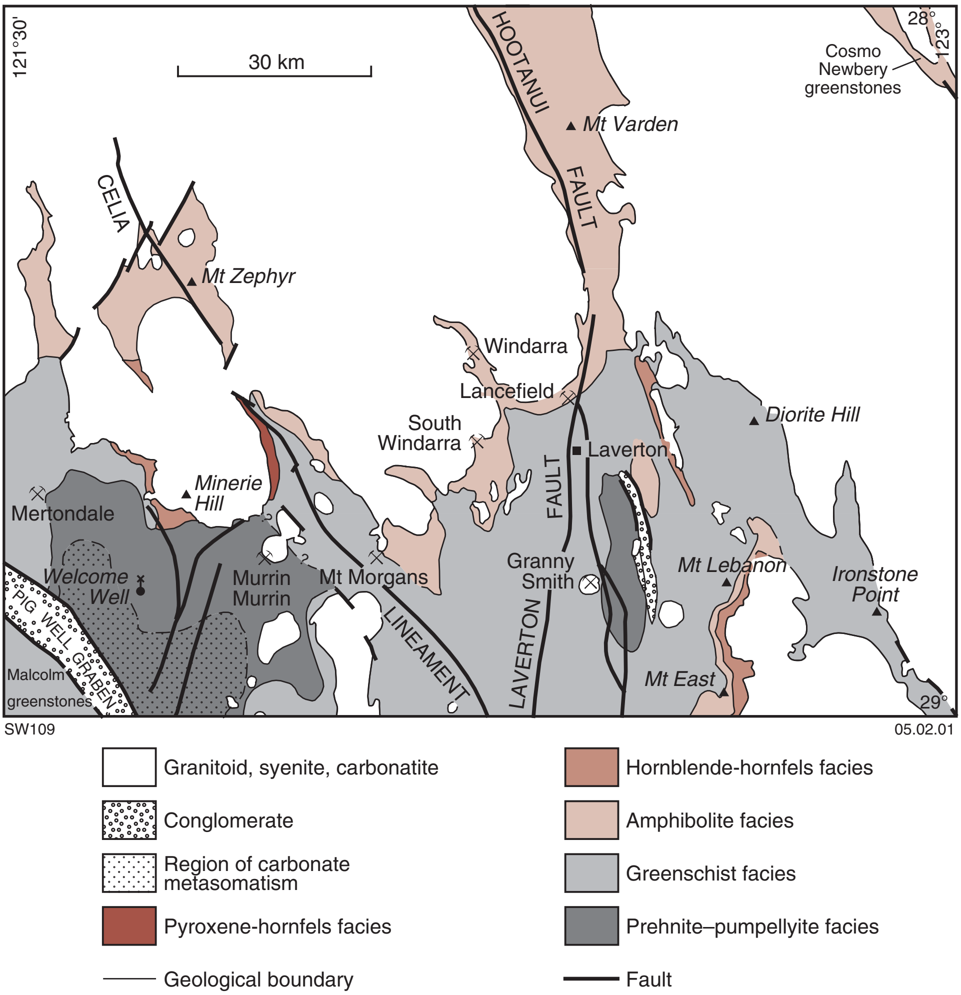


Figure 3. Metamorphic facies map of LAVERTON (1:250 000)

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).

The prehnite–pumpellyite facies occupies a large area in the southwestern part of LAVERTON (1:250 000), and a smaller, northerly trending elongate area in the southeast (Fig. 3). In the southwest, metasomatic calcite and dolomite were introduced on a regional scale into the prehnite–pumpellyite facies. In these rocks, up to 17% by modal volume is disseminated carbonate grains (Hallberg, 1985). In the southeast, the boundaries of the prehnite–pumpellyite facies cut across several northerly striking faults.

Amphibolite-facies rocks are most abundant in the centre and north of LAVERTON (1:250 000), where they form elongate zones near or beside granitoid masses in the Mount Morgans – Windarra and Mount Lebanon – Mount East areas. Binns et al. (1976) depicted the greenstones of the Mount Varden area as largely low- to mid-amphibolite facies, together with a strip, about 5 km wide, of mid- to high-amphibolite facies along the western side.

Contact metamorphism affected greenstones close to some, but not all, of the granitoid masses on LAVERTON (1:250 000). Zones of hornblende- and pyroxene-hornfels facies, 1–2 km wide, are present respectively along the western and eastern margins of the granite of the Minerie Hill area, but not along its southern margin. In the Mount Lebanon – Mount East area, a strip of penetratively deformed, hornblende-hornfels facies greenstones is interposed between the amphibolite-facies greenstones and granitoid to the east. A similar strip of pyroxene-hornfels facies greenstones is present along the western side of the elongate syenite body 15 km east of Laverton (Fig. 3). The large area of pyroxene-hornfels facies greenstones delineated by Hallberg (1985) in the Diorite Hill area ('possibly … granulite' according to Gower, 1976) is now recognized as norite belonging to a layered mafic intrusion.

PALAEOZOIC GEOLOGY

PERMIAN SEDIMENTARY ROCKS (*Pt*, *PAf*)

On LAVERTON (1:250 000), rounded boulders and claystone (*Pt*) are exposed in the southwest in the Mertondale area, and in the centre around Lancefield. At Mertondale, the deposits comprise 13.5 m of blue-green clay containing well-rounded pebbles, cobbles, and boulders of granite and quartz, many with one side flattened (Clarke, 1921). In the Lancefield area, the deposits are a fluvioglacial diamictite of angular pebbles of basalt and granitoid in a poorly consolidated clayey matrix (Hallberg, 1985). The Paterson Formation (*PAf*), north of Laverton Downs, consists of surface exposures of granitoid, greenstone, and porphyry boulders. In the Shay Cart Range in the southeast, the Paterson Formation is exposed in breakaways as weathered granitoid clasts in ferruginous clay (Gower, 1976).

CAINOZOIC GEOLOGY

Cainozoic sedimentary deposits cover large parts of the LAVERTON 1:250 000 sheet. Three major palaeochannels cross the sheet area (van de Graaff et al., 1977): the Carey Palaeoriver from northwest to south; the Raeside Palaeoriver in the southwest corner; and an unnamed palaeochannel in the northeast. These palaeochannels, now filled with playa-lake and associated deposits, are relics of a Mesozoic to Cainozoic, southeasterly directed drainage system (van de Graaff et al., 1977; Ollier et al., 1988; Chan et al., 1992).

Cainozoic deposits formed in situ are: extensive lateritic duricrust or ferricrete (*Czl*) breakaways and rises on greenstone; silcrete (*Czz*) and silcrete or silicified kaolinized granitoid (*Czzg*) as horizontal cappings and breakaways over kaolinized granitoid in the east and southeast; yellow-brown silcrete (silica cap rock; *Czu*) on ultramafic rock in the south at Mount Jumbo, in the west in the Bernie Bore – Mount Korong area, and in the north near Mount Clarke; and calcrete (*Czk*) around the shore of Lake Carey.

Transported deposits comprise:

- Proximal colluvial deposits, which are: pebble gravel, sand, and talus (*Czc*) mantling hills and rises of greenstone and granitoid; pebbly ironstone colluvium and alluvium (*Czf*) surrounding and derived from laterite; aprons of colluvial quartz–feldspar sand and gravel (*Czg*) derived from granitoid, particularly in the northwest and west; and quartz gravel talus (*Czq*) adjacent to quartz veins.

- Distal colluvium (*Cza*) composed of sand, silt, clay, and pebbles forming plains that extend for up to 15 km from granite and greenstone exposures.
- Alluvial gravel, sand, silt, and clay (*Qa*) in channels brought down by streams flowing from granitoid and greenstone areas out on to the surrounding plains. A claypan (*Qac*) has formed beside a granite hill at (MOUNT VARDEN AMG 360480).
- Sheets of sand (*Czs*) with local dunes, which occupy much of the flat country between bedrock outcrops, and are formed by eolian reworking of the colluvial plains (*Cza*; Mabbutt, 1977, p. 215).
- Lacustrine deposits that filled the palaeochannels in the northwest, centre, south, southwest, and northeast. The deposits include widespread playa-lake evaporites, sand, and clay (*Czp*), clay flats with subordinate quartz sand dunes (*Czb*), and extensive areas and islands of quartz and gypsum dunes (*Czd*).

ECONOMIC GEOLOGY

LAVERTON (1:250 000) includes parts of the Mount Malcolm, Mount Morgans, and Mount Margaret districts of the Mount Margaret Goldfield. Gold is the most important commodity in the area, and has been mined from some 200 deposits, most of them small. Other commodities in the area include nickel, cobalt, silver, copper, zinc, phosphate, rare earth elements, niobium, tantalum, and tungsten. Table 2 summarizes recent statistics for the 17 major mineral deposits in the area.

GOLD

Gold production to December 1988 was 171.5 t (Table 2), and Gower (1976) recorded 1.97 t silver. The major deposits are briefly described below in order of production or resource (with source references after the titles).

Granny Smith (Hall and Holyland, 1990)

The Granny Smith deposit was discovered in 1979. Gold is located in an easterly dipping, brittle–ductile shear located at the contact between metasedimentary rocks (siltstone, shale, greywacke, polymictic conglomerate, and tuff) and intrusive diorite–granodiorite. Early shearing was ductile, but later movement formed openings on the irregular fault surface, and these were filled with aplite and albite–quartz pegmatite veins, and then with veins composed of quartz, ankerite, gold as discrete grains, and small amounts of pyrite, galena, sphalerite, and chalcopyrite. Wallrock alteration included the formation of sericite and chlorite in the matrices of the metasedimentary rocks, biotite after ferromagnesian minerals or chlorite after biotite in the intrusive rocks, and albite, carbonate, quartz, alkali feldspar, magnetite, hematite, and pyrite in the mineralized shear rock. The fluid source is unclear — it may have originated from metamorphic dewatering, or from the dioritic intrusion.

Lancefield (Hronsky et al., 1990)

Lancefield was discovered in 1899. The gold is in quartz veins, sulfidic ferruginous chert, and altered host rocks in an easterly dipping sequence of komatiite, high-Mg basalt, sulfidic chert (West lode), basalt, banded ferruginous chert, doleritic-textured basalt, sulfidic ferruginous chert (Main lode), tholeiitic basalt, and felsic volcaniclastic conglomerate. A dip-slip fault with some dextral shear at the komatiite – high-Mg basalt contact forms the footwall. In the West lode, gold is in quartz–chlorite–carbonate–sulfide chert layers or veins, and in altered high-Mg basalt and metasedimentary rocks. In the Main lode, the gold is

Table 2. Mineral commodity statistics for LAVERTON (1:250 000)

Name	*Sheet*	*AMG coordinates*	*Status*	*Production (t)*	*To date*	*Remaining resources[(a)] (t)*	*Grade (g/t)[(b)]*
Gold							
Burtville	BURTVILLE	658197	Closed	4.0	Dec 1987	–	–
Cork Tree Well	MOUNT VARDEN	415650	Closed	0.588	1986	750 000	2.40
Granny Smith[(c)]	LAVERTON	436126	Operating	72.2	Dec 1998	27 500 000	2.81
Ida H	LAVERTON	485234	Closed	9.0	Mar 1994	1 845 000	2.10
Innuendo	LAVERTON	350325	Deposit	–	Mar 1999	560 000	2.49
Lancefield	LAVERTON	390407	Closed	43.7	1995	4 424 000	5.10
Mertondale	MINERIE	576270	Closed	1.88	1911	1 297 000	4.30
Mount Morgans	LAVERTON	090170	Closed	40.1	Dec 1988	3 360 000	3.64
Rumour	LAVERTON	325285	Deposit	–	Mar 1999	2 650 000	2.10
Wallaby	LAVERTON	322084	Deposit	–	Nov 1999	41 670 000	2.86
Whisper	LAVERTON	325300	Deposit	–	Mar 1999	2 650 000	2.54
Nickel							
Murrin Murrin	MINERIE	925157	Operating	–	1999	307 000 000	0.80%
Mount Windarra	MOUNT VARDEN	248484	Closed	97 582	Dec 1991	4 100 000	1.33%
South Windarra	LAVERTON	257345	Closed	40 704	Apr 1986	–	–
Cobalt							
Murrin Murrin	MINERIE	894156	Operating	–	1997	116 800 000	0.08%
Silver							
Eulaminna	MINERIE	798951	Closed	–	1987	475 363	9.53
Copper[(d)]							
Eulaminna	MINERIE	798951	Closed	4 274	1908	475 363	1.62%
Nangaroo	MINERIE	836991	Closed	275.7	1908	14 000	18.00%
Zinc							
Eulaminna	MINERIE	798951	Closed	–	1987	475 363	3.36%
Phosphate							
Mount Weld[(e)]	BURTVILLE	561075	Deposit	–	2000	260 000 000	18%
Rare earth oxides							
Mount Weld	BURTVILLE	561075	Deposit	–	2000	1 927 000	19.7%
						67 000	18.7%
Niobium pentoxide							
Mount Weld	BURTVILLE	561075	Deposit	–	2000	273 000 000	9 000
Tantalum pentoxide							
Mount Weld	BURTVILLE	561075	Deposit	–	2000	145 000 000	340
Tungsten[(f)]	MOUNT VARDEN	347958	Closed	1.8	1955	–	–

SOURCE: AGSO's National mineral deposits dataset (OZMIN)

NOTES:
(a) At date noted in 'To date' column
(b) Except where otherwise indicated, refers to remaining resources
(c) Includes production from other mines
(d) Production and To date figures at Eulaminna and Nangaroo from Marston (1979)
(e) Phosphate, rare earths, niobium, and tantalum figures at Mount Weld supplied by D. Townsend, GSWA, April 2000
(f) Production and To date figures for tungsten from Gower (1976)

mostly in pyritic chert, with lesser amounts in black shale and hydrothermally altered tholeiitic basalt in the hanging wall. The deposit is attributed to epigenetic silicification of sulfidic shale and chert in structural sites produced by dextral slip along the footwall contact fault. Oxygen isotope and fluid inclusion data are consistent with a metamorphic or magmatic origin for the fluid.

Mount Morgans (Jackson, 1905; Hobson and Miles, 1950)

Mount Morgans was discovered in 1896 and was the first discovery on the LAVERTON 1:250 000 sheet. The host rocks are metabasalt on either side of a ridge of sheared and imbricated BIF intruded by a concordant dyke of quartz–feldspar porphyry, 50–400 m wide. The iron formation forms an elongate stockwork along the eastern margin of the dyke. The mineralization comprises gold-bearing quartz leaders and stringers in the iron formation, as well as in the metabasalt east of the ridge. The veins also contain pyrite and veinlets of chlorite and calcite.

Ida H (Gibson, 1906; Hobson and Miles, 1950)

The Ida H deposit is hosted in a white quartz vein about 60 cm wide in altered greenstone schist (probably metasedimentary; Hobson and Miles, 1950). Associated minerals are pyrite and sphalerite. Below ground level, the schist carries sulfide ore and, at about 100 m depth, bands of massive, weakly gold-bearing pyrite up to 1 m thick parallel the vein, but 2.5 – 7 m from it.

Burtville (Gibson, 1906; Maitland, 1906)

The Burtville deposits are hosted in amphibolitic greenstone and rare BIF is intruded by a foliated granite body 1.5 – 3 km across. Parallel quartz veins up to 45 cm wide are located in the granite and, to a lesser extent, in the greenstone. The gold-bearing quartz reefs were most abundant in the granite.

Mertondale (Nisbet and Williams, 1990)

The Mertondale deposits are located in a west-to-east sequence of felsic volcanic rocks, metabasalt with felsic porphyry lenses, and mixed basalt, dolerite, and carbonaceous sedimentary rock. The metabasalt–porphyry unit hosts the gold. Mineralized portions of this unit are bounded by steep shear zones, 20–40 m apart, which form a northerly striking zone 50–150 m wide called the Mertondale Fault Zone. A stretching lineation in the fault zone is horizontal to gently plunging, indicating strike slip. There are three types of mineralization. Shear lodes in altered basalt are steeply dipping, about 1 m thick and 50–100 m long, cleaved, and carry about 30 g/t gold associated with disseminated pyrite and arsenopyrite. Intershear lodes are horizontal to easterly dipping quartz veins up to 40 cm thick, and bordered by alteration selvages up to 12 m thick. Subhorizontal, mineralized rock lenses, 35 m thick and up to 300 m long, formed at the metabasalt–porphyry contact and carry pyrite and arsenopyrite. Alteration in the host rocks involved the introduction of carbonate, potassium (which formed sericite), and silica. The deposit formed in a north-northeasterly jog in the northerly striking fault system (D_4), which directed fluid to a region of high competency contrast along the metabasalt–porphyry contact, or into dilational shear openings.

Cork Tree Well (Mock et al. 1987)

The Cork Tree Well deposit consists of multiple veins, discordant to layering, in hornblende-bearing mafic lavas and tuffaceous sedimentary rocks. The veins are composed of gold, pyrite, and pyrrhotite in a quartz–calcite gangue.

Wallaby (Nielsen and Currie, 1999)

The Wallaby deposit was discovered in 1997, and consists of silicified lode shears hosted by magnetite-altered polymictic conglomerate. The conglomerate comprises clasts of mafic and felsic volcanic rock, BIF, and argillite, is metamorphosed to upper greenschist facies, and intruded by syenite, monzonite, and carbonatite dykes. The mineralization is in southeasterly dipping shear zones formed during northerly thrusting, which localized a gold–carbonate–silica–sulfur-bearing fluid. Alteration of the adjoining rocks produced a silica–carbonate–sericite–pyrite(–fuchsite) and hematite assemblage. In the syenite dykes, alteration produced carbonate, hematitic, and potassic assemblages. Mineralization took place after the main dykes were emplaced, but before the carbonatite arrived. The ore assemblage is in equilibrium with the metamorphic assemblage, indicating that the gold-bearing fluid was introduced during peak metamorphism.

Rumour, Whisper, and Innuendo (Johnson and Ryall, 1999)

The Rumour, Whisper, and Innuendo deposits along the Chatterbox Shear were discovered in 1997. The shear is a 30 km-long, northerly striking, easterly dipping, brittle–ductile normal fault zone with some dextral movement in easterly dipping greenstones, on the eastern limb of the Margaret Anticline. The footwall sequence comprises peridotite and talc–chlorite schist intruded by granitoids. The main host to mineralization is a 25 m-thick, overlying sequence of felsic extrusive and intrusive rocks, dolomite–ankerite rock, carbonaceous shale, and chert. Gold mineralization is concentrated along the footwall ultramafic contact, and in the felsic and sedimentary rocks. These are all intensely weathered to soft porous material with secondary quartz and iron oxide, which obliterate primary textures. Gold distribution is 75% in the felsic igneous and sedimentary rocks, 15% in footwall granitoids, 5% in carbonate rock, and 5% in the footwall ultramafic rocks. The gold is associated with weak sulfide alteration that produced pyrite (with rare gold inclusions), pyrrhotite, marcasite, and arsenopyrite.

NICKEL

Two nickel mines, Mount Windarra (underground) and South Windarra (opencut and underground), operated between 1974 and 1991, and produced 138 286 t of nickel (Table 2). The Murrin Murrin lateritic opencuts began production in 1999.

Mount Windarra and South Windarra (Reddell and Schmulian, 1990)

Mount Windarra and South Windarra are in the same stratigraphic sequence, but some 17 km apart. The sequence comprises basal BIF (bordered to the west by granitoid), overlain by ultramafic and mafic volcanic rocks with thin, interflow sedimentary units of BIF, carbonaceous shale, and chert. Rocks have been metamorphosed to amphibolite facies. The nickel sulfide bodies are at the base of partly overlapping, partly offset, peridotite flows that commonly overlie an interflow iron-formation or, where this is absent, the lowest ultramafic unit. The mineralization ranges from massive to disseminated assemblages of pyrrhotite, pentlandite, pyrite, and chalcopyrite. Disseminated ore is the dominant type with grades of 8–16% Ni.

Murrin Murrin (Fazakerley and Monti, 1998)

The Murrin Murrin nickel–cobalt lateritic deposits were discovered in 1969, but remained undeveloped as extraction was then thought impossible. Investigation resumed in 1993, and nine deposits were defined. The protolith of the host rock is serpentinized peridotite with cumulate and spinifex textures. It lies within a sequence of feldspathic clastic and volcaniclastic sedimentary rocks (derived from felsic volcanic centres north of Welcome Well), and mafic volcanic rocks and sills. Granitoid and felsic to mafic dykes intrude the sequence. The metamorphic facies is prehnite–pumpellyite. Weathering has formed about 35 m of regolith, which comprises a basal 10–15 m of saprolite (which preserves primary rock textures) composed of serpentine, chlorite, and smectite; 2–10 m of smectite (90%, ferruginous in the upper half) with lesser chlorite, serpentine; and iron, manganese, and chromium oxides overlain by a ferruginous zone (7–15 m) of goethite, hematite, and minor clay. Duricrust forms a hard cap on top. Nickel–cobalt mineralization (0.5% Ni cutoff) is hosted mainly in the smectite and saprolite zones, with smaller amounts in the ferruginous zones. The highest nickel grades are in nontronite, and locally in iron-rich montmorillonite.

COPPER AND ZINC

Eulaminna (Anaconda) and Nangaroo (Marston, 1979*)*

The Eulaminna and Nangaroo copper deposits in the southwest are located near the top of a folded sequence of volcaniclastic sedimentary rocks, carbonaceous shale, rhyolite, dacite, and mafic volcanic rocks. Carbonate alteration is common. The Eulaminna deposit is on the easterly dipping, western limb of the Kilkenny Syncline, and the Nangaroo deposit is on the westerly dipping, eastern limb, in the same sequence as, and in a similar stratigraphic position to, the Eulaminna deposit. At Eulaminna, four ore shoots dip east at various pitches, one to the northeast and three to the south, and are composed of massive pyrite, sphalerite, and chalcopyrite in chlorite–calcite gangue. The sulfide shoots are in a lenticular unit of sedimentary grit to breccia, comprising angular to rounded clasts of felsic volcanic rock, siltstone, black shale, and massive sulfide clasts (commonly pyrite) in a lithic-chloritic matrix with disseminated sulfide. At Nangaroo, the host rocks are similar, but with a greater felsic volcanic component. Four gently northerly pitching ore shoots consist of pyritic sulfides, with pyrrhotite, iron-bearing sphalerite and chalcopyrite, and some combined silver and cassiterite. There are angular to subrounded pieces of the same sulfides in sedimentary to volcanic breccias overlying, underlying, and laterally contiguous with the massive sulfide shoots. The deposits are volcanic-hosted massive sulfides, which were coeval with subaqueous gravitational slumping that produced the grit and breccia, followed by further sulfide precipitation.

PHOSPHATE, RARE EARTHS, NIOBIUM, AND TANTALUM

Mount Weld (Duncan and Willett, 1990)

The Mount Weld Carbonatite intrudes a sequence of mafic and intermediate volcanic and metasedimentary rocks, serpentinite, and polymictic conglomerate. The carbonatite consists of cumulate calcitic and dolomitic carbonates, apatite, biotite, magnetite, and many accessory minerals containing rare earth elements (REE), Y, Sr, Ba, Nb, and Ta. A 500 m-wide annulus of fenitized (alkali-metasomatized) mafic volcanic rock surrounds the carbonate core. The mineral deposits are in the regolith overlying the carbonatite. The regolith has a lower (residual) zone where resistant igneous minerals have been concentrated by the removal of carbonate, and an upper (supergene) zone where weathering of the igneous minerals has formed insoluble Al-oxides, clays, secondary phosphates, REE oxides, Mn-wad, and ferric iron oxides with adsorbed Nb, Ta, Ti, V, Y, and Cr.

TUNGSTEN (Berliat, 1954; Gower, 1976)

Scheelite is associated with quartz lenses 1.5 km east-southeast of Ogilvies gold workings near Mount Amy. The lenses are up to 30 m long and 0.75 m wide, and formed along the junction of granitized and unaltered greenstones respectively, over a length of 400 m. Mineralization is patchy and irregular, and in places is associated with stringers and veinlets of quartz in the granitized greenstone adjoining the quartz lenses.

REFERENCES

BEARD, J. S., 1974, Vegetation survey of Western Australia, Great Victoria Desert, 1:1 000 000 Vegetation Series, Explanatory Notes to Sheet 3, The vegetation of the Great Victoria Desert area: Nedlands, Western Australia, University of Western Australia Press, 50p.

BEARD, J. S., 1990, Plant life of Western Australia: Kenthurst, N.S.W., Kangaroo Press, 319p.

BERLIAT, K., 1954, Report on Laverton scheelite prospect P.A.2548T, P.A.2554T, P.A.2555T, Laverton, Mt Margaret Goldfield: Western Australia Geological Survey, Annual Report 1951, p. 32.

BINNS, R. A., GUNTHORPE, R. J., and GROVES, D. I., 1976, Metamorphic patterns and development of greenstone belts in the eastern Yilgarn Block, Western Australia, *in* The early history of the Earth *edited by* B. F. WINDLEY: London, John Wiley and Sons, p. 303–313.

CHAMPION, D. C., and SHERATON, J. W., 1997, Geochemistry and Nd isotope systematics of Archaean granites of the Eastern Goldfields, Yilgarn Craton, Australia: implications for crustal growth processes: Precambrian Research, v. 83, p. 109–132.

CHAN, R. A., CRAIG, M. A., HAZELL, M. S., and OLLIER, C. D., 1992, Kalgoorlie regolith terrain map commentary, Sheet SH51 Western Australia, 1:1 000 000 Regolith Series: Australia BMR, Record 1992/8, 71p.

CHEN, S. F., 1998, Local compressional structures induced by strike-slip movement in the Edjudina–Laverton area, eastern Yilgarn Craton: Western Australia Geological Survey, Annual Review 1997–98, p. 99–103.

CHEN, S. F., 1999, Edjudina, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 32p.

CHENOWETH, L. M., 1969, The geochemistry and geology of the Lancefield gold mine, Laverton, Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

CLARKE, E. de C., 1921, Note on occurrences of boulders, possibly glaciated, near Leonora and Laverton, about lat. 28°30' south: Royal Society of Western Australia, Journal and Proceedings, v. 6, p. 27–32.

CLARKE, E. de C., 1925, The field geology and broader mining features of the Leonora–Duketon district, including parts of the North Coolgardie, Mount Margaret, and East Murchison Goldfields, and a report on the Anaconda copper mine and neighbourhood, Mt Margaret Goldfield: Western Australia Geological Survey, Bulletin 84, 66p.

DAVIDSON, J. E., 1970, A petrological and geochemical study of three diamond-drill holes through the Mt Windarra ultramafics and zone of mineralization: University of Adelaide, BSc Hons thesis (unpublished).

DRAKE, J. R., 1972, The structure and petrology of banded iron-formations at Mount Windarra, Western Australia: University of Western Australia, BSc Hons thesis (unpublished).

DREW, G. J., 1971, A geochemical study of the weathering zone at Mt Windarra, Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

DUGGAN, M. B., 1995, McMillan, W.A. Sheet 3441 (preliminary edition): Australian Geological Survey Organisation, 1:100 000 Geological Series.

DUGGAN, M. B., WHITAKER, A. J., and SEDGMEN, A., 1997, Burtville, W.A. Sheet 3440 (preliminary edition, version 2): Australian Geological Survey Organisation, 1:100 000 Geological Series.

DUNCAN, R. K., 1988, Discovery of the Mt Weld carbonatite, *in* R and D for the Minerals Industry, Conference '88, Kalgoorlie, WA, 1988, Western Australian School of Mines, Papers, p. 86–93.

DUNCAN, R. K., and WILLETT, G. C., 1990, Mount Weld carbonatite, *in* Geology of the mineral deposits of Australia and Papua New Guinea — 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 591–597.

FALCONER, L. J., 1983, Epigenetic versus syngenetic models for BIF-hosted gold deposits: evidence from Mt Korong, Western Australia: University of Western Australia, BSc Hons thesis (unpublished).

FAZAKERLEY, V. W., and MONTI, R., 1998, Murrin Murrin nickel–cobalt deposits, *in* Geology of Australian and Papua New Guinean mineral deposits *edited by* D. A. BERKMAN and D. H. MacKENZIE: Australasian Institute of Mining and Metallurgy, Monograph 22, p. 329–334.

FLETCHER, I. R., LIBBY, W. G., and ROSMAN, K. J. R., 1987, Sm–Nd dating of the 2411 Ma Jimberlana dyke, Yilgarn Block, Western Australia: Australian Journal of Earth Sciences, v. 34, p. 523–525.

GEE, R. D., BAXTER, J. L., WILDE, S. A., and WILLIAMS, I. R., 1981, Crustal development in the Yilgarn Block, Western Australia, *in* Archaean Geology *edited by* J. E. GLOVER and D. I. GROVES: Geological Society of Australia; Second International Archaean Symposium, Perth, W.A., 1980, Proceedings, Special Publication no. 7, p. 43–56.

GIBSON, C. G., 1906, The Laverton, Burtville and Erlistoun auriferous belt, Mt Margaret Goldfield: Western Australia Geological Survey, Bulletin 24, 79p.

GILES, C. W., and HALLBERG, J. A., 1982, The genesis of the Archaean Welcome Well volcanic complex, Western Australia: Contributions to Mineralogy and Petrology, v. 80, p. 307–318.

GILLMAN, J., 1989, Structure of the Ogilvies area, Laverton Greenstone belt, with special reference to controls on gold mineralization at the King of Creation gold mine: University of Western Australia, BSc Hons thesis (unpublished).

GOWER, C. F., 1976, Laverton, W.A. (1st Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 30p.

GOWER, C. F., and VOGWILL, R. I. J., 1975, Laverton, W.A. Sheet SH 51-2 (1st edition): Western Australia Geological Survey, 1:250 000 Geological Series.

GRIFFIN, T. J., 1990, Eastern Goldfields province, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 77–119.

HALL, G. C., and HOLYLAND, P. W., 1990, Granny Smith gold deposit, *in* Geology of the mineral deposits of Australia and Papua New Guinea — 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 519–524.

HALLBERG, J. A., 1985, Geology and mineral deposits of the Leonora–Laverton area, northeastern Yilgarn Block, Western Australia: Carlisle, Western Australia, Hesperian Press, 140p.

HAMMOND, R. L., and NISBET, B. W., 1992, Towards a structural and tectonic framework for the central Norseman–Wiluna greenstone belt, Western Australia, *in* The Archaean — terrains, processes and metallogeny *edited by* J. E. GLOVER and S. E. HO: University of Western Australia, Geology Department and University Extension, Publication no. 22, p. 39–50.

HAYWARD, N., 1983, The geology and petrogenesis of the nickeliferous inter-banded iron formation ‘A’ shoot, Mt Windarra: University of Melbourne, BSc Hons thesis (unpublished).

HOBSON, R. A., and MILES, K. R., 1950, Part 1 — Geology of portion of the Mount Margaret Goldfield: Western Australia Geological Survey, Bulletin 103, p. 1–107.

HRONSKY, J. M. A., PERRIAM, R. P. A., and SCHMULIAN, M. L., 1990, Lancefield gold deposit, Laverton, *in* Geology of the mineral deposits of Australia and Papua New Guinea — 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 511–517.

JACKSON, C. F. V., 1905, Geological features and auriferous deposits of Mount Morgans, Mount Margaret Goldfield: notes on the geology and ore deposits of Mulgabbie: Western Australia Geological Survey, Bulletin 18, 36p.

JACOBSON, E. P., 1971, A structural interpretation of a gravity and magnetic survey over greenstone rocks at Mt Windarra in Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

JAGODZINSKI, E. A., WHITAKER, A. J., and SEDGMEN, A., 1996, Nambi, W.A. Sheet 3241 (preliminary edition): Australian Geological Survey Organisation, 1:100 000 Geological Series.

JAQUES, A. L., 1976, An Archaean tholeiitic layered sill from Mt Kilkenny, Western Australia: Geological Society of Australia, Journal, v. 23, p. 157–168.

JOHNSON, G. I., and RYALL, A. W., 1999, Innuendo, Whisper and Rumour — the discovery of the Chatterbox Shear gold deposits, *in* New Generation Gold Mines ’99: Australian Mineral Foundation and Keith Yates and Associates; Conference Proceedings, Perth, W.A., 1999, p. 15–27.

LEAHY, J. E., 1973, The geology and nickel–copper mineralogy of the 'D' shoot, Mount Windarra, Western Australia: University of Tasmania, BSc Hons thesis (unpublished).

LE BAS, M. J., and STRECKEISEN, A. L., 1991, The IUGS systematics of igneous rocks: Journal of the Geological Society of London, v. 148, p. 825–833.

LIU, S. F., GRIFFIN, T. J., WYCHE, S., WESTAWAY, J. M., and FERGUSON, K. M., 1998, Geology of the Sir Samuel 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 26p.

MABBUTT, J. A., 1977, An introduction to systematic geomorphology — Volume 2: Desert Landforms: Canberra, Australian National University Press, 340p.

MAITLAND, A. G., 1906, Annual progress report of the Geological Survey for the Year 1905: Perth, Western Australia, Department of Mines, 24p.

MARSTON, R. J., 1979, Copper mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 13, 208p.

MILES, K. R., 1950, Part II Garnetised gabbros from the Eulaminna district, Mt Margaret Goldfield: Western Australia Geological Survey, Bulletin 103, p. 108–130.

MOCK, C. M., ELLIOTT, B. G., EWERS, G. R., and LORENZ, R. P., 1987, Gold deposits of Western Australia: Australia BMR MINDEP Datafile, Resource Report 3, 35p.

NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.

NELSON, D. R., CHIVAS, A. R., CHAPPELL, B. W., and McCULLOCH, M. T., 1988, Geochemical and isotopic systematics in carbonatites and implications for the evolution of ocean-island sources: Geochimica Cosmochimica Acta, v. 52, p. 1–17.

NEWTON, P. G. N., GIBBS, D., GROVE, A., JONES, C. M., and RYALL, A. W., 1998, Sunrise–Cleo gold deposit, *in* Geology of Australian and Papua New Guinean mineral deposits *edited by* D. A. BERKMAN and D. H. MacKENZIE: Australasian Institute of Mining and Metallurgy, Monograph 22, p. 179–186.

NIELSEN, K. I., and CURRIE, D. A., 1999, The discovery of the Just In Case/Wallaby gold deposit, Laverton district, Western Australia, *in* New Generation Gold Mines '99: Australian Mineral Foundation and Keith Yates and Associates; Conference Proceedings, Perth, W.A., 1999, p. 1–13.

NISBET, B. W., and WILLIAMS, C. R., 1990, Mertondale gold deposits, Leonora, *in* Geology of the mineral deposits of Australia and Papua New Guinea — 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 337–342.

OLLIER, C. D., CHAN, R. A., CRAIG, M. A., and GIBSON, D. L., 1988, Aspects of landscape history and regolith in the Kalgoorlie region, Western Australia: Australia BMR, Journal of Australian Geology and Geophysics, v. 10, p. 309–321.

PASSCHIER, C. W., 1994, Structural geology across a proposed Archaean terrane boundary in the eastern Yilgarn Craton, Western Australia: Precambrian Research, v. 68, p. 43–64.

PIDGEON, R. T., and WILDE, S. A., 1990, The distribution of 3.0 Ga and 2.7 Ga volcanic episodes in the Yilgarn Craton of Western Australia: Precambrian Research, v. 48, p. 309–325.

POLL, N. J., 1987, Gold distribution and trace element composition of sulphide phases in the Lancefield and North Kalgoorlie gold deposits, Western Australia: University of Western Australia, BSc Hons thesis (unpublished).

RATTENBURY, M. S., JAGODZINSKI, E. A., DUGGAN, M. B., CHAMPION, D. C., BLAKE, D. H., WHITAKER, A. J., and SEDGMEN, A., 1997, Mount Varden, W.A. Sheet 3341 (preliminary edition, version 2): Australian Geological Survey Organisation, 1:100 000 Geological Series.

REDDELL, C. T., and SCHMULIAN, M. L., 1990, Windarra nickel deposits, Laverton *in* Geology of the mineral deposits of Australia and Papua New Guinea — 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 561–566.

ROBINSON, W. B., STOCK, E. C., and WRIGHT, R., 1973, The discovery and evaluation of the Windarra nickel deposits, Western Australia: Western Australia Conference 1973, Papers Australasian Institute of Mining and Metallurgy Conference Series, v. 2, p. 69–90.

ROTH, E., 1988, Petrogenesis of aluminosilicate-bearing assemblages in the Archaean greenstone terrains of the Leonora and Malcolm districts, Western Australia: University of Western Australia, BSc Hons thesis (unpublished).

SANTUL, J., 1975, The geology, geochemistry and mineralization of the South Windarra nickel ore deposit, Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

STEWART, A. J., 1998, Recognition, structural significance, and prospectivity of early (F_1) folds in the Minerie 1:100 000 sheet area, Eastern Goldfields, Western Australia: Australian Geological Survey Organisation, Research Newsletter, v. 29, p. 4–6.

SWAGER, C. P., 1997, Tectono-stratigraphy of late Archaean greenstone terranes in the southern Eastern Goldfields, Western Australia: Precambrian Research, v. 83, p. 11–42.

SWAGER, C. P., GRIFFIN, T. J., WITT, W. K., WYCHE, S., AHMAT, A. L., HUNTER, W. M., and McGOLDRICK, P. J., 1995, Geology of the Archaean Kalgoorlie Terrane — an explanatory note (reprint of Record 1990/12): Western Australia Geological Survey, Report 48, 26p.

SWAGER, C. P., WITT, W. K., GRIFFIN, T. J., AHMAT, A. L., HUNTER, W. M., McGOLDRICK, P. J., and WYCHE, S., 1992, Late Archaean granite–greenstones of the Kalgoorlie Terrane, Yilgarn Craton, Western Australia, *in* The Archaean — terrains, processes and metallogeny *edited by* J. E. GLOVER and S. E. HO: University of Western Australia, Geology Department and University Extension, Publication no. 22, p. 107–122.

TALBOT, H. W. B., and CLARKE, E. de C., 1917, A geological reconnaissance of the country between Laverton and the South Australian border (near south latitude 26º), including part of the Mount Margaret Goldfield: Western Australia Geological Survey, Bulletin 75, 207p.

TIPPER, D. B., and GERDES, R., 1971, Laverton–Edjudina airborne magnetic and radiometric survey, Western Australia, 1969: Australia BMR, Bulletin 118, 36p.

van de GRAAFF, W. J. E., CROWE, R. W. A., BUNTING, J. A., and JACKSON, M. J., 1977, Relict early Cainozoic drainages in arid Western Australia: Zeitschrift fur Geomorphologie N.F., v. 21, p. 379–400.

VAN KLINKEN, G. A., 1974, Part 1. A geophysical survey at South Windarra, near Laverton, WA. Part 2. A geophysical survey near Kilkivan, SE Queensland: University of Queensland, BAppSc thesis (unpublished).

WATCHMAN, A. L., 1971, A study of two geological sections and the petrology and geochemistry of the ultramafic rocks — Mount Windarra ore body, Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

WILLIAMS, P. R., 1993, A new hypothesis for the evolution of the Eastern Goldfields Province, *in* Kalgoorlie 93 — an international conference on crustal evolution, metallogeny, and exploration of the Eastern Goldfields *compiled by* P. R. WILLIAMS and J. A. HALDANE: Australian Geological Survey Organisation, Record 1993/54, p. 77–83.

WILLIAMS, P. R., 1998, Geology, structure, and gold resources of the Leonora 1:100 000 sheet, W.A.: Australian Geological Survey Organisation, Record 1998/9, 71p.

WILLIAMS, P. R., DUGGAN, M. B., CURRIE, K. L., BASTRAKOVA, I., WHITAKER, A. J., and SEDGMEN, A., 1997a, Minerie, W.A. Sheet 3240 (preliminary edition, version 3): Australian Geological Survey Organisation, 1:100 000 Geological Series.

WILLIAMS, P. R., DUGGAN, M. B., JAGODZINSKI, E. A., CHAMPION, D. C., STEWART, A. J., WHITAKER, A. J., and SEDGMEN, A., 1997b, Laverton, W.A. Sheet 3340 (preliminary edition, version 2): Australian Geological Survey Organisation, 1:100 000 Geological Series.

WILLIAMS, P. R., and WHITAKER, A. J., 1993, Gneiss domes and extensional deformation in the highly mineralized Archaean Eastern Goldfields Province, Western Australia: Ore Geology Reviews, v. 8, p. 141–162.

WILLIAMS, R. E., 1969, An environmental study of base metal sulphide mineralization, Eulaminna, Western Australia: University of Adelaide, BSc Hons thesis (unpublished).

Appendix 1

Gazetteer of localities

Locality	*AMG coordinates* *Easting*	*Northing*	*Locality*	*AMG coordinates* *Easting*	*Northing*
Admiral Hill	448450	6840700	Mertondale mine	357600	6827000
Allan Well	355550	6807150	Minerie Hill	379500	6825500
Barnicoat Well	449800	6829900	Mistletoe Bore	407000	6895200
Beasley Well	436000	6845000	Mount Ajax	432680	6824000
Benalla Hill	369750	6809200	Mount Amy	433100	6895900
Bernie Bore	392140	6835360	Mount Barnicoat	450000	6829700
Bore No. 8	439200	6820170	Mount Clarke	436800	6898000
Brewery Well	417350	6811650	Mount Crawford	440730	6838450
Brook Tank	447480	6806500	Mount Dennis	488000	6792600
Butcher Well	361650	6809050	Mount East	466300	6795000
Camel Hump	434600	6880500	Mount Jumbo	436800	6823000
Cardinia Bore	364900	6811000	Mount Korong	397000	6830900
Cardinia Hill	366120	6814300	Mount Kowtah	400500	6805000
Cement Tank Well	376700	6803450	Mount Lebanon	464500	6812900
Christmas Well	381300	6822400	Mount Margaret	421000	6810400
Clifton Well	360550	6861000	Mount Margaret Mission	420300	6814250
Corkscrew Well	377150	6814900	Mount McKenna	455700	6840200
Corktree Well	442950	6867600	Mount Morgans	409000	6817000
Corner Well	460200	6824900	Mount Murrin Murrin	385000	6798700
Cudi Bore	366700	6821100	Mount Phoenix	408400	6818100
Darby Well	453050	6896300	Mount Redcastle	395400	6794700
David Well	395400	6857400	Mount Stewart	360200	6799200
Diorite Hill	469200	6838300	Mount Varden	440650	6884050
Doris Well	440000	6888600	Mount Weld	453400	6820800
Eight Foot Well	415700	6827850	Mount Weld Homestead	445220	6817000
Eighteen Mile Well	465500	6840430	Mount Zephyr	381700	6859150
Federation Well	380400	6809600	Murphy peak	425300	6900010
Fleming Bore	412400	6832400	Murrin Murrin mine	392500	6815700
Freshwater Bore	449880	6870080	No. 10 Well	368000	6833500
Garden Well	400870	6813050	North Well	398600	6841200
Geyer Well	400100	6836750	Nulerie Waterhole	420250	6888950
Gibson Well	445350	6902100	Pub Well	370200	6804300
Golden Ring Well	458050	6800300	Pumping Station Well	438450	6865900
Goose Hill	427000	6825750	Randwick Hill	371550	6826280
Granny Smith mine	443600	6812500	Red Flag Well	432200	6821900
Hacks Well	453700	6795400	Roman Well	356750	6872000
Hanns Camp	451100	6838700	Rotorua Well	475400	6828000
Harold Well	440100	6813000	Russell Well	463230	6804500
Hillside Well	439400	6811750	Shay Cart Range	498000	6820000
Homestead Well	356800	6826200	Smith Well	434250	6841550
Ida Hill Well	446800	6821400	South Pinnacle	431000	6901100
Ironstone Point	487500	6808750	South Windarra mine	425700	6834500
Jubilee Hill	458350	6797000	Spinifex Well	431850	6854800
Kauri Well	372250	6823620	Steve Well	374750	6843550
Kirkpatrick Well	435900	6893600	Swincer Well	443120	6872800
Lake Carey	428000	6800000	Toomey Hill	391800	6807850
Lancefield	439500	6840650	Two Mile Well	490200	6899100
Laverton township	441000	6833500	Victor Well	373650	6879400
Laverton Downs Homestead	444700	6851900	Weebo Well	427750	6843050
Lawson Well	448150	6825300	Welcome Well	373200	6811800
Lent Well	391650	6865800	White Cliffs	494650	6854400
Macey Hill	379000	6792800	Windarra mine	424800	6848400
Mailman peak	377900	6800200	Windy Bore	368840	6815220
Mallock Well	462900	6802000	Winston Well	360200	6868550
Manger Bore	372700	6816600	Woodline Well	417700	6835250
Maurice Bore	370800	6831700	Woolshed Well	366100	6868700

Appendix 2

Altered granitoid localities on LAVERTON (1:250 000)

Site id[(a)]	*Rock type*	*Comments*	*100 000 sheet*	*Easting*	*Northing*	*Intensity[(b)]*
Carbonate alteration						
90963076	Feld porphyry	–	LAVERTON	447341	6805979	–
90963114	Qtz–feld porphyry	–	LAVERTON	435037	6828623	–
92969122	Biotite granite	Beasley Well	LAVERTON	431136	6845783	Minor
93962146	Granodiorite	Granophyric rims on feld phenocrysts	LAVERTON	426522	6842904	Trace
93964053	Granodiorite	Mount Lucky	LAVERTON	451102	6818926	Minor
93964114	Quartz diorite	Golden Ring	BURTVILLE	460267	6798514	Minor
93964145	Feld-phyric syenite	Probably albite	BURTVILLE	454776	6837612	Minor–common
93964152	Biotite granite	Probert Well	BURTVILLE	466656	6826416	Minor
93964344	Biotite monzogranite	Meredith Well	BURTVILLE	464418	6823999	Minor
93969031	Biotite granite	–	BURTVILLE	499502	6844064	–
93969032	Biotite granite	–	MOUNT VARDEN	496372	6852042	Slight
93969053	Biotite granite	–	MOUNT VARDEN	448446	6874819	–
94969577	Fine-grained granite	Dykes in basalt	LAVERTON	412397	6820455	Minor
94969578	Amph–plag-phyric granodiorite	Mount Lucky	LAVERTON	446892	6819255	Trace
94969579	Clouded, medium-grained granodiorite	Mount Lucky	LAVERTON	446547	6820330	Minor
94969581	Amph–plag granodiorite	Mount Lucky	LAVERTON	446047	6820555	Trace
94969582	Granodiorite	Granny Smith	LAVERTON	443731	6812582	Minor–common
94969584	Diorite	Granny Smith	LAVERTON	443600	6812180	–
94969584	Pyritic granodiorite	Granny Smith	LAVERTON	443600	6812180	–
94969586	Granodiorite	Granny Smith	LAVERTON	443680	6812180	Trace–minor
94969590	Granodiorite	Mount Crawford	LAVERTON	441312	6838410	Trace
94969591	Gar–musc–biot granite	The Boats	LAVERTON	423477	6836425	Trace
94969592	Pyritic granodiorite	Granny Smith	LAVERTON	444116	6811900	Common
94969592	Pyritic monzonite or quartz diorite	Granny Smith	LAVERTON	444116	6811900	Minor–common
94969594	Amph–qtz–biot–feld porphyry	Dyke in sedimentary rock at Granny Smith	LAVERTON	444096	6812020	Minor–common
94969597	Biot–feld–qtz porphyry	Hawks Nest	LAVERTON	426177	6824485	Minor
94969601	Granodiorite	Russell Well	BURTVILLE	465552	6803250	Trace–minor
94969602	Granodiorite	Russell Well	BURTVILLE	466382	6804570	Trace
94969603	Tonalite	Mount Lucky	LAVERTON	451037	6820840	Trace
95969790	Qtz–feld porphyry	Jerusalem (small chips)	BURTVILLE	462217	6809860	Minor–trace
95969791	Quartz diorite	Jerusalem (small chips)	BURTVILLE	462237	6810410	Common
95969792	?Ferromag–qtz–feld porphyry	Jerusalem (chip sample)	BURTVILLE	462337	6810560	Common
95969800	Qtz–?ferromag–feld porphyry	Club Ridge	LAVERTON	442480	6816400	Common
95969801	?Ferromag–qtz–feld porphyry	Keringal	BURTVILLE	453200	6800320	Common
96969090	Ferromag–feld porphyry	Club Ridge (drill chips)	LAVERTON	442540	6816600	Common
Albite alteration						
94969584	Pyritic granodiorite	Granny Smith	LAVERTON	443600	6812180	–
94969592	Pyritic granodiorite	Granny Smith	LAVERTON	444116	6811900	–
Hematite alteration						
92969122	Granite	Fluorite also	LAVERTON	430999	6845623	–
94969592	Granodiorite	–	LAVERTON	443979	6811740	–
94969584	Granodiorite	–	LAVERTON	443600	6812180	–
95969791	Diorite	–	BURTVILLE	462100	6810250	–
Potassic alteration						
94969592	Granodiorite	–	LAVERTON	443979	6811740	–
Pyritic alteration						
94969584	Granodiorite	–	LAVERTON	443600	6812180	–

NOTES:
(a) In AGSO's OZROX database
(b) – signifies 'undocumented'

Qtz: Quartz
Feld: Feldspar
Amph: Amphibole
Plag: Plagioclase
Gar: Garnet
Musc: Muscovite
Biot: Biotite
Ferromag: Ferromagnesium minerals