Department of
Industry and Resources

REPORT
84

EAST YILGARN GEOSCIENCE DATABASE 1:100 000 GEOLOGY OF THE LEONORA–LAVERTON REGION EASTERN GOLDFIELDS GRANITE–GREENSTONE TERRANE — AN EXPLANATORY NOTE

by M. G. M. Painter, P. B. Groenewald, and M. McCabe

Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Perth 2003

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REFERENCE
The recommended reference for this publication is:
PAINTER, M. G. M., GROENEWALD, P. B., and McCABE, M., 2003, East Yilgarn Geoscience Database, 1:100 000 geology of the Leonora–Laverton region, Eastern Goldfields Granite–Greenstone Terrane — an explanatory note: Western Australia Geological Survey, Report 84, 45p.

National Library of Australia
Cataloguing-in-publication entry

Painter, M. G. M.
East Yilgarn Geoscience Database, 1:100 000 geology of the Leonora–Laverton region, Eastern Goldfields Granite–Greenstone Terrane — an explanatory note

Bibliography.
ISBN 0 7307 5739 0

1. Geology — Western Australia — Eastern Goldfields — Databases.
2. Geological mapping — Western Australia — Eastern Goldfields — Databases.

I. Groenewald, P. B.
II. McCabe, M., 1965–.
III. Geological Survey of Western Australia.
IV. Title. (Series: Report (Geological Survey of Western Australia); 84).

559.416

ISSN 0508–4741

Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid Australia (MGA) coordinates, Zone 51. All locations are quoted to at least the nearest 100 m.

Copy editor: D. P. Reddy
Cartography: L. S. Cosgrove
Desktop publishing: K. S. Noonan
Printed by Haymarket Printing, Perth, Western Australia

Published 2003 by Geological Survey of Western Australia

Copies available from:
Information Centre
Department of Industry and Resources
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
Telephone: (08) 9222 3459 Facsimile: (08) 9222 3444
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Cover photograph:
The historic mine site at Mount Windarra (MGA 425200E 6848550N) in the Margaret Anticline northwest of Laverton, where sulfide mineralization associated with komatiitic lavas made this the second-largest Australian source of nickel from 1974 to 1979.

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Abstract

Eighteen 1:100 000-scale geological maps of the central Eastern Goldfields Granite–Greenstone Terrane, Western Australia, have been collated as geospatially referenced digital information in Phase 3 of the East Yilgarn Geoscience Database project. This approximately 50 000 km^2 area around Leonora and Laverton includes most of the Laverton, Murrin, and Malcolm greenstone belts, as well as parts of the Illaara, Mount Ida, Agnew–Wiluna, Yandal, Duketon, and Cosmo Newbery greenstone belts. Original map boundary discrepancies have been resolved and standardized rock type definitions applied to provide a seamless map of outcrop and regolith. Additional data themes include an aeromagnetic interpretation of concealed lithological and structural features; a 1:500 000-scale interpretation of Precambrian geology beneath younger cover; mine site, mineral occurrence, and exploration data; mineral resource locations and statistics (MINEDEX); tenement distribution and status information (TENGRAPH); and pseudocolour images derived from Landsat TM data.

The outcrop geology of this poorly exposed region reveals only segments of Archaean lithostratigraphy, with little continuity within the greenstone belts and no definitive data to allow correlation between them. Interpretations of tectonic settings and the complex deformation history are limited by the lack of fresh outcrop. There are a few minor exposures of Permian conglomerates and sandstones. Most of the area is covered by transported and residual regolith.

There is gold mineralization in most of the greenstone belts and despite more than a century of productive mining, additional gold resources have been discovered in the area during the last decade. Nickel sulfide ores have been mined from Mount Windarra and South Windarra in the Laverton belt, and extensive nickel–cobalt laterite deposits are currently being exploited at Murrin Murrin.

KEYWORDS: Archaean geology, greenstones, GIS data base, Yilgarn Craton, Eastern Goldfields, Southern Cross, Leonora, Laverton, remote sensing, mineral resources, gold, nickel.

Introduction

The Geological Survey of Western Australia (GSWA) and Geoscience Australia (formerly the Australian Geological Survey Organisation — AGSO) collaborated in the National Geological Mapping Accord (NGMA) to complete geological mapping of the Eastern Goldfields Granite–Greenstone Terrane at 1:250 000 and 1:100 000 scales. The first phase of the East Yilgarn Geoscience Database collated twenty 1:100 000-scale map sheets from the southern Eastern Goldfields Granite–Greenstone Terrane (Fig. 1) as a seamless digital dataset (Groenewald et al., 2000). The second phase incorporated eighteen 1:100 000-scale maps from the northern Eastern Goldfields Granite–Greenstone Terrane (Groenewald et al., 2001). Eighteen published NGMA 1:100 000-scale geological maps (Table 1), covering the central 48 708 km^2 of the Eastern Goldfields Granite–Greenstone Terrane around Leonora and Laverton (Fig. 1), are collated in this Report as the third phase of the East Yilgarn Geoscience Database. Continuous upgrading of the East Yilgarn Geoscience Database, including planned improvements such as an upgraded 1:100 000-scale regolith layer and expansion to include recent GSWA mapping in the southeastern Eastern Goldfields, Southern Cross Terrane, and Earaheedy Basin, will maintain currency and expand the usefulness of a powerful spatial data resource for future advances in mineral exploration.

Because only two of the eighteen 1:100 000-scale maps within the area are accompanied by Explanatory

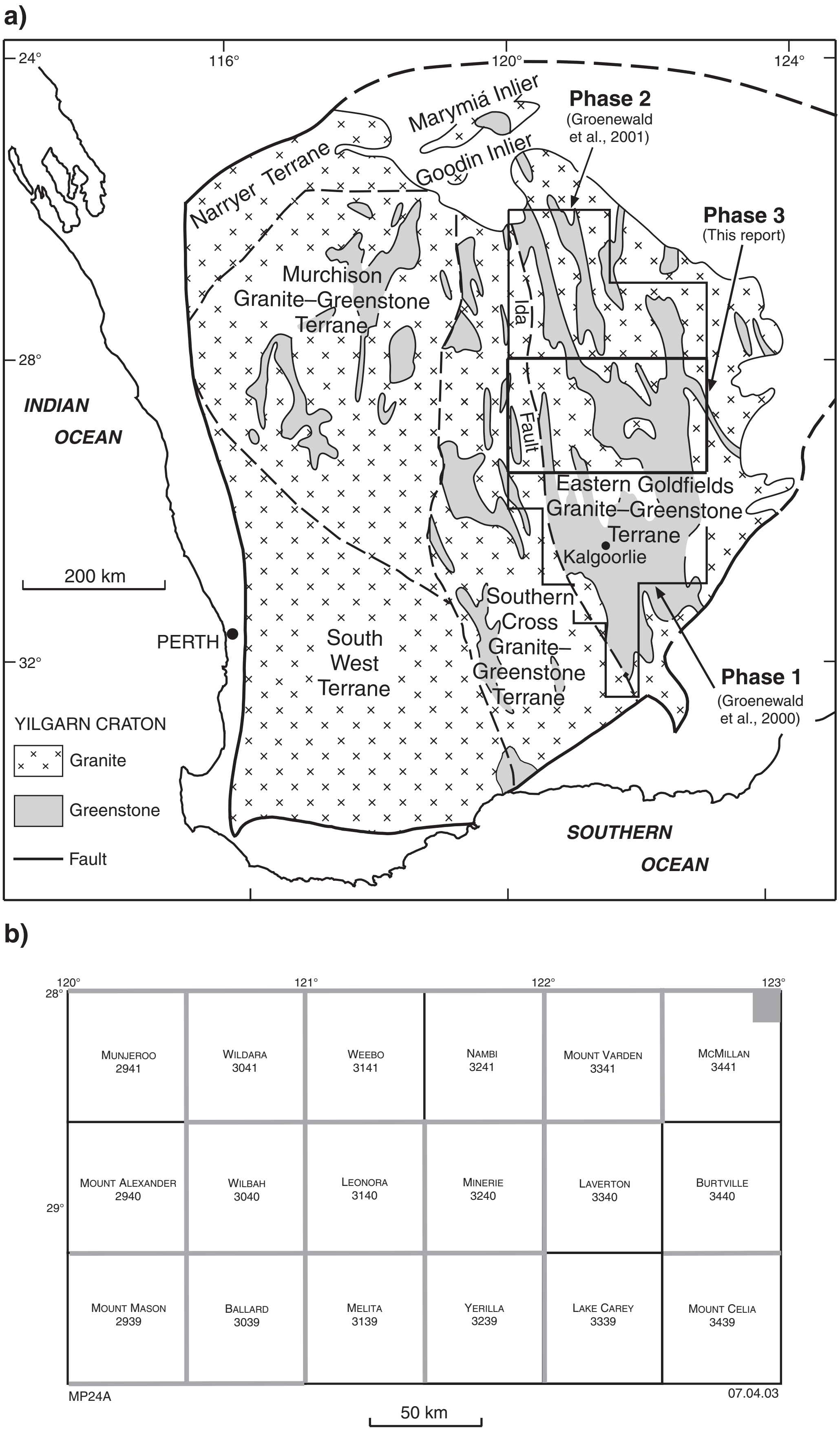


Figure 1. **a) Areas covered in the three phases of the East Yilgarn Geoscience Database project; b) the 1:100 000-scale maps collated in Phase 3 of the database (this report). Margins adjusted in this compilation are indicated by heavy lines, with an area in northwestern McMillan also remapped**

Table 1. The eighteen 1:100 000-scale geological maps and Explanatory Notes collated in the third phase of the East Yilgarn Geoscience Database project

Sheet	*Number*	*Source*	*Map reference*	*Explanatory Notes reference*
BALLARD	3039	GA	Rattenbury and Stewart (2000)	
BURTVILLE	3440	GA	Duggan (1995a)	
LAKE CAREY	3339	GA	Rattenbury and Swager (1994)	
LAVERTON	3340	GA	Williams et al. (1997)	
LEONORA	3140	GA	Stewart and Liu (1997)	Williams (1998)
MCMILLAN	3441	GA	Champion and Stewart (1996)	
MELITA	3139	GSWA	Witt (1992)	Witt (1994)
MINERIE	3240	GA	Williams et al. (1995)	
MOUNT ALEXANDER	2940	GA	Duggan (1995b)	
MOUNT CELIA	3439	GA	Duggan (1995c)	
MOUNT MASON	2939	GA	Duggan and Rattenbury (1996)	
MOUNT VARDEN	3341	GA	Rattenbury et al. (1996)	
MUNJEROO	2941	GA	Duggan et al. (1996b)	
NAMBI	3241	GA	Jagodzinski et al. (1996)	
WEEBO	3141	GA	Oversby et al. (1996a)	
WILBAH	3040	GA	Duggan et al. (1996a)	
WILDARA	3041	GA	Oversby et al. (1996b)	
YERILLA	3239	GA	Oversby and Vanderhor (1995)	

NOTES: GA Geoscience Australia, formerly Australian Geological Survey Organization (AGSO)
GSWA Geological Survey of Western Australia

Notes (LEONORA* and MELITA; Table 1), an overview is provided of the geology of the central Eastern Goldfields Granite–Greenstone Terrane. This Report also provides an explanation of the nature and origin of the digital themes into which the data have been divided, with details of metadata, data attributes, and look-up tables provided in the 'readme' and data dictionary files on the accompanying compact discs. Rock types and the identification codes used in the map data are defined in Appendix 1.

Although all Archaean rock types in the area covered have been metamorphosed, protoliths are commonly recognizable and the terminology used in this Report is based on primary compositions.

Location, access, and physiography

The eighteen 1:100 000-scale maps comprising this dataset cover an area between latitudes 28°S and 29°30'S and longitudes 120°E to 123°E. This includes the LEONORA (SH 51-1) and LAVERTON (SH 51-2) 1:250 000 map sheets, and the northern halves of the MENZIES (SH 51-5) and EDJUDINA (SH 51-6) 1:250 000 map sheets (Figs 1 and 2), encompassing an area of 48 708 km^2.

In the area covered by the database, populated gazetted townsites include Leonora, Laverton, Agnew, and Kookynie. Aboriginal communities include Mount Margaret on the old Leonora–Laverton Road and Morapoi on the Kookynie Road (Fig. 2). Access to most of the region is very good. Sealed roads connect the major centres of the region, including the Goldfields Highway that passes from Kalgoorlie in the south, through Leonora and northwest towards Wiluna, and the Leonora–Laverton Road (Fig. 2). Good-quality gravel roads extend throughout most of the region, from which an extensive network of variably maintained pastoral tracks and fence lines can be accessed. In the west the road from Leonora to Mount Ida extends to meet the Menzies–Sandstone Road, at the Perrinvale Outcamp to the west and the Riverina Outcamp to the south. The old main road from Leonora to Agnew traverses the northwestern part. In the northern part of the area good access is provided by well-maintained roads from Leonora to Nambi, Nambi to Weebo, and Nambi to Laverton via Erlistoun. Roads between Malcolm, Kookynie, Glenorn, Yerilla, and Yundamindra allow easy access in the south (Fig. 2). North and east of Laverton, the Bandya road provides access to the north and the Warburton Range Road (which is to be renamed the Outback Highway) extends northeast from Laverton and ultimately to Uluru in the Northern Territory. Recent mining activity has disrupted older access roads south of Laverton. Users of these roads should contact the Laverton Shire Council or the relevant mining companies for the most recent topocadastral maps of the area.

A railway line extends south from Leonora through Kookynie to Kalgoorlie. Leonora and Laverton have public access airports, and many mine sites and stations have private airstrips.

The topography of the area is subdued, with elevation ranging from a low of around 330 m above the Australian Height Datum (AHD) at Lake Raeside and Lake Minigwal in the southeast of the region to 565 m (AHD) at Mount Clark on MOUNT VARDEN. The physiography comprises three main landform components, all related to the underlying geology:

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

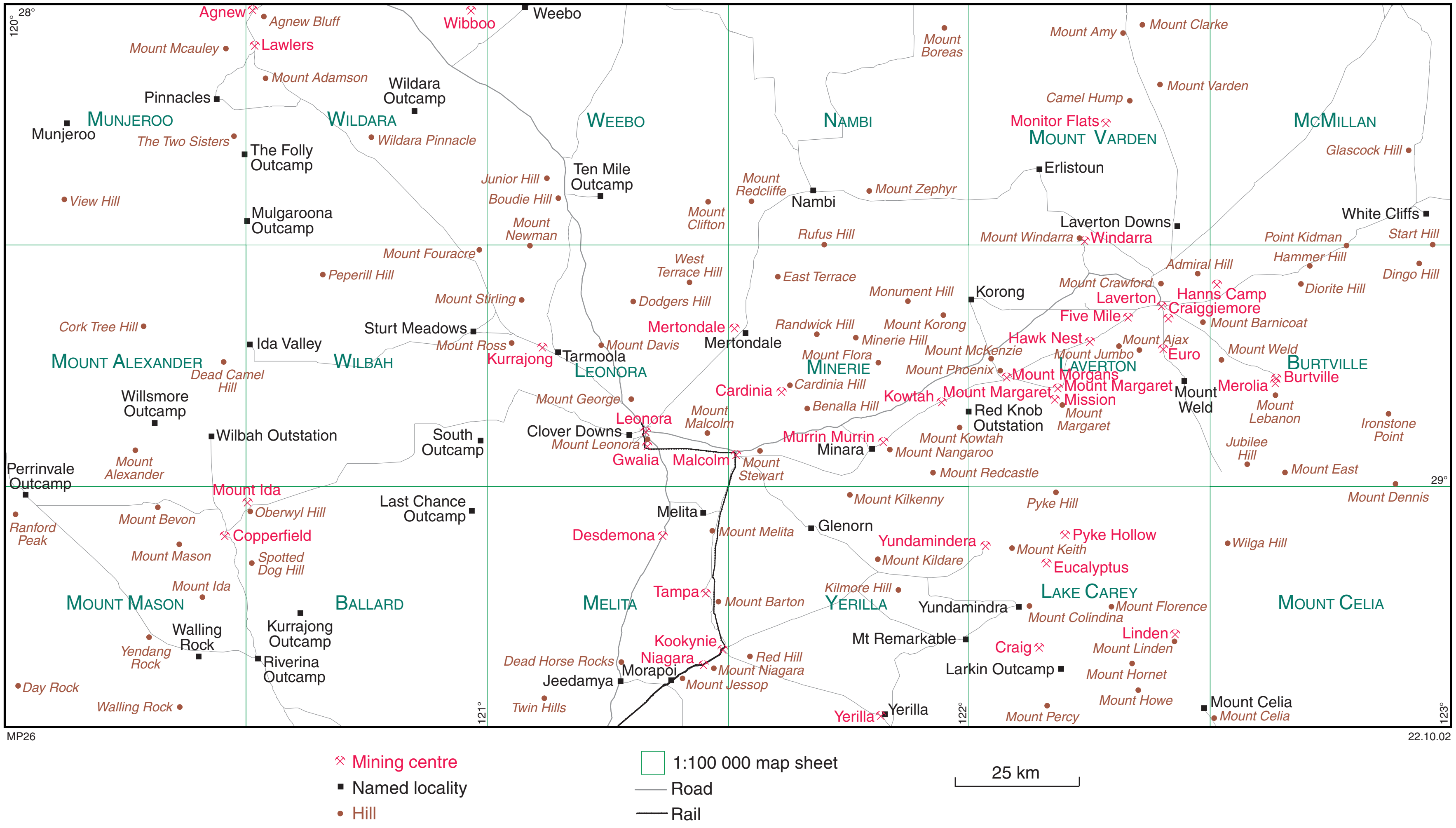


Figure 2. Cultural and topographic features of the central Eastern Goldfields Granite–Greenstone Terrane

- Several large playa lakes, claypans, and associated alluvial channels are flanked by dunes of quartz sand or gypsum (or both) that are typically stabilized by vegetation. These dunes separate many small peripheral lakes and saltpans. The lake and dune systems represent southeasterly trending palaeodrainage systems that have evolved since the Early Cretaceous, possibly reflecting control by post-Archaean faulting or Palaeozoic valleys.
- Expansive undulating plains, irregularly disrupted by breakaways or scarps, are underlain by granitoid, gneiss, and their weathered products. Sandy soils of granitic composition overlie siliceous duricrust and kaolinitized granite and, less commonly, fresh rock. The extensive areas covered by siliceous or ferruginous duricrusts ('laterite' in many early descriptions) indicate an extended period of landscape evolution.
- Subdued strike ridges are interspersed with plateaus of duricrust and deeply weathered bedrock over the greenstone belts of the area. Most greenstone outcrop is deeply weathered. The most pronounced topography is around the area near Mount Clarke and the Murphy Hills (MGA 436800E 6898190N) on MOUNT VARDEN, and near Mount Florence south of Lake Carey (MGA 431590E 6764430N) where chert units form prominent ridges in otherwise subdued landscapes.

The database

Phase 3 of the East Yilgarn Geoscience Database is the last major instalment of the Geographic Information System (GIS) package that covers the Eastern Goldfields Granite–Greenstone Terrane (Fig. 1a), and fills the gap between Phases 1 (Menzies to Norseman) and 2 (Cunyu to Cosmo Newbery).

The original versions of the 1:100 000-scale geological maps were created either through direct digital compilation by Geoscience Australia, or by digitizing of hand-drawn GSWA compilations. Precision and fidelity of data transfer to the format appropriate for the current work were maintained through comparison with the published maps. Any discrepancies between adjacent map sheets were resolved to provide seamless continuity. Many adjustments could be made confidently after examination of aerial photographs or Landsat TM (Thematic Mapper) images, although the boundaries between several adjacent maps (Fig. 1b) were remapped to confirm the continuity, identity, and distribution of several rock units or structural features.

The definitions of rock units or subdivisions shown on the maps have been checked against field notes, Explanatory Notes, or other published material to allow application of the standardized codes developed for Phases 1 (Groenewald et al., 2000) and 2 (Groenewald et al., 2001) of the database. Where necessary, new rock codes have been added to the standardized set. Definitions of all the codes applied in the database are provided in Appendix 1.

The database was assembled using the Environmental Systems Research Institute (ESRI) software ArcInfo 8.0.1 to yield seamless layers within a digital map library. The library was then converted into formats suitable for application of the popular GIS software packages ArcView, ArcExplorer, and MapInfo. Details of the directory structure, data dictionary, and other metadata are provided in text files on the compact disk.

Themes

The database comprises a variety of types of data in necessarily diverse formats, all linked by their spatial attribute of geographic location. This requires subdivision of the data into different packages that may be thought of as different layers of information or 'themes'. Much of the power of Geographic Information Systems stems from this subdivision in that it allows selective access to data for the application of analytical methodology. The themes used in this database are detailed below.

Geology

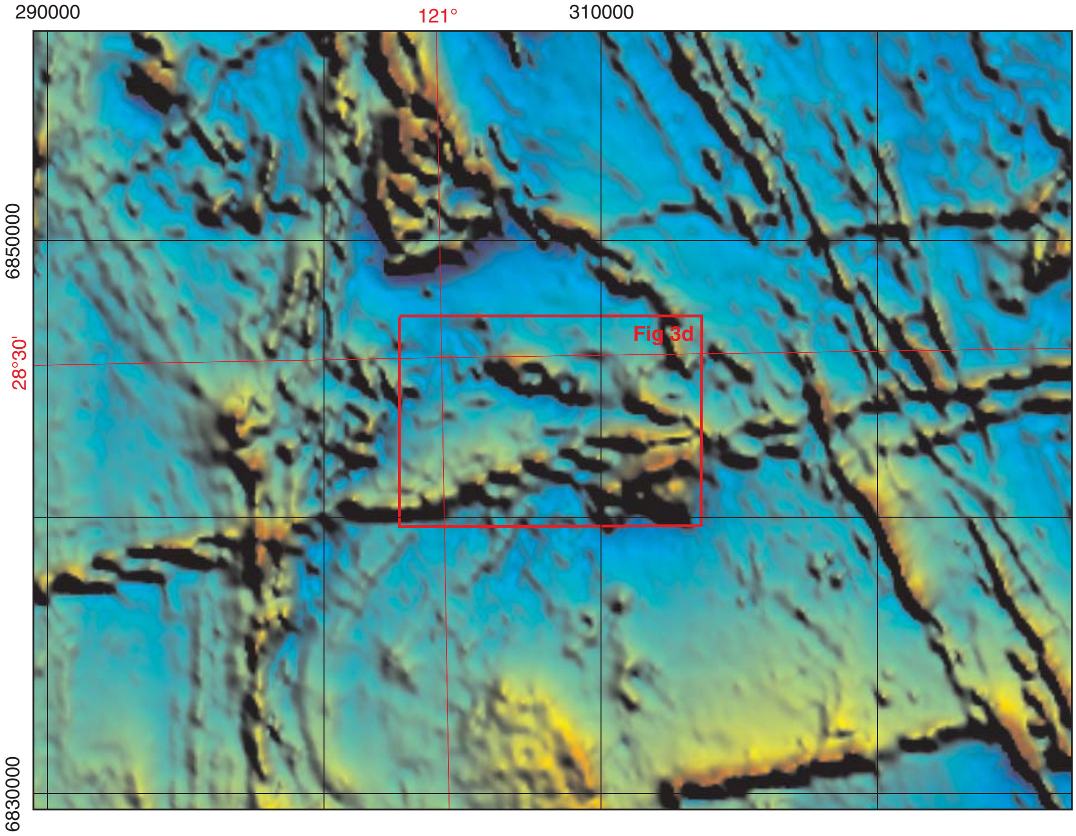
The geological data are subdivided according to various attributes, as follows:

- The position of outcrop geology is recorded in layers according to data type, and is represented as either polygons or lines, depending on the form of the rock units. Outcropping planar units that have widths too narrow to be represented as polygons on the original maps are presented as linear features.
- Attributes of each rock unit include an identification label code, for which standardized definitions are provided in look-up tables (Appendix 1).
- Subsurface records of rock types (from drillholes and costeans) are provided as points in the mine workings and exploration coverage (see below).
- Outcropping faults or shears are included in the line data layer.
- The concealed geology layer shows the inferred positions of geological boundary features, faults, and dykes interpreted from aeromagnetic images. Structural orientation records are in a point data layer, with measurements provided in the clockwise format (with dip direction taken as 90° greater than strike).
- Outcrop fold annotation is also provided in the point data layer.

Figure 3 shows an example of the outcrop geology content of the database and possible data combinations that can be generated using the various themes described below.

It should be noted that outcrop geology data have been derived almost entirely from published map sheets, seventeen of which were mapped by Geoscience Australia and one (MELITA) by GSWA (Table 1). Although regional-scale remapping of the central Eastern Goldfields Granite–Greenstone Terrane was beyond the scope of this project, numerous local areas were studied to ensure continuity across former map sheet boundaries. An exception is the Cosmo Newbery greenstone belt, on northeastern MCMILLAN (Fig. 4), which was remapped because the poor resolution of previous 1:100 000 mapping was such that polygons could not be matched with COSMO NEWBERY to the north.

a)


290000
121°
310000
6850000
28°30'
6830000
Fig 3d

b)


290000
121°
310000
6850000
28°30'
6830000
Fig 3d
MP30
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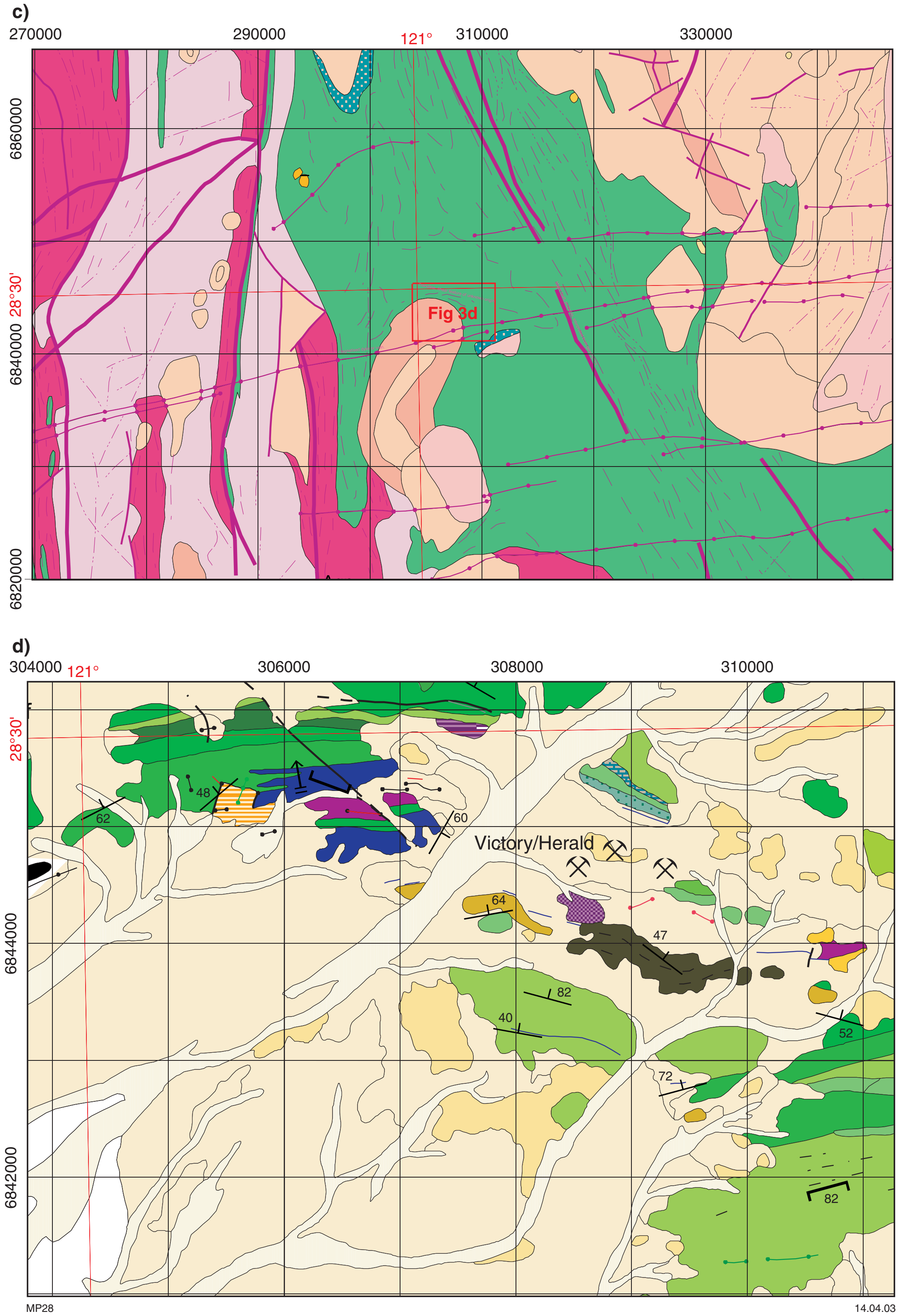

Figure 3. Illustrative plots generated from the database for a small part of coverage: a) total magnetic intensity image illustrating the pronounced dykes and greenstones; b) Landsat TM coverage of an area with outlines of the observed geology superimposed on the pseudocolour image; c) an extract from the regional interpreted geology theme of the database covering the area shown in 3a and b; d) outcrop geology comprising polygons (coded as in Appendix 1), observed fault (solid line) and dykes, and standard structural symbols, with mine site and subsurface data points

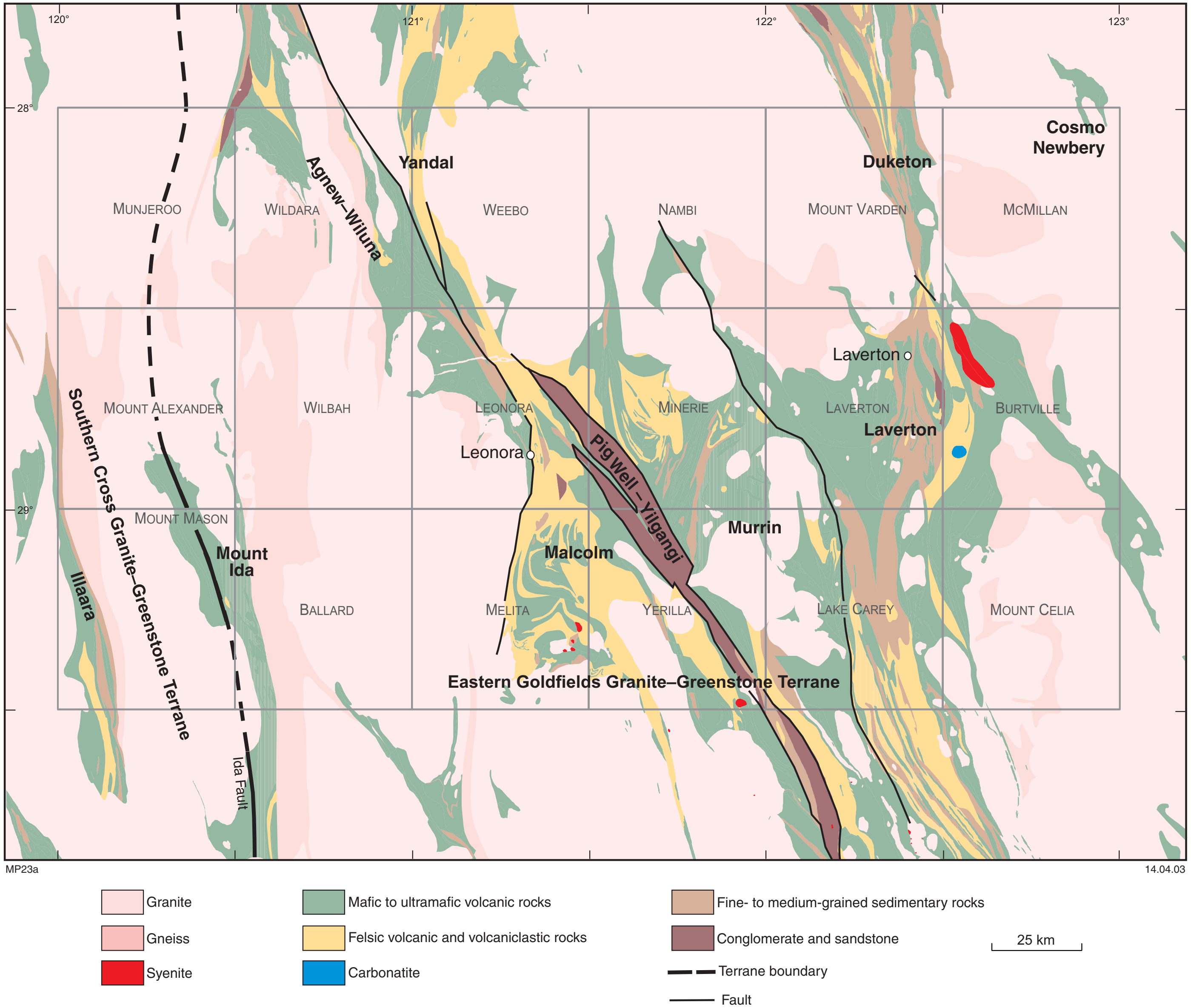

Figure 4. **Tectonic units of the Leonora–Laverton region (after Hallberg, 1985; Swager et al., 1995; Swager, 1995; Chen et al., 2001). Bold text represents greenstone belt names used in this report**

Regional interpreted bedrock geology

The interpreted bedrock geology theme provided in the database is a map of the interpreted distribution of Precambrian rock types beneath younger cover. This is a segment of the continuous Western Australian 1:500 000 coverage completed in 2001 by GSWA. Polygon and line data are in separate layers. Note that the map of interpreted solid geology was compiled for presentation at a scale of 1:500 000 and thus may not conform in detail and precision to the 1:100 000-scale outcrop maps.

Airborne magnetic survey

The airborne magnetic survey theme has been derived from the Geoscience Australia dataset, comprising earlier (1965–67) Bureau of Mineral Resources and more recent (1995) AGSO data. The false-colour image has been rendered in red, green, and blue intensity layers to allow replication of the standard geophysical pseudocolour spectrum in ArcView. Although the pixel size of 100 m used in this coverage may not allow detailed interpretation of the outcrop geology at 1:100 000 scale, it does contribute to interpretation of the geology on a regional scale, particularly in areas of very poor outcrop. The original data may be acquired from Geoscience Australia at a nominal cost.

Magnetic interpretation

Magnetic features identified in the detailed airborne magnetic coverage (400 m flight-line spacing) are provided as the magnetic interpretation theme in the database. This represents an examination of features, such as linear anomalies, boundaries around zones of different magnetic texture, and inferred discontinuities with reference to the mapped geological characteristics to provide a carefully constrained geophysical interpretation. This previously unpublished coverage was created by Mr A. Whitaker and has been released with authorization by Geoscience Australia. A part of the detailed aeromagnetic coverage used in this interpretation was provided to the NGMA by Fugro Inc. (Fig. 1b).

Landsat TM

The Landsat TM theme comprises two Landsat TM images, prepared using data collected in January and February 1998, providing coverage in which many of the recent exploration grids are visible. Data from the sample dates have been merged and normalized by the Western Australian Department of Land Administration (DOLA), using robust regression techniques, to provide a seamless Landsat image. Spatial accuracy better than 50 m with a pixel size of 25 m has been preserved. Raw data may be purchased from the Satellite Remote Sensing Services branch of DOLA.

A monochromatic (grey-scale) layer shows principal component values derived from Landsat TM bands 1, 4, and 7 using standard eigenvector formulae. In addition, a pseudocolour image was prepared using ratios between bands 2, 3, 4, 5, and 7 to distinguish between iron- and silica-rich areas, and between vegetation- and outcrop-dominated areas. Light-tan colouration is equivalent to recent alluvium, the lakes are light blue, mafic rock outcrops commonly range from purple through Prussian blue to lighter blue-green, lateritic areas are dark brown, and kaolinite-enriched areas (granitic) are a bluish off-white.

Localities of mine workings, prospects, and subsurface observations

This theme shows the localities of historical and currently operating mines and batteries, as well as prospects, mineral occurrences, and subsurface rock types revealed by mineral exploration. In view of the predominance of gold workings in the area, a mine site is only labelled with a commodity code in the database when it is not gold. The high level of exploration activity throughout the region in the 1980s and 1990s resulted in a marked increase in the resource inventory, particularly near abandoned mines. For this reason, the more recent finds, as shown by the Department of Industry and Resources' (DoIR, formerly Department of Mineral and Petroleum Resources) mines and mineral deposits information database (MINEDEX; see below), may have historical names for localities slightly different from those shown in the historical mine-workings dataset. Similarly, present large-scale opencut mining operations have commonly amalgamated several historical mine sites.

MINEDEX — mineral resources

The extract from the MINEDEX database included in the present database provides the following information, either directly as point attribute information or in look-up tables:

- commodity groups, projects, and sites;
- corporate ownership and percentage holding;
- site type and stage of development;
- site coordinates;
- current (at date of compact disc compilation) mineral resource estimates.

Details of the classifications and abbreviations used in the tables are provided in Appendix 2.

TENGRAPH — a record of the extent, location, and status of tenements

The tenement information within the database is extracted from DoIR's electronic tenement graphics system (TENGRAPH). The information demarcates the extent and location of tenements, with the following additional data in the attribute table:

- tenement identification (Tenid; e.g. M 2600261 refers to mining licence M 26/261;
- survey status (Survstatus), indicating whether or not the tenement has been surveyed;
- status of the tenement (Tenstatus), referring to whether the tenement application has been granted (L) or is under application (P);
- dates and times of submission of application, granting, and expiry of tenement holding.

In view of the continuous and ongoing changes in the tenement situation, current tenement plans should be viewed at the DoIR offices in Perth and Kalgoorlie before any land-use decisions or tenement applications are made.

Geological setting of the Leonora–Laverton region

The region covered by Phase 3 of the East Yilgarn Geoscience Database predominantly covers the Eastern Goldfields Granite–Greenstone Terrane, but also incorporates granites and the easternmost greenstone belts of the Southern Cross Granite–Greenstone Terrane in the southwest (Fig. 1a).

The Eastern Goldfields Granite–Greenstone Terrane makes up the eastern third of the Archaean Yilgarn Craton (Fig. 1a; Gee et al., 1981; Griffin, 1990a,b; Myers, 1997). The Ida Fault in the Menzies–Coolgardie area (Figs 1a and 4) marks the western limit of the terrane, and is an east-dipping, crustal-scale structure (Swager et al., 1997) separating the Eastern Goldfields Granite–Greenstone Terrane from the largely older succession of the Southern Cross Granite–Greenstone Terrane. The northward continuation of this fault is not well defined, but is inferred to lie west of the Agnew–Wiluna greenstone belt.

The mafic-dominated greenstone sequences of the Southern Cross Granite–Greenstone Terrane are constrained to a c. 3000–2900 Ma age by sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon analyses of various rock types (Pidgeon and Wilde, 1990; Nelson, 1999). This is significantly older than the greenstone sequences of the Eastern Goldfields Granite–Greenstone Terrane, which have been constrained to between 2750 and 2655 Ma (Kent and Hagemann, 1996; Nelson, 1995, 1996, 1997a,b, 1998, 2000; Krapez et al., 2000). No basement or rock types older than 2750 Ma have been identified in the Eastern Goldfields Granite–Greenstone Terrane (with the exception of the Norseman greenstones in the south; e.g. Nelson, 1995). Nevertheless, xenocrystic zircons older than 3000 Ma in felsic metavolcanic rocks suggest pre-existing continental crust (Compston et al., 1986; Nelson, 1997a). This is supported by the trace element geochemistry of some mafic rocks that indicate contamination of a primitive ultramafic magma by older sialic crust (Arndt and Jenner, 1986; Barley, 1986; Lesher and Arndt, 1995), and geochemistry of granitoids indicating generation through repeated crustal reworking (e.g. Wyborn, 1993). Widespread felsic volcanism occurred in the Yilgarn Craton between c. 2760 and 2700 Ma (Pidgeon and Wilde, 1990; Pidgeon and Hallberg, 2000), with several such volcanic centres within this database coverage.

Boundary between the Eastern Goldfields and Southern Cross Granite–Greenstone Terranes

The definition of the boundary between the Eastern Goldfields and Southern Cross Granite–Greenstone Terranes is controversial. Various authors have implied that the boundary is along the Ida Fault continuation within the Mount Ida greenstone belt (e.g. Swager, 1995a) or in granites west of the belt (e.g. Griffin, 1990a,b; Fig. 4). Stratigraphic relationships of the southern part of the Mount Ida greenstone belt (south of the database area) indicate that the ultramafic-bearing eastern part of the belt is part of the Eastern Goldfields Granite–Greenstone Terrane and that the basalts and cherts of the western part are part of the Southern Cross Granite–Greenstone Terrane (e.g. Wyche, 1999). Recent aeromagnetic interpretations suggest that the Ida Fault is discontinuous along strike (e.g. Whitaker, 2001). Whether the shear propagates through to the northern part of the Mount Ida greenstone belt (within the database area) is unclear, but similar rock relationships exist here (see below). The boundary between the Eastern Goldfields and Southern Cross Granite–Greenstone Terranes is therefore considered to be the Ida Fault within the Mount Ida greenstone belt, but is probably obscured by granitoids to the north (Figs 4 and 5).

Subdivision of the southern part of the Eastern Goldfields Granite–Greenstone Terrane

Swager et al. (1990, 1995) and Swager (1995a, 1997) subdivided the greenstones of the southern part of the Eastern Goldfields Granite–Greenstone Terrane into several postulated tectono-stratigraphic ‘terranes’ bounded by major shear zones. Other interpretations have suggested subdivision into a back-arc rift and a volcanic arc (Barley et al., 1989; Morris and Witt, 1997), or into the Kalgoorlie and Edjudina–Laverton greenstones (Groenewald et al., 2000), with possible smaller structural domains within the lithotectonic settings. Extrapolation of suggested subdivisions to the north is hampered by the lack of exposure and detailed geochronology. The range of rock types is very similar in the northern and southern parts of the Eastern Goldfields Granite–Greenstone Terrane, and the similarity between successions in the Wiluna – Mount Keith area and the northwestern Kalgoorlie greenstones has been noted by Liu et al. (1998), and a direct correlation postulated by Libby et al. (1997).

Greenstone belts

The Eastern Goldfields Granite–Greenstone Terrane in the Leonora–Laverton area consists of expanses of granitoids intruding or in faulted contact with a broad region of Archaean supracrustal rocks stretching from Agnew in the northwest and Duketon in the northeast, through Laverton and Leonora in the centre, to the Yilgangi area in the south (Fig. 4). Geophysical and field evidence indicate that the supracrustal rocks are dissected by numerous regional-scale shear zones across which subtle differences in lithology can be recognized. This suggests continuity or structural coalescence of these rock units; however, the differences in various areas of outcrop allow subdivision into discrete greenstone belts. For this reason the central expanse of supracrustal rocks is best described in terms of individual greenstone belts.

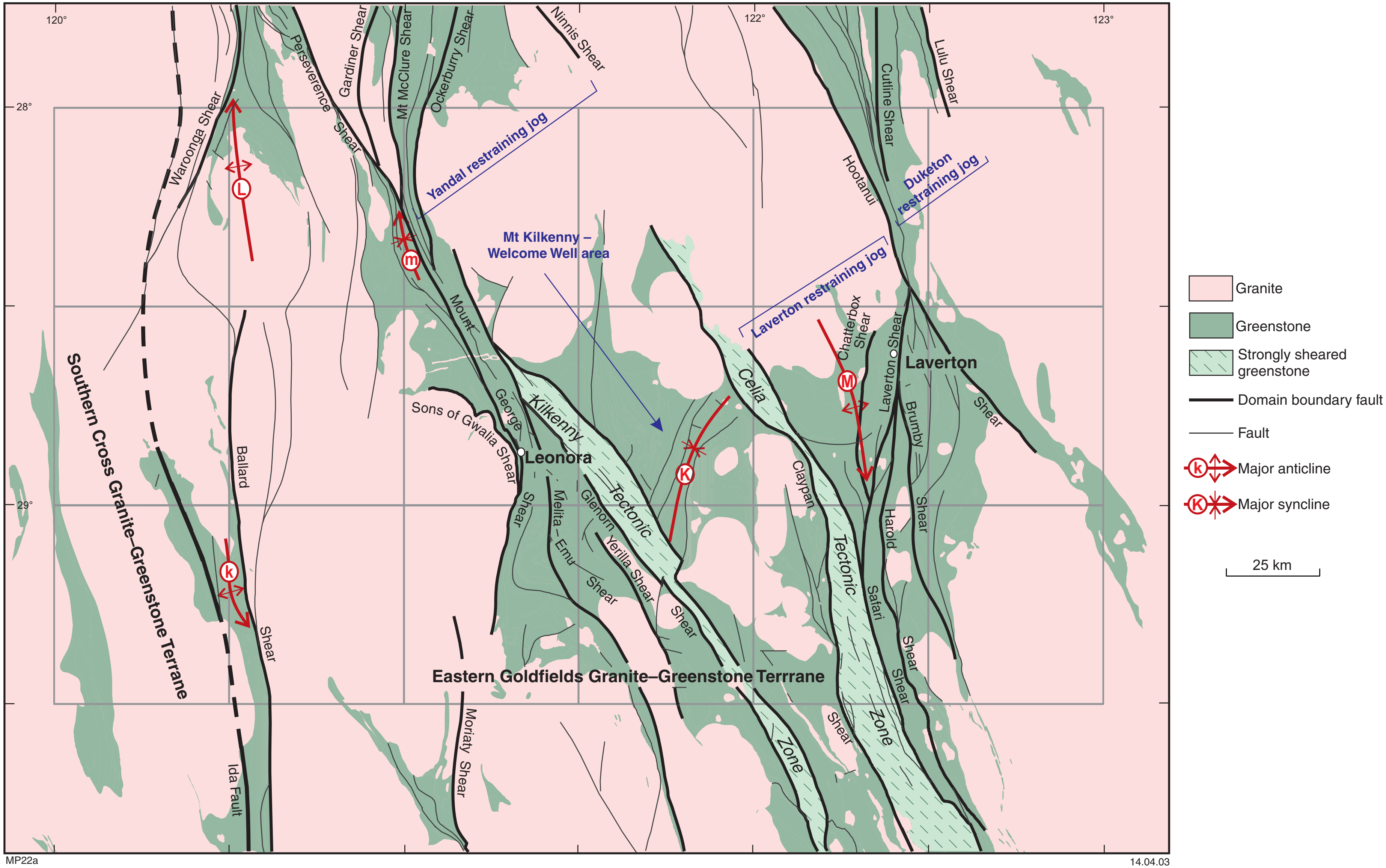

Figure 5. Major structural features of the Leonora–Laverton region (after Hallberg, 1985; Swager et al., 1995; Swager, 1995a,b; Chen et al., 2001), including major faults and shear zones, and folds mentioned in the text (k = Kurrajong Anticline, K = Kilkenny Syncline, L = Lawlers Anticline, m = Marshall Pool Syncline, M = Margaret Anticline). The Celia and Kilkenny Tectonic Zones are broad zones of shear bound by distinct shear zones

The subdivision of the Leonora–Laverton region into individual greenstone belts permits correlation with the parts of the Eastern Goldfields Granite–Greenstone Terrane to the north and south. The greenstones consist of metamorphosed ultramafic, mafic, and felsic volcanic or intrusive igneous rocks and immature sedimentary rocks typical of Archaean supracrustal successions. The typically poor exposure makes recognition or correlation of lithostratigraphic sequences difficult. Although indicators of younging direction are rarely preserved in the greenstones, pillow lavas and sedimentary structures as well as differentiation trends in mafic intrusions provide consistent younging directions in many areas. Much of the geological interpretation summarized here is based on field mapping data and interpretation of regional (400 m line spacing) and local, more detailed, airborne magnetic surveys.

Illaara greenstone belt, Southern Cross Granite–Greenstone Terrane

Only the central part of the Illaara greenstone belt (Griffin, 1990a) is within the report area (Fig. 4). Wyche (1999) and Wyche et al. (2001) noted the regionally distinctive lithostratigraphy of the Southern Cross Granite–Greenstone Terrane, in keeping with the westward dip and younging direction evident in the Illaara greenstone belt (Kriewaldt, 1970; Stewart et al., 1983). From the base up the stratigraphy comprises sandstone, quartzite, and banded iron-formation (BIF) overlain by tholeiitic to komatiitic basalt and komatiite, and an upper, poorly exposed sequence of felsic to intermediate volcanic and volcaniclastic rocks. Thin BIF and chert units become less common up sequence. The base of the sequence is intruded by granitoids and is tectonized. A sequence of tholeiitic basalt with minor interbands of chert, BIF, and shale is exposed in the western side of the belt, but is faulted against the eastern side and the stratigraphic relationship is unclear. Wyche (1999) noted lateral variation in the lower part of the stratigraphy, particularly in the quartzite that lenses out to the south. Wyche et al. (2001) noted that the Illaara greenstone belt cannot be correlated with certainty with other greenstone belts of the Southern Cross Granite–Greenstone Terrane to the west.

On the YOUANMI 1:250 000 sheet to the west a steeply northward-plunging anticline and syncline pair dominates the structural pattern of the northern part of the Illaara greenstone belt. South of this, particularly within the area covered by the database, the stratigraphy dips uniformly steeply westward. The bulk of the belt has been metamorphosed to greenschist to amphibolite facies, with the higher grades predominating toward its margins and to the south (Ahmat, 1986; Wyche, 1999).

Detrital zircons from the lowermost quartzite unit indicate a maximum depositional age of c. 3300 Ma (Wyche et al., 2001).

Mount Ida greenstone belt

The Mount Ida greenstone belt (Fig. 4), as recognized by Griffin (1990b), extends from Willsmore Outcamp (MGA 237700E 6803550N) in the north (Fig. 2) to south of Davyhurst. The greenstone belt comprises an eastern and western segment. The eastern segment contains mafic to ultramafic volcanic and intrusive rocks and is part of the Eastern Goldfields Granite–Greenstone Terrane. The western segment is dominated by a thick sequence of tholeiitic basalt with common BIF units, and shows a closer affinity to rocks of the Southern Cross Granite–Greenstone Terrane to the west (Wyche, 1999). The boundary between the terranes is defined at the Ida Fault to the south (see above). On MOUNT MASON the location of what may be a continuation of the Ida Fault is obscured by lateritic and related colluvial material, but continuity of magnetic trends suggest that the fault is near the Bottle Creek gold mine (in the Copperfield mining centre) and further to the north-northwest between West Bluff (MGA 250900E 6779150N) and Mount Bevon (MGA 238250E 6784150N, Fig. 2). Further northward on MOUNT ALEXANDER the Ida Fault is interpreted to continue north-northwesterly, probably between the BIF and quartzite units around Mount Alexander and the hills of mafic rock several kilometres to the east.

The eastern sequence of the Mount Ida greenstone belt is part of the Kalgoorlie greenstones (as defined by Groenewald et al., 2000), and is dominated by basalt and ultramafic rocks in the lower part of the stratigraphy. Hill et al. (1995, 2001) included these rocks in the Walter Williams Formation, which they defined as 'a layered body… consisting of a lower zone of olivine cumulates and an upper zone of gabbroic rocks'. The formation is interpreted to be a part of a large ponded komatiitic flow, in which in situ fractionation was fed by several influxes of fresh lava (Gole and Hill, 1990). The Walter Williams Formation is folded about the southward-plunging Kurrajong Anticline on BALLARD (k on Fig. 5). The name 'Walter Williams Formation' has not been used within the database due to uncertainty concerning the absolute spatial extent of the formation.

In the west a thick sequence of predominantly tholeiitic basalt contains interbeds of BIF, chert, and shale, and local lenses of gabbro and komatiitic basalt. Banded iron-formation dips shallowly to moderately westward at Mount Ida. Near Mount Alexander the sequence is dominated by steeply southwesterly dipping BIF and quartzite units. The western margin of the sequence is largely an intrusive contact with regional monzogranites.

Metamorphic grade ranges from lower to upper amphibolite facies (Binns et al., 1976; Wyche, 1999), but primary textures are commonly preserved (e.g. Hill et al., 2001).

No geochronology is available for the Mount Ida greenstone belt within the area covered by the database. The 2640 ± 8 Ma (Nelson, 1995) Clarke Well Monzogranite on RIVERINA to the south of the study area intruded the Ida Fault and post-dates movement along the fault (Wyche, 1999). Further south the Ularring Monzogranite intruded the greenstone belt, with a sample from Ularring Rock (MGA 263390E 6686890N) providing a SHRIMP U–Pb zircon age of 2632 ± 4 Ma (Nelson, 2000).

Agnew–Wiluna greenstone belt

The southernmost part of the Agnew–Wiluna greenstone belt is incorporated in this dataset (Fig. 4; see Groenewald et al., 2001, for a synopsis of the geology of the northern part), and includes the western Agnew and eastern Mount Clifford domains, which are separated by granitoids and faults.

The Agnew domain is dominated by the Lawlers Anticline (L on Fig. 5), which plunges 30–40° northward (e.g. Aoukar and Whelan, 1990). The anticline has a core of granitoid rocks that appear to intrude the supracrustal lithologies, whereas to the west the domain is in faulted contact with granitoids along the Waroonga Shear Zone. To the east the relationship to granitoids is unclear, but is probably largely intrusive in nature. The southeasternmost and southwesternmost parts of the domain are characterized by folds that are attenuated between faults and the major granitoid intrusions. Several overturned early generation folds are refolded by the Lawlers Anticline.

A distinct stratigraphy comprising two distinct sequences separated by an unconformity has been recognized for the supracrustal lithologies of the Agnew–Wiluna greenstone belt, and this can be recognized in the Agnew domain (Naldrett and Turner, 1977). The lower sequence is exposed in the Lawlers Anticline near Yakabindie and the upper sequence is exposed elsewhere in the belt. The oldest recognized rocks in the Agnew domain are basalt, komatiitic basalt, and komatiite and their coeval subvolcanic intrusives, and associated interflow sedimentary rocks (Platt et al., 1978; Inwood, 1998). The mafic to ultramafic sequence is overlain by locally preserved and volumetrically minor felsic volcanic rocks (Aoukar and Whelan, 1990). Granite, leucogranite, and diorite to tonalite of the 'Lawlers Tonalite' (Foden et al., 1984) intruded the greenstone sequence at 2652 ± 20 Ma (Rb–Sr whole-rock age; Cooper et al., 1978). A strongly deformed sedimentary sequence of mudstone to conglomerate, known locally as the 'Scotty Creek Formation' (but reclassified as the Jones Creek Conglomerate by Wyche and Griffin, 1998), unconformably overlies these rocks (Inwood, 1998).

The Mount Clifford domain is bound to the east by the Perseverance and Mount George Shear Zones (Fig. 5; Williams et al., 1989), and incorporates the Corktree Well and Sons of Gwalia domains to the southwest (Williams, 1998). A regional-scale stratigraphy has not been determined for this domain due to extensive folding and faulting, but Hill et al. (2001, p. 31) noted that 'the nature of the komatiites is consistent with correlation with the upper greenstone sequence of the Agnew–Wiluna greenstone belt farther north'. Common rock types include ultramafic to basaltic flows and felsic pyroclastic rocks associated with dunitic lenses (Naldrett and Turner, 1977) that probably represent differentiates of either layered flows or subvolcanic intrusions. The southwestern boundary of the Mount Clifford domain varies in nature. In the south the arcuate Sons of Gwalia Shear Zone is an early extensional structure (Williams et al., 1989) that separates the supracrustal rocks from the Raeside Batholith, which is largely composed of granodiorite and monzogranite, but is tonalitic near Leonora (Dudley et al., 1990). In the north a broad shear zone trending north–south, west of the Bannockburn and Slaughter Yard mine sites and east of Wildara Outcamp on WILDARA, separates gneissic granitoid and granitic gneiss from sheared greenstone lithologies. The Robes Well pluton intrudes the supracrustal sequence between Sturt Meadows (on WILBAH) and Mount Ross (on LEONORA).

The geochronology of the Agnew–Wiluna greenstone belt is poorly constrained, particularly within the area covered by this database. Just north of the field area a conventional U–Pb zircon age of 2795 ± 38 Ma for a granophyric differentiate of the Kathleen Valley layered gabbro (Cooper and Dong, 1983) may represent the age of the lower supracrustal succession between the Lawlers Anticline and Yakabindie (Naldrett and Turner, 1977). Also to the north the Jones Creek Conglomerate has a maximum depositional age, based on SHRIMP U–Pb data from zircon populations, of 2667 ± 6 Ma (Nelson, 2000).

Early deformational episodes are locally well preserved in the southern part of the Agnew–Wiluna greenstone belt. Early extension produced low-angle shear zones along belt margins (Williams et al., 1989; Williams, 1998). The arcuate Sons of Gwalia Shear Zone is an extensional deformational (D_{e1}) structure that dips radially away from the Raeside Batholith and contains mineral lineations that plunge down-dip along the shear plane (Williams et al., 1989; Williams, 1998; see **Deformation**). Minor F_1 folds are preserved in gabbro and basalt, and are refolded around the Lawlers Anticline creating an F_2 structure (e.g. Blewett, 2001; see **Deformation**). The Agnew–Wiluna greenstone belt has been metamorphosed largely to greenschist facies, with higher grades prevalent adjacent to granitoid and gneiss contacts (Platt et al., 1978).

Several large gold deposits are present within the Agnew–Wiluna greenstone belt in the database area, including Tower Hill, Son of Gwalia, Harbour Lights, Tarmoola, Agnew, Emu, and Lawlers (see **Economic geology** and the references therein for descriptions and production figures).

Yandal greenstone belt

The Yandal greenstone belt is east of the Agnew–Wiluna greenstone belt (Fig. 4) and is equivalent to the Yandal, Lake Violet, and Millrose greenstone belts as defined by Griffin (1990b). Only the southernmost part of the Yandal greenstone belt, where it converges with the Agnew–Wiluna and Malcolm greenstone belts, is within the area covered by this database. More details on the rest of the belt are provided by Phillips and Anand (2000) and Groenewald et al. (2001).

Rock exposure is minimal in the southern Yandal greenstone belt; only deeply weathered felsic volcanic rocks and rare basalt outcrop amongst extensive laterite cover, and so a stratigraphy has not been determined specifically for this area. The Mount McClure and

Ockerburry Shear Zones bound the 8 km-wide belt of supracrustal rocks to the west and east respectively (Fig. 5). This area is intensely sheared and is also called the Yandal Shear Zone (e.g. Messenger, 2000). Aeromagnetic data suggest intense north–south shearing in the northwestern corner of WEEBO that swings towards the south-southeast near the southern termination of the belt.

Malcolm greenstone belt

The Malcolm greenstone belt (Fig. 4; Griffin, 1990b) largely corresponds to the Keith–Kilkenny Tectonic Zone of Hallberg (1985), and appears to be the northern equivalent of the Kurnalpi domain, and possibly the Gindalbie domain of Groenewald et al. (2000). The belt is bound by the Mount George Shear Zone to the west and the Glenorn Shear Zone to the east (Fig. 5). The Glenorn Shear Zone forms the western edge of the broad Kilkenny Tectonic Zone, and was considered by Williams (1993) to correspond to the area east of the Melita–Emu Shear Zone (a concept not adopted here). The northern extremity of the greenstone belt and the area south of Niagara are intruded by granite. The belt is broadest on MELITA and YERILLA, and is strongly sheared farther southeast.

The Malcolm greenstone belt hosts three significant bimodal and felsic subalkaline volcanic complexes known as the Melita, Teutonic Bore, and Jeedamya Complexes. The Melita Complex is a bimodal package comprising rhyolitic to dacitic lavas and volcaniclastic rocks that are interlayered with pillow basalts and mafic hyaloclastites (Witt, 1994; Brown et al., 2001). Brown et al.'s (2001) definition of the Melita Complex differs from that of previous workers because it includes the interbanded volcanic, volcaniclastic, and intrusive mafic units that Witt (1994) and Hallberg (1985) excluded from the Melita Complex. The felsic rocks in particular are enriched in incompatible elements, more so than other felsic rocks of the Eastern Goldfields Granite–Greenstone Terrane. Morris and Witt (1997) considered the sequence to have resulted from anhydrous melting of tonalite, whereas Brown et al. (2001) considered the sequence to represent partial melting of intermediate arc-type crust. Hallberg (1985) and Witt (1994) inferred a volcanic centre east of Mount Melita.

The Teutonic Bore Complex is strongly deformed and attenuated, but is similar in character to the Melita Complex, comprising andesite and pillow basalt interbedded with thick beds of silicic volcaniclastic rocks and rhyolite lava (Brown et al., 2001). Compositionally similar alkaline intrusive rocks associated with this complex are probably genetically related to the volcanic rocks (Brown et al., 2001).

The Jeedamya Complex is a calc-alkaline intermediate–silicic complex consisting predominantly of rhyolitic to rhyodacitic pyroclastic and volcaniclastic rocks (Witt, 1994). A broad area of laterite separates the Jeedamya and Melita Complexes, so the nature of the contact between them is unclear.

Both the Melita and Jeedamya Complexes have acted as structural buttresses and contain the least deformed rocks of the belt. Other more highly deformed areas, particularly north of Leonora, contain common sedimentary rocks with subordinate silicic volcanic rocks, but exposure is typically poor.

Geochronological constraints on the Malcolm greenstone belt are limited to felsic rocks of the volcanic complexes. Rocks of the Teutonic Bore Complex record a U–Pb zircon age of 2692 ± 4 Ma (Nelson, 1995); felsic rocks near Mount Germatong immediately east of Leonora (MGA 342050E 6807250N) record a similar age (2692 Ma, U–Pb zircon; Pidgeon, 1986) and are probably part of this complex. The felsic volcanic rocks near Mount Germatong gold mine provided an extremely discordant U–Pb zircon age of 2735 ± 10 Ma (Pidgeon and Wilde, 1990), which is older than most other recorded ages for felsic volcanic rocks throughout the Eastern Goldfields Granite–Greenstone Terrane. The same study yielded a date of 2697 ± 3 Ma for felsic volcanic rocks at Pig Well, about 7 km to the northeast. The Melita Complex is younger, recording a U–Pb zircon age of 2683 ± 3 Ma (Brown et al., 2002), which is within error of the U–Pb zircon age of 2681 ± 4 Ma for the Jeedamya Complex to the south (Nelson, 1996).

The Malcolm greenstone belt contains numerous small gold deposits, but no major deposits. The only recently exploited economical base metal deposit of the Eastern Goldfields Granite–Greenstone Terrane is Teutonic Bore in the northern part of the belt.

Pig Well – Yilgangi belt

The Pig Well – Yilgangi belt extends from Gambier Lass Well in the north to Lake Rebecca in the south, and is rarely more than 8 km wide (Fig. 4). It is dominated by fine- to coarse-grained siliciclastic deposits that overlie, or are in faulted contact with, the adjacent Malcolm and Murrin greenstone belts (Hallberg, 1985). This belt incorporates both the Pig Well and Yilgangi Conglomerates, and the northern part is commonly referred to as the 'Pig Well graben' (e.g. Hallberg, 1985). It falls entirely within the broad Kilkenny Tectonic Zone and is locally strongly deformed.

A minimum U–Pb zircon age of 2662 ± 5 Ma is provided by a monzodiorite dyke that intrudes the Yilgangi Conglomerate (Nelson, 1996).

Murrin greenstone belt

The Murrin greenstone belt (Griffin, 1990b) is bound by the Glenorn Shear Zone on the western side of the broad Kilkenny Tectonic Zone, and by the Claypan Shear Zone to the east (Figs 4 and 5). To the north the greenstone belt is intruded by granitoids. To the south the belt may be equivalent to the Mulgabbie domain of Groenewald et al. (2000), but its relationship with that domain is unclear. Several elongate to ovoid granitoids of various sizes intrude the belt.

The Murrin greenstone belt consists of a sequence comprising predominantly mafic to ultramafic volcanic and intrusive rocks, with lesser proportions of andesite, intermediate volcaniclastic rocks, acid volcanic and volcaniclastic rocks, siltstone, and sandstone, which Hallberg (1985) called 'Association 2' (see **Laverton greenstone belt**). Intermediate volcanism is predominantly preserved within the Welcome Well Complex, which is defined as 'a sequence of subalkaline to intermediate volcanic rocks and associated epiclastic rock' (Brown et al., 2001). It is dominated by felsic volcaniclastic rocks with subordinate andesite and basalt, and hyaloclastite, and is intruded by extensive dolerite (Brown et al., 2001). The Welcome Well Complex has been interpreted as the subaqueous proximal to medial facies of an andesitic stratovolcano (Giles and Hallberg, 1982), although subaerial andesitic volcanism and sedimentation have been inferred (Janka and Cas, 2001).

Layered intrusions are common in the Murrin greenstone belt near Mount Kilkenny (e.g. Kilkenny Gabbro) and the Eucalyptus mine. They probably represent subvolcanic sills that commonly grade from olivine-bearing cumulate to leucogabbro. The mafic to ultramafic Murrin Murrin complex, which forms the deepest part of the Kilkenny Syncline, has been recognized as an extensive ponded komatiitic unit in which differentiation led to the formation of substantial olivine orthocumulates (Hill et al., 2001). Extensive laterite development over these ultramafic rocks has formed large supergene nickel–cobalt deposits at Murrin Murrin.

Structurally, large-scale D_2/D_3 folds and D_3 faults control the distribution of rock units (see **Deformation**). Between Welcome Well and Mount Kildare, shallowly plunging D_3 folds trend north-northeasterly and are truncated by north-northwesterly trending D_3 shear zones and bound by reverse faults. Chen et al. (2001) considered such juxtaposition of regional grains to be a function of localized compression during sinistral D_3 transpression in right-stepping restraining jogs. Metamorphic grade throughout the Murrin greenstone belt is variable, but typically low.

No SHRIMP geochronology data are available for the Murrin greenstone belt.

Laverton greenstone belt

The Laverton greenstone belt (Fig. 4) is equivalent to the Margaret and Merolia greenstone belts of Griffin (1990b) and is equivalent to that described by Chen (1999) and Stewart (2001). To the east and north the belt is intruded by granitoids, whereas the western edge of the Celia Tectonic Zone (the Claypan Shear Zone) forms the western margin, incorporating the regional Margaret Anticline (M on Fig. 5). To the north a portion of the Hootanui Shear Zone probably demarcates the boundary with the Duketon greenstone belt, although exposure is poor. To the south the Laverton greenstone belt incorporates the Edjudina, Pinjin, and Linden terranes (Swager, 1997) or domains (Groenewald et al., 2000) of the southern Eastern Goldfields Granite–Greenstone Terrane.

In contrast to adjacent greenstone belts the Laverton greenstone belt contains abundant BIF, which is typically rare in the Eastern Goldfields. Banded iron-formation is common in the central part of the Laverton greenstone belt near Laverton township, becoming more abundant and more iron rich south of the Margaret Anticline and Lake Carey. Banded iron-formation units are hosted by intensely deformed sedimentary sequences of siltstone through to fine sandstone, some of which are possibly of volcaniclastic origin. The Margaret Anticline and eastern areas of the belt are dominated by basalt, komatiitic basalt, dolerite, and gabbro. Siltstone, sandstone, felsic volcanic and volcaniclastic rocks, and ultramafic rocks are locally significant.

Hallberg (1985) described two distinct stratigraphic associations for the greenstones that comprise the Laverton greenstone belt, but these have not been dated or adopted by subsequent mapping geologists (e.g. Rattenbury et al., 1996; Williams et al., 1997; Stewart, 2001). Hallberg's (1985) scheme has not been used in the East Yilgarn Geoscience Database, but is worthy of note here. The lowermost sequence, Association 1, is exposed in the Margaret Anticline only; the upper Association 2 is exposed elsewhere. Association 1 is characterized by several BIF horizons associated with ultramafic rocks (usually komatiite) and komatiitic basalt within a sequence dominated by basalt and topped by conglomerate, siltstone, and shale. The lowermost part of the stratigraphy is preserved at Mount Windarra and South Windarra, where basal BIF is overlain by ultramafic schist and basalt. Association 2 lies conformably on Association 1 and is compositionally similar to it, except that BIF and komatiite are rare.

The Laverton greenstone belt hosts a number of unusual intrusions. The extensive Diorite Hill layered intrusive complex (12 × 8 km) east of Laverton is typically noritic in composition (Stewart, 2001). It is exposed at a few localities, but is commonly covered by regolith. Foliated porphyritic syenite near Mount McKenna, also east of Laverton, is the largest syenitic intrusive of the Eastern Goldfields Granite–Greenstone Terrane (13 × 2 km) and contains a moderately easterly dipping foliation. The Mount Weld Carbonatite (4 km diameter) is not exposed, but is in the subsurface south of Laverton. Deeply weathered tonalite is exposed 12 km north of Laverton.

In the north the Laverton greenstone belt is structurally dominated by the Margaret Anticline, which is a reclined, eastward-plunging regional-scale D_2 fold (Stewart, 2001; see **Deformation**). A number of D_1 folds are refolded by this anticline. A D_3 restraining jog between the Celia Shear Zone and the Hootanui Shear was proposed by Chen (1998) and Chen et al. (2001) to explain complex fault, fold, and rock unit orientation geometries for that region (see **Deformation**). Amphibolite-grade metamorphism is present adjacent to the granite contact on the eastern side of the belt. Elsewhere, metamorphic grades are commonly low, with prehnite–pumpellyite-facies metamorphism southeast of Laverton.

No SHRIMP geochronology data are available for the Laverton greenstone belt.

Duketon greenstone belt

Only the southern part of the Duketon greenstone belt (Griffin, 1990b) is within the study area (on MOUNT VARDEN). In this area the belt is bound to the west by the Hootanui Shear and is in intrusive contact with granitoids to the east (Figs 4 and 5).

In the western part of the belt in the study area, deformed mafic and ultramafic rocks are interbanded with minor felsic rocks, and are overlain predominantly by siltstone interlayered with minor conglomerate, sandstone, and chert. Chert bands define folding and are exposed as prominent ridges, but younging indicators are rare. The eastern part of the belt is dominated by basalt to dolerite with less common ultramafic rocks. Extensive laterite development has obscured much of the Archaean geology. Poor exposure and structural complexity have precluded establishment of a stratigraphy for the Duketon greenstone belt. The metamorphic grade varies from lower greenschist to lower amphibolite facies on MOUNT VARDEN.

The portion of the Duketon greenstone belt on MOUNT VARDEN is strongly sheared. Chen et al. (2001) proposed a D_3 restraining jog between the Lulu and Hootanui Shears to explain structural complexity (see **Deformation**). Only the southern part of that restraining jog is within the study area. The degree of shearing has obscured recognition of earlier deformation fabrics.

No SHRIMP geochronology data are available for the Duketon greenstone belt.

Cosmo Newbery greenstone belt

Only the southern portion of the Cosmo Newbery greenstone belt (Griffin, 1990b) is within the study area (Fig. 4), and the following relates to that portion only. The belt is bound to the west by a shear and to the east by porphyritic monzogranite. Basalt with subordinate dolerite constitutes the bulk of the belt, with tremolitic schist on the western margin. Several gabbroic dykes of inferred Proterozoic age are exposed in fresh outcrops. Basalt units dip uniformly steeply eastward. Pervasive north-northwesterly striking subvertical foliation throughout the supracrustal sequence is subparallel to feldspar phenocryst alignment in the porphyritic monzogranite to the east. Bedding and foliation intersections commonly plunge shallowly to moderately southward.

Archaean geology

This section contains brief descriptions of the major rock types of the Leonora–Laverton region of the Eastern Goldfields Granite–Greenstone Terrane. A description of each of the rock types present is beyond the scope of this volume, but all rock code descriptions used are listed in Appendix 1. A major hindrance to the compilation of this section has been the lack of Explanatory Notes for 1:100 000-scale maps throughout the area covered. Explanatory Notes have been published for MELITA (Witt, 1994) and LEONORA (Williams, 1998), and the notes for the 1:50 000 mapping of Hallberg (1985) east of Leonora have been of use. Explanatory Notes for each of the 1:250 000 sheets (EDJUDINA — Williams et al., 1976 (1st edition); Chen, 1999 (2nd edition); LAVERTON — Gower, 1976 (1st edition); Stewart, 2001 (2nd edition); LEONORA — Thom and Barnes, 1977; and MENZIES — Kriewaldt, 1970) are useful, but do not provide the detail required. Although all rock types described below have been subjected to metamorphism under lower greenschist- to upper amphibolite-facies conditions, igneous or sedimentary names and terminology are used where protolith characteristics are recognized.

Rock types

Ultramafic rocks

Ultramafic rocks form a small, but widespread and significant, proportion of the greenstone belts in the Eastern Goldfields Granite–Greenstone Terrane and several publications provide comprehensive descriptions of these rock types, such as Hill et al. (1990, 1995, 2001). In the Leonora–Laverton area, where about 6.5% of the aerial extent of Archaean supracrustal rocks is ultramafic, the most extensive outcrops are on WILDARA, WEEBO, BALLARD, MINERIE, LEONORA, MELITA, and MOUNT VARDEN. These include undivided ultramafic rock (*Au*), komatiite (*Auk*), peridotite (*Aup*), tremolite schist (*Aur*), serpentinite (*Aus*), talc–chlorite schist (*Aut*), and pyroxenite (*Aux*). Peridotite and komatiite are respectively the most and least abundant ultramafic rock types in outcrop; however, Hill et al. (1995, 2001) established a close petrogenetic linkage between these rock types. The ultramafic rocks commonly form concordant lenses or sheets in the greenstone sequences, and contain up to 10% magnetite. The magnetite content is responsible for the strong anomalies on aeromagnetic images, and thus aids in the interpretation of the extent of the supracrustal sequences concealed beneath regolith.

Deeply weathered, highly altered, and intensely deformed ultramafic rocks are classified as 'undivided' (*Au*) because protoliths cannot be determined with certainty. A secondary silica 'caprock' (*Rzu*) is associated with these rocks at some localities and elsewhere they are variably ferruginized.

In the Murrin and Laverton greenstone belts, unassigned ultramafic rocks (*Au*) outcrop near Gibson Well in the north, in the central area 5 km north of Laverton Downs Homestead (MGA 444700E 6851900N), near Minerie Hill (MGA 379500E 6825500N) in the southwest, and on the shores of Lake Carey in the south.

Unassigned ultramafic rocks are widespread in the Agnew–Wiluna, Malcolm, and Mount Ida greenstone belts. On northeastern MELITA there are several square kilometres of ultramafic rocks that are too altered and poorly exposed for classification, but in places have characteristics typical of the layered komatiitic units. For example, siliceous caprock with relict orthocumulate texture west of Snowy Well (MGA 347550E 6778260N) overlies unsilicified ultramafic rocks in which local primary harrisitic textures are represented by metamorphic serpentine, tremolite, and magnetite pseudomorphs after skeletal olivine. Unassigned ultramafic rocks are poorly exposed on LEONORA, except for the hills east of Tarmoola (MGA 318700E 6821330N) that are composed of foliated serpentinized and carbonated ultramafic rocks with no relict primary igneous structures. These ultramafic rocks overlie less deformed sedimentary rocks, with S–C fabrics that suggest emplacement of the ultramafic rocks as a thrust slice over the felsic rocks (Williams, 1998). On BALLARD minor areas of unassigned ultramafic rock associated with peridotites represent part of the Kurrajong komatiitic assemblage described by Hill et al. (1990). Extensive areas of unassigned ultramafic rocks in the Mount Clifford and Marshall Pool areas have komatiitic protoliths similar to those identified in the Kurrajong assemblage (Donaldson et al., 1986).

Komatiite (*Auk*) is the ultramafic volcanic rock distinguished by olivine spinifex texture. The dominant mineral assemblages are now serpentine–chlorite in areas with low metamorphic grade, or tremolite–chlorite in areas with higher metamorphic grade. Talc and magnetite are common minor or accessory minerals. Primary olivine is very rare and primary chromite is in low concentrations, but widespread. Although olivine is almost universally serpentinized, it is commonly pseudomorphed and this allows recognition of spinifex texture even in highly altered rocks. Replicas of large (commonly 50–150 mm, but up to 700 mm, across) platy skeletal olivine crystals are arranged most commonly as book-like stacks, but are also dispersed in random orientations in the uppermost part of a lava flow. In areas of low strain, relict textures in the lower part of a flow allow recognition of original olivine-cumulate rocks. Thus, original komatiitic lava flows have been identified despite the ubiquitous metamorphism and alteration, with primary flow thickness ranging from less than a metre to more than several hundred metres. Fractionated successions with a total thickness of up to 800 m in lobes of the komatiite flows probably reflect enormous outpouring of lava leading to the development of large flow fields (Hill et al., 2001). Lateral extents of about 100 km are recognized for some flows, with major lateral variations attributed to different sub-environments within the voluminous and regionally extensive eruptions (Hill et al., 1990). These flow fields are represented in the database by the extensive peridotite outcrops described below.

Outcrops of komatiite (*Auk*) in the southwestern part of BALLARD are associated with other ultramafic rock types such as serpentinite, peridotite, tremolite schist and talc–chlorite schist. Hill et al. (1990) attributed these rocks to the Kurrajong Complex, which is a differentiated komatiite unit. MOUNT VARDEN, LAVERTON, and MOUNT CELIA contain minor outcrops of komatiite.

The most extensive outcrops of ultramafic rocks are peridotite (*Aup*), typically representing rocks in which assemblages of serpentine, amphibole, chlorite or talc preserve textures that reveal the original mineralogical and cumulate characteristics. The largest of these are in the Mount Clifford – Marshall Pool area, about 50 km north of Leonora in the southernmost extent of the Agnew–Wiluna belt, where extensive ultramafic complexes are overlain by spinifex-textured flows. Excellent examples of diagnostic komatiitic textures are preserved in the Marshall Pool area (MGA 302860E 6857800N) in outcrops too small to record at the scale of mapping. Similarly, several exposures of spinifex-textured rock indicate that the extensive surrounding peridotites represent differentiated komatiitic rocks in the Kilkenny Syncline on MINERIE.

Other peridotite exposures are on western BALLARD, northwestern LEONORA, northwestern WILDARA, eastern MELITA, and southeastern MINERIE. In all instances the peridotite units are at or near the base of differentiated bodies. Relict textures represented by fine-grained pseudomorphic aggregates of serpentine and magnetite, with minor but variable talc, tremolite, and carbonate components, reveal cumulate protolith characteristics.

Talc–chlorite schist (*Aut*) is commonly fine grained and strongly schistose. Talc is dominant, chlorite varies from 10 to 40 vol. %, magnetite is a common accessory mineral, carbonate reaches up to 20%, and tremolite and antigorite are present in some samples. The most extensive outcrops of talc–chlorite schist are on WILDARA, about 3 km west of Anderson Bore (MGA 299170E 6880760N) where these rocks outcrop in a belt that is 12 km long and up to 0.5 km wide. There are numerous small outcrops in the Mount Clifford (MGA 303740E 6851460N) and Bannockburn (MGA 293790E 6550150N) areas, near Mount Newman (MGA 312990E 6845630N) on the boundary between LEONORA and WEEBO, in the hills east of Tarmoola (MGA 318700E 6821330N), east of Mount Ross (MGA 309420E 6823290N), and at mine sites immediately northwest and southwest of the Leonora town site. In the Duketon belt on MOUNT VARDEN, talc–chlorite schist is exposed as several elongate strips up to 500 m wide and several kilometres long. Further south on LAVERTON two similar northwest-trending units, 5–6 km in length and up to 300 m wide, are exposed west of Windarra Well (MGA 425500E 6845500N) and at Mount Phoenix (MGA 408300E 6818000N).

Tremolite schist (*Aur*) is fine to medium grained, and composed mainly of tremolite or actinolite needles or blades up to 10 mm long. The microstructural fabric varies from completely random orientation of the acicular tremolite, to a planar arrangement defining the schistosity, to a mineral lineation. Chlorite and talc are the other main minerals, with carbonate at some localities. This rock type forms two elongate bodies on BURTVILLE, up to about 1 km thick, within more extensive basalt at Ironstone Point (MGA 487500E 6808750N). Smaller bodies are exposed at Mallock Well on BURTVILLE (MGA 462900E 6802000N) and further northeast near Two Mile Well on MCMILLAN (MGA 490200E 6899100N; Fig. 2). On northwestern MCMILLAN a narrow unit of tremolite schist is exposed along the contact between layered tholeiitic basalts and granitoids, possibly representing an ultramafic basal portion of a differentiated flow. On northwestern BALLARD several outcrops of medium- to coarse-grained tremolite schist, containing minor talc, chlorite, and carbonate minerals, may be metamorphosed pyroxenite or high-Mg basalt.

Serpentinite (*Aus*) is fine grained and composed of serpentine (20–90%), actinolite, relict olivine, chlorite, epidote, plagioclase, hornblende, magnesite, opaque minerals, and chalcedony. It is even grained to weakly blastoporphyritic, massive to foliated, and in places grades into talc schist or chlorite–magnetite schist. The rock forms elongate bodies several kilometres long, and is exposed on LAVERTON at Jubilee Hill and east of Laverton Downs. The only other extensive serpentinite units are in the Snakehill Syncline and Kurrajong Complex on BALLARD.

Metapyroxenite (*Aux*) is a rock consisting predominantly of tremolite or serpentine pseudomorphs after clinopyroxene. Deformed and more strongly recrystallized samples contain moderate to large amounts of chlorite and talc. This rock forms the basal parts of layered mafic sills on MELITA, and is exposed on the eastern limb of the Lawlers Anticline on WILDARA. There are also several outcrops of pyroxenite on LAVERTON.

Mafic volcanic rocks

Mafic volcanic rocks make up about 50% of the exposed greenstone sequences, and contain both tholeiitic and komatiitic (high-Mg) types. Characteristic textures are not always preserved in the rocks. For example, massive, fine- to medium-grained metabasites (*Ab*) are mainly tholeiitic basalts, but may include intercalations of komatiitic basalt. Pillow structures are present at several localities, but are not widely recognized, probably because the rocks are too poorly exposed. The strong deformation in some areas also masks such structures.

High-Mg or komatiitic basalt (*Abm*), which amounts to about 2% of the exposed Archaean supracrustal sequences and about 5% of the basaltic rocks, is distinguished by relict pyroxene spinifex, variolitic textures, and its chemical composition (i.e., 10–18 wt % anhydrous MgO). Grey to pale-green tremolite–actinolite is the main constituent mineral, with up to about 30% plagioclase, accessory amounts of opaque oxides (typically magnetite), and secondary chlorite. The common relict pyroxene-spinifex texture consists of tremolite–actinolite pseudomorphs of acicular clinopyroxene ranging in length from a few millimetres up to several centimetres. Clusters of pseudomorphs can assume dendritic or fan-like forms. Komatiitic basalt flows vary laterally in physical characteristics, with spinifex textures completely absent from substantial portions in some cases. Although pillow structures are present, these are rarely well exposed in surface outcrop and are probably obscured by the deformation in many areas.

On northwestern WILDARA relatively unaltered komatiitic basalt is exposed in the eastern limb of the Lawlers Anticline. The rock is characterized by coarse pyroxene spinifex, and pillow structures that, although poorly exposed, indicate northeasterly younging of steeply northeasterly dipping flows. On southwestern WILDARA komatiitic basalt outcrops northwest of Marshall Well, about 3 km south of Kents Bore at the northwestern extremity of the Marshall Pool Syncline, and in the Bannockburn gold mine workings.

On LEONORA komatiitic basalts outcrop east of Mount Stirling (MGA 311380E 6833290N), where individual flows are identified by the position of pillowed flow tops. The flows range from 100 to 300 m in thickness, and vary in grain size from gabbroic in patches to glassy at the flow margins. The bulk of the flow is medium grained and equigranular. On southeastern BALLARD komatiitic basalt forms the upper portion of the ultramafic sequence described by Hill et al. (1995) in the Kurrajong Anticline and the Snake Hill Syncline to the south. West of Paradise Well (MGA 343540E 6787400N) on MELITA, komatiitic basalts are exposed as strongly foliated, fine- to coarse-grained, tremolite-rich mafic schist in which flattened varioles are obvious on foliation surfaces, and spinifex is locally evident. Komatiitic basalt is associated with peridotite in extensive areas around the Kilkenny Syncline in the Murrin greenstone belt. In the Laverton greenstone belt komatiitic basalt is exposed 5 km south-southeast of Mount Varden (MGA 440650E 6884050N) and east of Mount Margaret Mission (MGA 420300E 6814250N).

There are extensive outcrops of tholeiitic basalt (*Abv*) in all greenstone areas and these amount to about 70% of all mafic volcanic rocks. This rock type is typically equigranular, very fine to fine grained (but locally medium or coarse grained), and composed of blue-green actinolite, plagioclase, and opaque minerals (ilmenite and magnetite). Locally, other minerals include green hornblende instead of actinolite, epidote after plagioclase, hematite, quartz, carbonate, and titanite. These are typically massive rocks, but may be amygdaloidal (*Abvy*) or porphyritic (*Abvp*). Pillow structures and flow top breccias are rarely exposed or poorly preserved. In areas where the texture of the basaltic rocks ranges from aphyric to fine-grained subophitic, the term basalt/dolerite (*Abd*) has been used. These areas probably represent crystallization of thicker, possibly ponded, flows or numerous subvolcanic intrusions. These rocks make up extensive parts of the greenstones on MOUNT ALEXANDER, southeastern MINERIE, and MCMILLAN.

Coarsely porphyritic basalt (*Abvp*) has plagioclase phenocrysts ranging from 2 to 30 mm in length, locally in glomeroporphyritic clusters, set in a fine- to medium-grained hornblende and plagioclase matrix. Although an uncommon rock type, the porphyritic basalt forms stratigraphic marker units that can be recognized in areas of otherwise indeterminate bedding. For example, the 5 km-long unit east of Mount George (LEONORA, MGA 335000E 6810700N) contains the only recognized bedding in a 5 km^2 area of basalt/dolerite (*Abd*). The porphyritic basalt outcrops in several places on YERILLA and LAKE CAREY.

Amygdaloidal basalt (*Abvy*) is a distinctly vesicular rock that can be distinguished from very fine grained, non-vesicular tholeiitic basalts. The most extensive outcrops of amygdaloidal basalt are in the Mount Clifford greenstone belt on WEEBO, in the Malcolm greenstone belt on YERILLA, in the Murrin greenstone belt near Cement Tank Well (MGA 376700E 6803450N) on MINERIE, and in the Laverton greenstone belt 4 km north of Morgans (MGA 409000E 6817000N), and at Mallock Well (MGA 462900E 6802000N) and Golden Ring Well (MGA 458050E 6800300N) in the southeast. The amygdaloidal basalt around Cement Tank Well is underlain, overlain, and interbedded with thick units of sandstone, forming a steeply easterly dipping, upright sequence that is about 3300 m thick.

Where mafic rocks are completely recrystallized and no vestiges of primary textures remain, they are classified as amphibolite (*Aba*). Prismatic amphibole and fine, polygonal, granoblastic plagioclase that shows little or no twinning are the main constituents, with local clinopyroxene. Compositional variations are reflected by different proportions of plagioclase relative to amphibole. In cases where metamorphic foliation is very well developed and the nature of the protolith is obscured by advanced recrystallization and alteration, these rocks are classified as mafic schists (*Ala*).

Felsic extrusive rocks

Felsic rocks of probable volcanic and volcaniclastic origin amount to about 15% of the greenstone belts. Where protolith classification is hindered by deep weathering or advanced metamorphism, these are simply called felsic rocks (*Af*) or schistose felsic rocks (*Afs*). The felsic rocks (*Af*) typically consist of fine-grained, equigranular quartz, feldspar, and biotite, and are locally porphyritic with phenocrysts of typically subhedral quartz crystals 2–6 mm across or subhedral feldspar up to 8 mm in length, and rare biotite and hornblende. The schistose rocks (*Afs*) are common in major fault or shear zones, and contain a schistosity typically defined by white mica. In saprock variants, quartz grains are commonly hosted by a mass of clay minerals that may or may not preserve a foliation, but remnant quartz phenocrysts locally display embayments that are indicative of their volcanogenic origin.

Felsic volcanic and volcaniclastic rocks (*Afv*) have been recognized by the clearly extrusive textures, such as flow banding, embayed quartz or feldspar phenocrysts (or both), fragmental clastic deposits, and finely layered tuffites. These rocks are most common on MINERIE, MELITA, YERILLA, and LAKE CAREY.

The distribution of felsic pyroclastic rocks in the database area is relatively restricted, particularly as mappable units. Tuffaceous rock (*Aft*) is finely banded and fine to medium grained, and contains quartz and feldspar phenocrysts. It is almost exclusively restricted to MINERIE and BURTVILLE, in units up to 500 m thick, with a few minor exposures on WILDARA, WEEBO, and LAKE CAREY. Ignimbrite (*Aftn*) is exposed on LAKE CAREY and YERILLA, where it consists of quartz and feldspar crystals and lithic fragments encased in a banded siliceous matrix that retains textural evidence of welding and differential compaction around phenocrysts and clasts. Elongate hollows and some fine-grained quartzofeldspathic laths in these rocks are interpreted to be after fiamme, which represent pumice fragments compressed subparallel to primary layering during accumulation of the ignimbrite.

Intermediate volcanic rocks only locally make up a significant proportion of the greenstone sequences. Intermediate volcanic rocks (*Afiv*) are fine grained, quartzofeldspathic, and have either volcaniclastic or flow textures. The criteria commonly used for recognition of these rocks are a fine grain size and a felsic composition with plagioclase, but no quartz phenocrysts. A coarsely porphyritic variant is also exposed on YERILLA near Salt Bush Creek (MGA 380000E 6754000N), in the Mount Ida greenstones on BALLARD, and in the Laverton greenstone belt on MOUNT VARDEN. The foliated equivalents (*Afivf*) also outcrop on MOUNT VARDEN.

Andesite (*Afid*) is a dominant rock type in three volcanic centres. Andesites in the Welcome Well Complex, in the Murrin greenstone belt between Kauri Well (MGA 377250E 6823620N) and Corkscrew Well (MGA 377150E 6814900N) on MINERIE, include variable assemblages of massive to pillowed to auto-brecciated flows, agglomerates or coarse mass-flow deposits, epiclastic sandstone and conglomerate, and mafic to intermediate subvolcanic sill complexes. The Ida Hill Complex around Lawson Well (MGA 448150E 6825300N) on LAVERTON and the Bore Well Complex on LAKE CAREY also have significant proportions of andesite. The Lawson Well locality includes porphyritic and amygdaloidal andesite, together with agglomerates containing andesitic clasts up to 0.5 m long.

Hornblende(–plagioclase)-phyric intermediate lava (*Afivh*) and its foliated variant (*Afivf*) outcrop in the Murrin greenstone belt 4–5 km west of Minerie Hill (MGA 397500E 6825500N) and in the Ida Hill Complex of the Laverton greenstone belt around Lawson Well (MGA 448150E 6825300N).

Porphyritic felsic rocks are widespread in the felsic volcanic successions. These are typically feldspar–quartz porphyritic (*Afp*) or quartz(–feldspar) porphyritic (*Afpq*), with a fine-grained dacitic to rhyolitic groundmass. Plagioclase-phyric andesite (*Afip*) is also recognized. These lithologies are typically volcanic to subvolcanic in setting and association, and are most common on MELITA and LEONORA.

Basaltic andesite (*Abi*) is a pale-green to grey-green, fine-grained, massive to pillowed rock, which is commonly exposed as rounded cobbles and boulders, with well-preserved pillows at several localities. Amygdales are common in most exposures. Larger gas pipes and cavities locally coalesce into irregular quartz-cemented breccia zones that may represent flow tops. Basaltic andesite consists of plagioclase, tremolite–actinolite, rare chlorite, and accessory titanite or leucoxene in a fine-grained groundmass containing abundant plagioclase microlites. Basaltic andesite outcrops extensively on northeastern MELITA.

Clastic sedimentary rocks

All greenstone belts in the study area contain clastic sedimentary rocks but they are more common in the Illaara, Murrin, and Duketon greenstone belts. Sedimentary structures are difficult to recognize, particularly in the fine- to medium-grained rocks, but younging and palaeocurrent indicators can be identified with persistence.

Undivided sedimentary rock (*As*) is either poorly exposed, deeply weathered or comprises a sedimentary rock sequence that cannot be subdivided at 1:100 000 scale. Shale and slate (*Ash*) are very common and may be used locally as marker units. These rock types are common as interflow sedimentary units in volcanogenic sequences, where shale units have taken up strain so that the cleavage is either parallel or subparallel to compositional layering.

Siltstone through to fine sandstone (*Ass*) predominates in the Duketon and Laverton greenstone belts. Sandstone (*Ast*) is more common in the Murrin greenstone belt and in the Pig Well – Yilgangi belt, where it is associated with conglomerate (*Asc*). Volcaniclastic conglomerate containing andesitic clasts (*Ascfi*) is restricted to the Welcome Well volcanic complex in the Murrin greenstone belt. Conglomerate containing clasts of quartz, quartzite, and chert (*Ascq*) is common in the Illaara greenstone belt where it overlies and is interbedded with quartzite. Quartzite (*Asq*) is present in the Southern Cross Granite–Greenstone Terrane as a prominent strike-ridge along the eastern side of the Illaara greenstone belt and as a small exposure in the western part of the Mount Ida greenstone belt. Several very minor exposures have been recorded in the Eastern Goldfields Granite–Greenstone Terrane, but their validity has not been ascertained here.

Chemical sedimentary rocks

Of the chemical sedimentary rocks, chert (*Ac*) predominates in the Eastern Goldfields Granite–Greenstone Terrane whereas BIF (*Aci*) predominates in the Southern Cross Granite–Greenstone Terrane. Banded iron-formation forms a significant proportion of the rock exposure in the Illaara and the western Mount Ida greenstone belts. Both the Murrin and Laverton greenstone belts contain a higher proportion of BIF in the north, whereas to the south virtually all chemical sedimentary rocks are chert. Chert rather than BIF is common in the Duketon greenstone belt, where it is typically associated with siltstone and sandstone (*Ass*). Chert and BIF are not common rock types in the Malcolm, Agnew–Wiluna, and Yandal greenstone belts within the database area.

Topographically, chert and BIF units commonly form prominent strike-ridges. They typically define the best available markers for remotely sensed correlation of outcrops or delineation of structures, particularly through use of aerial photography or magnetic imagery.

Mafic intrusive rocks

Mafic intrusive rocks are common throughout Archaean supracrustal sequences of the Eastern Goldfields Granite–Greenstone Terrane and constitute about 12% of all greenstone belts. Although metamorphic amphibole has commonly replaced original pyroxene, it is typically pseudomorphic and primary textures are recognizable, allowing the use of igneous terminology in most instances.

Dolerite or microgabbro (*Aod*) locally forms cross-cutting intrusions, but commonly forms concordant layers in basalt. It is unclear whether these rocks represent sills or coarser grained portions of thick lava flows, but both modes of origin are likely. In moderately deformed sequences basalt tends to preferentially absorb strain so that only a weak foliation is developed in doleritic layers. Intersertal to ophitic textures are commonly preserved in weakly deformed specimens despite amphibole and chlorite pseudomorphism. High-magnesium dolerite (*Aodm*), recognized by the pyroxene spinifex texture, is a derivative of the komatiitic basalts, probably as intra-volcanic intrusions.

Tabular bodies of gabbro (*Aog*) are common as concordant units within all the supracrustal packages of the study area. Most units were probably emplaced as sills, although weathering and poor exposure typically obscure their relationship with the country rocks. Gabbro is typically interlayered with either dolerite and basalt or with gabbronorites and ultramafic rock. Gabbro variants include equigranular gabbro (*Aoge*), coarse-grained gabbro (*Aogc*), olivine gabbro (*Aogv*), leucogabbro (*Aogl*), porphyritic gabbro (*Aogp*), and quartz-bearing gabbro (*Aogq*).

Gabbronorite and norite (*Aon*) are only exposed on MELITA and BURTVILLE. They typically have mesocumulate to adcumulate textures. Tabular to lath-shaped plagioclase with weak to moderate compositional zoning is the dominant mineral. Hypersthene is predominantly a cumulus phase (but less commonly an intercumulus mineral), and augite, also a cumulus phase in some samples, is more commonly oikocrystic. At Diorite Hill on BURTVILLE these rocks probably represent a portion of a large, poorly exposed, layered mafic intrusion.

Compositional and cumulus layering indicative of differentiation is evident in many gabbroic intrusions. Dolerite and cumulate-textured gabbronorite and gabbroic anorthosite, mainly in the Niagara mining area on MELITA, were grouped as the 'Niagara Layered Complex' by Witt (1994), who recognized similarities to the Carr Boyd Rocks Complex farther south. This definition has not been used here because the distribution of sills and dykes attributed to the complex was not shown on MELITA, and the sills on YERILLA included in the complex are not distinctive in the field. Witt (1994) suggested that the presence of anorthositic and quartz–magnetite-enriched gabbros was evidence of an extensive layered intrusion, and recorded the sills as up to about 400 m in thickness. Ultramafic cumulates are only locally recognizable in these sills.

Granitoid rock types

Granitoids are the dominant rock type in the Yilgarn Craton, but are commonly poorly exposed or strongly weathered. Most outcrops in the central Eastern Goldfields and central-eastern Southern Cross Granite–Greenstone Terranes are strongly degraded, either in breakaways where variably kaolinized and silicified granitoid is exposed below silcrete duricrust, or as variably weathered remnants in areas of quartzofeldspathic sand. Less commonly, relatively fresh outcrops are exposed as isolated whalebacks, pavements, and tors.

Champion and Sheraton (1997) and Champion (1997) argued that it is not possible to classify granitoids on the basis of age relative to deformational events in the poorly exposed Eastern Goldfields Granite–Greenstone Terrane, although some magmatism was synchronous with felsic volcanism in the greenstone belts and was pretectonic. On the basis of detailed petrographic and geochemical studies, Champion and Sheraton (1997) subdivided the granitoids in the north Eastern Goldfields Granite–Greenstone Terrane into five groups: high-Ca (>60% of total granites), low-Ca (>20–25%), mafic (<5–10%), high-HFSE (high field-strength element; <5–10%), and syenitic groups (<5%). Although this scheme is probably suitable for future work, it could not be applied in the present collation because of the lack of widespread geochemical information.

Large areas of granitoid outcrop are too weathered to allow classification, apart from the recognition of common granitic characteristics (*Ag*). Where grain size is consistent over an extended area, coarse- (*Agc*), medium- (*Agem*), and fine-grained (*Aga*) varieties are distinguished. Weathered exposures of strongly foliated granite (*Agf*) locally contain abundant mafic enclaves (*Agb*). Where degradation is more severe, residual granitoid regolith may be classified as deeply leached granitic laterite (Rgp_g) or silcrete with kaolinite after granitoids (Rzp_g; see below).

Monzogranite (*Agm*) is the most common identifiable granitoid rock type in the Yilgarn Craton and in the database area. It is commonly leucocratic (less than 10 modal percent mafic mineralogy) and varies locally from massive to foliated (*Agmf*) or porphyritic (*Agmp*). Identification as coarse- (*Agmc*), medium- (*Agmm*), and fine-grained (*Agma*) monzogranite indicates identifiably consistent grain size over an extended area.

The Bulla Rocks monzogranite (*Agbu*) intrudes the Murrin greenstone belt between Mount Kildare (MGA 384600E 6774750N) and the Yundamindera mining centre (MGA 403500E 6779300N). It is a porphyritic biotite(–hornblende) monzogranite that is foliated about its margins and contains mafic xenoliths (Chen, 1999). The Galah monzogranite (*Aggl*) near Jeedamya Homestead (MGA 332500E 6746000N) differs from most monzogranites of the region in that it has two primary micas (biotite and muscovite), secondary carbonate, epidote, fluorite, common internal pegmatitic segregations, and a halo of pegmatite dykes around its margin (Witt, 1994). The Jungle monzogranite (*Agju*) is an elongate biotite monzogranite that intruded along a major north-northwesterly trending fault (Chen, 1999). The crystallization history of monzogranite within the database area is not constrained by publicly available geochronology data, but a synopsis of recent age constraints in the northern and southern Eastern Goldfields Granite–Greenstone Terrane was provided by Groenewald et al. (2000, 2001).

Strongly foliated to gneissic granitoid (*Agn*) is concentrated in regions dominated by granitoids to the west of the Agnew–Wiluna greenstone belt and to the east of the Laverton and Duketon greenstone belts, with lesser amounts in granitoids to the northwest of the Laverton greenstone belt. Compositional banding, rotated feldspar porphyroblasts, and mineral elongation lineations are common features of this rock type. Attenuated enclaves of metamorphosed mafic rock are locally common. This rock unit is transitional between foliated granitoid (*Agf*, *Agmf*) and granitoid gneiss (*Ang*). The large number of authors for the original maps, combined with the problem of checking all outcrops being beyond the scope of this compilation, means that some overlap in rock type definition is to be expected.

The Hick Well pluton, within the Raeside Batholith west of Leonora (Williams, 1998), contains a substantial proportion of granodiorite (*Agg*). Granodiorite predominates over monzogranite between Metzke Bore (MGA 312700E 6802700N) and White City Well (MGA 312700E 6802700N) and the intensity of deformation varies from weak to moderately strong. Monzogranite tends to predominate south of White City Well. A large pluton of granodiorite (with minor tonalite and diorite), centred on Yundamindra Homestead (MGA 412500E 6764000N), forms prominent hills with whalebacks and tors, and is probably related to several smaller intrusions southward toward Larkin Outcamp (MGA 421050E 6849500N).

Tonalite (*Agt*) intrudes greenstone lithologies at Linden (MGA 446350E 6756950N) and west of Gardiner Well (MGA 407650E 6774000N), forms several elongate intrusions north of Mount Weld Homestead (MGA 445950E 6820200N), and intrudes granitoids north of Lancefield (MGA 440300E 6845200N). Tonalite and more voluminous porphyritic tonalite (*Agtp*) constitute the Lawlers Tonalite that forms the cores of the Lawlers Anticline and has an intrusive contact with the Agnew–Wiluna greenstone belt. On the basis of detailed field observations, Platt et al. (1978) suggested that the Lawlers Tonalite intruded the Agnew–Wiluna greenstone belt as a tabular body before the first deformation event in the area. Tonalite from Outcamp Bore just south of the database area has a U–Pb zircon age of 2710 ± 6 Ma (Nelson, 1997a), which suggests that the first deformation event was c. 2710 Ma or younger.

Diorite (*Agd*) intrusions are volumetrically minor. A series of intrusions are centred about an area west of Wilsons Patch (MGA 317900E 6869800N), 10 km north of Teutonic Bore mine. Minor diorite intrudes monzogranite between the Digger and Woolshed Wells (MGA 365750E 6869800N).

Syenogranite (*Agy*) constitutes most of the granitoids exposed on WEEBO. Elsewhere, syenogranite is uncommon, although there is a cluster of small intrusions near Kookynie. The Carpet Snake Syenogranite (*Agcs*), which is 3 to 8 km north of Jeedamya Homestead (MGA 332500E 6746000N), is similar to the Galah Monzogranite (*Aggl*) in that it contains two primary micas, secondary carbonate, epidote, fluorite, internal pegmatite segregations, and pegmatite dyke concentrations intruding alternating granite and greenstone lithologies along its margin (Witt, 1994).

A large syenite (*Ags*) intrusion in the Mount McKenna area east of Laverton (MGA 455200E 6836800N) commonly displays a moderately east-northeasterly dipping foliation (*Agsf*) defined by the alignment of orthoclase phenocrysts, and contains large enclaves of amphibolite. Most syenite intrusions are small and scattered throughout the region, including the Mount Margaret area. The McAuliffe Well Syenite (*Agmw*; MGA 396200E 6737200N) varies to quartz syenite in composition, and has a U–Pb zircon age of 2651 ± 5 Ma (Nelson, 1997a). The syenite intrudes a bimodal sequence of volcanic rocks with a U–Pb zircon age of 2696 ± 6 Ma (Nelson, 1998).

Dykes and veins

Numerous dykes and veins crosscut the lithologies of the central Eastern Goldfields and central-eastern Southern Cross Granite–Greenstone Terranes. The most common varieties are quartz veins and pods (*q*), aplite (*a*), granite (*g*), and pegmatite (*p*). Lamprophyre dykes (*l*) are clustered on southern MINERIE, but are rare elsewhere. Ages for these rocks are uncertain, but field relations commonly suggest an Archaean age.

Metamorphic rocks

Although all Archaean rock types in the area have undergone at least low-grade metamorphism, protoliths are commonly recognized. However, there are several areas in which protolith identity is obscure, largely because of intense deformation combined with recrystallization. Such rocks are classified using metamorphic terminology.

Of the low- to medium-grade metamorphic rocks, the more common lithologies are: amphibolite (*Ala*); quartzofeldspathic schists that contain biotite (*Alqb*), or muscovite (*Alqm*), or are very felsic (*Alqf*); and mafic chloritic schists (*All*). There is a high-grade pyroxene hornfels (*Ahbx*) adjacent to noritic rocks on northwestern BURTVILLE.

Gneissic rocks

Distinction between gneissic granitoid (*Agn*) and strongly foliated granitoid (e.g. *Agf, Agmf*) is somewhat subjective and, apart from map sheet boundary discrepancies, there has been no effort to standardize usage of these terms throughout the Leonora–Laverton area. Rather, the terminology used in the published map sheets is retained.

Strongly foliated to gneissic granite shows a systematic variation in the dip of the foliation or gneissosity relative to distance from the faulted greenstone contact in the Murphy Hills area (MGA 424300E 6901600N) on MOUNT VARDEN. Adjacent to the faulted granite and greenstone contact, the foliation or gneissosity dips steeply (70–80°) towards the east-northeast, parallel to the contact. Over the 4 km of sparse outcrop west of the contact, the dip of the foliation or gneissosity lessens gradually with distance to around 30°, but its strike stays relatively constant.

Deformation

Early deformation events

Deformation events prior to the D_2 regional compression are only sporadically preserved. Consequently, opinion differs as to the nature and number of pre-D_2 deformation events. Williams and Currie (1993) argued that early extension (D_{e1}) led to core complex development (their D_e) in the Leonora area (Table 2). Vanderhor and Witt (1992) proposed that during this extensional event (their D_1) recumbent folding in the Leonora and Yerilla areas developed by gravitational sliding. In contrast, Williams and Currie (1993) and Williams (1998) preferred development of F_1 folds during a subsequent thrust-related compressional event (their D_1). The absolute timing of this early deformation has not been established.

Earliest deformation events are characterized by tight isoclinal recumbent folds (that are now refolded) and thrusting that has duplicated the stratigraphy (D_1; Table 2). These structures are present in all greenstone belts of the central Eastern Goldfields Granite–Greenstone Terrane (e.g. Chen, 1999; Harris et al., 1997; Hammond and Nisbet, 1992; Platt, 1980; Platt et al., 1978; Stewart, 2001; Vanderhor and Witt, 1992; Williams and Currie, 1993; Williams and Whitaker, 1993). Of particular note are the large-scale F_1 folds in and around the Melita and Jeedamya volcanic complexes, which are recognizable in aerial photographs (Witt, 1994). Less common is a north- to northwest-trending stretching lineation (L_1), which is locally present on the S_1 foliation in folded supracrustal sequences and early granitoids (Vanderhor and Witt, 1992; Witt, 1994). Evidence for an early extension and core complex development is best preserved in the Sons of Gwalia Shear at Leonora, where greenschist-facies supracrustal rocks are downthrown relative to the adjacent Raeside Batholith and amphibolite-grade supracrustal rocks (Williams and Currie, 1993).

The Kilkenny Syncline on southern MINERIE was assigned to F_1 by Stewart (1998) on the basis that this north-trending structure is cut by a strong northwest-striking foliation attributed to D_2. In this case a complex interdigitated outcrop pattern in the Margaret Anticline could represent D_2 refolding of an earlier recumbent antiformal structure.

Following development of the F_1 recumbent folds, further localized extension (D_{e2}) allowed accumulation of sandstone and conglomerate of the Pig Well – Yilgangi belt (Stewart, 2001; Table 2). Whether this belt represents a true pre-D_2 graben structure is unclear, hence the common name for the belt, the 'Pig Well Graben', is avoided.

D_2 event

Intense east-northeast–west-southwest compression during D_2 produced long-wavelength north-northwesterly trending folds and faults, and attenuation of the greenstone belts (Table 2). Two of the major structures produced during this deformation are the north-northwesterly plunging Lawlers Anticline in the Agnew–Wiluna greenstone belt and the overturned but east-plunging Margaret Anticline (Stewart, 2001) in the Laverton greenstone belt. At outcrop scale the most recognizable feature is the north-northwesterly trending S_2 foliation that varies in intensity according to rock composition, and becomes stronger with proximity to faults active during D_2 and to some granitoids (e.g. Chen, 1999). Shallow- to moderate-plunging bedding and S_2-foliation intersection lineations locally give a pencilled appearance to outcrop. South-plunging examples of these lineations are common

Table 2. Summary of regional deformation events in the Leonora–Laverton region

Event	*Structures*	*Locality or example*	*Timing constraint*
?D_{e1}	Extension and core complex development on granite–greenstone contacts[a]; recumbent folds[b]; variable movement directions[c]; bedding-parallel foliation[c]; synvolcanic granites[d]	Leonora; Mount Malcolm; Yerilla; Sons of Gwalia Shear at Leonora; Windarra; Lawlers	Felsic ash interbedded in komatiites c. 2705 Ma[e]; early granites c. 2680 Ma
D_1	Compression with recumbent folds[a–d, g–l] with bedding-parallel foliation[c]; northwest-trending stretching lineation[b,l]	All greenstone belts, good examples east of Leonora, and around the Melita and Jeedamya complexes	
?D_{e2}	Extension and development of limited clastic basins[k]	Pig Well, Yilgangi	Pre-dates 2662 ± 5 Ma[m] felsic dyke crosscutting Yilgangi Conglomerate
D_2	Intense ENE–WSW compression[c,k,n,o], with shallow plunging upright folds, widespread WNW-trending foliation, and bedding–foliation intersection lineation	Large to regional-scale folds and penetrative S_2 foliation common in all greenstones	Not constrained in database area; 2675–2657 Ma[p] or 2650–2630 Ma[q] for southern Eastern Goldfields
D_3	Regional sinistral transpression[l,n,o]: NNW-trending strike-slip shears and drag folds[c,d,f,k]; development of regional-scale restraining jogs[r] with N- to NNE-trending folding at shear terminations and within jogs[r]; tightening of F_2 folds[n,o]; late steeply dipping reverse faults[c]	Most major shears including Celia and Kilkenny tectonic zones[r]; Laverton, Duketon, and Yandal restraining jogs; Melita and Niagara	Not constrained in database area; 2663–2645 Ma[o,p] for southern Eastern Goldfields
D_4	Minor brittle ENE-striking faults	Commonly observed as brittle offsets on chert and BIF units	Not constrained in database area; 2620–2600 Ma[o] for southern Eastern Goldfields
D_5	Wide-spaced crenulation[f]	Leonora area	

SOURCE: (a) Williams and Currie (1993) (b) Vanderhor and Witt (1992) (c) Witt (1994) (d) Hammond and Nisbet (1992) (e) Nelson (1997a) (f) Williams (1998) (g) Chen (1999) (h) Harris et al. (1997) (i) Platt (1980) (j) Platt et al. (1978) (k) Stewart (2001) (l) Williams and Whitaker (1993) (m) Nelson (1996) (n) Swager et al. (1995) (o) Swager (1997) (p) Nelson (1997 b) (q) Krapez et al. (2000) (r) Chen et al. (2001)

in the Cosmo Newbery greenstone belt. The absolute timing of D_2 has not been determined in the database area, but comparison with the southern Eastern Goldfields Granite–Greenstone Terrane suggests an age of 2675–2657 Ma (Nelson, 1997b), although Krapez et al. (2000) preferred an age of 2650–2630 Ma.

D_3 event

Regional sinistral transpression dominated during the D_3 event (Table 2), which may represent a continuation of D_2 following clockwise rotation of the far-field stress regime (Williams and Whitaker, 1993). Widespread sinistral movement on north-northwesterly trending shear zones occurred at this time, but varied shear sense was recorded on north- to northeast-trending shears and the development of similarly oriented folds was enigmatic (Hammond and Nisbet, 1992; Williams, 1998). A viable transpressional mechanism for the development of these obliquely aligned features during D_3 was proposed by Chen (1998), Liu and Chen (1998a,b), and Chen et al. (2001). The major shears of the region have a right-stepping regional distribution, so differential compression between the shears developed regional-scale restraining jogs. North- to northeast-trending folding, and similarly trending reverse, dextral, and sinistral shearing and faulting developed continuously within these restraining jogs throughout the duration of D_3. Chen et al. (2001) identified three major restraining jogs, all of which are partly in the database area (Fig. 5). These are the Duketon restraining jog (Duketon greenstone belt, between the Lulu and Hootanui Shears), the Laverton restraining jog (Laverton greenstone belt, between the Celia Tectonic Zone and the Hootanui Shear), and the Yandal restraining jog (Yandal greenstone belt, between the Ninnis and Perseverance Shears). They also identified the Mount Kilkenny to Welcome Well area of the Murrin greenstone belt as a similarly deformed area, representing D_3 compressional folding and faulting on the northeastern side of the northern termination of the Kilkenny Shear.

The absolute timing of D_3 has not been determined in the database area, but comparison with the southern Eastern Goldfields Granite–Greenstone Terrane suggests an age of 2663–2645 Ma (Nelson, 1997b; Swager, 1997).

D_4 and D_5 events

Deformation after D_3 was relatively minor and appears to be localized. Brittle east-northeasterly striking D_4 faulting commonly offsets shears and stratigraphic markers such as chert and BIF units (Table 2). Senses of fault offsets are variable, and probably contain a significant vertical component in addition to easily observed lateral components. Swager (1997) placed the age of D_4 around 2620–2600 Ma. A localized, southeast-striking, widely spaced crenulation (D_5) that is commonly gently dipping has been reported in the Leonora area (Williams, 1998; Table 2).

Metamorphism

A number of metamorphic events affected the rocks of the central Eastern Goldfields Granite–Greenstone Terrane. Regionally, the central parts of the greenstone belts contain metamorphic grades of prehnite–pumpellyite to lower greenschist facies. A continuum through to upper amphibolite facies is commonly exhibited close to granitoid intrusions (Binns et al., 1976; Hallberg, 1985). The distribution of the metamorphic facies is mainly the result of two temporally distinct periods of metamorphism. Before these, however, it is likely that hydrothermal seafloor alteration caused alteration of mafic rocks and serpentinization of ultramafic rocks immediately after deposition (e.g. Williams and Hallberg, 1973).

Metamorphism associated with the first phase of regional deformation resulted in development of locally preserved D_1 fabrics. Williams and Currie (1993) documented an abrupt change in metamorphic grade across the D_1 Sons of Gwalia Shear near Leonora, from greenschist facies above and east of the shear, to amphibolite facies below and west of the shear (adjacent to the Raeside Batholith). This, in conjunction with sense of shear indicators, was used to imply core complex development during early extension. For the Melita area, Witt (1994) calculated regional temperatures of around 350°C augmented by extensive granitoid intrusion to develop high metamorphic grades in the contact aureoles.

Regional metamorphism associated with D_2/D_3 deformation resulted in the widespread development of the northerly to north-northwesterly trending S_2 foliation or cleavage. On Yabboo immediately south of the database area, porphyroblasts have overgrown this foliation, constraining the metamorphic peak to late D_2 to D_3 (Swager, 1995a,b). Thermal perturbations created by intrusion of syn-D_2 granitoids allowed further development of higher grade zones adjacent to granitoids, such as a zone of pyroxene hornfels near Mount Windarra in the Margaret Anticline (Hallberg, 1985).

Hallberg (1985) also noted a number of regionally important metasomatic styles of alteration. Low-temperature quartz–andalusite–chloritoid(–kyanite) metasomatism was described in the Mount Leonora and Mount Malcolm areas. Carbonate flooding over a large area of the Murrin greenstone belt adjacent to the Kilkenny Shear Zone may be related to extensive D_3 deformation of that area.

Proterozoic geology

Mafic to ultramafic dykes

Fresh exposures of north-northwesterly and easterly trending gabbroic dykes (*Ɇdy*) in the Cosmo Newbery greenstone belt are undeformed and post-date greenstone deformation and granitoid intrusion, and are probably of Proterozoic age.

Regionally, compositions of Proterozoic dykes range from pyroxenite through gabbronorite to granophyre. The dykes intrude the Archaean granitoids and greenstone belts with easterly to northeasterly and north-northwesterly trends. Although locally exposed as low ridges, the great majority of dykes are covered by surficial deposits. Recognition of their widespread distribution, abundance, and extent has depended upon regional airborne magnetic surveys. These intrusions were grouped as the Widgiemooltha dyke suite by Sofoulis (1966) and described in some detail by Hallberg (1987). A Palaeoproterozoic age (2418 ± 3 Ma; SHRIMP U–Pb baddeleyite age) was confirmed for an easterly trending dyke by Nemchin and Pidgeon (1998).

Permian geology

Outliers of Permian glacial deposits that unconformably overlie the Archaean Yilgarn Craton are mostly assigned to the Paterson Formation of the Gunbarrel Basin. Conglomerate (*Pac*) containing granite and greenstone clasts, commonly with striations, in a clay- and silt-rich matrix, is probably of glacigene origin. Sandstone to pebbly sandstone units (*Pas*) probably represent fluviatile deposits associated with the glaciation.

Regolith

Outcrop is largely obscured by regolith development throughout the Leonora–Laverton region. Unconsolidated or partially consolidated sedimentary material is most common, but lateritic profiles commonly overprint rock units in the greenstone belts, particularly highly mafic varieties. Deeply weathered ultramafic rocks are exploited for nickel at Murrin Murrin. The Yandal greenstone belt immediately north of the database area was the subject of a Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC-LEME) project, which recognized that weathering and drainage systems evolved over the last 60 million years (Anand, 2000). Weathering is common to depths of 150 m below the surface, and 90% of the area is covered by transported overburden ranging in thickness from 3 to 40 m, with palaeodrainage channels to a depth of 100 m (Anand, 2000).

The subdivision and classification of regolith types in the database has been modified to conform with the most recent classification system documented by Hocking et al. (2001). Several areas have been remapped in the course of eliminating discordance between the original sheets, resulting in reclassification of the regolith in large areas. The unit definitions are provided in Appendix 1.

Alluvial deposits

Alluvium (*A*) occupies present-day drainage channels and floodplains, and consists of unconsolidated clay through to boulders, although most sediment is of sand to gravel size.

Colluvial deposits

Colluvium (*C*) is common on sloping or irregular ground and contains a large component of coarse-grained proximal debris. The finer grained matrix material is locally ferruginous. Colluvium is also subdivided to indicate dominant provenance rock types, such as ferruginous gravel (*Cf*), ferruginized BIF (Cfc_i), quartz vein (*Cq*) or silica caprock after ultramafic rocks (*Czu*). Areas of particularly thin colluvium are indicated by composite codes, for example, areas where colluvium rests upon mafic volcanic rock are coded *C/Abv.*

Sheetwash deposits

Sheetwash (*W*) is common on broad, gently sloping plains, and consists of reddish, ferruginous fine sand to clay. The material has been transported and substantially reworked, and is generally distal to its source areas. Flat areas in which ferruginous gravel rests on these deposits are also distinguished (*Wf*).

Sandplain deposits

Plains and dunes of eolian sand (*S*) cover extensive areas as sheets of variable thickness adjacent to salt-lake margins and on duricrust plateaus overlying granitoid. This fine-grained quartz sand may contain layers of clay and ferruginous nodules. Unconsolidated deposits of sand within old valley systems (*Sv*) also have eolian characteristics in some areas. Quartzofeldspathic sand and gravel deposits overlying granitoids (*Sgp*) commonly contain some lithic fragments that indicate a largely proximal origin, and regolith deflation may have been an active mechanism.

Lacustrine deposits

Playa deposits within salt lakes and claypans (L_l) consist of interbedded clay, sand, and evaporite minerals (gypsum and halite), locally intermixed with sandplain deposits (L_m). These are commonly surrounded by dunes of sand, silt, and gypsum (L_d) derived from the lakes and sandplains. Many of these dunes are now stabilized by vegetation.

Residual deposits

Ferricrete or ferruginous duricrust (*Rf*), previously termed laterite on several of the published 1:100 000 maps, is widespread. Breakaways or erosional scarps commonly bound the ferruginous duricrust outcrops and reveal highly weathered (bleached and mottled) rocks that can be identified by locally preserved textural features. These lateritization profiles are up to 100 m thick. The ferricrete is typically yellowish brown to dark brown, locally black, and commonly massive to nodular or pisolitic. Where duricrust has formed directly from the underlying bedrock, original structures and textures are commonly preserved, which is represented by the use of composite codes (e.g. *Rf/Ab*).

Silcrete (*Rz*) is commonly light grey to white and subvitreous to vitreous, and overlies quartzofeldspathic rocks. Angular medium-grained quartz grains are common where it overlies granite, and the outcrop style commonly mimics that of fresh granite. Silica caprock (*Rzu*) is a subvitreous siliceous rock, typically light brown to off-white in colour, that is developed mainly over deeply weathered ultramafic rocks, particularly over serpentinized peridotite where olivine cumulate textures are locally preserved. Chrysoprase and jasperoidal chalcedony are present locally.

Deeply weathered rocks of uncertain origin

Deep and intense weathering has resulted in numerous areas where saprolitic residuum is recognizable, but original rock types cannot be determined. These have been coded X_w.

Economic geology

Gold and nickel are the principal mineral commodities produced in the region covered by Phase 3 of the East Yilgarn Geoscience Database. The region includes parts of the East Murchison, North Coolgardie, and Mount Margaret mineral fields

As outlined in the summary of data themes in the database, the themes MINOCC, MINEDEX, and TENGRAPH provide locality, resource, and tenement information respectively for the database area. The data in these layers are voluminous because of the large number of both historical and current mine sites, and continuing prospecting activity. However, these data are simply an index to details of exploration activities that are recorded in open-file statutory mineral exploration reports stored in the Western Australian mineral exploration database (WAMEX) in the DoIR library. At the time of writing, more than 1600 reports were publicly accessible from the Perth and Kalgoorlie offices of DoIR, with recent reports available directly through the Internet. The MINEDEX database and annual publications such as DoIR's MPR Statistics Digest provide resource and production statistics. Exploration and development statistics are presented in Flint (2002).

Brief overviews of the commodities in the central Eastern Goldfields Granite–Greenstone Terrane are presented below. More detailed descriptions are present in the references listed therein. Locations of the mines sites described in the text are shown in Figures 6 and 7.

Gold

The Western Australian gold rush of the 1890s led to European settlement of the area now known as the Eastern Goldfields. Gold mining centres were established at Leonora, Laverton, Agnew, Kookynie (Fig. 2), and various other sites in the middle to late 1890s. Gold production from the region peaked in the early 1900s, declining through to the 1920s. There was resurgence during the Great Depression of the 1930s and a major trough in the 1960s. Interest in the region was renewed in the 1980s and 1990s, leading to a number of new discoveries and the development of several major gold mining centres.

The major operational mines of the region (Fig. 6) include Emu, Sunrise, Wallaby, Lawlers, Tarmoola, Sons of Gwalia, Thunderbox, and Sunrise Dam (including Cleo). Past major producers include Granny Smith, Beasley Creek, Bottle Creek, Lancefield, Burtville, Kookynie, Harbour Lights, Tower Hill, and Mount Morgans, with smaller operations at Linden and Yundamindera. There are a number of deposits yet to be developed near Laverton and to the south, including the Chatterbox Shear deposits (Whisper, Rumour, Innuendo, and Garden Well). A list of these and other deposits, their production to date, and remaining resources is presented in Table 3.

Most gold mineralization is fracture controlled and hosted by either quartz-vein sets or by alteration haloes around these veins. Groves (1993) and Solomon and Groves (1994) proposed a continuum model for gold mineralization that has been applied to the deposits of the central Eastern Goldfields Granite–Greenstone Terrane, a model in which the deposits are described as ‘late-orogenic structurally controlled’ (Witt and Vanderhor, 1998) and ‘orogenic’ (Groves et al., 1998). The model interprets gold deposits of varying characteristics as having formed throughout the middle to upper crust adjacent to crustal-scale plumbing systems in response to a massive fluid flux. Evidence from gold mines throughout the Eastern Goldfields Granite–Greenstone Terrane, including those of the Leonora and Laverton regions, suggests that a regional mineralizing event at 2650–2630 Ma was responsible for the deposition of the vast bulk of the gold in terms of tonnage (Solomon and Groves, 1994; Yeats and McNaughton, 1997). Many major deposits have or had associated alluvial or eluvial gold, commonly as placer deposits, in regolith at or immediately beneath the surface.

Detailed descriptions of most of the major deposits of the region are available in Hughes (1990) and Berkman and Mackenzie (1998).

Nickel and cobalt

Intense nickel exploration in the late 1960s and 1970s focused on ultramafic-hosted nickel sulfide deposits in the Agnew–Wiluna, Murrin, and Laverton greenstone belts. The areas explored were around Mount Windarra and South Windarra in the database area (Fig. 7, Table 4), and at Mount Keith and in the Honeymoon Well and Perseverance areas north of the database area. Mount Windarra and South Windarra fall within the Laverton greenstone belt. At these deposits nickel sulfide ore is disseminated throughout peridotite at the base of a particular ultramafic volcanic flow, which is stratigraphically the lowermost ultramafic unit of the Margaret Anticline stratigraphy (Reddell and Schmulian, 1990). Other nickel sulfide deposits include Mount Clifford (Marriott), Weebo Bore, Allstate, Mount Newman, Schmitz Well, Woodline Well, and Heron Well. Descriptions of deposits are given by Marston (1984) and Knight (1975).

Lateritic nickel and cobalt mineralization has been mined at the Murrin Murrin laterite deposits, and similar deposits are at Lawlers, Marshall Pool, Pyke Hill, Waite Kauri, Eucalyptus Bore, and Mertondale (Fig. 7, Table 4). The Murrin Murrin deposit directly overlies folded layered komatiite flows containing basal peridotite in the Kilkenny Syncline (Fazakerley and Monti, 1998). These ultramafic rocks appear to be free of nickel sulfide (Fazakerley and Monti, 1998). Nickel–cobalt laterite mineralization is derived from in situ chemical weathering of ultramafic rocks. Nickel, as well as cobalt, is concentrated within various transitional minerals that are stable in near-surface conditions (Burger, 1996).

Lateritic nickel–cobalt deposits of the Yilgarn Craton have a prolonged weathering history and compared to other deposits have higher smectite and silica (chalcedony, chert) contents, coincident nickel and cobalt maxima relatively high in the weathering profile, nickel-poor saprolite, and complex internal geometries (Burger, 1996). Typically, nickel–cobalt laterite deposits of the Yilgarn Craton contain, at surface, dense hematite-rich duricrust that overlies a heterogeneous ferruginous zone dominated by siliceous goethite, limonite, and limonitic clay in varying proportions (Burger, 1996). Beneath this is a smectite zone containing nickeliferous smectite-clay minerals. At the base of the regolith profile is the saprolite zone. The thickness of these zones varies between deposits in the region, presumably related to variations in host mineralogy and the extent of leaching.

Copper, zinc, silver, and lead

Economic volcanic-hosted massive sulfide (VHMS)-style mineralization appears to be rare in the Eastern Goldfields Granite–Greenstone Terrane. Teutonic Bore, 55 km north-northwest of Leonora, is the largest (Fig. 7, Table 5) and most recently mined (1980 to 1984) VHMS-style deposit of the Eastern Goldfields Granite–Greenstone Terrane. The deposit consisted of a single lens of massive to banded sulfide hosted by pyritic black shale and siltstone, with crosscutting stringer mineralization in the basaltic and felsic volcanic–volcaniclastic footwall representing the feeder (Greig, 1984). The feeder zone contained strong quartz–chlorite–carbonate–sericite alteration. Greig (1984) suggested that the deposit formed on the flanks of a rhyolite dome, with sulfide accumulation in a palaeo-topographic low.

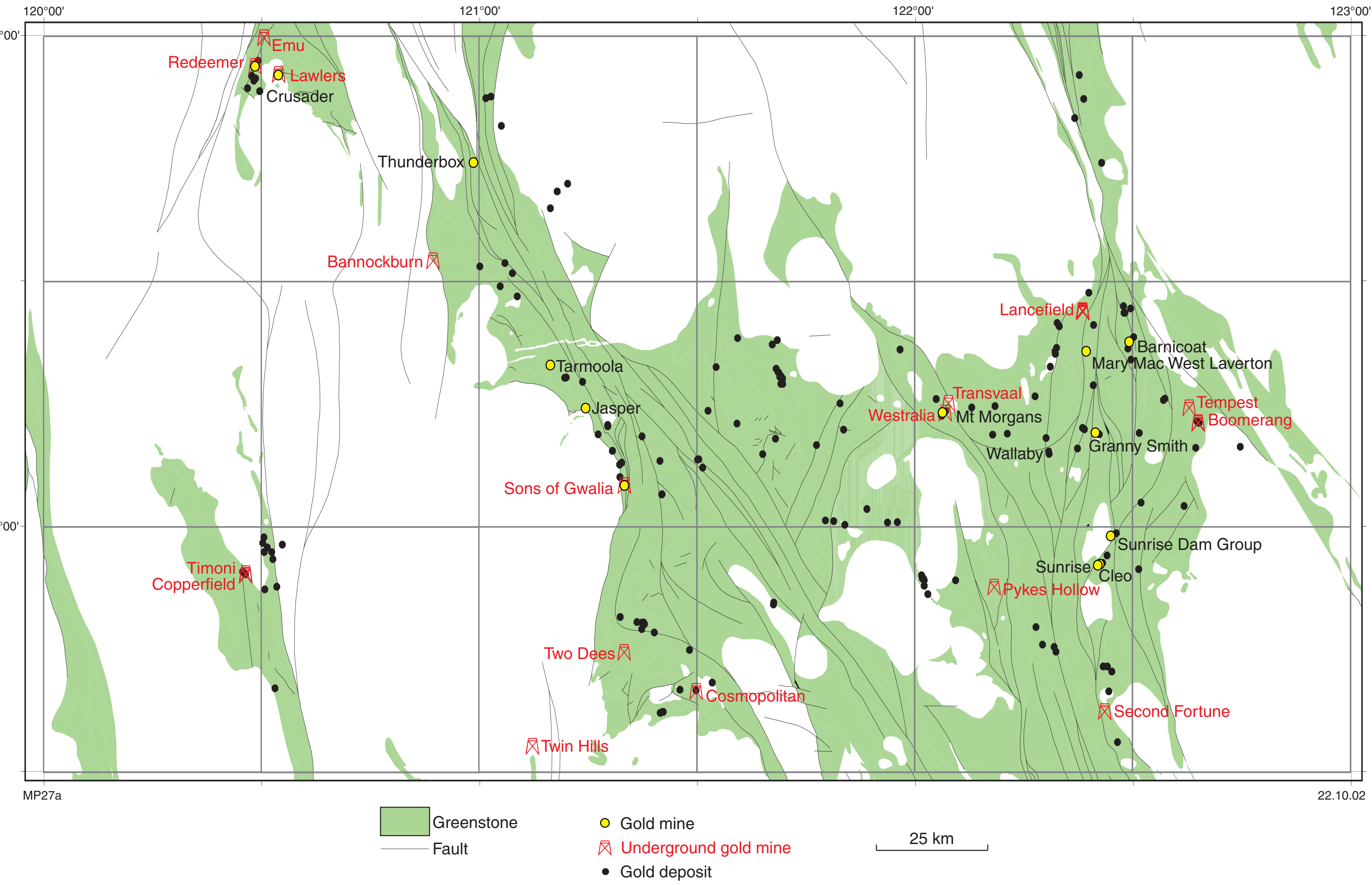

Figure 6. Gold mineralization in the Leonora–Laverton region

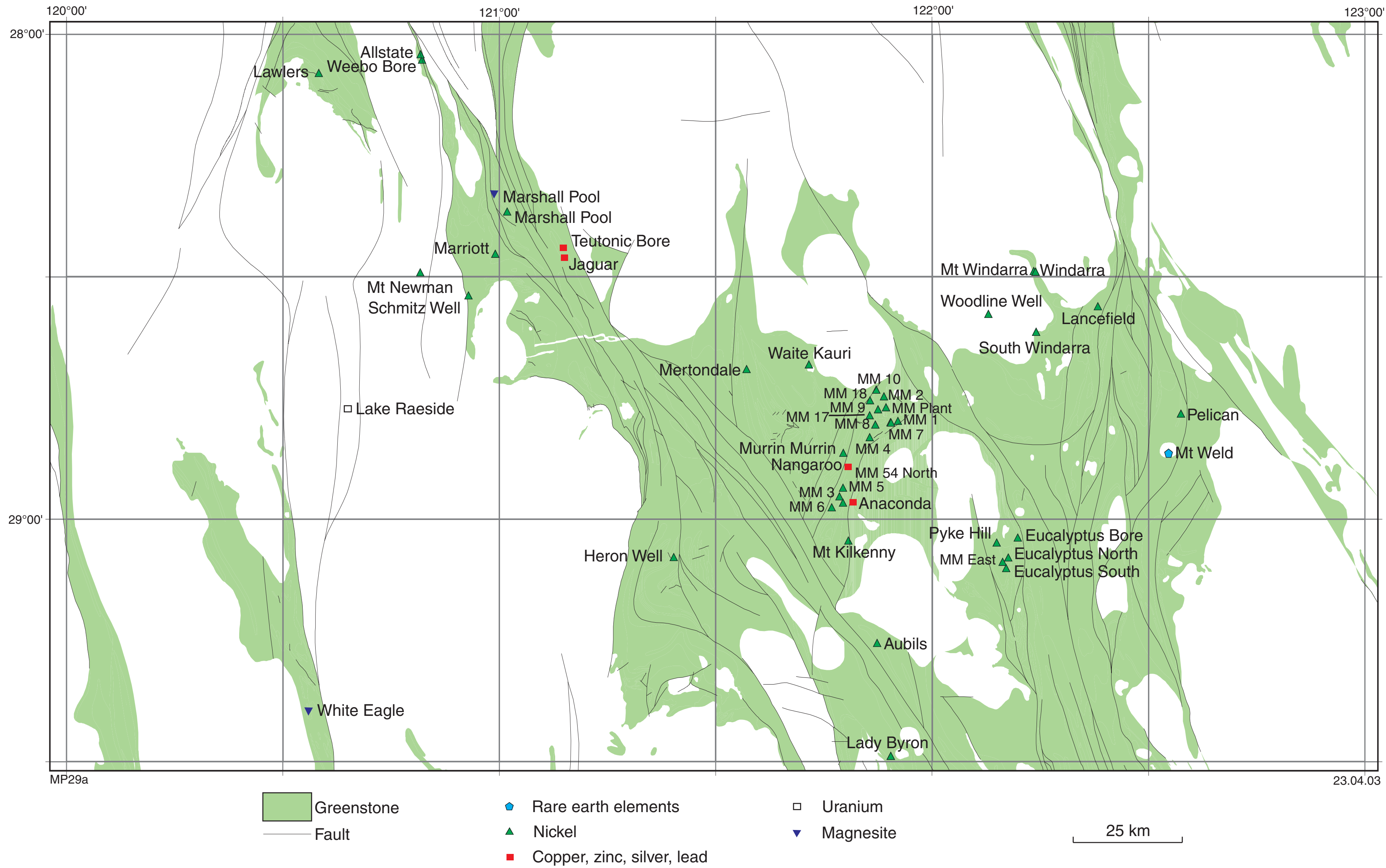

Figure 7. Mineralization other than gold in the Leonora–Laverton region (major laterites of the Murrin Murrin venture indicated as MM numbers)

Table 3. Gold production and indicated resources of the Leonora–Laverton region

Deposit	*MGA coordinates*		*Status*	*Past production*[a]	*Remaining resources*			*Total*[b]
	Easting (m)	*Northing (m)*		*Contained metal (kg)*	*Tonnage (Mt)*	*Grade (g/t)*	*Contained metal (kg)*	*Contained metal (kg)*
Bannockburn	294787	6850288	Closed	12 263	9.75	3.08	30 057	42 319
Beasley Creek	434061	6838930	Closed	see Lancefield[c]	–	–	–	–
Bottle Creek	251752	6770565	Closed	3 238	0.14	3.00	429	3 667
Burtville	464860	6817743	Closed	12 209	–	–	–	12 209
Cleo	443497	6783068	Operating	see Sunrise Dam[c]	–	–	–	
Emu (Agnew)	255060	6899950	Operating	70 688	17.02	4.44	75 624	146 312
Garden Well	433681	6831446	Undeveloped	–	0.35	2.52	883	883
Granny Smith	442811	6813040	Closed	187 521	27.50	2.81	77 275	264 796
Harbour Lights	336348	6804852	Closed	8 433	–	–	–	8 433
Ida H	451265	6826652	Closed	14 661	1.85	2.10	3 875	18 536
Innuendo	434056	6832190	Undeveloped	–	0.56	2.49	1 394	1 394
Kookynie – Orient Well	348468	6767517	Closed	12 188	4.27	3.87	16 508	28 695
Lancefield	439686	6840569	Closed	58 805	17.28	2.96	51 207	110 011
Lawlers	258119	6892005	Closed	34 663	4.76	5.71	27 155	61 818
Linden	445742	6760332	Closed	2 600	0.57	6.44	3 637	6 237
Mertondale	357776	6827608	Closed	5 930	–	–	–	5 930
Mount Morgans	408512	6817344	Closed	68 128	3.36	3.64	12 230	80 358
Niagara	346208	6748922	Closed	see Kookynie – Orient Well[c]	–	–	–	–
Rumour	432659	6827945	Undeveloped	–	2.65	2.10	5 565	5 565
SOG, Leonora	328546	6817453	Operating	137 993	38.71	3.51	135 920	273 913
Sunrise	443993	6783296	Operating	see Granny Smith[c]	–	–	–	
Sunrise Dam	446334	6789728	Operating	32 448	68.75	3.41	234 256	266 705
Tarmoola	320082	6826257	Operating	40 014	72.09	1.44	103 612	143 626
Tower Hill	336467	6802206	Closed	see SOG, Leonora[c]	–	–	–	–
Wallaby	432196	6808235	Operating	–	41.67	2.86	119 176	119 176
Whisper	433771	6830853	Undeveloped	–	2.65	2.54	6 731	6 731
Yundamindera	404207	6780651	Closed	1 832	–	–	–	1 832
TOTAL				703 612	313.93	2.88	905 533	1 609 146

SOURCE: MINEDEX (Department of Industry and Resources' mines and mineral deposits information database)

NOTES:
(a) Past production figures are a sum of pre-1988 (Hickman and Keats, 1990) and post-1988 (Royalties division, Department of Industry and Resources) production figures
(b) Total represents total pre-production gold content of the deposit and is derived by the sum of past production and remaining resource figures
(c) Deposit production figures are not available individually, but were historically summed with the quoted deposit
SOG: Sons of Gwalia

Successful exploration of this volcanic unit led to the discovery of a similar massive sulfide occurrence about 3 km south of Teutonic Bore in February 2002. This find, named Jaguar, consisted of seven drillholes that intersected high-grade copper (3–5%), zinc (9–16%) and silver-rich massive sulfides, 5–12 m thick, at depths between 480 and 540 m.

The Anaconda (Fig. 7; Eulaminna), Nangaroo, and Crayfish Creek (2.4 km south of Nangeroo) deposits are in the same stratigraphic horizon in the Kilkenny Syncline, around 45 km east of Leonora. The horizon is characterized by black shale, greywacke, and siltstone (probably of volcaniclastic origin) that overlies rhyodacitic volcanic and volcaniclastic rocks, and is overlain by pillow basalt (Ferguson, 1998). The deposits are small (Table 5), each representing venting of hydrothermal fluids onto the sea floor or infiltration of fluids below the sediment–water interface or both, and alteration and vent zones are recognized. Anaconda and Nangaroo were mined between 1899 and 1908, and Nangaroo was mined for copper between 1950 and 1967 (Ferguson, 1998).

Other VHMS-style deposits include Rio Tinto, Nambi (Mount Zephyr), Doyle Well, and Wendys Bore (Ferguson, 1998). Other copper, zinc, silver, and lead deposits include Copperfield (Kriewaldt, 1970), Dodgers Hill (Hallberg, 1985), and Wilsons Patch (Thom and Barnes, 1977). Witt et al. (1996) and Messenger (2000) compared trace element signatures of felsic volcanic sequences in the Eastern Goldfields Granite–Greenstone Terrane with those of VHMS-mineralized and barren domains of the Abitibi greenstone belt in Canada. They suggested that the Agnew–Wiluna and Yandal greenstone belts are not prospective for VHMS mineralization, whereas the Malcolm greenstone belt shows higher prospectivity.

Table 4. Nickel and cobalt production and indicated resources of the Leonora–Laverton region

Deposit	MGA coordinates Easting (m)	MGA coordinates Northing (m)	Status	Commodity	Past production Contained metal (t)	Remaining resources Tonnage (Mt)	Remaining resources Grade %	Remaining resources Contained metal (t)	Total[(a)] Contained metal (t)
Nickel sulfide deposits									
Mount Windarra	425192	6848551	Closed	Ni	[(b)]97 582	4.10	1.33	54 530	152 112
South Windarra	425811	6834702	Closed	Ni	[(b)]40 704	–	–	–	40 704
Nickel laterite deposits									
Eucalyptus Bore	421995	6787649	Undeveloped	Ni	–	69.8	1.01	703 490	703 490
				Co	–	69.8	0.06	41 880	41 880
Lawlers	(confidential)		Undeveloped	Ni	–	[(c)]190.00	[(c)]0.64	[(c)]1 221 000	1 221 000
				Co	–	[(c)]190.00	[(c)]0.04	[(c)]83 000	83 000
Marshall Pool	302543	6866315	Undeveloped	Ni	–	[(c)]186.00	[(c)]0.77	[(c)]1 430 000	1 430 000
				Co	–	[(c)]186.00	[(c)]0.04	[(c)]82 000	82 000
Murrin Murrin	393249	6813705	Operating	Ni	[(b)]34 992	[(c)]307.00	[(c)]0.80	[(c)]2 456 000	2 490 992
				Co	[(b)]1 757	[(c)]116.80	[(c)]0.08	[(c)]93 440	95 197
Pyke Hill	417222	6786476	Undeveloped	Ni	–	13.0	1.23	159 900	159 900
				Co	–	13.0	0.15	19 500	19 500
Waite Kauri	374535	6826805	Undeveloped	Ni	–	8.446	0.98	82 939	82 939
				Co	–	8.446	0.67	5 659	5 659

SOURCE: MINEDEX (Department of Industry and Resources' mines and mineral deposits information database)
NOTES:
(a) TOTAL represents total pre-production contained metal of the deposit and is derived by the sum of past production and remaining resource figures
(b Data sourced from Royalties division, Department of Industry and Resources
(c) Data sourced from Mulholland (2000)

Table 5. Production and indicated resources of other commodities of the Leonora–Laverton region

Deposit	MGA coordinates Easting (m)	MGA coordinates Northing (m)	Status	Commodity	Past production Contained metal	Remaining resources Tonnage (Mt)	Remaining resources Grade	Remaining resources Contained metal	Total[(a)] Contained metal
Copper, zinc, lead, and silver									
Anaconda	380268	6794985	Closed	Ag	–	0.48	9.53 g/t	4 530 kg	4 530 kg
				Cu	[(b)]4 274 t	0.48	1.62%	7 701 kg	11 975 kg
				Zn	–	0.48	3.36%	15 972 kg	15 972 kg
Nangaroo	383578	6799110	Closed	Cu	[(b)]276 t	0.01	18.00%	2 520 kg	2 796 kg
Teutonic Bore	318563	6856097	Closed	Cu	[(c)]87 850 t	3.025	1.38%	41 742 t	45 924 t
				Zn	[(c)]240 960 t	3.025	4.62%	139 707 t	149 593 t
				Pb	[(c)]20 080 t	–	–	–	20 080 t
				Ag	[(c)]366 460 kg	3.0	93.03 g/t	279 095 kg	294 196 kg
Magnesite									
Lawlers	(confidential)		Undeveloped	Mg	–	94.9	23.1%	21 921 kt	21 921 kt
Marshall Pool	302544	6866379	Undeveloped	Mg	–	21.9	22.8%	4 993 kt	4 993 kt
Murrin Murrin	(confidential)		Undeveloped	Mg	–	–	–	–	–
White Eagle	263246	6748144	Undeveloped	Mg	–	9.60	38.0%	3 648 kt	3 648 kt
Manganese									
Mount Lucky	(confidential)		Undeveloped	Mn	–	0.04	38.0%	15 200 t	15 200 t
				Fe	–	0.04	16.0%	6 000 t	6 000 t
Phosphate, rare earth elements, niobium, and tantalum									
Mount Weld	455871	6807156	Undeveloped	phosphate	–	260.00	18.00%	46.8 kt	46.8 kt
				REE oxides	–	1.70	19.61%	332.4 kt	332.4 kt
				tantalite	–	145.00	0.034%	49.3 kt	49.3 kt
				columbite	–	273.00	0.90%	2 457.0 kt	2 457.0 kt
Uranium									
Lake Raeside (BP)	277882	6813361	Undeveloped	U	–	6.70	0.253 kg/t	1 695 t	1 695 t
Lake Raeside (ESSO)	270441	6813712	Undeveloped	U	–	0.45	0.450 kg/t	112 t	112 t
Stakeyard Well	281149	6806989	Undeveloped	U	–	0.11	0.410 kg/t	45 t	45 t

SOURCE: MINEDEX (Department of Industry and Resources' mines and mineral deposits information database)
NOTES:
(a) Total represents total pre-production commodity content of the deposit and is derived by the sum of past production and remaining resource figures
(b) Data sourced from Ferguson (1998)
(c) Data sourced from Davies and Blockley (1990)
REE Rare earth elements

Magnesium

Magnesite is commonly spatially associated with, but forms discrete deposits to, the lateritic nickel–cobalt deposits of the Eastern Goldfields Granite–Greenstone Terrane. Topographically, the magnesium mineralization is typically downstream from and lower than its genetically related nickel–cobalt laterite. Magnesium resources have been identified at Marshall Pool, Murrin Murrin, White Eagle, and Joes Bore (MGA 3678500E 6892000N; Thom and Barnes, 1977) east of Lawlers (Fig. 7, Table 5).

Manganese and iron

Manganese and iron have been mined at Mount Lucky, 20 km southeast of Laverton. Psilomelane and pyrolusite are associated with jaspilite and BIF (Lord and de la Hunty, 1950; Tomich, 1956). Historic production was not recorded, but a small resource is present (Table 5).

Manganese oxide coatings are commonly associated with BIF throughout the Laverton greenstone belt.

Phosphate, rare earth elements, niobium, and tantalum

The Mount Weld phosphate, rare earth element, niobium, and tantalum deposits (Fig. 7) overlie the 2021 ± 13 Ma Mount Weld carbonatite, which is a cylindrical, predominantly sövitic intrusion of 4 km diameter that has intruded the Laverton greenstone belt (Duncan and Willett, 1990). The carbonatite is not exposed; almost all resources (Table 5) are in the karst-like regolith above the carbonatite, which is now covered by more recent alluvial material (Duncan and Willett, 1990). Residual apatite forms a continuous 6–30 m-thick sheet directly overlying fresh carbonatite, but grains are coated with iron oxides (and other minerals) that render the phosphate deposits largely unacceptable for industrial use. Residual concentrates of primary magmatic phases, such as pyrochlore, ilmenite, and niobian rutile, above the apatite zone contain subeconomic concentrations of niobium and tantalum. Rare earth elements in primary magmatic phases (monazite, apatite, synchysite) are dispersed throughout the carbonatite regolith. Local concentrations of secondary monazite contain very high proportions of lanthanides (up to 45% lanthanide oxides; Duncan and Willett, 1990). Little of the fresh rock, which is at depths greater than 50 m, has been assayed for these or other commodities.

Tungsten

Patchy scheelite mineralization is associated with 30 m-long by 0.75 m-wide quartz lenses in strongly metamorphosed mafic rocks, 1.5 km east-southeast of the Ogilvies gold workings, near Mount Amy on MOUNT VARDEN (Fig. 2; Berliat, 1954; Gower, 1976). Scheelite is also a common accessory mineral in many gold deposits of the Eastern Goldfields Granite–Greenstone Terrane (Ghaderi et al., 1999).

Uranium

Calcrete-hosted uranium deposits are hosted by the Tertiary palaeodrainage systems of the north and central Eastern Goldfields Granite–Greenstone Terrane. The uraniferous mineral carnotite forms coatings and fillings within the calcrete (Langford, 1974). A number of potential deposits have been identified beneath Lake Raeside (Fig. 7), including Stakeyard Well (Table 5), but none have been exploited.

Molybdenum

Molybdenite is in pegmatite at the Mount Molybdenite (Thomas' Show) deposit on LEONORA (approximately 25 km north of Leonora town) and in reaction zones adjacent to porphyry dykes at South Windarra on LAVERTON (Fig. 7; Baxter, 1978).

Bismuth

Hallberg (1985) noted that bismuth was common in gold deposits around Niagara on MELITA (Fig. 2). The Teutonic Bore VHMS deposit on WILDARA contains several sulfides of bismuth, copper, and lead (Fig. 7; Greig, 1984).

Gemstones

Chrysoprase is associated with silica caprock over ultramafic rocks. Several prospects have been identified at Marshall Creek on (WILDARA), Murrin Murrin (on MINERIE; Fig. 2), and near Eucalyptus (on LAKE CAREY; Fig. 2). Chrysoprase has been mined on a small scale from several localities, but there are no records of production. Operations at Boyce Creek, just south of the database area, resumed in July 2001.

Local occurrences of lace and honey opal have been reported 3 km north of Pyke Well on Yundamindra Station on LAKE CAREY (Williams et al., 1976). Moss opal was mined on a small scale with chrysoprase near Eucalyptus on LAKE CAREY (Hallberg, 1985).

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Appendix 1

Rock codes and definitions

Regolith

A	Clay, silt, sand, and gravel in channels and on floodplains
A_2	Older generation alluvium with heterogeneous composition; exposed in recent alluvial channels; locally silicified
A_pc	Clay and silt in claypans
C	Gravel and sand as proximal sheetwash and talus
Cf	Ferruginous gravel or reworked ferruginous duricrust
Cfc_i	Detritus and talus adjacent to ridges of banded iron-formation
Cq	Quartz-vein debris
Ld	Sand, silt, and gypsum in stabilized dunes adjacent to playa lakes
L_de_g	Kopi — lithified gypsum and clay in mounds and dunes adjacent to playa lakes
Lg	Silt, sand, and gravel in halophyte flats adjacent to playas
L_l	Saline and gypsiferous evaporites, clay, silt, and sand in playalakes
L_m	Mixed playa and sandplain terrain, commonly in palaeodrainages
Rf	Ferruginous duricrust and/or ferricrete; massive to rubbly; locally reworked
Rfi	Massive ironstone as ridge and capping
Rgp_g	Deeply weathered granitoid rock; mottled and leached zones of lateritic profile
Rk	Calcrete
Rz	Silcrete
Rzp_g	Silcrete and/or kaolinized granitoid rock
Rzu	Siliceous caprock over ultramafic rock; locally includes chalcedony and chrysoprase
S	Yellow sand with minor silt and clay; limonitic pisoliths near base; low, vegetated dunes locally common; pebbles of ferruginous duricrust
S_d	Yellow sand in stabilized dunes
Sv	Sandy colluvium with limonitic pisoliths on low plateaus associated with weathered granitoid
Sgp	Quartzofeldspathic sand and gravel over and adjacent to granitoid rocks
W	Clay, silt, and sand as extensive fans; locally ferruginous and/or gravelly
Xw	Weathered rock; protolith unrecognizable

Permian rocks: Gunbarrel Basin

Ps	Sedimentary rock; quartz pebble conglomerate, poorly sorted sandstone; glacigene deposit
Psc	Unassigned conglomerate; polymictic, poorly sorted; fluvioglacial deposit
Pac	PATERSON FORMATION: conglomerate, with sandstone and siltstone; probably of glacigene origin
Pas	PATERSON FORMATION: sandstone, with pebbly to bouldery siltstone, conglomerate, and mudstone; probably of fluviatile origin

Proterozoic mafic dykes

P_dg	Diorite dyke
P_dy	Mafic and ultramafic dykes; locally known as the Widgiemooltha dyke swarm

Dykes and veins

a	Aplite dyke
gd	Diorite
l	Lamprophyre dyke
p	Pegmatite dyke or pod
q	Quartz vein or pod; quartzolite; massive, crystalline, or brecciated
qxi	Goethite/hematite–quartz breccia

Archaean dykes and veins

Apf	Felsic (acid to intermediate) porphyry; feldspar and/or quartz phenocrysts
Apfh	Hornblende–feldspar porphyry
Apq	Quartz–feldspar porphyry

Granitoid rocks

Ag	Granitoid rock, undivided
Aga	Fine-grained granitoid rock; deeply weathered
Agb	Foliated granitoid rock interleaved with subordinate mafic rock; gneissic banding locally developed
Agc	Coarse-grained granitoid rock
Agd	Diorite to quartz monzodiorite; with hornblende, clinopyroxene and/or biotite; small dykes and stocks
Agem	Medium-grained, equigranular granitoid rock
Agf	Strongly foliated granitoid; locally gneissose; includes amphibolite lenses

Agg	Granodiorite; microgranitoid enclaves locally
Aggx	Granodiorite to monzogranite interleaved with granitoid schist and diverse greenstone lithologies on all scales
Agl	Leucocratic granitoid and microgranitoid rocks
Agm	Monzogranite; biotite bearing, local hornblende; commonly medium to coarse grained; minor granodiorite
Agma	Fine-grained biotite monzogranite
Agmc	Coarse-grained biotite monzogranite
Agmf	Strongly foliated biotite monzogranite, medium to coarse grained; minor granodiorite and pegmatite dykes
Agmm	Biotite monzogranite, medium grained
Agmp	Porphyritic monzogranite
Agn	Gneissic granitoid rock
Agp	Porphyritic granitoid, undivided
Agqs	Quartz-rich granitoid
Ags	Syenite and quartz syenite; numerous mafic schlieren and xenoliths; porphyritic locally
Agsf	Foliated syenite
Agt	Tonalite
Agtp	Porphyritic tonalite
Agy	Syenogranite
Agya	Syenogranite to alkali-feldspar granite, equigranular, aplitic

Granitoid rocks — named

Agmbu	BULLA ROCKS MONZOGRANITE: fine- to coarse-grained biotite-bearing monzogranite; K-feldspar phenocrysts, locally megacrystic; foliated
Agycs	CARPET SNAKE SYENOGRANITE: massive muscovite–biotite syenogranite; pegmatitic segregations
Agmgl	GALAH MONZOGRANITE: muscovite–biotite monzogranite; numerous pegmatitic segregations
Agmju	JUNGLE MONZOGRANITE: biotite monzogranite
Agsmw	McAULIFFE WELL SYENITE: medium- to coarse-grained quartz syenite; K-feldspar megacrysts
Agmmy	MYSTERY MONZOGRANITE: fine-grained, equigranular biotite monzogranite

Metamorphic rocks — low to medium grade

Ala	Amphibolite; schistose; clinopyroxene, cummingtonite, and/or garnet present locally; protolith unknown
Alaf	Amphibolite with lesser garnet-bearing porphyry, aplite dykes, schistose felsic volcanic rocks
Alap	Amphibolite with plagioclase porphyroblasts
Ald	Quartz–aluminosilicate rock within felsic volcanic sequences; highly poikilitic andalusite; minor kyanite locally
All	Chlorite schist
Allfn	Chlorite–albite–actinolite schist
Alqb	Quartz–biotite(–feldspar–muscovite) schist
Alqf	Quartz–feldspar(–muscovite) schist; locally deeply weathered
Alqm	Quartz–muscovite(–feldspar) schist
Ahbx	Pyroxene hornfels
Algn	Greisen

Gneisses

Anbi	Intermediate to basic schist or gneiss; includes some acid components
Ang	Quartzofeldspathic or banded granitoid gneiss; locally migmatitic; mafic bands

Mafic intrusive rocks (metamorphosed)

Aaa	Anorthosite
Ao	Mafic intrusive rock, undivided
Aod	Dolerite
Aode	Dolerite, equigranular
Aodm	High-Mg dolerite
Aodp	Porphyritic dolerite, with feldspar phenocrysts
Aog	Gabbro; minor pyroxenite or quartz gabbro components
Aogc	Gabbro, very coarse grained
Aoge	Gabbro, equigranular
Aogl	Leucogabbro; locally magnetite rich
Aogp	Porphyritic gabbro with plagioclase phenocrysts
Aogq	Quartz-bearing gabbro and quartz gabbro; locally granophyric
Aogv	Olivine gabbro
Aogx	Pyroxenitic gabbro
Aokk	KILKENNY GABBRO: gabbro sill; more leucocratic upwards
Aon	Gabbronorite and norite

Sedimentary chemical rocks (metamorphosed)

Ac	Chert and banded chert; locally includes silicified (black) shale, slate, or exhalite
Aci	Banded iron-formation, oxide facies; finely interleaved magnetite- and quartz-rich chert and/or siliceous slate
Acj	Jaspilite
Askl	Limestone
Acxi	Chert breccia, commonly cemented with goethite

Sedimentary clastic rocks (metamorphosed)

As	Sedimentary rock, undivided; includes sandstone, siltstone, shale, and chert; may have volcaniclastic component
Asc	Conglomerate with subordinate sandstone; pebbles and boulders include granitoid, chert, felsic porphyry, and mafic rock; matrix or clast supported
Ascb	Conglomerate and subordinate pebbly sandstone with gabbro and basalt clasts
Ascf	Oligomictic conglomerate with clasts mainly of felsic volcanic rock; subordinate sandstone; psammitic matrix
Ascfi	Volcaniclastic conglomerate, sandstone, and tuff with dominantly andesite clasts
Ascq	Oligomictic conglomerate with clasts mainly of quartz, quartzite, and chert
Asf	Volcaniclastic, tuffaceous, and other felsic sedimentary rocks; foliated; commonly deeply weathered and kaolinized
Ash	Shale–slate, in part chert; minor siltstone and sandstone; foliated; commonly silicified
Asjc	JONES CREEK CONGLOMERATE: conglomerate and sandstone; dominantly granitoid clasts in quartzofeldspathic matrix
Asjcp	JONES CREEK CONGLOMERATE: polymictic conglomerate
Asjct	JONES CREEK CONGLOMERATE: arkosic sandstone, fine to medium grained; rare pebbles
Asq	Medium-grained quartzite; locally quartz siltstone and quartz–muscovite schist
Ass	Sandstone to siltstone, locally partly conglomerate
Ast	Sandstone; locally pebbly, volcaniclastic or pelitic
Astf	Arkose

Felsic igneous rocks (metamorphosed)

Af	Felsic volcanic and volcaniclastic rocks; undivided; includes tuff; commonly deeply weathered and kaolinized
Afd	Dacite; commonly tuffaceous; locally brecciated
Aff	Foliated felsic rock
Afid	Andesite
Afih	Hornblende–plagioclase porphyry; felsic to intermediate
Afis	Intermediate hornblende–biotite–quartz–feldspar(–garnet) schist; variable hornblende content; interlayered with felsic and mafic schists
Afiv	Intermediate volcanic rock; local fragmental textures; variably foliated and chloritized; local intermediate schist and lithic wacke interlayers
Afivf	Foliated intermediate volcanic rock; hornblende-phyric
Afivh	Intermediate volcanic rock and breccia; plagioclase, hornblende and biotite phenocrysts, and local lithic fragments, in a fine-grained matrix
Afp	Feldspar–quartz porphyry; dacite to rhyodacite; volcanic or subvolcanic; locally schistose
Afpp	Felsic intrusive porphyritic rock; plagioclase phenocrysts; locally schistose
Afpq	Quartz–feldspar porphyry; weak to schistose foliation
Afr	Rhyolite lava flows, quartz-phyric, locally tuffaceous; weak to schistose foliation
Afrtx	Rhyolitic to rhyodacitic tuff and oligomictic breccia; massive to poorly bedded, with lithic clasts (>1 cm) in fine-grained to glassy matrix; includes some Afv
Afrkx	Mixed rhyolitic and trachytic tuff and oligomictic breccia
Afs	Schistose quartzofeldspathic micaceous rock derived from felsic volcanic or volcaniclastic protolith
Aft	Felsic tuffaceous rock; finely banded; foliated; fine to medium grained; quartz and feldspar phenocrysts
Aftn	Ignimbrite
Afv	Felsic volcanic and volcaniclastic rocks; quartz and/or feldspar phenocrysts; includes fragmental rock and finely layered tuff; variably foliated

Mafic extrusive rocks (metamorphosed)

Ab	Fine- to very fine grained mafic rock, undivided
Aba	Amphibolite, fine to medium grained; commonly weakly foliated or massive
Abc	Fine-grained mafic rock, strongly carbonatized, locally amygdaloidal
Abd	Basalt–dolerite; fine-grained basalt with common dolerite-textured layers or zones
Abf	Foliated fine-grained mafic rock; locally hornfelsed or epidotized
Abfv	Bimodal volcanic sequence; basalt with interlayers of rhyolite or dacite
Abg	Mafic rock interleaved with minor foliated granitoid rock
Abi	Basaltic andesite and andesite; amygdaloidal; locally plagioclase and/or hornblende phyric
Abk	Komatiitic basalt; pyroxene spinifex common; variolitic, pillowed locally
Abmf	Foliated high-Mg basalt
Abv	Basalt, undivided; includes feldspar–hornblende or chlorite schist; locally porphyritic; doleritic in parts
Abva	Basalt, aphyric
Abvc	Basalt, extensively carbonatized; includes massive carbonate lenses

Abvl	Pillow basalt; flow-top breccia with varioles or spinifex locally
Abvp	Porphyritic basalt; medium- to coarse-grained plagioclase phenocrysts; local intense epidotization
Abvs	Fine-grained schist derived from basalt; amphibole–chlorite assemblages; locally strongly metasomatized
Abvx	Basaltic fragmental rock; agglomerate, hyaloclastite peperite or breccia
Abvy	Amygdaloidal basalt

Ultramafic rocks (metamorphosed)

Au	Ultramafic rock, undivided; includes talc–chlorite(–carbonate) and tremolite–chlorite schist
Auc	Talc–carbonate(–serpentine) rock; commonly schistose
Auk	Komatiite; olivine spinifex texture; tremolite–chlorite, serpentinite, carbonate assemblages; silicified or weathered
Aup	Peridotite, commonly serpentinitized; relict olivine-cumulate texture; locally rodingitized or silicified
Aur	Tremolite(–chlorite–talc–carbonate) schist; locally serpentinized; derived from komatiitic or pyroxenitic basalt or pyroxenite
Aus	Serpentinite, commonly massive
Aut	Talc–chlorite(–carbonate) schist; minor tremolite–chlorite schist
Aux	Pyroxenite; commonly associated with peridotite in minor layered sills; variably tremolitized, locally schistose

Codes for simplified geology polygons

P	Predominantly clastic sediments
P_XX(od)	Dolerite dyke, sill, and plug; fine- to medium-grained dolerite
P_XXwe	Mount Weld Carbonitite
AYI(b)	Mafic volcanic rocks with minor mafic and ultramafic intrusive rocks; minor felsic rocks
AYI(bg)	Mafic rock interleaved with minor granitoid rock
AYI(bm)	Ultramafic volcanic rock; komatiitic basalt; high-Mg basalt; and tremolite–chlorite–talc schist
AYI(ci)	Banded iron-formation and chert; undivided
AYI(f)	Felsic to intermediate volcanic and volcanogenic rocks; undivided
AYI(fs)	Felsic volcanogenic sedimentary rocks; local felsic lava and tuff
AYI(g)	Granitoid rock; monzogranite dominant
AYI(gb)	Granitoid rock interleaved with minor mafic rock
AYI(gg)	Granodiorite
AYI(gm)	Monzogranite (adamellite)
AYI(gn)	Foliated; gneissic; and migmatitic granitoid
AYI(gs)	Syenogranite
AYI(gt)	Tonalite
AYI(gzq)	Quartz monzonite
AYI(iv)	Intermediate volcanic rock
AYI(ng)	Monzogranitic to tonalitic gneiss
AYI(nq)	Quartzofeldspathic gneiss
AYI(o)	Metamorphosed mafic intrusive rock; metagabbro and metadolerite
AYI(od)	Mafic intrusive rock; metadolerite
AYI(og)	Mafic intrusive rock; metagabbro
AYI(s)	Metasedimentary rock dominant
AYI(sc)	Metamorphosed conglomerate
AYI(sv)	Sedimentary and volcaniclastic rocks
AYI(u)	Metamorphosed ultramafic rock dominant
AYI(uk)	Komatiite; minor basalt; dolerite; and sedimentary rock
AYI(up)	Peridotite; commonly serpentinized; olivine-cumulate texture
AYI(xsf)	Interbedded sedimentary and felsic volcanic rocks

Codes for the magnetic interpretation

-PicM	Mount Weld carbonatite
Aa	Greenstone, undivided
Aa/Ag	Greenstone, undivided
Aa/Agmg	Greenstone, undivided
Ag_h	Granite; high magnetization
Ag_l	Granite; low magnetization
Ag_l/Aa	Granite; low magnetization
Ag_m	Granite; medium magnetization
Ag_m/Aa	Granite; medium magnetization
Agmg	Gneiss–migmatite–granite, undivided
Agmg_l	Gneiss–migmatite–granite; low magnetization
Agmg_m	Gneiss–migmatite–granite; medium magnetization
Agn	Granitoid gneiss / strongly deformed granite
Ai_h	Intrusive rock, unassigned; high magnetization
Ai_m	Intrusive rock, unassigned; medium magnetization
Ai_r	Intrusive rock, unassigned; remanent magnetism
Aogi	Layered intrusion

Appendix 2

MINEDEX commodity groups, mineralization types, and reference abbreviations

Commodity groups and minerals

Note: Mineral order represents the sequence of relative importance within the specific commodity group. Contaminant or gangue minerals in potential products have an order of 500 or greater.

Commodity group	*Order*	*Mineral*	*Mineral abbrev.*
Alunite	10	Alunite	ALUM
	20	Potash	K_2O
	30	Gypsum	$CaSO_4$
Andalusite	10	Andalusite	AND
Antimony	10	Antimony	Sb
Arsenic	10	Arsenic	As
Asbestos	10	Asbestos	ASB
Barite	10	Barite	$BaSO_4$
Bauxite–alumina	10	Alumina (available)	ABEA
	20	Bauxite	BAUX
	500	Reactive silica	$RESIO_2$
Bismuth	10	Bismuth	Bi
Chromite–platinoids	10	Chromite	Cr_2O_3
	20	Platinum	Pt
	25	Palladium	Pd
	31	Rhodium	Rh
	40	PGE	PGE
	50	PGE + gold	PGEAu
	55	Gold	Au
	60	Nickel	Ni
	70	Copper	Cu
	100	Iron	Fe
Clays	10	Attapulgite	ATTAP
	20	Bentonite	BENT
	30	Kaolin	KAOLIN
	35	Saponite	SAPON
	40	Cement clay	C.CLAY
	60	White clay	W.CLAY
Coal	10	Coal	COAL
	20	Lignite	LIGN
Construction materials	10	Aggregate	AGGREG
	20	Gravel	GRAVEL
	30	Sand	SAND
	40	Rock	ROCK
	50	Soil	SOIL
	300	Vanadium	V_2O_5
	310	Titanium dioxide	TiO_2
	320	Iron	Fe
Copper–lead–zinc	10	Zinc	Zn
	20	Copper	Cu
	30	Lead	Pb
	40	Silver	Ag
	50	Gold	Au
	60	Molybdenum	Mo
	65	Cobalt	Co
	70	Barium	Ba
	80	Cadmium	Cd
	90	Tungsten	WO_3
Diamonds	10	Diamond	DIAM
Diatomite	10	Diatomite	DIATOM
Dimension stone	10	Dimension stone	DIM.ST
	20	Sandstone	SST
	30	Quartzite	QZTE
	40	Limestone	LST
	50	Black granite	B.GRAN
	55	Granite	GRAN
	60	Marble	MARBLE
	70	Dolerite	DOLER
	80	Slate	SLATE
	90	Spongolite	SPONG
Dolomite	10	Dolomite	DOLOM
Fluorite	10	Fluorite	CaF_2
Gem, semi-precious and ornamental stones	10	Amethyst	AMETH
	20	Emerald	EMER
	30	Opal	OPAL
	32	Tourmaline	TOURM
	35	Chrysoprase	CHRYSP
	37	Malachite	MALACH
	40	Tiger eye	T.EYE
	45	Jasper	JASPER
	50	Zebra rock	ZEBRA
	60	Chert (green)	CHERT
Gold	10	Gold	Au
	20	Silver	Ag
	30	Copper	Cu
	40	Nickel	Ni
	50	Cobalt	Co
	54	Lead	Pb
	55	Zinc	Zn
	60	Tungsten	WO_3
	70	Molybdenum	Mo
	500	Antimony	Sb
	510	Arsenic	As
Graphite	10	Graphite	GRAPH
	20	Carbon (fixed)	C
Gypsum	10	Gypsum	$CaSO_4$
	30	Alunite	ALUM
	500	Salt	SALT
Heavy mineral sands	10	Heavy minerals	HM
	20	Ilmenite	ILM
	30	Leucoxene	LEUCO
	50	Rutile	RUTILE
	60	Zircon	ZIRCON
	70	Monazite	MONAZ
	80	Xenotime	XENO
	90	Garnet	GARNET
	100	Kyanite	KYAN
	130	Synthetic rutile	SYN.R
	510	Slimes	SLIMES
	520	Titanium dioxide	TiO_2
	530	Zirconia	ZrO_2
Industrial pegmatite minerals	10	Mica	MICA
	20	Beryl	BERYL
	30	Feldspar	FELDS
	35	Alkalis	K+Na
	37	Alumina	Al_2O_3

Commodity groups and minerals (continued)

Commodity group	*Order*	*Mineral*	*Mineral abbrev.*
	40	Quartz	QUARTZ
	505	Ferric oxide	Fe_2O_3
Iron ore	10	Iron	Fe
	20	Manganese	Mn
	500	Phosphorus	P
	510	Alumina	Al_2O_3
	520	Silica	SiO_2
	525	Sulfur	S
	530	Loss on ignition	LOI
Limestone–limesand	10	Calcium carbonate	$CaCO_3$
	20	Limestone–limesand	LIME
	50	Shell grit	SHELL
	70	Chalk	CHALK
	100	Lime	CaO
	200	Magnesite	$MgCO_3$
	501	Silica	SiO_2
Magnesite	10	Magnesite	$MgCO_3$
	10	Manganese	Mn
	100	Iron	Fe
	510	Silica	SiO_2
	520	Alumina	Al_2O_3
	530	Phosphorus	P
Nickel	10	Nickel	Ni
	20	Copper	Cu
	25	Cobalt	Co
	30	Nickel + copper	Ni+Cu
	35	Nickel equivalent	Ni EQU
	40	Gold	Au
	50	Platinum	Pt
	55	Palladium	Pd
	70	Chromite	Cr_2O_3
	80	Silver	Ag
	90	Magnesia	MgO
	500	Silica	SiO_2
Other	10	Gold	Au
Peat	10	Peat	PEAT
Phosphate	10	Phosphate	P_2O_5
Pigments	10	Ochre	OCHRE
	20	Hematite pigment	HEM
Potash	10	Potash	K_2O
	10	Sulfur	S
	20	Iron	Fe
	30	Zinc	Zn
	40	Copper	Cu

Commodity group	*Order*	*Mineral*	*Mineral abbrev.*
	50	Lead	Pb
Rare earths	10	Rare earth oxides	REO
	20	Yttrium	Y_2O_3
	25	Lanthanides	LnO
	30	Tantalite	Ta_2O_5
	40	Columbite	Nb_2O_5
	50	Tin (cassiterite)	SnO_2
	60	Xenotime	XENO
	70	Gallium	Ga
	80	Zirconia	ZrO_2
	90	Hafnium	HfO_2
	100	Beryl	BERYL
	510	Alumina	Al_2O_3
Salt	10	Salt	SALT
	20	Gypsum	$CaSO_4$
Silica – silica sand	10	Silica	SiO_2
	20	Sand	SAND
	30	Quartzite	QZTE
	510	Ferric oxide	Fe_2O_3
	520	Titanium dioxide	TiO_2
	530	Alumina	Al_2O_3
	540	Heavy minerals	HM
Talc	10	Talc	TALC
Tin–tantalum–lithium	10	Tin (cassiterite)	SnO_2
	20	Tantalite	Ta_2O_5
	30	Columbite	Nb_2O_5
	40	Spodumene	Li_2O
	50	Kaolin	KAOLIN
	510	Ferric oxide	Fe_2O_3
Tungsten–molybdenum	10	Tungsten	WO_3
	20	Molybdenum	Mo
	30	Copper	Cu
	40	Antimony	Sb
	50	Vanadium	V_2O_5
	60	Gold	Au
Uranium	10	Uranium	U_3O_8
	20	Vanadium	V_2O_5
	30	Copper	Cu
Vanadium–titanium	10	Vanadium	V_2O_5
	20	Titanium dioxide	TiO_2
	30	Iron	Fe
	40	Gold	Au
Vermiculite	10	Vermiculite	VERMIC

Mineralization types

Abbreviation	*Mineralization type*
ALLAKE	Alunite in lake sediments
ANDSED	Andalusite in metasedimentary rocks
ASBAMP	Metasomatic asbestos deposits in amphibolites
ASBBIF	Asbestos deposits in banded iron-formations
ASBDLM	Asbestos deposits in dolomite intruded by dolerite
ASBSER	Asbestos deposits in serpentinites
ASBUM	Asbestos veins in ultramafic rocks
ASMASS	Stratiform massive arsenopyrite in metasediments
ASQTZV	Arsenic associated with auriferous quartz veins
AUALL	Alluvial–eluvial gold deposits
AUBIF	Gold in banded iron-formation and related sediments
AUCONG	Gold in conglomerate within greenstones
AUEPI	Epigenetic gold deposits in Precambrian terrains
AUFVOL	Felsic volcanic rocks and/or volcanogenic sediments containing auriferous quartz veins and/or shear zones
AUGRAN	Gold deposits along granite–greenstone contacts and in granitoid rocks
AULAT	Lateritic gold deposits
AUPLAC	Precambrian placer gold deposits
AUPOR	Gold associated with felsic porphyry within greenstones
AUSHER	Basalt and/or dolerite containing auriferous quartz veins along faults or shear zones
AUSTOK	Dolerite or gabbro containing auriferous quartz stockworks or veins
AUSYN	Syngenetic gold deposits in Precambrian terrains
AUUM	Gold deposits in ultramafic rocks
BABED	Stratabound bedded barite deposits
BACAV	Vein and cavity-fill deposits
BAPEGM	Pegmatite-hosted barite deposits
BAUKAR	Karstic bauxite deposits
BAULAT	Lateritic bauxite deposits
BIPEGM	Bismuth in quartz-rich pegmatites
BIQTZV	Bismuth associated with gold mineralization
BMMASS	Volcanogenic Cu–Zn deposits
BMMISS	Mississippi Valley-type Pb–Zn deposits
BMPOR	Porphyry Cu–Mo deposits
BMSED	Sedimentary Cu–Pb–Zn deposits
BMSHER	Base metal deposits in quartz veins and/or shear zones
CADUNE	Limesand in coastal dune sands
CALAKE	Calcareous material in lake sediments
CALIME	Limestone deposits
CASEA	Offshore limesand deposits
CLBED	Bedded sedimentary clay deposits
CLRES	Residual clay deposits
CLTRAN	Transported clay deposits
COJSBT	Jurassic sub-bituminous coal
COLIGN	Eocene lignite deposits
COPBIT	Permian bituminous coal
COPSBT	Permian sub-bituminous coal
CRLAT	Lateritic chromium deposits
CRPGLY	Platinum group elements and/or chromium in layered mafic–ultramafic intrusions
CRPGUM	Platinum group elements and/or chromium in metamorphosed mafic–ultramafic rocks
DIAALL	Alluvial–eluvial diamond deposits
DIALAM	Lamproitic diamond deposits
DLMBED	Dolomite deposits in sedimentary sequences
DLMKAN	Residual kankar (dolomite) deposits
DLMLAK	Dolomite deposits associated with lake sediments
DLMSOM	Metasomatic dolomite deposits
DTMLAK	Diatomaceous lake deposits
FEBIF	Primary banded iron-formation deposits

Abbreviation	*Mineralization type*
FEBR	Iron ore deposits in the Brockman Iron Formation
FEGGT	Iron ore deposits in granite–greenstone terranes
FEMM	Iron ore deposits in the Marra Mamba Iron Formation
FEPIS	Pisolitic iron-ore deposits
FESCRE	Scree and detrital iron-ore deposits
FESED	Sedimentary basin iron-ore deposits
FGRAN	Fluorite deposits associated with granitic rocks
FPEGM	Pegmatite-hosted fluorite deposits
FVEIN	Vein fluorite deposits
GEMMET	Gem and/or semi-precious stones in high-grade metamorphic rocks
GEMPEG	Pegmatite-hosted gem and/or semi-precious stones
GEMSED	Sediment-hosted gem and/or semi-precious stones
GEMUM	Ultramafic-hosted gem and/or semi-precious stones
GEMVOL	Gem and/or semi-precious stones in volcanic rocks
GRMETA	Graphite deposits in metamorphic rocks
GRPEG	Pegmatite-hosted graphite deposits
GRQTZV	Graphite deposits in quartz veins
GRUM	Graphite as segregations in ultramafic rocks
GYBBAS	Gypsum in coastal barred-basin deposits
GYDUNE	Dunal gypsum deposits
GYLAKE	Gypsum in lake sediments
HMSCAP	Heavy mineral deposits in the Capel shoreline
HMSDON	Heavy mineral deposits in the Donnelly shoreline
HMSDUN	Heavy mineral deposits in the Quindalup shoreline
HMSEN	Heavy mineral deposits in the Eneabba shoreline
HMSGIN	Heavy mineral deposits in the Gingin shoreline
HMSHV	Heavy mineral deposits in the Happy Valley shoreline
HMSMES	Heavy mineral deposits in Mesozoic formations
HMSMIL	Heavy mineral deposits in the Milyeaanup shoreline
HMSMIS	Heavy mineral deposits — miscellaneous
HMSMUN	Heavy mineral deposits in the Munbinea shoreline
HMSWAR	Heavy mineral deposits in the Warren shoreline
HMSWRN	Heavy mineral deposits in the Waroona shoreline
HMSYOG	Heavy mineral deposits in the Yoganup shoreline
KBRINE	Potash deposits in brines and surface evaporites
KEVAP	Potash deposits in buried evaporite sequences
KGLAUC	Potash in glauconitic sediments
KLAKE	Potash associated with lake sediments
MGUM	Mafic–ultramafic rocks
MNCAV	Joint–cavity-fill manganese deposits
MNRES	Residual manganese deposits
MNSED	Sedimentary manganese deposits
MNSUPR	Precambrian supergene enrichment of manganiferous sediments
MOPOR	Porphyry Cu–Mo deposits
NABRIN	Salt in brines and surface evaporites
NAVAP	Salt deposits in buried evaporite sequences
NIINTR	Nickel in dunite phase of thick komatiite flows
NILAT	Lateritic nickel deposits
NISED	Nickel deposits in metasedimentary rocks
NITHOL	Nickel deposits in the gabbroic phase of layered tholeiites
NIVEIN	Vein-type nickel deposits
NIVOLC	Nickel associated with volcanic peridotites
PCARB	Carbonatite-hosted phosphate deposits
PEGPEG	Pegmatite-hosted industrial minerals
PGALL	Alluvial–eluvial platinoid deposits
PGUANO	Quaternary guano (phosphate) deposits
PIGHEM	Specular hematite pigment
PNOD	Seafloor (nodular) phosphate deposits
PSED	Phosphate deposits in Phanerozoic sediments

Mineralization types (continued)

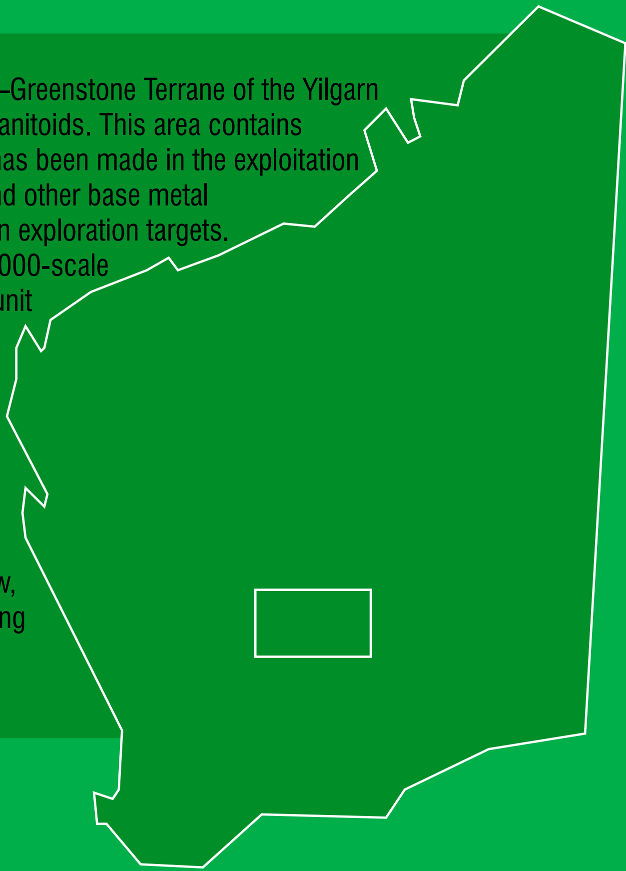
Abbreviation	*Mineralization type*
PVEIN	Vein phosphate deposits
REALL	Alluvial–eluvial rare earth deposits
RECARB	Carbonatite-hosted rare earth deposits
REFELS	Felsic volcanic-hosted rare earth deposits
REHMS	Rare earths in heavy mineral sands
REPPEG	Pegmatite-hosted rare earth deposits
RESST	Xenotime in sandstones
SBQTZV	Antimony associated with auriferous quartz veins
SIDUNE	Mesozoic dune and bedded silica sands
SIQTZ	Silica in vein quartz
SIQZTE	Silica in quartzite or chert or both
SMASS	Sulfur in massive sulfides
SNALL	Alluvial–eluvial tin–tantalum deposits
SNGREI	Tin–tantalum deposits in greisen zones
SNPEGM	Pegmatite tin–tantalum–lithium deposits
SNVEIN	Vein tin–tantalum deposits
SSEDQZ	Sulfur in sediments and/or quartz veins
TALDLM	Talc deposits associated with dolomite
TALUM	Talc deposits in ultramafic rocks

Abbreviation	*Mineralization type*
UCALC	Calcrete-related uranium deposits
UCAV	Secondary (cavity-fill) vein-like uranium deposits
UCONG	Conglomerate-hosted deposits
ULIGN	Lignite-hosted uranium deposits
UPEG	Pegmatite-hosted uranium deposits
USST	Sandstone-hosted uranium deposits
UUNCF	Unconformity-related uranium deposits
UVEIN	Uranium in veins associated with base metals
VCALC	Calcrete-related vanadium deposits
VERUM	Vermiculite deposits associated with weathered mafic and ultramafic bodies
VTIALL	Alluvial–eluvial vanadium–titanium deposits
VTILAT	Lateritic vanadium–titanium deposits
VTIMAG	Titaniferous magnetite deposits
VTIVN	Vanadium–titanium vein deposits associated with base metals
WMOGRE	Tungsten–molybdenum deposits in greisen zones
WMOPEG	Pegmatite tungsten–molybdenum deposits
WSKARN	Tungsten–molybdenum skarn deposits

Abbreviations of source references

Source	*Full title*
02208/93	Department of Industry and Resources (DoIR) mines file number
?	Unknown source
A_______	Accession number of open-file statutory mineral exploration report in DoIR library
AIMM PRO	Australasian Institute of Mining and Metallurgy Proceedings
AMH	Australian Mining Handbook
AMIQ	Australian Mineral Industries Quarterly
AR(CO)	Annual Report to Shareholders (abbreviated company name)
ASX(CO)	Report to Shareholders (abbreviated company name)
AUSIMM	Australasian Institute of Mining and Metallurgy Report
AUSIMM14	Australasian Institute of Mining and Metallurgy Bulletin and number
BHP	BHP correspondence
BMR	Bureau of Mineral Resources Report
BMR RR 1	Bureau of Mineral Resources Resource Report and number
BMR59/24	Bureau of Mineral Resources Record and number
BULL(NO)	Geological Survey of Western Australia (GSWA) Mineral Resource Bulletin (and number)
CO CORR/REP	Company report to shareholders
CO(CO)	Company report to shareholders (abbreviated company name)
CSIROPUB	CSIRO publication
DN	Daily News newspaper
EMP(NO)	Environmental management report (and number)
ER	Open-file statutory mineral exploration report in DoIR library
ERMP	Environmental Review and Management Program
F.NOTE	DoIR file note
FR	Financial Review newspaper
GG	Gold Gazette
GS BULL	GSWA Bulletin
GS REP	GSWA Report
GSWA AR	GSWA Annual Report
HI CORR/REP	Hamersley Iron correspondence or report
HOGAN	Hogan and Partners Investor's Sharewatch
HOMESWES	Homeswest report
HY(CO)	Half year report to shareholders (abbreviated company name)
I(NO)	Item number of open-file statutory mineral exploration report in DoIR library
IND MIN	Industrial Minerals magazine
KAL MIN	Kalgoorlie Miner newspaper
M(NO)	M number of open-file statutory mineral exploration report in DoIR library
MB SYMP	Metals Bulletin Symposium
MEM 3	GSWA Memoir and number
MG	Metals Gazette
MINER	Miner
MINMET	MINMET report
MJ	Mining Journal
MM	Mining Monthly
MRR(NO)	GSWA Mineral Resources Report (number)
NOI(NO)	Notice of Intent to mine (number)
PAYD	Paydirt
PER	Public Environmental Review
PERS COM	Personal communication
PRO(CO)	Company prospectus (abbreviated company name)
QR(CO)	Quarterly report to shareholders (abbreviated company name)
REC(NO)	GSWA Record (number)
REP 33	GSWA Report (number)
ROY REP	DoIR Royalty Report
STAT DEC	Statutory Declaration submitted to DoIR
WEST A	The West Australian newspaper

The Leonora–Laverton area in the Eastern Goldfields Granite–Greenstone Terrane of the Yilgarn Craton comprises a diverse range of greenstone belts and granitoids. This area contains several world-class gold mines, and considerable progress has been made in the exploitation of large nickel laterite deposits. Deposits of nickel sulfides and other base metal mineralization have been of great value in the past and remain exploration targets. This Report provides a digital compilation of eighteen 1:100 000-scale geological map sheets published in the last ten years. Rock unit definitions established in earlier stages of the East Yilgarn Geoscience Database combined with remapping of local areas has produced a seamless digital map covering an area of almost 50 000 km^2, accompanied by interpreted regional geology and an aeromagnetic interpretation, as well as mineral occurrence, tenement and topocadastral themes. Images produced from recent LandsatTM and magnetic survey data are also provided. Files are formatted for ArcView, ArcINFO, and Mapinfo software, but may also be viewed using the free software provided on the disc, ArcExplorer.



Further details of geological publications and maps produced by the Geological Survey of Western Australia can be obtained by contacting:

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www.doir.wa.gov.au

PAINTER et al.   **East Yilgarn Geoscience Database, 1:100 000 geology of the Leonora–Laverton region, Eastern Goldfields Granite–Greenstone Terrane — an explanatory note**   **REPORT 84**