Department of
Industry and Resources

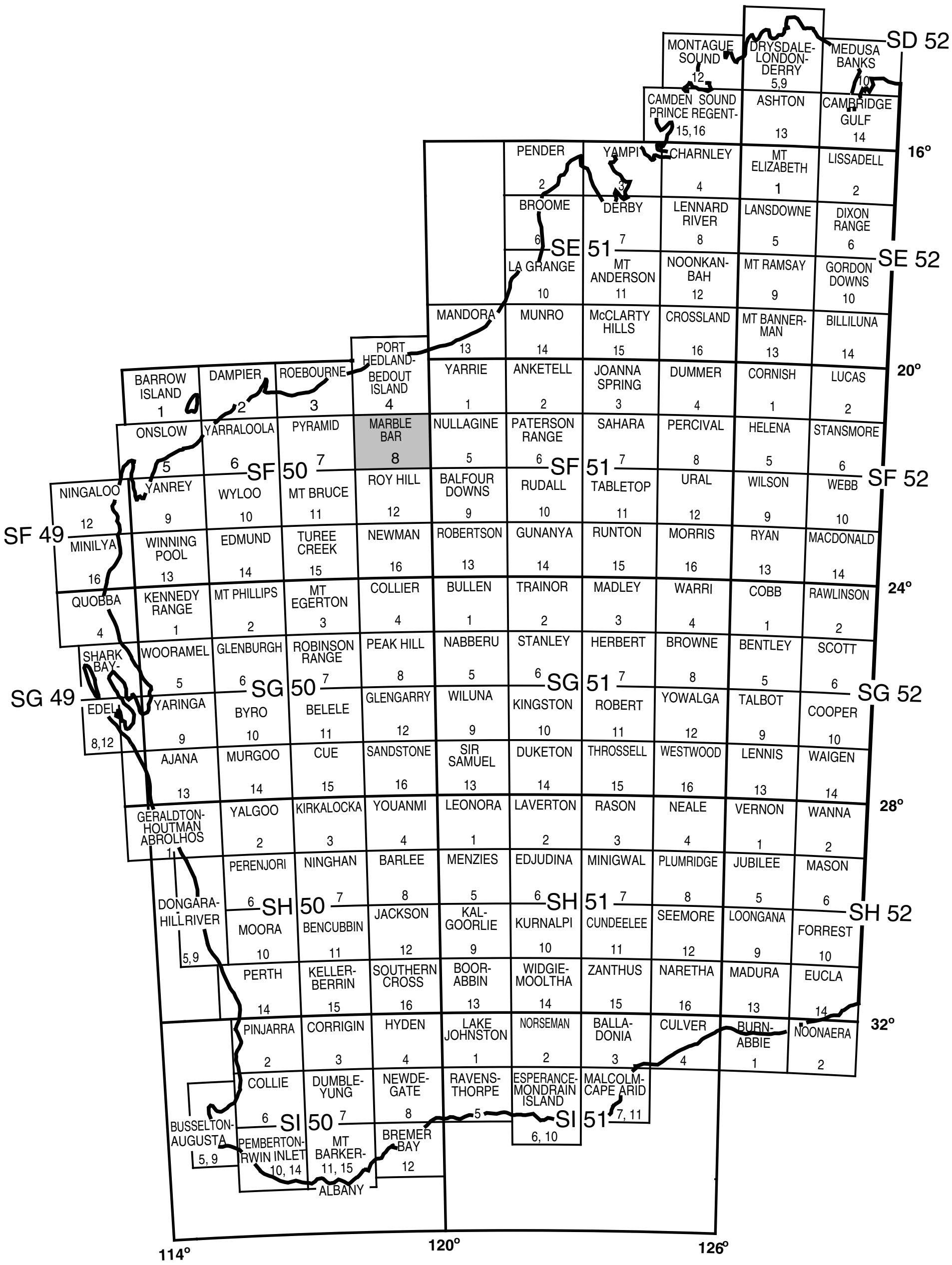
EXPLANATORY NOTES

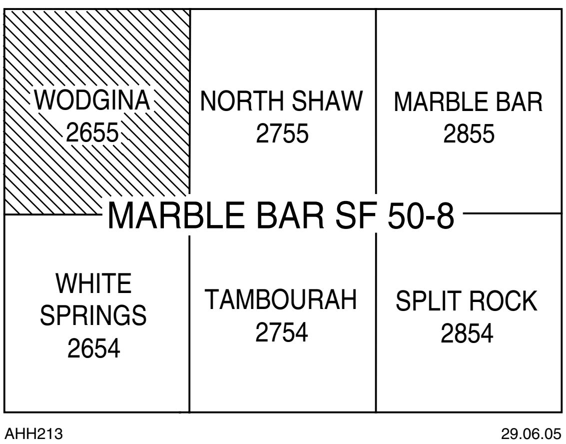
GEOLOGY OF THE WODGINA 1:100 000 SHEET

by R. S. Blewett and D. C. Champion

1:100 000 GEOLOGICAL SERIES

Geological Survey of Western Australia





AHH213

29.06.05

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE WODGINA 1:100 000 SHEET

by
R. S. Blewett[1] and D. C. Champion[1]

[1] Geoscience Australia, GPO Box 378, Canberra, ACT 2601

Perth 2005

MINISTER FOR STATE DEVELOPMENT
Hon. Alan Carpenter MLA

DIRECTOR GENERAL, DEPARTMENT OF INDUSTRY AND RESOURCES
Jim Limerick

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Tim Griffin

REFERENCE
The recommended reference for this publication is:
BLEWETT, R. S., and CHAMPION, D. C., 2005, Geology of the Wodgina 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

National Library of Australia Card Number and ISBN 1 74168 015 8

ISSN 1321–229X

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 50. All locations are quoted to at least the nearest 100 m.

Copy editor: D. P. Reddy
Cartography: D. Sutton
Desktop publishing: K. S. Noonan

Published 2005 by Geological Survey of Western Australia
This Explanatory Note is published in digital format (PDF) and is available online at www.doir.wa.gov.au/gswa/onlinepublications. Laser-printed copies can be ordered from the Information Centre for the cost of printing and binding.

Further details of geological publications and maps produced by the Geological Survey of Western Australia are available from:
Information Centre
Department of Industry and Resources
100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
Telephone: +61 8 9222 3459 Facsimile: +61 8 9222 3444
www.doir.wa.gov.au/gswa/onlinepublications

Cover photograph:
Upright F_3 folds in banded iron-formation in the western part of the Wodgina greenstone belt on WODGINA (MGA 672890E 7653890N).

Contents

Appendix

Figures

Tables

Geology of the Wodgina 1:100 000 sheet

by

R. S. Blewett[1] and D. C. Champion[1]

Abstract

The WODGINA 1:100 000 sheet lies in the northern part of the Pilbara Craton, in the western part of the well-exposed East Pilbara Granite–Greenstone Terrane (EPGGT). Apart from thin Cenozoic regolith cover, WODGINA is entirely underlain by Archean rocks, including volcanic, sedimentary, and mafic–ultramafic intrusive rocks of the Pilbara and De Grey Supergroups, and a variety of granitic rocks in two major granitic complexes (Carlindi and Yule Granitoid Complexes).

All four groups of the Pilbara Supergroup outcrop on WODGINA: the c. 3515–3425 Ma Warrawoona Group, the 3350–3315 Ma Kelly Group, the c. 3255–3235 Ma Sulphur Springs Group, and the undated, but older-than-c. 3000 Ma, Gorge Creek Group. On a regional scale the c. 2950–2940 Ma De Grey Supergroup comprises a number of clastic groups that unconformably overlie the Pilbara Supergroup.

The predominantly volcanic Coonterunah Subgroup of the Warrawoona Group is subdivided into the Table Top, Coucal, and Double Bar Formations, and is unconformably overlain by rocks of the Kelly Group, which on WODGINA is composed of the Strelley Pool Chert and the Euro Basalt.

The unassigned Golden Cockatoo Formation is locally preserved as infolded remnants of shelf-type supracrustal rocks in the Yule Granitoid Complex, and is separated from the basal parts of the Sulphur Springs Group by a shear zone. The Sulphur Springs Group, which locally unconformably overlies the Warrawoona Group, is subdivided from base to top into the Leilira, Kunagunarrina and Kangaroo Caves Formations. The Gorge Creek Group includes the clastic and chemical sedimentary rocks (banded iron-formation) of the Pincunah Hill Formation, and clastic metasedimentary rocks of the Corboy Formation. The De Grey Supergroup outcrops in the Pilbara Well greenstone belt on northwestern WODGINA, where it is locally represented by the Croydon Group of the Mallina Basin.

The Carlindi and Yule Granitoid Complexes are multicomponent units with intrusive, sheared intrusive, or tectonic contacts with surrounding greenstones. A major gravity low centred over the Yule Granitoid Complex is caused by a rock mass of at least 100 km in diameter and up to 14 km deep.

WODGINA contains a variety of economic, subeconomic, and prospective mineral deposits. Historically, the most prominent mining activity was for epigenetic gold in the Lynas Find – Mount York mining centre. Recently there has been a major redevelopment of the old Wodgina tin mining area, and the Wodgina mine is now one of the largest tantalum mines in the world. Numerous other tin–tantalum prospects are widespread across the sheet area, but most are considered to be subeconomic.

KEYWORDS: Archean, Pilbara Craton, Pilbara Supergroup, East Pilbara Granite–Greenstone Terrane, structural evolution, gold, tantalum, tin.

Introduction

The WODGINA* 1:100 000 sheet (SF 50-8, 2655), bound by latitudes 21°00' and 21°30'S and longitudes 118°30' and 119°00'E (Fig. 1), lies within the northwestern part of the MARBLE BAR 1:250 000 sheet (SF 50-8), and is in the East Pilbara Mineral Field.

WODGINA is underlain by folded and metamorphosed, early to middle Archean (c. 3.51–2.83 Ga) volcanic, sedimentary, and granitic rocks that are in the eastern part of the East Pilbara Granite–Greenstone Terrane (EPGGT; Fig. 1). Most of the supracrustal rocks (‘greenstones’) are assigned to the Pilbara Supergroup (Hickman, 1983). On the WODGINA 1:100 000 map (Blewett et al., 2001) the greenstone succession is subdivided into five groups (the Coonterunah, Warrawoona, Sulphur Springs, Gorge Creek, and De Grey Groups) following the lithostratigraphic nomenclature of Van Kranendonk (1998, 2000). A recent regional revision of the stratigraphy of the northern Pilbara

[1] Geoscience Australia, GPO Box 378, Canberra, ACT 2601.

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

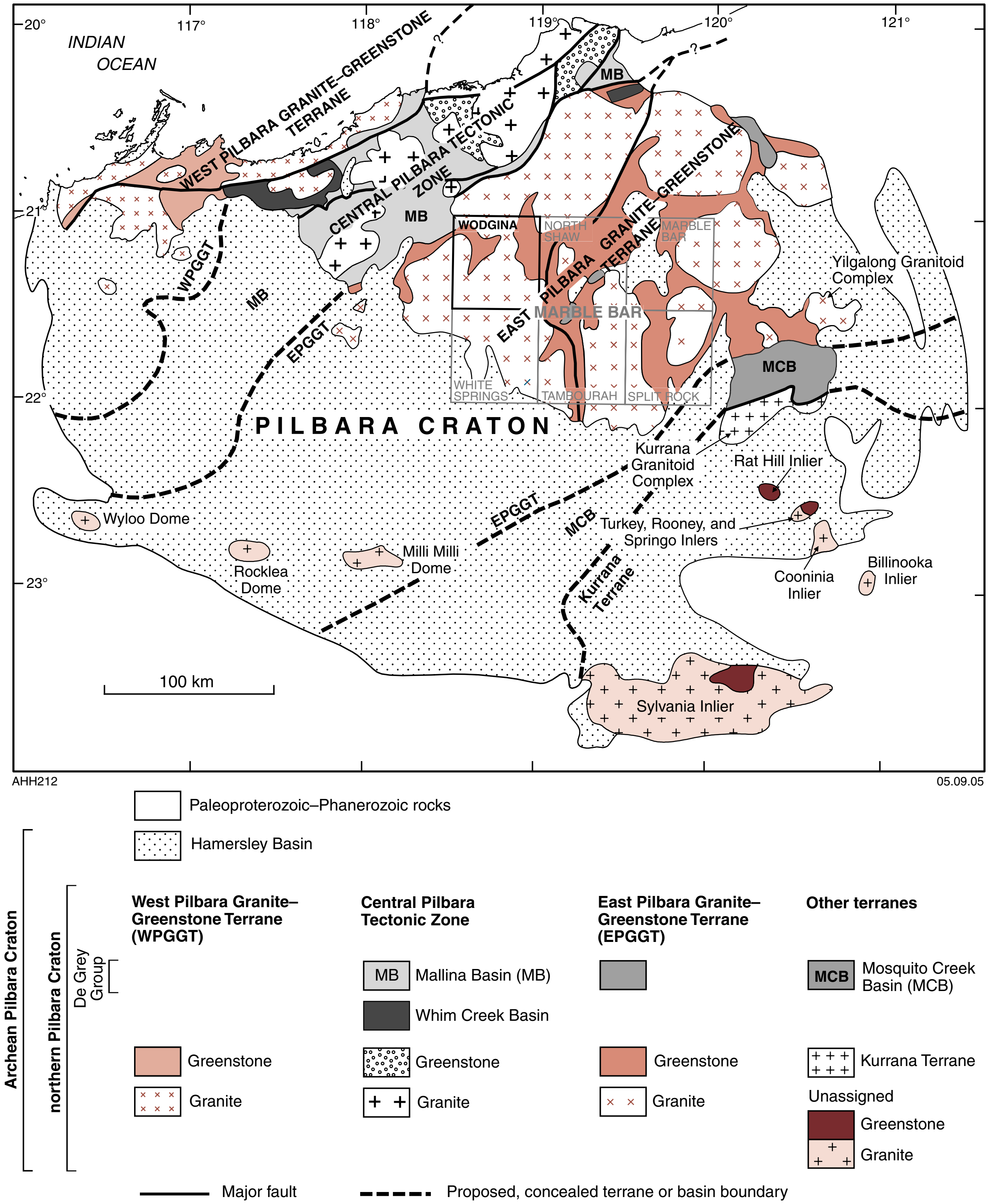


Figure 1. Regional geological setting of WODGINA within the Pilbara Craton

Craton (Van Kranendonk et al., 2004) resulted in the Coonterunah Group being reclassified as a subgroup of the Warrawoona Group. Additionally, the upper part of the Warrawoona Group on WODGINA (comprising the Strelley Pool Chert and Euro Basalt) is now assigned to the Kelly Group. The Kelly Group is unconformably overlain by the Sulphur Springs and Gorge Creek Groups. In the stratigraphic revision by Van Kranendonk et al. (2004) the De Grey Group is excluded from the Pilbara Supergroup, and is reclassified as the De Grey Supergroup. Regionally, the De Grey Supergroup comprises several groups, but the clastic succession of northwestern WODGINA is now assigned to the newly defined Croydon Group. These Explanatory Notes apply the revised stratigraphic nomenclature (Van Kranendonk et al., 2004) to the greenstone successions on WODGINA, and Table 1 shows differences between the new nomenclature and that used on the 2001 map. For ease of reference to the map, codes used on the map are retained in the following descriptions, despite revisions of stratigraphic nomenclature.

Large parts of the Pilbara Supergroup on WODGINA were mapped lithologically, and still cannot be reliably stratigraphically assigned because of inadequate geochronological data. Granitic rocks coeval with the greenstone succession form parts of the multicomponent (c. 3490–2850 Ma) Yule and Carlindi Granitoid Complexes.

Mapping of WODGINA (1997–98) was undertaken by staff of the Australian Geological Survey Organisation (AGSO), now Geoscience Australia (GA), as a contribution to the National Geoscience Mapping Accord (jointly established with the Geological Survey of Western Australia, GSWA, in 1995). Parts of western WODGINA were mapped by GSWA staff and information from field mapping was used in the compilation of the Abydos and Pincunah greenstone belts. GSWA staff also added sections to these Explanatory Notes to update the stratigraphic nomenclature of the supracrustal succession (including Table 1) and various geochronological constraints since the map was printed.

Access and land use

Access is provided by the sealed Great Northern Highway which runs north–south through the centre of WODGINA (Fig. 2). Subparallel to this the unsealed private road that services and runs alongside the Port Hedland – Newman railway line provides additional access in the east. Roads servicing pastoral stations (encompassing Yandeearra Station) and numerous exploration and mine haulage roads around Lynas Find provide good vehicle access. Parts of WODGINA are accessible only to four-wheel drive vehicles, and most tracks are not maintained.

There are no extant settlements other than a tin–tantalum mining camp at Wodgina. Grazing is the only agricultural activity, with cattle being run by the Mungarinya Aboriginal Community and Wallareenya pastoral lease to the north.

Table 1. Revised stratigraphic nomenclature for greenstone successions on WODGINA (from Van Kranendonk et al., 2004)

Stratigraphic nomenclature used on WODGINA (Blewett et al., 2001) *Supergroup/Group/ Subgroup*	*Formation*	*Revised stratigraphic nomenclature (Van Kranendonk et al., 2004)* *Supergroup/Group/Subgroup*	*Formation*
Pilbara Supergroup De Grey Group	Unnamed ferruginous siltstone, shale, and iron formation	**De Grey Supergroup** Croydon Group	Unnamed ferruginous siltstone, shale, and iron formation
~ ~ ~	~ ~ ~ *Unconformity*	~ ~ ~	~ ~ ~
Gorge Creek Group	Cleaverville Formation Corboy Formation Pincunah Hill Formation	Not assigned to supergroup or group	Cleaverville Formation
		Pilbara Supergroup Gorge Creek Group	Corboy Formation Pincunah Hill Formation Nimingarra Iron Formation Tank Pool Quartzite
Sulphur Springs Group	Kangaroo Caves Formation Kunagunarrina Formation Leilera Formation	Sulphur Springs Group	Kangaroo Caves Formation Kunagunarrina Formation Leilera Formation
~ ~ ~	~ ~ ~ *Unconformity*	~ ~ ~	~ ~ ~
Not assigned to a group	Golden Cockatoo Formation	Not assigned to a group	Golden Cockatoo Formation
~ ~ ~	~ ~ ~ *Unconformity*	~ ~ ~	~ ~ ~
Warrawoona Group Salgash Subgroup	Euro Basalt Strelley Pool Chert	Kelly Group	Euro Basalt Strelley Pool Chert
~ ~ ~	~ ~ ~ *Unconformity*	~ ~ ~	~ ~ ~
Coonterunah Group	Double Bar Formation Coucal Formation Table Top Formation	Warrawoona Group Coonterunah Subgroup	Double Bar Formation Coucal Formation Table Top Formation

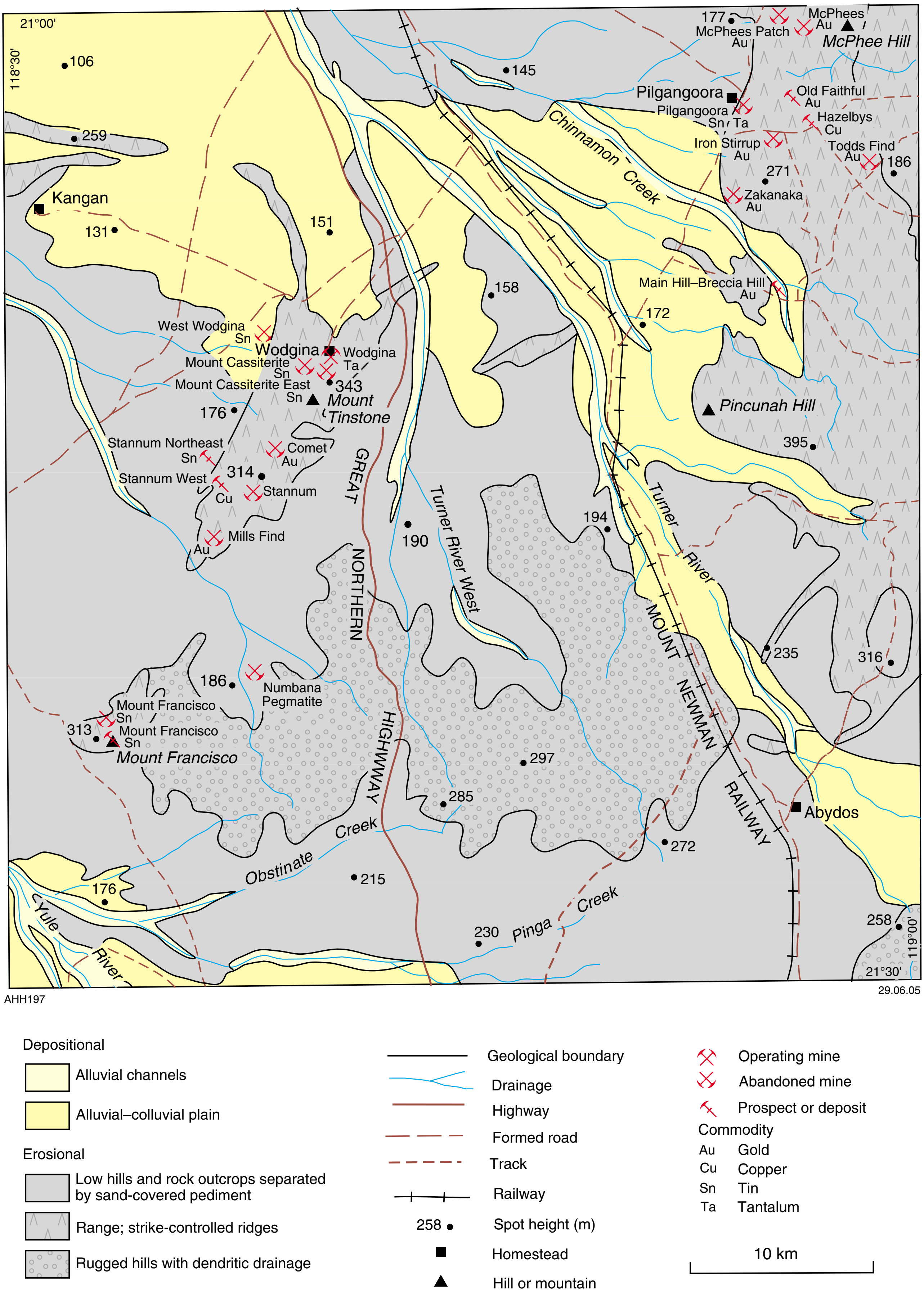


Figure 2. Physiography and access on WODGINA

Physiography

The erosional physiographic divisions of WODGINA (Fig. 2) are strongly controlled by underlying bedrock geology. Archean volcano-sedimentary successions (greenstones) are typically steeply inclined, and consist of alternating units with differing resistance to weathering. Consequently, these successions outcrop as strike ridges of resistant rock separated by valleys underlain by less resistant units. The ridges reach a maximum height of 402 m (AHD) in northeastern WODGINA. Granitic rocks are more deeply eroded, and outcrop is generally poor. In south-central WODGINA massive granitic rocks of the Numbana Granite form rugged hills with dendritic drainage patterns. Other granitic units are more extensively eroded, and generally outcrop in isolated low hills separated by colluvial, alluvial, and eluvial sandplain.

Depositional areas of WODGINA can be classified into two main divisions. The rivers and larger creeks follow narrow alluvial channels that are flanked by wide alluvial–colluvial plains. Parts of the alluvial–colluvial plain division, particularly in northwestern WODGINA, include local eolian sandplain with isolated dunes. Other parts of this division include colluvial fans, as seen west of the range division in the eastern part of WODGINA, or alluvial levees and overbank deposits, as seen along the Turner River in southeastern WODGINA.

Only small areas of dissected Cenozoic plateaus (too small to show on Fig. 2) are preserved in the highest points in the ranges east of Pincunah Hill, and in the range division of the Wodgina greenstone belt, and are capped by ferruginous duricrust. Inverted drainage is observed in the form of several lateritized palaeochannels that once drained the greenstone highlands of the Wodgina and Pincunah Hill areas.

A digital elevation model (DEM) produced from the 400 m flight line-spacing airborne data is available from Geoscience Australia. The DEM is an improvement on the national nine-second grid dataset.

Previous investigations

Hickman (1983) reviewed the early history of geological investigations in the east Pilbara region. Finucane (1935) described the geology and gold mineralization around the McPhees Patch area. Finucane and Telford (1939) remapped the Wodgina tin field during a survey of tantalum-mineralized areas, and this area was remapped by Blockley (1971a).

Noldart and Wyatt (1958) published the first edition MARBLE BAR 1:250 000 map sheet and placed the 'Warrawoona Series' and 'Mosquito Creek Series' in the 'Archaeozoic'. They recognized two episodes of deformation, including an early set of northeast-trending folds accompanied by granite intrusion, and a later period of northwest-trending cross-folds. Noldart and Wyatt (1962) further refined the stratigraphy, identifying an older 'Warrawoona Succession' and a younger 'Mosquito Creek Succession', the latter including the 'Gorge Creek Formation' of quartzite, conglomerate, and banded iron-formation. Ryan (1964) envisaged a single geosynclinal cycle for the geological evolution of the craton, culminating in the Pilbara Orogeny, and Ryan (1965) suggested that the dome-and-syncline pattern developed due to cross-folding. Brown et al. (1968) suggested that the granitoid masses were mantled gneiss domes.

Blockley (1971b) described lead (galena) occurrences at the Lynas Find gold mine and the Wodgina tin mine. Detailed descriptions of the more extensive tin and associated mineral deposits on WODGINA are given by Blockley (1980).

In 1972, the regional 11 km-spaced gravity data were presented as a Bureau of Mineral Resources map (BMR Survey 6914), and regional magnetic and gamma-ray data were collected by BMR with 1500 m flight line-spacing and 150 m ground clearance.

Ingram (1977) included results of mapping of the WODGINA and ABYDOS areas, and divided the stratigraphy into a 'Lower' Archean Warrawoona Succession, and an 'Upper' Archean Mosquito Creek Succession.

The stratigraphic model for the east Pilbara was modified by Hickman and Lipple (1978) and Hickman (1983), who divided the Warrawoona Group into nine formations and the Gorge Creek Group into six formations, with the Lalla Rookh Sandstone and Mosquito Creek Formation at the top.

Hickman (1983) correlated sedimentary rocks in the core of the 'Pilgangoora Syncline', in the northeastern part of WODGINA, with the Lalla Rookh Sandstone, but later detailed studies indicated that these rocks formed an upper part of the Gorge Creek Group (Wilhelmij and Dunlop, 1984). Eriksson (1981) showed that the Gorge Creek Group was deposited in a platform(alluvial)-to-trough (submarine fan) environment and proposed a setting across a continental–marine transition with a narrow continental shelf. Sedimentary rocks of what Wilhelmij and Dunlop (1984) referred to as the Strelley Block were interpreted by these authors as parts of two depositional cycles, represented by the Gorge Creek Group and the Lalla Rookh Sandstone. Wilhelmij (1986) showed that deposition of the Gorge Creek Group in both the Pincunah and East Strelley greenstone belts occurred in a series of fault-bound extensional basins.

The east Pilbara stratigraphy was again modified when Hickman (1990) suggested that sedimentary rocks of the Mosquito Creek Formation in the eastern part of the craton, the Lalla Rookh Sandstone in the centre, and the Mallina Formation in the west could be correlated and were unconformable on the Gorge Creek Group. These rocks were accordingly assigned to a distinct group, which Hickman (1990) named the De Grey Group.

Unpublished company reports and maps by MIM Exploration Pty Ltd, Sipa Resources Ltd, and Lynas Gold NL were based on exploration activity in the East Strelley greenstone belt during the 1980s and 1990s. Neumayr (1993) established a mineral paragenesis for the Mount York district (Zakanaka, Main Hill, and Breccia Hill deposits) and dated mineralization at 2888 ± 6 Ma

(Pb–Pb isochron). Ferguson and Ruddock (2001) reviewed all reported mineral exploration on WODGINA as part of a regional economic summary of the east Pilbara.

New magnetic, gamma-ray, and elevation data were acquired over the MARBLE BAR 1:250 000 sheet (Geoscience Australia survey P649) with a 400 m flight line-spacing and 80 m ground clearance (Richardson, 1997). Wellman (1999) provided an overview of the geophysical framework and geophysical research in the Pilbara Craton. Blewett et al. (2000) included a thematic series of regional geophysical maps and images for WODGINA.

Sweetapple and Collins (2002) provided a new genetic framework and classification of the rare metal pegmatites for the Pilbara Craton, including detailed descriptions from WODGINA. Baker et al. (2002) outlined the structural history and timing of gold mineralization in the Mount York to McPhees Patch areas of the East Strelley greenstone belt.

A number of regional geological reviews of the northern Pilbara Craton were published between 2001 and 2004 (e.g. Van Kranendonk et al., 2002; Huston et al., 2002; Blewett, 2002; Hickman, 2004; Hickman and Van Kranendonk, 2004). New data from mapping, geochemistry, and geochronology, mainly from the east Pilbara, have recently been used in a major reinterpretation of crustal evolution and stratigraphy (Van Kranendonk et al., 2004). This included division of the region's granitic rocks into suites and supersuites. These Explanatory Notes do not apply the extensive new suite–supersuite stratigraphy to the granitic rocks of WODGINA, but new nomenclature affecting some units of the supracrustal succession is provided. A comprehensive recoding of granitic units will be undertaken within a new digital database for the northern Pilbara Craton.

Regional geological setting

WODGINA is near the western margin of the EPGGT, which is one of five granite–greenstone terranes in the Pilbara Craton (Fig. 1), containing rocks ranging in age from 3660 to 2830 Ma. Current geochronological data indicate that the EPGGT is the oldest of the five terranes, and is characterized by circular to elliptical granitic complexes with diameters between 35 and 110 km, and intervening arcuate belts of generally steeply dipping volcano-sedimentary rocks (greenstone belts). All five terranes are unconformably overlain by the c. 2770–2400 Ma Hamersley Basin (Arndt et al., 1991; Blake, 1993). The Hamersley Basin outcrops across about 70% of the Pilbara Craton, and is composed of the volcano-sedimentary succession of the Mount Bruce Supergroup. Part of this succession, elsewhere several kilometres in thickness, was probably also deposited across WODGINA, but has been completely eroded.

Most early studies of the stratigraphy of the Pilbara Supergroup were made on greenstone belts exposed east of WODGINA, mainly on NORTH SHAW and MARBLE BAR. Previous work in the latter areas indicated that the greenstone belts are composed of four unconformity- or intrusion-bound supracrustal sequences deposited over about 575 million years (Hickman, 1983; Horwitz, 1990; Thorpe et al., 1992; McNaughton et al., 1993; Krapez, 1993; Buick et al., 1995; Van Kranendonk et al., 2002). A revised regional stratigraphy, including the classification of all intrusive rocks into suites and supersuites, was provided by Van Kranendonk et al. (2004).

WODGINA contains six greenstone belts (the Pilbara Well, Wodgina, Mount Francisco, Abydos, Pincunah, and East Strelley greenstone belts; Fig. 3) and two granitic complexes (the Carlindi and Yule Granitoid Complexes). The granitic complexes, which intrude the greenstone belts, outcrop in the north and south of WODGINA respectively (Fig. 3) and are partially covered by transported and relict or residual regolith materials.

The oldest rocks include the c. 3515 Ma, bimodal volcanic sequences of the Coonterunah Subgroup (Van Kranendonk, 1998), which is around the southern margin of, and intruded by, the 3470–2935 Ma Carlindi Granitoid Complex (Buick et al., 1995; Van Kranendonk and Morant, 1998).

Elsewhere, the oldest exposed rocks of the Pilbara Supergroup consist of undated mafic–ultramafic volcanic rocks at the base of the Warrawoona Group (Hickman, 1983) and conformably overlying felsic volcanic rocks of the 3472–3463 Ma Duffer Formation (Thorpe et al., 1992; McNaughton et al., 1993). These are in turn overlain by interbedded chert and basalt (Towers Formation), the Apex Basalt, and 3458–3426 Ma felsic volcaniclastic rocks of the Panorama Formation, which all belong to the Salgash Subgroup of the Warrawoona Group (Hickman, 1983; Thorpe et al., 1992). The Strelley Pool Chert comprises silicified siliciclastic rocks and evaporites with common wavy to domal laminated structures of probable stromatolitic origin (Buick et al., 1995; Hoffman et al., 1999). Although locally exposed on WODGINA, this distinctive unit of the Kelly Group is best observed to the east, in the western part of the East Strelley greenstone belt, the North Pole Dome, and southeast of the Corunna Downs Granitoid Complex. In the East Strelley greenstone belt it conformably overlies the Panorama Formation, and unconformably overlies the Coonterunah Subgroup (Buick et al., 1995). Above the Strelley Pool Chert is a thick section of ultramafic to basaltic, and rare felsic, volcanic rocks of the upper part of the Kelly Group (exposed on WODGINA).

The c. 3240 Ma Sulphur Springs Group (Van Kranendonk, 1998) is a bedded sequence of komatiite, pillow basalt, and felsic volcanic rocks. An unconformable relationship between the Sulphur Springs Group and underlying formations was documented by Van Kranendonk (1997). The Sulphur Springs Group is conformably overlain by the Gorge Creek Group (Van Kranendonk et al., 2002), which consists of a thick sequence of siliciclastic and chemical sedimentary rocks, and rarer felsic volcanic and volcaniclastic rocks, passing into mafic volcanic rocks (Hickman, 1983).

The clastic De Grey Supergroup (De Grey Group of Hickman, 1990) is unconformable on the Gorge Creek Group, and was deposited between c. 3000 and c. 2940 Ma in ensialic rifts (Smithies et al., 1999).

Granitic complexes of the EPGGT range from 35 to 110 km in diameter, with centres spaced an average of 60 km apart. Older plutonic components of the Carlindi and Yule Granitoid Complexes include c. 3450 Ma tonalite–trondjhemite–granodiorite (TTG) plutons and gneisses (Bickle et al., 1983; Williams et al., 1983, McNaughton et al., 1988, 1993; Williams and Collins, 1990; Buick et al., 1995; Dawes et al., 1994), and c. 3420 Ma granitic rocks (Nelson, 1999). These older components are intruded by c. 3240 Ma granitic rocks in the eastern Yule Granitoid Complex (Van Kranendonk, 2000), and younger late- (c. 2950–2930 Ma) to post-tectonic (c. 2850–2830 Ma) granites, which represent the final stages of cratonization (Bickle et al., 1989). Wellman (1999) was able to map increasing differentiation of granites by changes in gamma-ray response, with older, less evolved, granites progressively intruded by younger, more evolved, granites. This spatial and temporal relationship in the Yule Granitoid Complex was also recently noted by Champion and Smithies (2000).

Archean Pilbara Craton

Pilbara Supergroup

The East Pilbara Granite–Greenstone Terrane comprises metamorphosed volcanic, sedimentary, and mafic–ultramafic intrusive rocks, and Archean granitic rocks ranging in composition from tonalite to syenogranite. All supracrustal successions except the clastic formations of the De Grey Supergroup are assigned to the Pilbara Supergroup (Hickman, 1983), which is now known to have an age range from c. 3515 to c. 3000 Ma (Van Kranendonk et al., 2002).

Warrawoona Group

The Coonterunah Subgroup (Table 1), mapped on WODGINA as the Coonterunah Group (after Van Kranendonk, 1998, 2000), and accordingly coded *AO-* on the map, was redefined by Van Kranendonk et al. (2004) as the oldest subgroup of the Warrawoona Group. The subgroup consists of mafic volcanic rocks, interbedded iron formation and chert, and felsic volcanic rocks, all metamorphosed between lower greenschist and lower amphibolite facies. These rocks are exposed only in the East Strelley greenstone belt (Fig. 3).

Van Kranendonk (1998) defined three formations from base to top: the Table Top, Coucal, and Double Bar Formations (Table 1). The Coonterunah Subgroup is locally affected by a set of tight folds that are not found in overlying rocks, indicating an early (pre-Salgash Subgroup, i.e. >3458 Ma) phase of deformation (D_1) on WODGINA. A rhyolitic hyaloclastic rock of the Coucal Formation on NORTH SHAW has been dated at 3515 ± 3 Ma (Buick et al., 1995).

Table Top Formation (AOt, AOtci)

The Table Top Formation (Van Kranendonk, 1998) is predominantly composed of fine- to medium-grained amphibolite, mafic schist, and rare metamorphosed banded iron-formation (*AOt*). In part, the massive nature of this unit is due to metamorphic recrystallization as a result of its proximity to the Carlindi Granitoid Complex. Immediately adjacent to the Carlindi Granitoid Complex, mafic rocks are affected by a contact metamorphic aureole up to 100 m wide. The mafic component of this unit is metamorphosed tholeiite, which comprises fine- to medium-grained intergrowths of actinolite, plagioclase, and opaque minerals. Feldspar laths are typically euhedral, but are sieved with sericite and have recrystallized margins intergrown with actinolite.

A 200 m-thick member of metamorphosed, thinly bedded banded iron-formation and interleaved mafic schist (*AOtci*) forms a low ridge coinciding with a magnetic-high zone along the eastern edge of the East Strelley greenstone belt on WODGINA. A small gold prospect (Todds Find) is within the member. The mafic schist component includes interleaved mafic chlorite schist, amphibolite, and lesser talc schist.

Coucal Formation (AOci, AOcbi, AOcbc)

The base and the top of the Coucal Formation (Van Kranendonk, 1998) are marked by between one and three, 2–10 m-thick beds of centimetre-layered, black and white, banded iron-formation and interleaved mafic schist (*AOci*). The beds of banded iron-formation vary from evenly layered rocks with 1–2 cm-thick black and white layers, to more thinly layered rocks with black, white, and less commonly red jasper chert layers, to black chert with sparse, irregularly spaced white chert layers.

Adjacent to the southern margin of the Carlindi Granitoid Complex, the Coucal Formation contains up to 1 km of massive, fine-grained metamorphosed doleritic andesite and basalt (*AOcbi*). The degree of deformation within the unit increases to the west and north, and on WODGINA the dominant rock type is a fine-grained mafic (chloritic) schist with variable alteration and silicification.

Outcrops of altered mafic schist and amphibolite (*AOcbc*) wrap around the northeastern part of the East Strelley greenstone belt. The alteration (silicification) is commonly concordant to a composite penetrative fabric (most intensely fractured and foliated rock types), although silica-rich bands locally crosscut the fabric. These light-coloured alteration bands are visible on the aerial photographs and on gamma-ray spectrometric images. The magnetic susceptibility drops to zero and the potassium count increases by almost an order of magnitude into these alteration zones or bands.

Double Bar Formation (AOd)

The Double Bar Formation (Van Kranendonk, 1998; *AOd*) is dominated by metamorphosed fine-grained, massive tholeiitic basalt, but also includes pillowed and amygdaloidal tholeiitic basalt and interbedded basaltic volcaniclastic rocks, as well as mafic schist and amphibolite. The top of the formation is heavily weathered and oxidized, perhaps indicating palaeoregolith development before deposition of younger units of the Warrawoona Group.

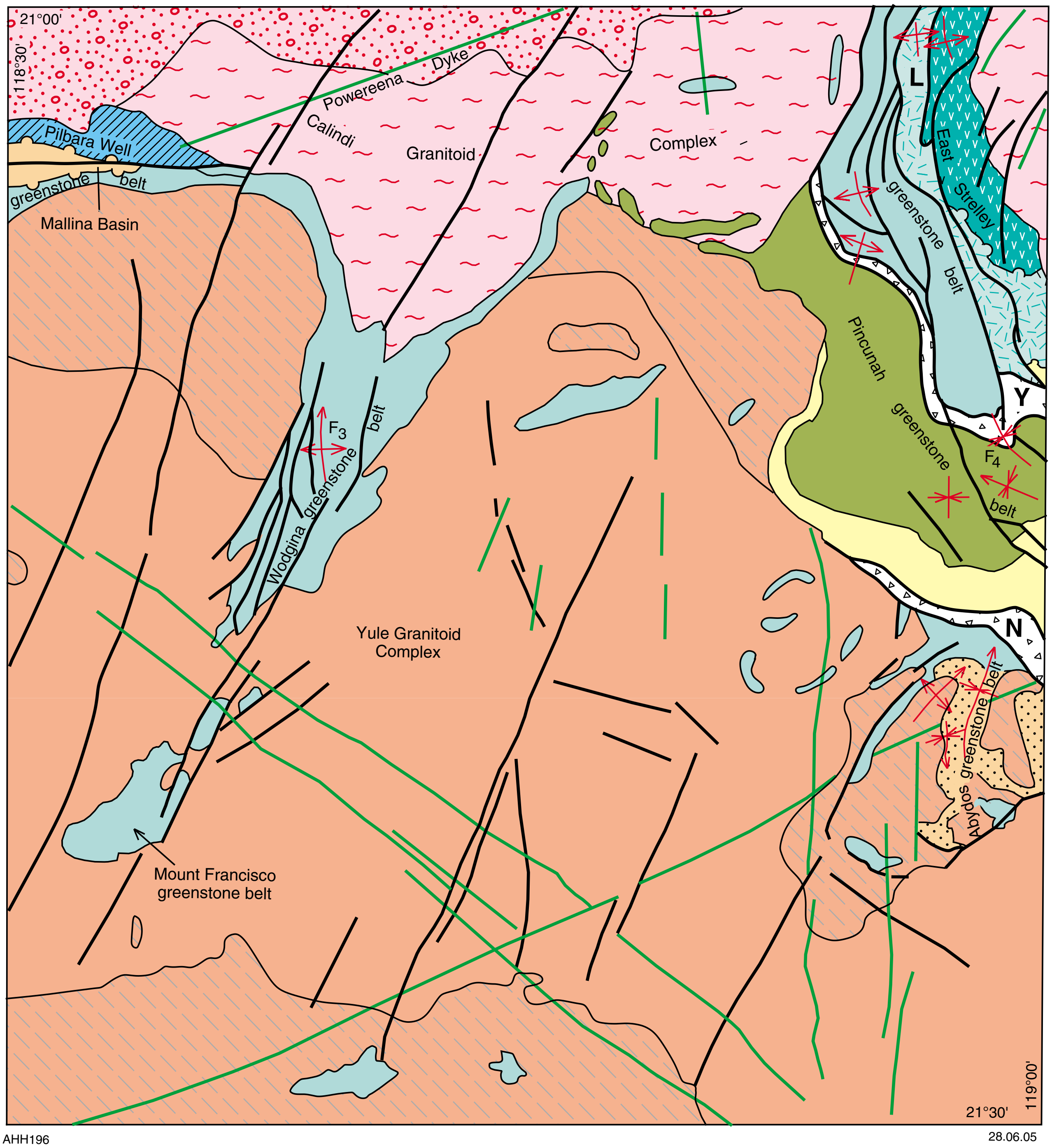
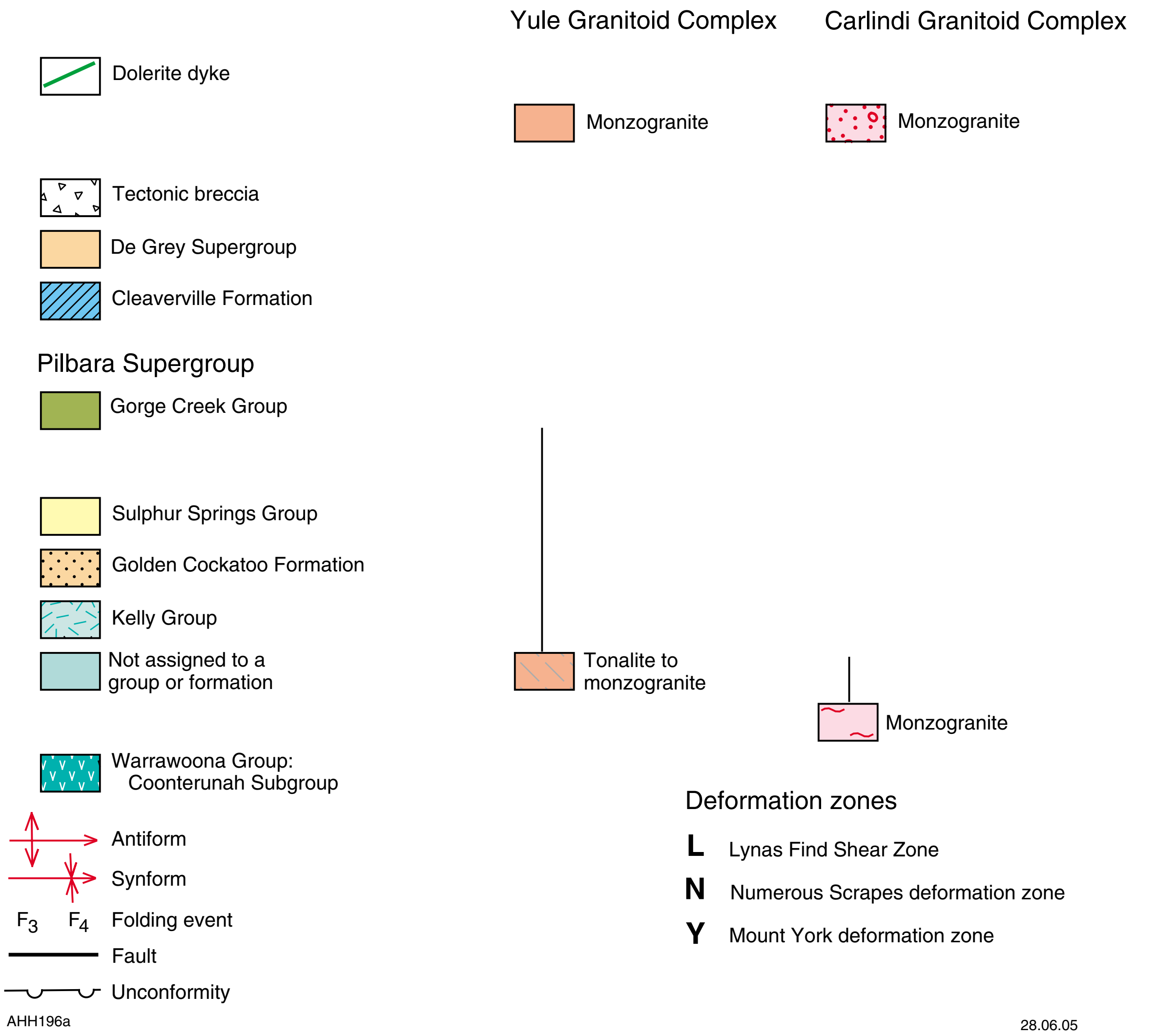


Figure 3. Simplified stratigraphy and structural geology of Wodgina

On North Shaw, Van Kranendonk (2000) described the metabasalt as having a texture of interlocking plagioclase laths, with recrystallized mafic minerals having an assemblage of chlorite or actinolite–chlorite–zoisite–epidote – opaque minerals. Some flows contain up to 50% stubby, rectangular crystals (probably originally clinopyroxene, but now a mixture of carbonate, chlorite, and plagioclase) in a chlorite–plagioclase matrix with coarse clots of opaque minerals.

Unassigned rocks of the Pilbara Supergroup

In the absence of definitive geochronological data, and a lack of any identified stratigraphic marker units, the metamorphosed volcanic, sedimentary, and mafic–ultramafic intrusive rocks of the Wodgina, Pilbara Well, and Abydos greenstone belts were not lithostratigraphically assigned on Wodgina. Hickman (1983) correlated these



greenstones with the dominantly volcanic Warrawoona Group and the predominantly sedimentary Gorge Creek Group. However, subsequent recognition of the intervening Sulphur Springs Group (also volcanic) on NORTH SHAW (Van Kranendonk, 2000) established that this group also outcrops on eastern WODGINA, but its extent westwards through the Wodgina and Pilbara Well greenstones belts remains to be tested by geochronology. Large greenstone enclaves within the Yule Granitoid Complex cannot be confidently assigned to any particular stratigraphic section of the Pilbara Supergroup.

Ultramafic rocks (Au, Aud, Aup, Aur, Aurq, Auk, Aupb, Aubs, Auph, Auc, Aux)

A variety of ultramafic rocks throughout WODGINA cannot be confidently correlated either to a particular intrusive suite or formation. Undivided ultramafic rocks (*Au*) outcrop in the Numerous Scrapes and Mount York deformation zones (Van Kranendonk, 1998), on the eastern margin of WODGINA (Fig. 3), and form a significant component of the Wodgina greenstone belt and the Mount Francisco area. In the Pilbara Well greenstone belt, ultramafic rocks typically form lenses and layers, mostly less than 200 m thick, within the mafic sequence. Unassigned ultramafic rocks also form scattered enclaves throughout the Yule and Carlindi Granitoid Complexes, particularly in the southern part of WODGINA, and form dykes cutting the Carlindi Granitoid Complex.

Weathered or strongly deformed ultramafic rocks were mapped as undivided ultramafic rock (*Au*) in most areas of WODGINA. Better exposed ultramafic rocks were subdivided into serpentine(–talc–tremolite–chlorite) rock after dunite (*Aud*), serpentine–chlorite schist after peridotite (*Aup*), and tremolite–chlorite(–talc–serpentine) schist (*Aur*).

Serpentine–chlorite schist after peridotite (*Aup*) is the most abundant ultramafic rock type. In larger bodies the rock is typically fine to medium grained and massive, with a relict orthocumulate texture. Locally, phenocrysts of olivine are up to 5 mm and oikocrysts of clinopyroxene are up to 10 mm. Olivine is largely replaced by serpentine and lesser amounts of talc, magnetite, tremolite, and carbonate, whereas clinopyroxene is replaced by tremolite, talc, and fine-grained magnetite.

Serpentine(–talc–tremolite–chlorite) rock after dunite (*Aud*) is a minor local variant in many bodies of metaperidotite. The best exposure of dunite is in the northeast of WODGINA, in the core of the Pilgangoora Syncline in the northern part of the East Strelley greenstone belt.

Tremolite–chlorite(–talc–serpentine) schist (*Aur*) is common on the margins of the larger ultramafic bodies and in ultramafic units less than about 50 m thick. The rock is typically fine grained and well foliated, and comprises acicular tremolite with subordinate amounts of chlorite and fine-grained opaque minerals. Along the western side of the Wodgina greenstone belt, tremolite-rich ultramafic schist and quartzite (*Aurq)* are finely interleaved.

An ultramafic xenolith (MGA 694000E 7646400N) in the eastern part of the Yule Granitoid Complex is a weakly deformed serpentine–talc–tremolite rock that locally preserves a well-developed olivine-spinifex texture (*Auk*). However, most of the ultramafic rocks that form xenoliths and roof pendants within the Yule Granitoid Complex are ultramafic rock interleaved with mafic schist (*Aupb*), ultramafic schist interleaved with amphibolite and mafic schist (*Aubs*), serpentine–chlorite schist after peridotite (*Aup*), or tremolite–chlorite(–talc–serpentine) schist (*Aur*).

In the far northeast of WODGINA (e.g. MGA 706000E 7674000N) the Shilliman dyke is a metamorphosed and faulted, medium- to coarse-grained harzburgite dyke (*Auph*) with an arcuate intrusion pattern. The main part of the dyke contains serpentinized olivine and fresh to altered intercumulus orthopyroxene. Along the western contact the dyke is differentiated into a coarse-grained gabbro with a well-preserved igneous texture of plagioclase laths and ?igneous hornblende phenocrysts (Van Kranendonk, 2000). The dyke must be younger than the host leucogranite (*AgLl*) and, according to Van Kranendonk (1998), may be part of the Dalton Suite which is exposed on NORTH SHAW.

The Numerous Scrapes deformation zone (N on Fig. 3) separates the high-grade Golden Cockatoo Formation from the relatively low grade Sulphur Springs Group in the far central-eastern part of WODGINA. The following descriptions of unassigned ultramafic rocks in this region have been modified from Van Kranendonk (2000). Intensely sheared ultramafic rocks envelop rafts up to 2 km long of disaggregated supracrustal rocks and less strongly deformed pods of serpentinized peridotite (*Aup*). The ultramafic matrix to this megabreccia zone is a strongly foliated, and commonly lineated talc–carbonate and talc–carbonate–chlorite schist (*Auc*), with abundant oxidized opaque minerals. The rocks are medium grained with mineral elongation lineations defined by talc and chlorite. Typically, the rocks contain centimetre-scale lenses of relatively more competent, serpentinized and carbonate-altered peridotite, surrounded by an anastomosing network of talc–chlorite schist. Pods and dykes of dark-brown-weathered carbonate suggest large-scale mobilization of carbonate.

The Mount York deformation zone contains weakly deformed serpentinized peridotite and dunite (*Aup* and *Aud*) in a strongly deformed serpentine–chlorite–talc schist 'matrix', and juxtaposes the Gorge Creek Group and unassigned mafic rocks, probably belonging to the Warrawoona Group, in an arcuate zone up to 1 km wide (Y on Fig. 3). Slivers of metamorphosed peridotite and undivided ultramafic rocks, and altered talc–carbonate–chlorite schist (*Auc*), extend northward from Chinnamon Creek to Mount York, where these rock types and related faults control mineralization at Main Hill – Breccia Hill and Zakanaka. Both deformation zones contain magnetic rocks (up to 3000 × 10^{-5} SI units) that are easily mapped on the magnetic image.

Mafic rocks (Ab, Aba, Abacz, Abm, Abas, Abaz, Aod, Aog, Ao, Aolx)

Strongly deformed or structurally isolated mafic rocks (or both) outcrop on eastern WODGINA, in the Wodgina and Mount Francisco greenstone belts, and as enclaves and pods in the Yule Granitoid Complex. Undivided basaltic rock (*Ab*) is commonly a greenschist-facies, massive to pillowed metabasalt. Medium- to coarse-grained massive amphibolite and amphibolite schist (*Aba*) form a significant component of each of the greenstone belts on WODGINA, except for the Pilbara Well greenstone belt. Massive amphibolites commonly represent low-strain zones, especially in the East Strelley greenstone belt, but typically grade into mafic schist in the high-strain zones. Along the western edge of the Wodgina greenstone belt, mafic schist and amphibolite have been strongly carbonate altered and silicified (*Abacz*). The magnetic susceptibility of amphibolite (*Aba*) is typically 50–70 × 10^{-5} SI units and the gamma-ray response is low to very low. Metamorphosed high-Mg basalt (*Abm*) is common in the Pilbara Well greenstone belt and is also exposed in the East Strelley greenstone belt. This rock type is distinguished from other basaltic units by a paler weathering colour, small-scale pyroxene-spinifex texture, and ocelli.

A structurally mixed mapping unit of mafic schist and amphibolite, locally interleaved with quartzite and chert (*Abas*), outcrops in the Main Hill – Breccia Hill gold deposits along the sheared margin between the Pincunah and the East Strelley greenstone belts. Here, mafic chlorite schist is interleaved with banded iron-formation and metasediment (quartzite), probably of the Pincunah Hill and Corboy Formations (Gorge Creek Group) respectively. The main schistosity defined by mostly chlorite is commonly a composite of two fabrics, with the overprinting fabric (main) being an intense crenulation or a shear-band foliation.

Silicified volcanic and intrusive rocks, predominantly mafic schist after extremely altered basalt (*Abaz*), as well as local minor felsic volcanic rock are particularly common in the East Strelley and Wodgina greenstone belts and at the Lynas Find and Main Hill – Breccia Hill deposits. This unit is also present in the Wodgina greenstone belt. The mafic schist becomes bleached to white by alteration and subsequent weathering, resulting in an elevated gamma-ray response (K) and demagnetization. This unit is also distinguished on Landsat 5 TM images from relatively unaltered basaltic rock (*Ab*) and amphibolite (*Aba*).

Metamorphosed dolerite (*Aod*), gabbro (*Aog*), and dolerite and gabbro (*Ao*) dykes and sills intrude rocks of the Pilbara Supergroup, particularly in the East Strelley greenstone belt in the northeast of WODGINA. An 8 km-long by 1 km-wide body of dolerite and fine-grained gabbro in the East Strelley greenstone belt is characterized by an elevated thorium anomaly on the gamma-ray spectrometric data. Larger bodies of gabbroic and doleritic rocks generally outcrop as low rounded hills, and have darker tones on the colour aerial photographs.

Little-deformed intrusions contain fresh clinopyroxene phenocrysts and plagioclase in a groundmass of actinolite–epidote–rutile. More strongly deformed dykes are completely recrystallized to an equigranular, fine-grained assemblage of plagioclase–chlorite–carbonate – opaque minerals. A coarse-grained light-brown pyroxene leucogabbro (*Aolx*) intrudes near the base of the Euro Basalt in the east of WODGINA. The gabbroic texture is defined by centimetre-scale, brown-weathering prismatic crystals of pyroxene in a white matrix of plagioclase. Van Kranendonk (2000) noted that in thin section the gabbro contains coarse intergrowths of plagioclase laths in subophitic augite, with 5% free quartz and 3–5% ilmenite. Variable alteration has resulted in the growth of leucoxene, and chlorite–epidote–titanite(–serpentine–carbonate).

Metasedimentary rocks (As, Ash, Ast, Acq, Ac)

Unsubdivided metasedimentary rocks, with protoliths including sandstone, siltstone, conglomerate, and secondary chert (*As*) outcrop near the Stannum West prospect in the southern part of the Wodgina greenstone belt and east of the McPhees gold mine in the northern East Strelley greenstone belt. The main outcrop of this unit is on the western edge of the East Strelley greenstone belt, just east of the Main Hill – Breccia Hill gold mines. Rock types here include saccharoidal quartzite interbedded with silvery grey, fine- to very fine grained mica schist; thick-bedded quartzite breccia to conglomerate (cherty clasts); white altered 'felsite' with β-quartz 'eyes' up to 5 mm in diameter (?altered rhyolite); black chert; and ferruginous metabasalt.

Pelitic schist (*Ash*) outcrops in the southern and southwestern parts of the Wodgina greenstone belt as fine-grained muscovite and muscovite–andalusite–quartz schist. Andalusite porphyroblasts up to 1 cm in diameter are mostly retrogressed to sericite. Outcrop is generally recessive and partly covered by scree and colluvium from surrounding hills.

Metamorphosed gritty sandstone and minor polymict conglomerate with interbeds of pelitic schist (*Ast*) outcrop in the southern part of the Wodgina greenstone belt as strike ridges (Fig. 2). The rocks are commonly ferruginized, and lateritized (*Czrf*). The conglomerate and pebbly sandstone contain quartzite-rich cobbles and pebbles that are locally highly attenuated into a linear fabric (Fig. 4).

Low strike ridges of the sandstone, conglomerate, and pelitic schist unit (*Ast*) are interleaved with mafic and ultramafic schist bands along the western margin of the Wodgina greenstone belt. Here, this unit resembles the interbedded banded chert, quartzite, and pelitic schist unit


AHH198 29.06.05

Figure 4. Deformed cobble conglomerate (*ASt*) in the southern part of the Wodgina greenstone belt (MGA 668550E 7647520N)

(*Acq*), but lacks the distinctive banded iron-formations of the latter.

The main hills of the Wodgina greenstone belt are made up of banded chert, thick-bedded quartzite, and highly magnetic banded iron-formation (*Acq*), and their lateritized byproducts (*Czrf*). Complex folds are common in the banded chert and iron-formation. The quartzite is commonly thickly bedded and contains a recrystallized saccharoidal texture. In the northwestern part of the Wodgina greenstone belt, and in the adjacent Pilbara Well greenstone belt to the west, discrete units of layered chert (*Ac*) are thick enough to be represented at map scale.

Kelly Group

Elsewhere in the EPGGT the stratigraphic succession of the Warrawoona Group comprises up to 15 km of predominantly volcanic rocks, but on WODGINA the central and upper parts of the succession (3490–3425 Ma) were either never deposited or had been eroded by c. 3425 Ma. The Coonterunah Subgroup is unconformably overlain by two formations of the Kelly Group — the Strelley Pool Chert (precise age not determined) and the c. 3350 Ma Euro Basalt (Table 1). For ease of reference to the map (which puts these two formations in the Salgash Subgroup of the Warrawoona Group), the following description retains codes that were applied on the map (*AW-* codes).

Strelley Pool Chert (AWs)

The Strelley Pool Chert (Lowe, 1983; Van Kranendonk and Morant, 1998) overlies the Coonterunah Subgroup unconformably (Buick et al., 1995). It comprises laminated grey and white chert, silicified siliciclastic and chemical sedimentary rocks, and local carbonate rocks (*AWs*). On WODGINA the characteristic white, or layered white and grey, chert is typically exposed as a prominent ridge. Lowe (1983) described five members in the type area, from base to top: Member 1 — a quartzite deposited in a high-energy, shallow-water environment; Members 2 and 3 — a regressive succession that includes subaqueous wavy laminate, stromatolite and evaporite, chert, and intraformational detrital units deposited under intermittent to predominantly exposed conditions; and Members 4 and 5 — a progradational sequence of a volcaniclastic alluvial fringe.

Van Kranendonk (2000) noted that silicification of the Strelley Pool Chert (like many 'cherts' on WODGINA) was a post-Archean feature (possibly related to recent silcrete development), because deeply eroded sections through the chert show the original mineralogy to be dominated by brown carbonate.

The regional unconformity between the Coonterunah Subgroup and the Kelly Group, outlined by contrasting strike, is best portrayed 3 km southeast of Green Well. Elsewhere, the Kelly Group is disconformable on or in faulted contact with the underlying Coonterunah Subgroup.

Euro Basalt (AWeb, AWebc, AWebm, AWebk, AWec)

The Euro Basalt conformably overlies the Strelley Pool Chert in the northeast of WODGINA. The majority of the Euro Basalt includes metamorphosed tholeiitic and high-Mg basalt, mafic schist, amphibolite, and metamorphosed dolerite (*AWeb*), which is typically fine to medium grained, schistose to massive, and locally contains fine-grained magnetite and sulfides.

Carbonate-altered and schistose basalt (*AWebc*) outcrops in the region around Lynas Find. Alteration associated with local mineralization has resulted in bleaching of the mafic schists and the development of secondary 'chert' units. Careful examination shows that the alteration and 'chert' units crosscut the main foliation. These altered Euro Basalts form the footwall to the main Lynas Find alteration system (Iron Stirrup and McPhees gold mines), although the Old Faithful deposit lies within altered basalt, in the potassium-enriched alteration zone. The 'chert' units are exposed as ridges of potassium-enriched, demagnetized mafic schist in high-strain or fault zones. Many of the 'cherts' are only present high in the landscape and pass gradationally into sheared mafic schist on the lower slopes of hills and in valleys crosscutting the ridges, suggesting that they are silcretes developed in a regolith (possibly as inverted relief).

In the northeast East Strelley greenstone belt the Euro Basalt is readily lithologically subdivided, and in ascending stratigraphic order consists of:

- fine-grained pillowed and lesser spinifex-textured metamorphosed high-Mg basalt (*AWebm*);
- coarse-grained spinifex-textured, massive and pillowed metamorphosed komatiitic basalt, as lavas and subvolcanic intrusions (*AWebk*), which is transformed into mafic schist in high-strain zones;
- metamorphosed tholeiitic and high-Mg basalt, mafic schist, amphibolite, metamorphosed dolerite, and interbedded cherts (*AWeb*), interbedded with a series of chert band (*AWec*).

Metasedimentary rocks above the Kelly Group

On WODGINA, NORTH SHAW, and TAMBOURAH a metamorphosed sequence of sedimentary rocks overlying the eastern margin of the Yule Granitoid Complex was named the Golden Cockatoo Formation by Van Kranendonk (1998). This formation is structurally isolated from the Warrawoona and Kelly Groups, and until recently its age was uncertain. Since WODGINA was mapped, however, a metamorphosed sandstone from the Golden Cockatoo Formation on TAMBOURAH was dated by Nelson (2004), using the SHRIMP (sensitive high-resolution ion microprobe) U–Pb zircon method. The sample (GSWA 178045) contained several populations of zircons, the youngest large group having a calculated age of 3273 ± 14 Ma, indicating the maximum depositional age of the sandstone. Previously, Van Kranendonk (1998) noted that the formation was intruded by c. 3240 Ma granitic rocks, constraining the minimum age of the formation. These geochronological data establish that the formation is too young to be part of either the Warrawoona Group or the Kelly Group, and that it probably stratigraphically underlies the upper, dated part of the Sulphur Springs Group (3255–3235 Ma) that is preserved on NORTH SHAW and WODGINA.

Golden Cockatoo Formation (Aji, Ajp, Ajq, Ajfr)

On WODGINA the Golden Cockatoo Formation (Van Kranendonk, 1998) is preserved in the Abydos greenstone belt in the central-eastern margin of the Yule Granitoid Complex (Fig. 3). The formation has been metamorphosed to upper-amphibolite facies and is subdivided into four mappable units, dominated by banded iron-formation, metapelite, metaquartzite, and rhyolite.

Brown, cherty banded iron-formation, and shale (*Aji*) have a distinctive regular, 1–5 cm-scale layering defined by alternating layers of blue-grey and white chert. Where weathered, the unit is a dark, rusty red-brown and grey chert. The banded iron-formation is complexly deformed, commonly tightly to isoclinally folded, and locally refolded. The metamorphic assemblage includes grunerite (iron-rich amphibole) and magnetite, defining a foliation between fine recrystallized quartz.

Pelite, pelitic schist, and quartzite (*Ajp*) are commonly recessive and consist mostly of fine-grained muscovite schist, with interbedded quartzite, and are locally interlayered with mafic schist of unknown origin. Aluminium silicate minerals such as andalusite and sillimanite (now mostly retrogressed to sericite) are a local component. Quartzite or metaquartz arenite interbeds are typically 10 cm to 1 m thick. A 10 cm-wide quartzite layer on the western edge of the map sheet contains 0.5 cm-diameter garnets together with biotite and muscovite. Quartzite, interbedded with pelitic schist, typically displays poorly defined bedding at a 10 cm scale, subparallel to a penetrative metamorphic foliation defined by alignment of micas. Pelites are strongly foliated to schistose, with a composite main fabric.

Muscovite-bearing quartzite (*Ajq*) forms strike ridges of interleaved thin-bedded to massive saccharoidal quartzite, garnet-bearing amphibolite, mica schist, and sillimanite–tourmaline–mica schist. The quartzite component commonly shows a well-developed linear fabric and isoclinal folding.

Metamorphosed rhyolite (*Ajfr*) is a banded and laminated, pale-coloured, fine-grained equigranular rock with fine- to medium-grained muscovite. The banding is locally tightly to isoclinally folded.

Sulphur Springs Group

On Wodgina the Sulphur Springs Group (Van Kranendonk, 1998) consists of a succession of volcanic and sedimentary rocks forming the sheared southern margin of the Pincunah greenstone belt (Fig. 3). Based on SHRIMP U–Pb zircon dating and model Pb–Pb ages from galena mineralization, the group has an age range of 3260 to 3235 Ma (Vearncombe, 1996; Morant, 1998; Van Kranendonk et al., 2002). Van Kranendonk (1998) subdivided the group into four formations, but the lowermost of these was later assigned to the Kelly Group (Van Kranendonk et al., 2004); the other three are exposed on Wodgina.

Leilira Formation (ASls, ASlf)

The Leilira Formation predominantly consists of interbedded lithic wacke and greywacke, with local volcanogenic sandstone, shale, and quartzite (*ASls*). Laminated metasandstones are deformed by soft-sediment folds with examples of fold limb transposition. Some of the sandstones contain pebbles, which include fuchsite chert. The rocks are typically sandstones, but locally vary to coarse–pebbly sandstone, and siltstone. Metamorphism increases to the west, towards the contact with the Yule Batholith, with pelitic rock types outcropping as foliated schist and psammitic rock types outcropping as foliated and lineated quartzite. Silicification of schists high in the present landscape has resulted in the development of hilltop chert.

Along the southern margin of the Pincunah greenstone belt, the Leilira Formation consists of massive vesicular rhyolite and felsic tuff (*ASlf*). These felsic rocks are interbedded or interleaved with silicified schist and sheared pods of mafic schist.

Kunagunarrina Formation (ASkbc, ASkbm, ASkuk, ASkcw, ASkcg, ASkbp, ASkbd, ASkb)

The lower unit in the Kunagunarrina Formation is massive to locally schistose carbonate–chlorite–sericite rock (*ASkbc*) derived from metamorphosed high-Mg basalt (*ASkbm*) and spinifex-textured komatiite (*ASkuk*). It is up to 500 m thick and locally contains interbeds of white and grey layered chert (*ASkcw*). The lower altered basaltic unit (*ASkbc*) typically has a magnetic susceptibility up to 1000×10^{-5} SI units. In thin section the rocks of komatiitic protolith typically have euhedral, but completely altered, olivine phenocrysts set in a matrix of microspinifex-textured augite. This unit is capped by a 10 m-thick unit of green chert (*ASkcg*), which varies from green-grey massive chert and bright-green chert at the base to laminated black and bright-green chert at the top

AHH199 29.06.05

Figure 5. Komatiitic pillow basalt of the Kunagunarrina Formation (*ASkuk*; MGA 706659E 7649650N)

Immediately above the green chert unit is a distinctive unit of dark-brown-weathering komatiite and basaltic komatiite (*ASkuk*). On Wodgina this unit is typically preserved as fine-grained tremolite–actinolite schist and a coarse-grained tremolite schist. Van Kranendonk (2000) noted that on North Shaw there were textural variations from base to top, consisting of: a basal olivine-cumulate layer, ocellar and pillow-textured volcanic rocks (Fig. 5), a unit of coarse fragmental tuff, pillowed and ocellar volcanic rocks, coarse olivine-spinifex-textured rocks, fragmented pillows, another layer of coarse olivine-spinifex-textured rocks, and massive rocks. A number of laminated grey and white thin chert horizons outcrop as ridges in the generally recessive mafic volcanic rocks of the Kunagunarrina Formation.

The komatiite and basaltic komatiite unit (*ASkuk*) is overlain by an approximately 850 m-thick layer of locally vesicular pillowed basalt (*ASkbp*) and massive basalt (*ASkbd*). These rocks typically contain fine plagioclase laths in a fine-grained matrix of metamorphic chlorite, epidote, and minor carbonate. The massive basalt unit locally includes intercalations of finely laminated grey-green chert and medium-grained melanocratic gabbro with 50–60% clinopyroxene. At Turner Well an outcrop of the Kunagunarrina Formation, in a 2 km-wide valley extending west to the Turner River, consists of mafic volcanic rocks and schist (*ASkb*) that could not be lithologically subdivided at map scale. It is composed of a mixture of calcretized mafic schists (chlorite and talc–tremolite schist), amphibolite, and local pyroxenite pods.

Kangaroo Caves Formation (AScbi, AScbt, AScc)

On Wodgina the Kangaroo Caves Formation (Van Kranendonk, 1998) consists of three units: andesitic tuff, with locally interbedded sandstone, shale, and chert (*AScdt*); grey-brown, fine- to medium-grained andesitic to basaltic lava and associated sills (*AScbi*); and white and blue-grey to black, layered ferruginous chert, volcaniclastic sandstone, and shale (*AScc*).

The andesitic tuff unit is typically pyritic, dark-yellow weathering, pale green, fine grained, well indurated, and displays bedding at a 0.5–40 cm scale. Thicker beds are slightly coarser grained with distinct clear crystal fragments of quartz. The tuff unit also locally includes light-grey porphyritic rhyolite, with β-quartz phenocrysts up to 6 mm.

The chert unit contains millimetre- to centimetre-scale bedded volcaniclastic rocks of felsic to intermediate composition, with some centimetre-thick beds containing 50–60% angular fragments of monocrystalline volcanic quartz. A marker chert at the top of the Sulphur Springs Group, up to 100 m thick, is typically composed of centimetre-layered, grey-blue and white, silicified, fine-grained volcaniclastic and epiclastic detritus.

Gorge Creek Group (*AG*)

Rocks of the Gorge Creek Group in the Pincunah greenstone belt on WODGINA are mapped as the Pincunah Hill and Corboy Formations. However, a recent reinterpretation of the group's regional stratigraphy (Van Kranendonk et al., 2004) suggests that four formations are present (Table 1). The Pilbara Well greenstone belt includes outcrops of the Cleaverville Formation. Until recently this c. 3020 Ma formation was correlated with the 3235–3000 Ma Gorge Creek Group of the east Pilbara (Hickman, 1983, 2001; Smithies, 1998; Smithies and Farrell, 2000). However, Van Kranendonk et al. (2004) questioned and suspended this correlation based on a new tectonic model in which the east and west Pilbara evolved separately before an interpreted collision event at 2990 Ma. Under this interpretation, the depositional basin of the c. 3020 Ma Cleaverville Formation in the west Pilbara would be unrelated to any contemporaneous deposition basin of the Gorge Creek Group in the east Pilbara.

The Gorge Creek Group forms hills and ranges from the eastern edge of WODGINA westwards to Pincunah Hill. To the north the Gorge Creek Group is more recessive and partly concealed around the upper reaches of Chinnamon Creek and the drainage system leading to Tank Pool. Sheared (mylonitized) schistose rocks form narrow outcrops along the western edge of the Pincunah greenstone belt between the Yule Granitoid Complex to the west and Warrawoona Group mafic volcanic rocks to the east. A probable infolded remnant of Gorge Creek Group is exposed 1 km west of the McPhees gold mine, where it has been mapped as undivided sedimentary rock.

Pincunah Hill Formation (AGii, AGiq, AGih)

The Pincunah Hill Formation (Van Kranendonk, 1998) outcrops in the Pincunah greenstone belt and forms a high (up to 344 m AHD) east-trending ridge from the sheet boundary with NORTH SHAW in the east to Pincunah Hill in the west.

A unit of red and black, thinly bedded banded iron-formation, black and white layered chert, and purplish-red to purplish-grey shale, siltstone, and sandstone (*AGii*), up to 1 km thick, locally forms the base of the formation. Soft, yellow-weathering felsic tuff and tuffaceous siltstone form a layer up to 5 m thick in the central part of the unit. The banded iron-formation component of the unit locally dominates and is fine grained, thin bedded, highly magnetic, and has intrafolial isoclinal folds. This rock is commonly interbedded with laminated chert and ferruginous, fine-grained clastic metasediment. Deformation and metamorphism increase in intensity to the north, and near Tank Pool strongly lineated mylonitic quartzite and semipelitic schist (*AGiq*) contain minor banded iron-formation.

Along the northern limb of the Pilgangoora Syncline (e.g. MGA 704000E 7654600N), a unit comprising dark-red to purple ferruginous shale, and minor interbedded siltstone, red and black banded iron-formation, thin-bedded nonmagnetic chert, sandstone, and conglomerate (*AGih*) is in faulted contact with the Corboy Formation. The thin-bedded chert is commonly folded, with well-developed isoclinal folds and intense limb transposition. The banded iron-formation has magnetic susceptibilities of up to 3000×10^{-5} SI units, and therefore forms a distinctive anomaly on aeromagnetic images.

Corboy Formation (AGc, AGcs, AGcc, AGct, AGcg, AGcz, AGci)

The Corboy Formation (*AGc*; Hickman and Lipple, 1975) dominates outcrop of the Gorge Creek Group on WODGINA, and consists predominantly of quartz sandstone, conglomerate, pebbly sandstone, and other clastic rocks. The formation conformably overlies rocks of the Pincunah Hill Formation, and is best exposed as a series of high ridges (up to 402 m AHD) in the southern Pincunah greenstone belt, where Wilhelmij and Dunlop (1984) and Wilhelmij (1986) described several distinct lithofacies and identified synsedimentary faults.

On WODGINA the basal unit of the Corboy Formation is of interbedded sandstone and siltstone, locally with pebbly conglomerate (*AGcs*), and in places is up to 800 m thick. In detail it comprises interbedded ferruginous siltstone, shale, and quartz sandstone with lesser coarse-grained sandstone, conglomerate, and β-quartz porphyritic felsic volcanic rock, and minor dark-grey to black banded iron-formation and chert. Ridges are locally dominated by the coarse-grained sandstone and conglomerate. The banded iron-formation and banded chert are tight to isoclinally folded with steep-plunging fold axes.

The sandstone and siltstone unit (*AGcs*) passes sharply up into an up to 200 m-thick unit of massive pebble to cobble conglomerate and interbedded arkosic sandstone (*AGcc*) that locally also includes red shale. The conglomerate and sandstone unit is typically poorly sorted and thick bedded, and contains graded beds and local fining-up sequences. Thickness variations reflect the depositional control of north-trending faults that cut the Corboy Formation, and the unit thins to the west and is not found west of a major north-trending fault splay of the Mount York deformation zone (Fig. 3).

The conglomerate and sandstone unit (*AGcc*) is overlain by a unit comprising sandstone with pebble

Figure 6. Large concretions in the Corboy Formation (*AGct*; MGA 703122E 7653035N)

conglomerate interbeds and local siltstone and shale (*AGct*). The sandstone is ferruginous, coarse grained, massive, poorly bedded, and purple to grey, whereas interbedded shale and slate is red and nodular. Locally, sandstones develop elliptical concretions up to 50 cm in diameter (Fig. 6). With increasing metamorphic grade the pelitic component of this unit becomes more slaty or phyllitic.

In the core of a syncline in the east-central part of the Pincunah greenstone belt a homogeneous unit comprising brown-weathering, poorly bedded greywacke and lithic arenite, locally with coarse sandstone to pebble conglomerate, siltstone, and shale (*AGcg*), overlies the sandstone and pebble conglomerate unit (*AGct*).

At the western edge of the Pincunah Hill ranges the Corboy Formation is intruded by the Yule Granitoid Complex. In this region, pelitic and psammitic rocks of the formation are metamorphosed to mica schist, andalusite–garnet–mica schist, quartzite, and conglomerate (*AGcz*). The rocks extend in an arcuate belt northward and form part of the hangingwall to the Main Hill – Breccia Hill mineralization system. The aspect ratio reaches 5:1 for pebble and cobble clasts in some metaconglomerate bands.

A unit of banded iron-formation and shale (*AGci*), that outcrops as a narrow small ridge 1.5 km northeast of Tank Pool, is clearly distinguished from surrounding rocks by its high magnetic response.

Cleaverville Formation (*AGl*, *AGlc*, *AGli*)

Rocks correlated to the Cleaverville Formation outcrop in the northwestern part of Wodgina, where they form the eastern extension of the Pilbara Well greenstone belt. The formation dominantly comprises chert and banded iron-formation, with minor felsic clastic and volcaniclastic rocks (*AGl*). Locally, banded white and grey chert (*AGlc*) and banded iron-formation (*AGli*) form prominent ridges that trend eastward along the northern margin of the Pilbara Well greenstone belt. The map reference erroneously includes three additional units (*AGlb*, *AGlsh*, and *AGlur*) that were not mapped on Wodgina.

The banded chert (*AGlc*) has a variable texture, from relatively massive with diffuse patches and swirls of colour to well layered and finely laminated. The iron-oxide content is highly variable and is typically reflected by the colour of the chert, from cream or pale grey to dark blue-grey or dark brown. Some layers contain abundant dispersed magnetite and iron hyroxides, and in places the rock has a distinct centimetre-scale banding. This banding comprises alternating layers of white and red chert (jasper) or layers with up to 70% magnetite (banded iron-formation). Graphite is a minor component of many of the rocks, which have discontinuous layers, up to 5 mm thick and containing up to 30% graphite, in places.

Banded iron-formation (*AGli*) consists of 1–2 cm-thick bands of magnetite-free to magnetite-rich chert, and forms mappable layers that alternate with chert units (*AGlc*).

De Grey Supergroup

As noted above (in **Introduction** and Table 1), the De Grey Group (Hickman, 1990), as mapped on Wodgina, has recently been renamed the De Grey Supergroup (Van Kranendonk et al., 2004). Across the entire northern Pilbara Craton this supergroup comprises four groups deposited in at least three separate clastic sedimentary basins. One of these, the Mallina Basin, encroaches onto northwestern Wodgina, where it contains metasedimentary rocks of the Croydon Group.

Ferruginous siltstone and shale, and iron formation (AD(he))

Ferruginous siltstone and shale, and iron formation (*AD(he)*) are exposed between the two east-trending ridges that form the eastern end of Pilbara Well greenstone belt. The siltstone and shale contain quartz, iron oxides (now goethite), biotite, sericite, clay minerals, chlorite, and zoisite. The iron formation contains up to 50% iron oxides (now goethite), and has local centimetre-scale banding defined by variations in the abundance of goethite. The rocks locally contain 1–2 cm-thick interbeds of poorly sorted, fine- to medium-grained sandstone containing quartz, biotite, feldspar, and chlorite.

Granitic complexes

Felsic intrusive rocks cover more than 75% of Wodgina, and include named and unnamed plutons and dykes of the Yule and Carlindi Granitoid Complexes. The Yule Granitoid Complex (*AgY*) covers the southern three-quarters of Wodgina (Fig. 3), and is separated from the Carlindi Granitoid Complex (*AgL*) by the major greenstone outcrops (Wodgina and Pincunah greenstone belts) and the adjoining thin septum of greenstones (largely interpreted from aeromagnetic data).

The Yule Granitoid Complex on Wodgina includes nine named plutons, in order of increasing age: the Numbana Monzogranite (*AgYnu*), Gillam Monzogranite (*AgYgi*), Woodstock Monzogranite (*AgYwo*), Abydos Monzogranite (*AgYab*), Pincunah Monzogranite (*AgYpi*), Mungarinya Monzogranite (*AgYug*), Cheearra Monzogranite (*AgYch*), Sifleetes Granodiorite (*AgYsf*), Kavir Granodiorite (*AgYka*), and the Yallingarrintha Tonalite (*AgYla*); other components are the Petroglyph Gneiss (*AgYpe*), and a number of unnamed units.

The Carlindi Granitoid Complex on WODGINA is subdivided into the Minnamonica Monzogranite (*AgLmi*), Poocatche Monzogranite (*AgLpo*), Motherin Monzogranite (*AgLut*), and several unnamed units.

The only dated unit on WODGINA is an older gneissic component of the Cheearra Monzogranite (*AgYchm*) which, since the map was compiled (data not in Legend), has yielded an age of 3421 ± 2 Ma (Nelson, 1999). The Mungarinya Monzogranite (*AgYug*) has been dated from its continuation onto the eastern part of SATIRIST, yielding an age of 2938 ± 3 Ma (Nelson, 1999). Similarly, an unnamed hornblende leucogranite (*AgLl*), an unnamed biotite monzogranite (*AgLm*), and an unnamed quartz–feldspar porphyry (*AgLp*), all from the Carlindi Granitoid Complex on NORTH SHAW, provided ages of 3469 ± 2 Ma (Nelson, 1999), 3484 ± 4 Ma (Nelson, 1999), and 3468 ± 4 Ma (Buick et al., 1985) respectively. On WALLARINGA, north of WODGINA, the Motherin Monzogranite (*AgLut*) was dated at c. 3475 Ma (Baker, D. E. L., 2001, written comm.).

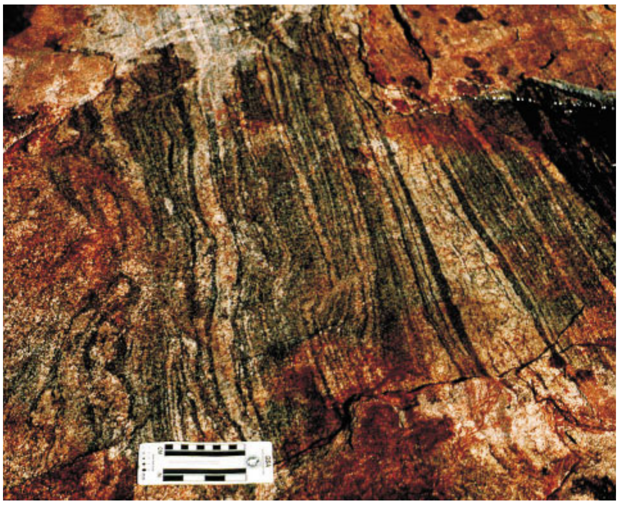
Carlindi Granitoid Complex

The Carlindi Granitoid Complex on WODGINA is a weakly deformed body of granitic rocks with generally well preserved intrusive contacts into the surrounding greenstones. In the northeast of the sheet area, this complex contains very old crustal components, such as the c. 3475 Ma Motherin Monzogranite (*AgLut*) noted above, which is folded around the nose of the Pilgangoora Syncline. On NORTH SHAW an unnamed monzogranite (*AgLm*) that also outcrops in the far northeast of WODGINA was dated at c. 3485 Ma (Nelson, 1999). The remainder of the complex on WODGINA consists of biotite-bearing monzogranite and younger muscovite(–garnet)-bearing monzogranite.

Motherin Monzogranite (AgLut, AgLutx)

The Motherin Monzogranite (*AgLut*) outcrops in the northeastern and northern parts of the Carlindi Granitoid Complex on WODGINA. The unit is heterogeneous, comprising variably quartz–feldspar-porphyritic to seriate, medium- to coarse-grained, biotite monzogranite to (hornblende–)biotite granodiorite, with common to abundant dykes of various rock types. The unit is typically moderately to strongly foliated, although there are unfoliated rocks in places. The rocks are cryptically to strongly banded, and locally gneissic. Banding, defined by biotite-rich (8 to >15%) layers, and schlieren are commonly folded (Fig. 7).

A major characteristic of the Motherin Monzogranite is the presence of at least four phases of dykes or pods (or both) including:



AHH201 29.06.05

Figure 7. Banding, locally folded (near scale), within the Motherin Monzogranite (*AgLut*; MGA 695523E 7673106N)

- foliated, fine- to medium-grained, equigranular biotite monzogranite to granodiorite;
- variably foliated biotite leucogranite;
- massive to moderately foliated, equigranular to sparsely (quartz–)feldspar-porphyritic, and locally muscovite-bearing, biotite monzogranite;
- various generations of pegmatite.

Pegmatite bodies, which locally form a common to very abundant component, are both concordant and discordant, and include both foliated and massive variants. The monzogranite unit also includes isolated greenstone xenoliths and regions of more common greenstone enclaves (*AgLutx*). The main phases of the Motherin Monzogranite are magnetic (up to 600×10^{-5} SI units), and the unit is clearly defined on regional aeromagnetic images. Metamorphic grade is typically high (middle-amphibolite facies), but does not appear to have reached temperatures required for partial melting.

Intermixed banded to strongly foliated granodiorite and porphyritic monzogranite (AgLi)

Poorly outcropping, undivided, banded to strongly foliated granodiorite and monzogranite (*AgLi*) outcrops in the southern and southwestern parts of the Carlindi Granitoid Complex on WODGINA, where the unit also includes massive to weakly foliated monzogranite with locally common pegmatite. The southwestern outcrops share many similarities with the Motherin Monzogranite, and possibly form part of this unit. In the region to the north of the Wodgina greenstone belt, this intermixed unit (*AgLi*) has been separated from the Motherin Monzogranite on the basis of aeromagnetic data, which shows significantly lower magnetization in the former unit. The aeromagnetic data suggest that the relationship between the two is both faulted and intrusive.

Biotite–hornblende leucogranite (AgLl)

The dominant rock type in the eastern half of the Carlindi Granitoid Complex on WODGINA is a weakly foliated biotite–hornblende leucogranite (*AgLl*), which outcrops in flat platforms. Van Kranendonk (2000) mapped the same unit on NORTH SHAW and described it as a medium-grained rock of monzogranitic to granodioritic composition containing 5–8% hornblende crystals, which are commonly altered to biotite, muscovite, and epidote. The rock is unfoliated and only the undulose extinction and subgrain boundary formation in quartz attests to it having been affected by tectonic strain. A sample of this unit (GSWA 153190) was dated at 3469 ± 2 Ma (Nelson, 1999).

Fine- to coarse-grained biotite monzogranite (AgLm)

Fine- to coarse-grained biotite monzogranite (*AgLm*) outcrops in the far northeastern corner of WODGINA. Similar monzogranite was mapped on NORTH SHAW, although it was ubiquitously fine grained (Van Kranendonk, 2000). The rocks are typically weakly to nonfoliated, equigranular biotite monzogranites. A sample taken from NORTH SHAW was dated at 3484 ± 4 Ma (Nelson, 1999).

Quartz–feldspar porphyry (AgLp)

Quartz–feldspar porphyry (*AgLp*) has intruded to a high structural level. It outcrops in the far northeastern corner of WODGINA and probably represents a high-level equivalent of the biotite–hornblende leucogranite (*AgLl*). These high-level intrusions have a distinctly porphyritic texture and have been described by Van Kranendonk (2000). They consist of large (≤6 mm) phenocrysts of clear, unstrained quartz, plagioclase, K-feldspar, and muscovite in a fine- to medium-grained quartzofeldspathic (+ local magnetite) matrix. Feldspar phenocrysts are commonly euhedral, with growth zoning around their edges, whereas quartz phenocrysts are typically round and locally show resorbed embayments.

Biotite monzogranite (AgLmp)

K-feldspar porphyritic to seriate biotite monzogranite (*AgLmp*) forms a large proportion of the Carlindi Granitoid Complex on WALLARINGA and is also common in the northern part of WODGINA. It is typically massive to weakly foliated. Euhedral phenocrysts of microcline are up to 2.5 cm long, contain abundant inclusions of quartz and plagioclase, and appear to be a late crystallizing phase. Biotite is the sole mafic phase and its abundance never exceeds 5%. These rocks closely resemble seriate to K-feldspar-porphyritic monzogranites of the Yule Granitoid Complex (e.g. the Powdar and Mungarinya Monzogranites on SATIRIST), which have been dated at between 2935 and 2930 Ma (Nelson 1999).

Minnamonica Monzogranite (AgLmi)

The Minnamonica Monzogranite is a grey to white, medium-grained, sparsely quartz–feldspar-porphyritic, biotite–muscovite monzogranite that varies from massive to very weakly foliated. Sparse phenocrysts of feldspar (<3% of the rock) are up to 1.5 cm and quartz phenocrysts are up to 1.0 cm. Biotite is the dominant mica mineral (5–6% of the rock with grains up to 5–8 mm), with subordinate muscovite (<3% of the rock). Mica is locally concentrated into schlieren. The unit contains rare biotite-rich or granodioritic enclaves, up to 15 cm, as well as rare pegmatite dykes. The unit is strongly reduced, forming a magnetic low on aeromagnetic images.

Biotite and muscovite–biotite monzogranite (AgLmu)

Equigranular, grey, fine- to medium-grained, biotite and muscovite–biotite monzogranite (*AgLmu*) forms small bodies within the coarser grained, porphyritic Minnamonica Monzogranite (*AgLmi*). These bodies are locally associated with enclaves and pendants of foliated, banded, and folded gneissic granite, most probably related to the Motherin Monzogranite. Similar, small monzogranite pods (with or without muscovite) are throughout the Motherin Monzogranite.

Poocatche Monzogranite (AgLpo)

The Poocatche Monzogranite outcrops in the southern part of WODGINA, where it has intruded the Minnamonica Monzogranite (*AgLmi*). The Poocatche Monzogranite is typically a coarse- to very coarse grained, seriate to K-feldspar-porphyritic muscovite–biotite monzogranite. The rocks are massive to weakly foliated. Phenocrysts of microcline enclose all groundmass phases and are a late crystallizing phase. Biotite is commonly the sole mafic phase, but accessory garnet is noted in some samples. Muscovite is both an alteration product of microcline and forms late-magmatic euhedral ‘books’ up to 5 mm in intergranular spaces. Fracture surfaces are also commonly lined with muscovite.

Yule Granitoid Complex

Granitic units of the Yule Granitoid Complex were originally subdivided and defined by Hickman and Lipple (1975) as part of the regional mapping of the Pilbara region. These authors recognized a number of distinct granite phases and complexes, largely based on textural and structural criteria. These units were described and defined by Hickman (1983) with some modifications from Hickman and Lipple (1975), and Blockley (1980), in particular the Numbana Granite. Hickman (1983) formally identified six granite units: the Numbana, Nardoopiquithanna, Kangan, Pincunah, Abydos, and Woodstock granitic intrusions. In this study the Numbana Granite and Nardoopiquithanna Adamellite have been redefined as the Numbana Monzogranite (*AgYnu*). The Kangan Adamellite was redefined and renamed the Mungarinya Monzogranite (*AgYug*) by Smithies and Farrell (2000). The three other units have been retained with some modification to boundaries.

Petroglyph Gneiss (AgYpe)

The Petroglyph Gneiss is the oldest recognized unit of the Yule Granitoid Complex and is a migmatitic tonalitic orthogneiss with sheeted pegmatitic granite veins (*AgYpe*; Van Kranendonk, 1998). The well-developed gneissic layering is defined by sheeted veins of pegmatitic monzogranite. The precursor to the gneiss was a sheeted complex of blue-grey tonalites with slight variations in texture (equigranular to weakly porphyritic) and composition (trondhjemite, tonalite, quartz diorite). The banding is locally isoclinally folded. The magnetic susceptibility is low. In thin section the tonalites have a granoblastic texture of quartz, plagioclase, and accessory titanite, with aligned flakes or clots of biotite and opaque minerals that defined a foliation parallel to the gneissic layering in the rocks. A distinctive component mapped within the gneiss is a 5–10 m-thick band of corundum-bearing anorthosite. In thin section coarse muscovite surrounds the corundum porphyroblasts. Dating of xenocrystic zircons from a metre-wide dyke cutting the Petroglyph Gneiss indicate an age for the Petroglyph Gneiss of c. 3470 Ma (Van Kranendonk, 2000).

Banded orthogneiss and hornblende–biotite–titanite granodiorite (AgYin, AgYinx)

Banded, grey and black, fine- to medium-grained, hornblende–biotite–titanite felsic gneiss and lesser variably banded and foliated hornblende–biotite–titanite granodiorite (*AgYin*), locally with abundant greenstone enclaves (*AgYinx*), outcrop in the central-eastern part of Wodgina. These units, together with the Petroglyph Gneiss (*AgYpe*), form the southern and eastern parts of a domal granitic mass partly rimmed by greenstone pendants, and pass to the west and south into interleaved strongly foliated granite, granodiorite, and pegmatite (*AgYi*). The orthogneiss component is best exposed along the Turner River (e.g. MGA 699000E 7636700N), where it outcrops as a banded, grey and black, fine- to medium-grained, titanite–hornblende–biotite felsic gneiss. Layering is typically strongly to moderately well developed, with individual layers up to 10 cm thick. It is defined by changes in texture, from equigranular to moderately feldspar porphyritic, and changes in rock types, from granodiorite to tonalite (up to 13% biotite and hornblende) and leucocratic monzogranite (6% biotite ± hornblende). Other layers include thin fine- to medium-grained granite veins, thin biotite–hornblende-rich layers and schlieren, and common concordant pegmatite veins. The granite and pegmatite layers commonly have mafic selvedges suggestive of migmatite formation. Greenstones, typically amphibolite, metamorphosed ultramafic rocks, and quartzite within the gneiss form pendants up to several kilometres in size to more widespread but generally minor boudinaged or elongate enclaves (or both) between 10 and 20 cm in size. The gneissic banding is folded (Fig. 8) and locally crenulated, axial planar to the folds. The gneiss is cut by discordant pegmatite veins and moderately foliated biotite granite dykes, and younger essentially undeformed, equigranular, medium-grained, biotite granite bodies. Magnetic susceptibility of the gneiss is variable, ranging from nonmagnetic to strongly magnetic. Elsewhere, hornblende–biotite–titanite and biotite granodiorite, locally with incipient banding, forms the only or dominant rock type. The relationships between these rocks and the banded gneiss are not always clear, but it is evident that the granodiorites at least locally represent younger phases, related to the Kavir Granodiorite (*AgYka*) to the east and the Pincunah Monzogranite (*AgYpi*) to the south and west. The banded orthogneiss is considered to be of similar age to the Petroglyph Gneiss.

AHH202 29.06.05

Figure 8. Folded layers of gneiss and pegmatite in a gneiss (*AgYii*) of the Yule Granitoid Complex (MGA 702322E 7634546N)

Yallingarrintha Tonalite (AgYla)

The Yallingarrintha Tonalite (*AgYla*) comprises moderately to strongly foliated, coarse-grained biotite–hornblende tonalite to granodiorite. On Wodgina these rocks are only along the southern margin of the Pilbara Well greenstone belt, where they have been dated at 3421 ± 2 Ma (GSWA 142170; Nelson, 1999). The rocks range from biotite(–hornblende) granodiorite to hornblende(–biotite) tonalite.

Biotite(–hornblende) granodiorite is a strongly foliated rock that has a well-formed mineral segregation defined by tectonic elongation of originally porphyritic plagioclase and quartz. Hornblende(–biotite) tonalite has an intergranular texture with subhedral to euhedral grains of plagioclase, up to 0.8 cm, forming an interlocking framework enclosing hornblende, biotite, and quartz. Hornblende and biotite together constitute less than 15% of the rock. Hornblende is typically altered to actinolite or chlorite or both, biotite is locally altered to chlorite, and plagioclase is locally altered to sericite and epidote. Quartz is typically strongly granoblastic.

Kavir Granodiorite (AgYka)

The Kavir Granodiorite (*AgYka*) outcrops in the central-eastern part of Wodgina as an ovoid mass associated with the Petroglyph Gneiss, and as irregular bodies intruding greenstone and gneiss (*AgYii*) to the south of this. The unit comprises leucocratic equigranular to porphyritic biotite granodiorite (Van Kranendonk, 2000). A strongly lineated leucocratic granodiorite, intrusive into gneiss (*AgYii*) and equated with the Kavir Granodiorite, contains minor hornblende and relatively common titanite (primary and secondary) and allanite. The Kavir Granodiorite has a reported age of c. 3240 Ma (Van Kranendonk, M. J., unpublished U–Pb SHRIMP zircon data, cited in Van Kranendonk, 2000). The unit varies from foliated to massive.

Cheearra Monzogranite (AgYchm)

Moderately to strongly foliated, equigranular to porphyritic biotite monzogranite (*AgYchm*) is present along the western edge of WODGINA, with the main outcrop lying between the Pilbara Well and Wodgina greenstone belts. The rocks are seriate to locally porphyritic in texture, with local quartz and K-feldspar phenocrysts up to 8 mm and 2 cm in length respectively. A foliation is defined by alignment of biotite and chlorite and flattened quartz grains, or zones of granoblastic quartz, micaceous schlieren, and K-feldspar phenocrysts. Rocks of granodioritic, and less commonly tonalitic, composition contain hornblende and biotite, the latter commonly rimming the former. Biotite is the only mafic silicate mineral in the monzogranite and typically comprises less than 8% of the rock. Quartz (typically granoblastic), perthite, and biotite form interstitially to plagioclase, but are all locally included within large, late-crystallizing grains of microcline. Hornblende is locally altered to actinolite, epidote, and chlorite. Biotite is typically partially to completely chloritized, and feldspars are typically partially altered to sericite and epidote. Accessory minerals include apatite, zircon, rutile, titanite, allanite, and magnetite (now leucoxene). The Cheearra Monzogranite is locally banded, with banding defined by variations in biotite content (5 to 9%), quartz and feldspar phenocryst content (nonporphyritic to moderately porphyritic), or grain size. Banding is subparallel to foliation and locally folded (Fig. 9). The monzogranite also contains locally common enclaves of variably feldspar-porphyritic biotite-rich gneissic granodiorite with folded layering, and greenstone, the latter more common closer to the Wodgina greenstone belt. The Cheearra Monzogranite is also characterized by relatively common aplite and pegmatite, and small bodies and dykes of K-feldspar-porphyritic biotite monzogranite, interpreted to be related to the Mungarinya Monzogranite.

AHH203 29.06.05

Figure 9. Folded layering within the Cheearra Monzogranite (MGA 667364E 7623386N), cut by thin pegmatite layers (e.g. near base of hammer)

Unassigned granitic units (AgYipe, AgYipgn, AgYipex, AgYii, AgYiix, AgYi)

On southern WODGINA unassigned granitic units of the Yule Granitoid Complex form regions of complex mixing, resulting from episodic magmatism between c. 3470 Ma (age of the Petroglyph Gneiss) and c. 2850 Ma. These units are typically around the marginal zones of the Yule Granitoid Complex or in regions characterized by common greenstone xenoliths, here interpreted as either roof zones close to the original granite–greenstone surface above the Yule Granitoid Complex, or as remnants of greenstone septa originally separating granite domes. It is evident that granite complexity in general increases towards original granite–greenstone contacts, and that the older granites (and gneiss) are in the marginal zones of granitic complexes and domes.

Along the southern margin of WODGINA, the dominant unit comprises moderately to strongly foliated and regularly to irregularly banded and folded granodiorite, complexly intermixed with seriate to variably porphyritic monzogranite and pegmatite (*AgYipe*). Less deformed granite dykes and pods are locally common and some are related to the Mungarinya Monzogranite (*AgYug*) and Numbana Monzogranite (*AgYnu*). This assemblage grades into regions of abundant pegmatite containing enclaves and pods of foliated variably banded biotite granodiorite, foliated biotite monzogranite, and amphibolite, as well as granite dykes and younger crosscutting pegmatite dykes (*AgYipgn*), the latter suggesting that the earlier pegmatites are not related to the Numbana Monzogranite, even though the largest area of early pegmatite is along the margin of the monzogranite. The mixed assemblage (*AgYipe*) also contains locally abundant enclaves and pendants of greenstone material (*AgYipex*; typically metamorphosed ultramafic and mafic rock types).

The other main region of undivided granites comprises a domal mass of intermixed, weakly to strongly foliated, equigranular to variably feldspar-porphyritic (hornblende–)biotite granodiorite and biotite monzogranite (*AgYii*; including phases related to the Kavir Granodiorite and Pincunah Monzogranite) and pegmatite. This locally contains abundant pendants and enclaves of gneiss (*AgYin*) and greenstone (*AgYiix*).

Smaller areas of undivided interleaved granodiorite, granite, and pegmatite (*AgYi*) comprise many small outcrops within the poorly outcropping northeastern part of the complex.

Siffleetes Granodiorite (AgYsf)

The Siffleetes Granodiorite (*AgYsf*) is a moderately to strongly foliated, medium- to coarse-grained, sparsely porphyritic, biotite–hornblende granodiorite, with locally common elongate, metre-scale amphibolite and diorite enclaves. Phenocrysts include 1–2 cm feldspar and locally hornblende, up to 8 mm. Biotite and hornblende contents are variable, typically between 10 and 20%, but are locally higher, with incipient banding defined by variation in the abundance of mafic minerals. Titanite (up to 2%) is a minor but widespread mineral. The Siffleetes Granodiorite outcrops around the southern margin of, and is intrusive into, the Wodgina greenstone belt. It forms small outcrops that are typically strongly intruded by pegmatite and by pods and dykes related to the Mungarinya Monzogranite (*AgYug*) and Numbana Monzogranite (*AgYnu*). To the west and northwest the Siffleetes Granodiorite has been extensively intruded by the Mungarinya Monzogranite. There are also isolated zones with common enclaves that might be of Siffleetes Granodiorite west of the Wodgina greenstone belt.

Mungarinya Monzogranite (AgYug, AgYugx, AgYugp, AgYugs, AgYugsx)

The Mungarinya Monzogranite (*AgYug*), originally defined by Hickman (1983) as the Kangan Adamellite, outcrops over a large area straddling the boundary between WODGINA and SATIRIST (Smithies et al., 1999). The monzogranite is typically a medium-grained porphyritic biotite monzogranite. Perthite phenocrysts are tabular, up to 10 cm in length, and are late-crystallizing phases that overgrow all other major mineral phases. The unit is also sparsely quartz porphyritic, with quartz grains up to 8 mm. Biotite (now mostly chlorite) is the sole mafic silicate mineral. Accessory minerals include apatite, zircon, allanite, titanite, rutile, and opaque minerals. The rock is mostly massive to weakly deformed and has a locally prominent 'ghost banding' produced by vague mineralogical bands within individual parallel intrusive sheets of monzogranite (Fig. 10). Locally, the monzogranite contains abundant xenoliths of greenstone (*AgYugx*) or abundant sheets and dykes of pegmatite and leucogranite (*AgYugp*) probably related to the Numbana Monzogranite. A distinct mapping unit is also formed where the Mungarinya Monzogranite has intruded and complexly mixed with the Siffleetes Granodiorite, and this mixed unit (*AgYugs*) locally contains abundant greenstone xenoliths (*AgYugsx*).

Pincunah Monzogranite (AgYpi, AgYpip)

The Pincunah Monzogranite (*AgYpi*) forms a large unit along the eastern, northeastern and southeastern margins of the Numbana Monzogranite, over a significantly larger area than that originally defined by Hickman (1983). The unit is a medium grained, granular to granoblastic, porphyritic, (hornblende–)allanite–titanite–biotite granodiorite to monzogranite. The Pincunah Monzogranite is characterized by its moderate to strongly porphyritic nature with commonly well-aligned subhedral white K-feldspar phenocrysts up to 4 cm (locally up to 8 cm), and lesser anhedral quartz phenocrysts from 8 to 20 mm in length. Minor minerals include persistent subhedral allanite (1–2 mm) and less common anhedral titanite. The Pincunah Monzogranite has a weak to moderate foliation, best defined by aligned biotite, but also by aligned and locally elongate phenocrysts. Minor local banding is mainly defined by biotite-rich layers (up to 10 cm thick) and biotite schlieren, but also includes nonporphyritic and more felsic layers. The monzogranite contains minor to locally abundant equigranular to sparsely K-feldspar-porphyritic leucogranite dykes and pods, as well as moderate to common pegmatite dykes, particularly along its northern and northwestern margins.

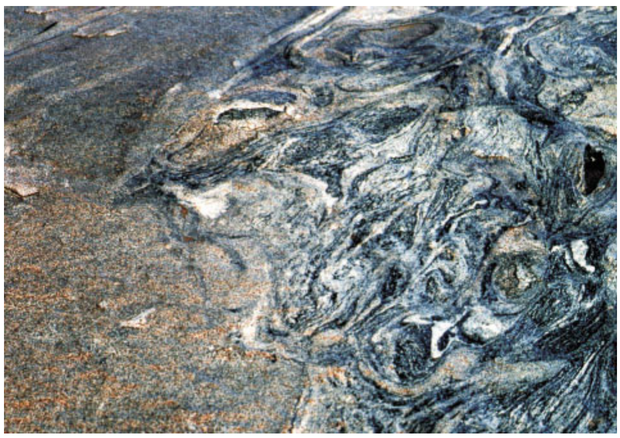
The eastern part of the Pincunah Monzogranite is characterized by more complex regions comprising monzogranite with enclaves and pendants of greenstone, banded granite, and gneiss (*AgYpip*), including a small but spectacular zone of entrained gneiss and amphibolite enclaves and schlieren exposed in the Turner River (Fig. 11; MGA 703624E 7628906N).

Abydos Monzogranite (AgYab)

The Abydos Monzogranite (*AgYab*) outcrops in the southeastern corner of WODGINA, continuing onto WHITE SPRINGS. The unit is a moderately to strongly foliated, K-feldspar(–quartz)-porphyritic biotite–titanite monzogranite to syenogranite. K-feldspar forms subhedral to euhedral phenocrysts up to 3 cm in length, whereas

AHH204 29.06.05

Figure 10. Subparallel banding within the Mungarinya Monzogranite, cut by later pegmatite veins (MGA 657479E 7646126N). Hammer is about 50 cm in length



AHH205 29.06.05

Figure 11. Complexly folded gneiss, and amphibolite enclaves entrained into and with the Pincunah Monzogranite, Turner River (MGA 703624E 7628906N)

anhedral quartz phenocrysts are typically less than 5 mm in diameter. Subhedral to euhedral prisms of titanite, up to 4 mm in length, are a distinctive feature of the rock. The strong foliation within the unit is manifest by aligned biotite and aligned and elongate phenocrysts, especially quartz. Banding is locally well developed and defined by a variable phenocryst content and by biotite-rich (up to 30%) and biotite-poor (<5%) layers up to 15 cm thick, subparallel to the foliation. The unit is cut by both deformed and undeformed granite dykes and pegmatite, the latter being locally abundant.

Woodstock Monzogranite (AgYwo, AgYwof)

The Woodstock Monzogranite, defined by Hickman and Lipple (1975) and Hickman (1983) as the Woodstock Adamellite, forms an irregular unit on the southeastern side of WODGINA and continues onto NORTH SHAW, TAMBOURAH, and WHITE SPRINGS. On TAMBOURAH this unit was described in detail by Van Kranendonk (2003) and dated at 2933 ± 3 Ma (Nelson, 1998).

The Woodstock Monzogranite is a medium-grained to locally coarse-grained, equigranular to moderately porphyritic biotite monzogranite, distinguishable from the Pincunah (*AgYpi*) and Abydos (*AgYab*) monzogranites by its lower phenocryst content. Phenocrysts include K-feldspar (up to 1.5 cm), plagioclase, and quartz (each up to 5 mm). On WODGINA the unit is typically weakly to moderately foliated, although it includes strongly foliated and locally mylonitized variants. The Woodstock Monzogranite locally contains subparallel, commonly subtle or cryptic, banding, defined by varying biotite content, with layers up to 1 m thick. The unit also contains thin discontinuous biotite schlieren. Pegmatite dykes are locally very common as are small pods and dykes of undeformed to mildly foliated equigranular to sparsely (quartz–)feldspar-porphyritic biotite granite. The latter locally contain zones characterized by large magnetite crystals up to 1 cm, similar to those in the Gillam Monzogranite (*AgYgi*). Other phases that intrude the Woodstock Monzogranite include moderately to strongly foliated porphyritic granite dykes and pods. A small body of grey, strongly foliated, fine- to medium-grained, equigranular, biotite monzogranite (*AgYwof*) intrudes the southern margin of the main body of the Woodstock Monzogranite and the Abydos Monzogranite (*AgYab*). Foliation in this rock is defined by aligned minerals and elongate quartz grains.

Seriate to porphyritic biotite leucogranite (AgYls)

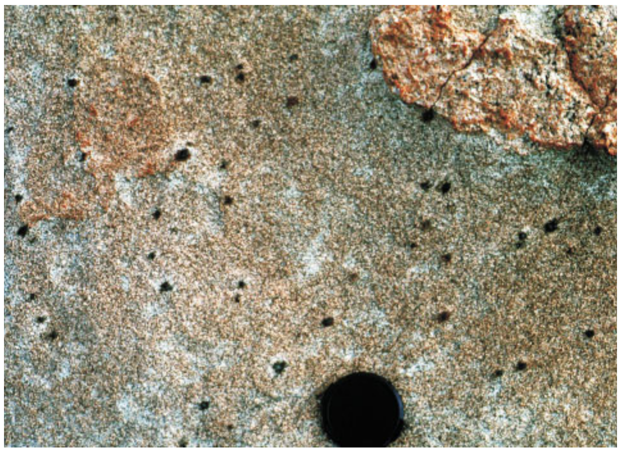
A small outcrop of massive and homogeneous medium-grained seriate to sparsely porphyritic biotite leucogranite (*AgYls*) outcrops within the Woodstock Monzogranite, in the southeastern part of WODGINA. Phenocrysts of K-feldspar are up to 1.5 cm, and characteristic darkened quartz phenocrysts are locally up to 8 mm. The granite also contains scattered biotite clots up to 1 cm. Although contact relationships are not exposed, the leucogranite is interpreted to have intruded the host Woodstock Monzogranite (*AgYwo*). This interpretation is consistent with the very high gamma-ray response of the leucogranite, which coupled with its reduced magnetic signature (<100 × 10^{-5} SI units) suggests that the unit is of similar type and age (c. 2850 Ma) as the Numbana Monzogranite (*AgYnu*).

Equigranular to weakly feldspar-porphyritic biotite(–muscovite) monzogranite (AgYme)

The northern contact between the Numbana Monzogranite and the Pincunah Monzogranite is marked by a medium-grained sparsely porphyritic to equigranular biotite monzogranite. K-feldspar forms phenocrysts up to 2 cm. The unit has a weak foliation that is subparallel to biotite schlieren and banding. The latter is defined by subtle variations in grain size (<3 to 5 mm), biotite content (<5 to 7+%), and phenocryst content, with layers from less than 2 cm to 2 m in width. The monzogranite also contains patches with common (2–3%) subhedral to euhedral magnetite crystals up to 1.5 cm, zones of which are locally aligned parallel to banding. The presence of magnetite crystals suggests some relationship with the nearby Gillam Monzogranite. Dykes within the unit include commonly discordant pegmatite and locally common garnet – two-mica monzogranite, most probably related to the Numbana Monzogranite. The unit also contains pods of moderately K-feldspar-porphyritic biotite monzogranite, similar to the Pincunah Monzogranite just to the north.

Gillam Monzogranite (AgYgi)

The Gillam Monzogranite forms small plutons up to 2 km in the central part of WODGINA. The unit comprises sparsely feldspar-porphyritic, medium-grained, biotite monzogranite. Feldspar phenocrysts are white and up to 1 cm. The monzogranite contains minor schlieren and biotite-rich clots, which appear to be more common near contacts with the Pincunah Monzogranite (*AgYpi*). The unit varies from unfoliated to weakly foliated. Muscovite-rich 'greisen' veins are locally present. The Gillam Monzogranite is typically nonmagnetic, but contains conspicuous zones and patches characterized by large magnetite crystals from 5 mm to 2 cm (Fig. 12),



AHH206 29.06.05

Figure 12. Large subhedral magnetite crystals in the Gillam Monzogranite (*AgYgi*; MGA 687242E 7660906N)

which give a locally high magnetic signature. The Gillam Monzogranite intrudes the Pincunah Monzogranite, forming small plutons and dykes, mostly too small to show at map scale (1:100 000). Pegmatite in the Pincunah Monzogranite (*AgYpi*) may also be related to the Gillam Monzogranite. Lithological similarities suggest that the Gillam Monzogranite is related to the nearby Numbana Monzogranite (*AgYnu*).

Numbana Monzogranite (AgYnum, AgYnump, AgYnumf, AgYnumx, AgYnuli)

The Numbana Monzogranite forms a large composite body in the central part of WODGINA. The monzogranite is texturally variable and composite, although primarily a porphyritic to equigranular monzogranite (*AgYnum*). The dominant phase within the Numbana Monzogranite is the weakly to nonfoliated, moderately to strongly (quartz–)feldspar-porphyritic, medium- to coarse-grained monzogranite (*AgYnump*), comprising the southeastern and southern parts of the unit. This phase commonly exhibits aligned feldspar phenocrysts. Weakly to mildly foliated, equigranular to seriate, fine- to medium-grained biotite(–muscovite) monzogranite (*AgYnumf*) is clearly an early phase of the Numbana Monzogranite. It mainly forms enclaves and pods within medium- to coarse-grained monzogranite (*AgYnump*), but also appears to be locally intrusive, and is mainly confined to the northwestern third of the Numbana Monzogranite. The distribution of this phase (*AgYnumf*) is based on outcrop mapping and extrapolation of this mapping from gamma-ray spectrometric images (given the observation that this phase is not as radiometric as the porphyritic phase *AgYnump*). Both phases contain locally abundant pegmatite and dykes of two-mica granite, both garnetiferous in places.

The Numbana Monzogranite contains complexly intermixed phases, typically containing both feldspar-porphyritic monzogranite (*AgYnump*) and seriate to equigranular monzogranite (*AgYnumf*) as well as porphyritic to equigranular muscovite–biotite(–garnet) monzogranite and leucogranite, with local quench textures. Mixed phases form dykes, pods, or enclaves, largely within or marginal to greenstones, and are typically characterized by common to abundant pegmatite (Blockley, 1980). Small areas (<2 km^2) of the Numbana Monzogranite, characterized by common greenstone enclaves and pendants, with or without granodiorite enclaves (*AgYnumx*), are within or marginal to the Wodgina greenstone belt. Small regions (<2 km^2) of biotite–muscovite(–garnet) leucogranite (*AgYnuli*) with xenoliths and rafts of Pincunah Monzogranite or banded granite are in the northeast near Pincunah Waterhole and Mount Francisco respectively.

Phases of the Numbana Monzogranite are typically weakly to mildly foliated, but are locally strongly foliated close to greenstone-margin shear zones (e.g. north of Mount Francisco). The Numbana Monzogranite is readily identified on airphotos by its very good outcrop, characterized by large granite tors and domes. The unit is readily recognizable on both gamma-ray spectrometric and aeromagnetic images by its high radiometric response (high in total counts, K, Th and U) and strongly reduced nonmagnetic character (magnetic susceptibility typically ≤20 × 10^{-5} SI units).

The Numbana Monzogranite (and associated pegmatites) clearly intrudes the Wodgina greenstone belt and its continuations, in the Mount Francisco outlier to the south and at the Pinnacle Hill outlier to the east. Pendants of greenstone (largely ultramafic and mafic schists, peridotite, and amphibolite) also outcrop between the Wodgina greenstone belt and Mount Francisco, continuing south of the latter. The Numbana Monzogranite is the youngest major granitic unit on WODGINA.

Unassigned granites (Ag, Agl, Agp, p)

Numerous units of undivided granite (*Ag*) and leucogranite (*Agl*), and pods, dykes and veins of coarse- to very coarse grained pegmatite (*Agp*) and pegmatite (*p*) are mapped across WODGINA, and are particularly abundant in the Mount Francisco and Wodgina areas, and in the northwestern part of the East Strelley greenstone belt. The dykes typically range from tens to hundreds of metres in length, and up to several metres wide, although locally they may be significantly larger. Pegmatite dykes (*p*) are an important source of tin–tantalum mineralization in the Wodgina greenstone belt, and have been described by Sweetapple et al. (2001) and Sweetapple and Collins (2002).

Blockley (1971a) described lenticular 'sills' of 'felsite', here mapped as undivided granite (*Ag*), at Stannum (north of the Comet mine) and 2 km west of the Wodgina mining camp. The felsite is a fine- to very fine grained cream to chalky-white rock that pinches and swells along strike (like boudins). The subvertically dipping, mostly concordant, banded bodies extend for up to 1.5 km and appear to be involved in regional folding. In thin section a fine matrix of quartz and plagioclase contains small phenocrysts of altered plagioclase, amphibole, and chlorite. A foliation and north-plunging lineation are developed. Sulfide minerals are scattered throughout the rock.

Dolerite dykes and quartz veins (d, q)

Numerous dolerite dykes (*d*) have intruded granitic and supercrustal rocks on WODGINA and can be divided into several distinct sets. A northwest–southeast and east-northeast–west-southwest conjugate set of fine- to medium-grained dolerite dykes extends more than 200 km along strike. These dykes are reversely magnetized (type C of Wellman, 1999) and outside WODGINA have intruded rocks as young as the Brockman Iron Formation in the Hamersley Group, establishing that many are Proterozoic or younger. Locally, the northwest–southeast and east-northeast–west-southwest dykes contain common granitic enclaves and quartz xenocrysts (up to 7 mm; e.g. MGA 675470E 7674106N). A normally magnetized northeast-striking swarm of fine- to medium-grained dolerite dykes of uncertain age and affiliation cut the Carlindi Granitoid Complex in the northeastern corner of WODGINA. These massive but recrystallized dykes lie within faults that offset the Shilliman harzburgite dyke, and are cut by massive white quartz veins (*q*). In thin section the dolerite dykes consist of chlorite-altered laths of clinopyroxene within interstitial plagioclase. In southeastern Wodgina a similar set of dykes trends in a northerly direction.

Massive white monomineralic northerly and north-northeasterly trending quartz veins (*q*) within sinistral strike-slip faults cutting the eastern margins of the Mount Francisco and southern Wodgina greenstone belts, form long en echelon corridors within the Numbana Monzogranite and surrounding granites, and form pods, veins, and dykes within the Numerous Scrapes deformation zone. Northwest–southeast to west-northwest–east-southeast en echelon quartz veins are also present within the granites of the Yule Granitoid Complex. Prominent white quartz veins are also in faults in the Carlindi Granitoid Complex that cut a dolerite dyke swarm. Huston et al. (2002) described Pilbara-wide north-trending quartz veins that are locally associated with high-level (epithermal) mineral systems (gold bearing). These veins are interpreted to be syn-Fortescue Group in age (c. 2760 Ma).

Structure

Wodgina records a complex polyphase history that resulted in numerous mesoscale and macroscale folds, faults, and associated fabrics (Van Kranendonk, 1997; Blewett, 2000, 2002; Baker et al., 2002). Blewett (2002) recognized nine local deformation events, D_1 to D_9, in the Pilgangoora area (East Strelley and Pincunah greenstone belts). Six events in the Abydos greenstone belt correlate with D_2 to D_7 at Pilgangoora, and six events in the Wodgina greenstone belt correlate with D_3 to D_8 at Pilgangoora. In these Notes the deformation events of all parts of Wodgina are numbered according to correlations with Pilgangoora (e.g. the first deformation on Wodgina is referred to as D_3).

Within a regional study, Blewett (2002) correlated the Wodgina events to deformation events that he recognized in other parts of the northern Pilbara Craton and provided a regional tectonic interpretation. However, the processes responsible for the structural architecture of the wider northern Pilbara Craton, particularly that of the EPGGT, remain controversial (Zegers et al., 1996, 2001; Blewett, 2000, 2002; Kloppenburg et al., 2001; Van Kranendonk et al., 2002; Hickman and Van Kranendonk, 2004), and are not reviewed in these Notes.

Greenstone belts and adjacent granites

D_1

The earliest fabric (S_1), a slaty cleavage or schistosity, is found only in the c. 3515 Ma Coonterunah Group (Table 2), which is along the northern and eastern parts of the East Strelley greenstone belt.

D_2

The first fabric in the Kelly Group, which unconformably overlies the Coonterunah Group in the East Strelley greenstone belt, is a bedding-parallel S_2 schistosity. The 'main' fabric of the Kelly Group is a composite fabric, with S_2 as an S-plane, or S_2 crenulated by a later S_3 foliation.

The c. 3470 Ma Petroglyph Gneiss in the Abydos greenstone belt has a well-developed banding or gneissic fabric (interpreted as S_2) that is folded by isoclinal F_3 folds.

D_3

In the centre of the East Strelley greenstone belt, talc–chlorite–carbonate and talc–actinolite schists of the Lynas Find shear system (which is folded by a regional F_6 fold) have D_3 crenulation cleavages (S_2 in microlithons) that are overprinted by coarse magnetite grains. These magnetite grains and foliations are all deformed by later D_5 shearing.

The main S_3 foliation in the Abydos greenstone belt envelops the composite granitic plutons, as reflected in the scatter of poles to foliation. Northwest-plunging F_4 folds overprint S_3 and associated F_3 isoclinal folds, forming well-developed type II and type III (Ramsay, 1967) fold-interference patterns.

In the Wodgina greenstone belt F_3 folds are variable in form (Fig. 13). Isoclinal, long-limbed F_3 folds plunge northeasterly about upright axial surfaces, whereas reclined F_3 folds, with marked asymmetry and lower limb thinning and transposition, are locally veined by quartz along the axial traces. The S_3 cleavage mostly strikes northeasterly. A well-developed S_0/S_3 intersection and rarer mineral alignment define the L_3 lineation. A northwest-trending steeply dipping fracture cleavage (S_4) transects F_3 folds.

D_4

Throughout the Gorge Creek Group of the Pincunah greenstone belt, Type III fold-interference patterns result from northeast-plunging F_3 isoclinal folds being overprinted by northwest-plunging F_4 closed folds (Fig. 14), locally with well-developed S_4 crenulation cleavages. In the Abydos greenstone belt, isoclinal F_3 folding of the gneissic banding (S_2) is overprinted by dykes of granitic melt that were intruded into the axial traces of open F_4 folds. These dykes were dated at c. 3240 Ma (Van Kranendonk, 1997).

D_5

Northerly to north-northeasterly striking sinistral D_5 shear zones of the Mount York deformation zone (Van Kranendonk, 2000) deform andalusite porphyroblasts in pelitic schist and clinozoisite porphyroblasts in mafic (chlorite) schist. In the Lynas Find shear system in the East Strelley greenstone belt, muscovite-defined C' planes record sinistral shear. Along the eastern margin of the Yule and Carlindi Granitoid Complexes, the granites locally have well-developed D_5 sinistral S-C planes and associated stretching lineations that are subhorizontal.

Sinistral shear bands and S-C mylonites (D_5) in granite, granodiorite, and pegmatite of the Yule Granitoid

Table 2. Summary of the geological history of WODGINA

Age (Ma)	*East Pilbara Granite–Greenstone Terrane*
c. 3515	Deposition of rocks of the Coonterunah Subgroup, preserved in the East Strelley greenstone belt
>3470	Development of S_1 fabrics in rocks of the Coonterunah Subgroup
c. 3485–3470	Coonterunah Subgroup intruded by monzogranite of the Carlindi Granitoid Complex (Motherin Monzogranite); intrusion of tonalite, granodiorite, and monzogranite in the Yule Granitoid Complex
c. 3420	Intrusion of tonalite, granodiorite, and monzogranite in the Yule Granitoid Complex. Erosion of the Warrawoona Group
c. 3350–3325	Deposition of the Kelly Group, preserved now in the East Strelley greenstone belt (and possibly in the Wodgina and Mount Francisco greenstone belts)
c. 3420–3240	Development of S_2 fabrics in rocks of the East Strelley greenstone belt
c. 3270	Deposition of Golden Cockatoo Formation and Sulphur Springs Group
?	Development of S_3 fabrics in rocks of the East Strelley greenstone belt
?	Early development of the Tabba Tabba Shear Zone
3020–3015	Deposition of Cleaverville Formation
?	Development of $S_{5–6}$ fabrics in rocks of the East Strelley greenstone belt
2970–2940	Deposition of De Grey Supergroup in the Mallina Basin
2940–2925	Intrusion of monzogranite and granodiorite in the Carlindi and Yule Granitoid Complexes
?	Development of S_7 fabrics in rocks of the East Strelley greenstone belt
2850–2830	Intrusion of muscovite(–garnet), two-mica, and biotite monzogranite in the Carlindi and Yule Granitoid Complexes Intrusion of rare-element pegmatites into greenstones and granites
2770 and younger	Dip-slip faulting along major northeasterly trending faults
2770–755	Intrusion of dolerite dykes, including the east-northeast striking Mundine Well Dolerite Suite, and the west-northwest striking Round Hummock Dolerite Suite

Complex are up to 3 km south of the main Numerous Scrapes deformation zone (defined by ultramafic schist). Shear bands in amphibolites and ultramafic schist in the narrow septa between the granitic plutons of the Abydos greenstone belt record S-directed, greenstone-up sense of shear on lineations that plunge to the northeast. Locally, these D_5 shear zones are crenulated and overprinted by D_6 and D_7 fabrics.

The D_5 deformation event was intense along the western margin of the Wodgina greenstone belt, and developed a blastomylonitic fabric associated with S-C-C' planes that record sinistral shear. The L_5 stretching lineations plunge to the northeast. Locally, an early sinistral shear fabric is overprinted by further sinistral shear (C' planes or shear bands), possibly as a result of progressive D_5 deformation. The S_5 shear bands in the

AHH207 29.06.05

Figure 13. Upright F_3 folds in banded iron-formation in the western part of the Wodgina greenstone belt (MGA 672890E 7653890N)

AHH208 29.06.05

Figure 14. Type III 'hooked' fold interference between isoclinal F_3 folds and tight northwest-trending F_4 folds in the Corboy Formation (MGA 706797E 7650990N)

greenstones strike northeast to north-northeast, subparallel to the S_3 schistosity, developing a composite fabric (acute intersection of foliation planes) that indicates a component of sinistral shear. Along the eastern margin of the Wodgina greenstone belt, sinistral D_5 shear bands strike northeast and east-northeast, and are refolded by a macroscale F_6 fold in the centre of the Wodgina greenstone belt. Amphibolites associated with these shear bands have a strong L_5 mineral alignment that plunges to the northeast.

D_6

North-striking S_6 crenulations are axial-planar fabrics to a series of south-plunging, upright, tight F_6 folds. At Lynas Find these F_6 folds overprint the S_2/S_3 composite fabric, earlier folds, shear zones, and the alteration and mineralization of this mining area. Metamorphic grade during D_6 was locally high enough to form biotite.

In the Abydos greenstone belt the F_6 fold axes are doubly north and south plunging, and associated with a widespread S_6 crenulation cleavage defined by biotite (Fig. 15). Granitic veins, dated at c. 2950 Ma (Van Kranendonk, 1997), are subparallel to the axial trace of F_6 folds, which refold earlier F_3 folds in the Petroglyph Gneiss.

Along the western margin of the Wodgina greenstone belt the main S_5 mylonitic fabric is locally overprinted by pegmatite dykes and veins, which are folded about north-trending, tight F_6 folds. The south-closing synformal structure of the Wodgina greenstone belt is interpreted as a macroscale F_6 fold. Mesoscale chevron folds that plunge steeply north are associated with a steeply dipping spaced crenulation cleavage interpreted as D_6 structures.

D_7

Progressive deformation during D_7 resulted in east-northeast–west-southwest oriented folds and reworking of the D_5 shear zones in the East Strelley greenstone belt.

AHH209 29.06.05

Figure 15. North- and south-plunging S_6 crenulations in the axis of the Pilgangoora Syncline (MGA 701814E 7678582N)

AHH210 29.06.05

Figure 16. Well-developed S_7 crenulations in talc schist, adjacent to the Mount York Deformation Zone (MGA 697052E 7665550N)

Gold deposits in the Mount York area (Neumayr et al., 1998) and the McPhees gold mine area (Baker et al., 2000, 2002), are hosted in structures here interpreted as D_7. The S_7 crenulations are commonly coarse and broadly spaced (Fig. 16). In the Abydos greenstone belt the D_7 event developed northeast-trending S_7 crenulations and associated moderately to gently northeast-plunging F_7 folds. In the Wodgina greenstone belt the D_7 deformation event developed northeast-trending, steeply dipping crenulations and associated folds of the main S_3 fabric.

D_8

Fine-spaced S_8 crenulations oriented east–west are the only manifestation of the relatively minor D_8 deformation event that reflects minor north–south shortening. The fold style is locally chevron like, with moderately to steeply east-plunging hinges about steeply dipping crenulation axial surfaces. The intensity of the crenulation development varies considerably with the tightness of associated F_8 folds. The c. 2850–2830 Ma tin granites (e.g. Numbana Monzogranite) are locally deformed with a weak to moderate east-trending D_8 foliation.

D_9

Fine-scaled S_9 crenulations striking northwest–southeast overprint all other fabric elements (Fig. 17). Macroscale examples of the D_9 folds refold the F_6 Pilgangoora Syncline.

Granitic complexes

The majority of granites on WODGINA were emplaced at c. 2930 and c. 2850 Ma, and are characteristically weakly foliated to massive. For example, the largest (and youngest) unit on WODGINA — the Numbana Monzogranite — preserves a generally weak to very weak fabric (S_8), largely manifest as east–west aligned phenocrysts. Locally, strong fabrics are developed, a good example being along the northern margin of the Mount Francisco greenstone

AHH211 29.06.05

Figure 17. Intersection of L_6 and L_9 lineations in black chert east of McPhees mine (MGA 707171E 7676274N)

belt (Fig. 3). Variable deformation is recorded in the c. 2930 Ma granites, although most granites typically have a weak to moderate foliation, defined by mineral alignment or minor cryptic to subdued banding, with stronger fabrics close to greenstone margins and fault zones. For example, the Mungarinya Monzogranite is characterized by a moderate to weak east-striking fabric manifest as aligned minerals, banding, and schlieren that is overprinted to the east by a stronger fabric associated with the sheared western margin of the Wodgina greenstone belt. The Abydos Monzogranite is the most strongly deformed of the c. 2930 Ma granites on WODGINA, with a strong penetrative northeast-striking (?)shear D_7 fabric defined by mineral elongation and alignment, and parallel banding; this foliation appears to continue into the southern part of the Woodstock Monzogranite, but is absent elsewhere. The shear zone may well represent a splay off the nearby Pulcunnah Shear Zone, defined on NORTH SHAW by Van Kranendonk (1998).

The best evidence for earlier fabrics within the granites are preserved in the c. 3420 and c. 3470 Ma Petroglyph and other unnamed gneisses, particularly in the Yule Granitoid Complex. Within these rocks gneissic layering, which is isoclinally (F_3) to more openly (F_6) folded, is discordantly cut by younger units. Although the majority of the latter are c. 2930 Ma in age and younger, at least one unit, the Kavir Granodiorite, is significantly older (c. 3240 Ma, Van Kranendonk, 1997), indicating that high-grade metamorphism and subsequent F_3 folding of the banding at least locally pre-dates 3240 Ma (age from Van Kranendonk, 1997). For example, gneissic layering in the Turner River area (e.g. MGA 702322E 7634546N) is folded about shallow southeast-plunging fold axes, and overprinted by axial-planar foliation steeply dipping to the northwest that elsewhere is parallel to the gneissic banding (forming a composite fabric) and to foliation in crosscutting granite dykes. Later minor F_4 folds plunge 45° to the west, locally overprinting this composite S_2–S_3 fabric.

Some of the latest structures in the granites are subparallel north-northeasterly trending and less common (conjugate?) west-northwest faults, manifest as long, typically en echelon, quartz veins. The north-northeasterly trending faults have minor sinistral offsets, with the west block down (e.g. defining the eastern margin of the Mount Francisco greenstone belt). These north-northeasterly trending faults cut the Numbana Monzogranite (the youngest granitic pluton on WODGINA) and may be related to the development of the Hamersley Basin (now eroded on WODGINA).

Age constraints on deformation events

Evidence for D_1 is preserved only in the 3515 Ma Coonterunah Group, and its age is constrained by a later granite intrusion dated at c. 3470 Ma (Buick et al., 1995). The timing of D_2 structures is poorly constrained between 3315 and 3235 Ma because these structures are developed in the Warrawoona and Kelly Groups (>3315 Ma on WODGINA), but not in the <3235 Ma Gorge Creek Group. Deformed Gorge Creek Group rocks provide a maximum age of 3235 Ma for D_3 and younger structures. More geochronology is needed on deformed granites of the Carlindi and Yule Granitoid Complexes to constrain the minimum age of D_3 on WODGINA. The D_7 structures host the Mount York gold mineralization, which was associated with amphibolite-facies metamorphism and northeast–southwest folding dated at c. 2888 Ma (Neumayr et al., 1998). The D_8 and D_9 structures overprint this mineralization, and are therefore younger than c. 2888 Ma.

Metamorphism

Metamorphic grade in Pilbara Supergroup rocks varies throughout the map area, from areas of prehnite–pumpellyite facies in the Gorge Creek Group to greenschist facies throughout most of the Pincunah, Wodgina, and East Strelley greenstone belts. There are higher grade rocks, including upper greenschist to lower amphibolite facies, around the margins of the Yule Granitoid Complex. Rocks of the Golden Cockatoo Formation in the Abydos greenstone belt were also metamorphosed to amphibolite facies, and contain sillimanite–biotite–garnet–muscovite metapelite, garnet-bearing amphibolite, grunerite-bearing banded iron-formation, and corundum-bearing felsic gneiss. Older granitic phases (>3240 Ma) of the Carlindi and Yule Granitoid Complexes are also at amphibolite facies.

Cenozoic deposits

Calcrete (Czrk, Czak)

Massive, nodular, and cavernous calcrete, present throughout WODGINA, is either residual in origin (*Czrk*) or alluvial (*Czak*) along old drainage channels. Residual calcrete (*Czrk*) is most commonly developed over mafic and ultramafic rocks, where it is locally associated with minor deposits of magnesite. Calcrete also forms cement within high-level gravels (*Czag*), particularly along dissected contacts adjacent to the present-day drainage.

Ferruginous duricrust, including pisolitic limonite (Czaf)

Ferruginous duricrust, including pisolitic limonite deposits (*Czaf*), developed along palaeodrainage lines are now exposed on small plateau surfaces in the northeastern part of WODGINA, west of Pincunah Hill.

Colluvium (Czc, Czcf, Czcg)

Dissected and consolidated colluvium (*Czc*) occurs mainly in the northern part of WODGINA, where it is primarily derived from local outcrops, commonly granitic rocks (*Czcg*), and is deposited on adjacent low-angle slopes. These deposits consist of clay- or silica-cemented, poorly stratified silt, sand, and gravel. Adjacent to deposits of pisolitic limonite, these colluvium deposits locally contain abundant ferruginous silt, sand, and gravel bound by a limonitic cement (*Czcf*).

Ferricrete (Czrf)

Ferricrete (*Czrf*) or ferruginous duricrust, including ferruginous and pisolitic ironstone, forms a dissected laterite plateau on many hills on WODGINA, particularly on ferruginous shale and banded iron-formation in the Wodgina greenstone belt. Local alteration below laterite may extend to depths of several tens of metres.

Gravel deposits (Czag)

High-level gravel deposits (*Czag*) that are unrelated to and currently being dissected by the recent drainage are present throughout WODGINA, but are most common in the northeast, east of the Turner River, overlying granites of the Yule and Carlindi Granitoid Complexes and greenstones of the Pincunah greenstone belt. Gravels are matrix supported, with clasts from less than 5 to 25 cm, although mostly less than 15 cm. Clasts largely comprise angular to subrounded chert and banded iron-formation, subrounded quartz fragments, and rounded granitic pebbles.

Quaternary colluvium, sheetwash, quartzofeldspathic eluvial sand, and eolian sand (Qc, Qcq, Qw, Qwg, Qrg, Qs)

Colluvium, consisting of sand, silt, and gravel (*Qc*), is locally derived from elevated outcrops, including quartz veins (*Qcq*) and deposited as sheetwash and talus.

Sheetwash, including sand, silt, and gravel (*Qw*), is deposited on distal outwash fans. In some regions it overlies and is derived from granitic rocks (*Qwg*). Locally reworked by wind action, the sand deposits have generally been stabilized by extensive grass and shrub cover.

Quartzofeldspathic eluvial sand with quartz and rock fragments (*Qrg*) overlies and has been derived from a large proportion of granitic units of both the Yule and Carlindi Granitoid Complexes.

Eolian sand (*Qs*) forms minor east-southeasterly trending unstable dunes in the northwestern corner of WODGINA.

Quaternary alluvial deposits (Qaa, Qab, Qac, Qao, Qaoc)

Present-day drainage channels contain alluvial clay, silt, and sand in channels, and sand and gravel in rivers and creeks (*Qaa*). Alluvial clay, silt, and sand form overbank deposits on floodplains (*Qao*) and locally include areas of expansive clay with a gilgai surface (*Qab*). Gilgai is a clay-rich silt or sand deposit characterized by the development of numerous cracks and sinkholes. The clay expands and contracts according to water content, and in dry conditions produces an irregular 'crabhole' surface. Immediately adjacent to rivers, alluvial floodplains also include small, abundant, scattered lacustrine or claypan deposits (*Qaoc*), consisting of clay, silt, and evaporite in shallow depressions such as claypans (*Qac*).

Economic geology

Maps and summaries of various mineral deposits of the east Pilbara are provided by Blewett et al. (2000) and a review of mineralization was presented by Huston et al. (2002). Ferguson and Ruddock (2001) provided a comprehensive report on the mineral occurrences and exploration potential of the east Pilbara.

Epigenetic gold

The earliest reports on gold on WODGINA are those describing the McPhees Patch in the northern part of the East Strelley greenstone belt (Finucane, 1935). The average grade was approximately 9 g/t for crushings from crude ore from McPhees Patch (Finucane, 1935). More recent exploration in the Mount York district by MIM Exploration Pty Ltd, and later Lynas Gold NL, added to information on mineralization in that area (Ferguson and Ruddock, 2001; Huston et al., 2002). The detailed economic geology of the Mount York district was covered by Neumayr (1993), and the McPhees and Iron Stirrup deposits by Baker et al. (2002).

Gold mineralization in the Mount York district is associated with D_7 shear zones in Warrawoona Group rocks, or is at sheared contacts between metasediments of the Gorge Creek Group and mafic schist of the Warrawoona Group. Alteration associated with gold mineralization and peak amphibolite metamorphism at Zakanaka was dated by the Pb–Pb method at 2988 Ma (Neumayr et al., 1998). Galena from the McPhees deposit has been dated by the Pb–Pb method at 3142 Ma (unpublished Geoscience Australia data from their OZCHRON database).

In the Mount York district, Lynas Gold NL mined more than 125 000 oz of gold (1994–98) from the McPhees, Iron Stirrup, Zakanaka, Main Hill, and Breccia Hill deposits. A pit collapse at Iron Stirrup shortened the life of the nearby Lynas processing plant and resulted in selective high-grade extraction from the McPhees deposit.

Tin–tantalum

Tin (cassiterite) was discovered in the Wodgina district in 1902, and since then has been mined along with tantalum, beryl, and a little copper. The Wodgina district includes the mining centres of Wodgina, Stannum, Mills Find, Numbana, and Mount Francisco. Details of these and the Pilgangoora deposits may be obtained from Blockley (1980), Sweetapple (2000), Sweetapple et al. (2001), and Sweetapple and Collins (2002).

Blockley (1980) defined three types of tin-bearing and rare metal pegmatites in the Pilbara Craton: simple pegmatite, layered albite pegmatite, and complex zoned (rare metal) pegmatite. This classification was expanded by Sweetapple (2000), Sweetapple et al. (2001), and Sweetapple and Collins (2002). The relationship between rare metal pegmatites and the 'younger' granite suite (represented on WODGINA by the Numbana and Minnamonica Monzogranites) is well documented (Blockley, 1980; Hickman, 1983; Sweetapple and Collins, 2002), and supported by geochronology (e.g. Kennedy (1998) dated apatite (Pb–Pb), from a lepidolite–spodumene dyke near the main Wodgina pegmatite at 2870 ± 90 Ma). The spatial relationship between the source granites and pegmatites can commonly be clearly identified, showing that rare metal pegmatite bodies are typically no more than 5 km from their parent post-tectonic granites.

Quartz–tourmaline–mica–cassiterite veins, associated with tantalum–tin mineralized pegmatites, have been described for the Wodgina greenstone belt and the associated Mount Francisco greenstone belt (Blockley, 1980). This style of mineralization is invariably closely associated with mineralized pegmatites as offshoots of mineralized pegmatites. Blockley (1980) noted that these veins typically either follow the edges of pegmatite veins or occupy nearby parallel fractures. This style of mineralization was responsible for the bulk of the early hard-rock tin production, including the original Mount Cassiterite underground tin workings. Limited geochemical information suggests that they have a low tantalum content (Sweetapple, 2000). The main 'Tantalite Lode' 1 km northeast of the old Wodgina town is hosted in an east-dipping pegmatite that extends for about 700 m (Hickman, 1983).

Significant tantalum production was undertaken from the Wodgina pegmatite deposits during World War II. Most of the hard-rock tantalum has been derived since 1988 from openpit mining of the Wodgina albite-type pegmatites and the Mount Cassiterite albite–spodumene-type pegmatites to the south, in the Wodgina Pegmatite District (e.g., Sweetapple and Collins, 2002). About 150 534 lbs of tantalum were produced in fiscal 1998 from the Mount Cassiterite orebody. Combined with production from the Greenbushes pegmatite, in 2003 these deposits met 25% of the world's tantalum requirements. Tin and niobium have also been extracted as byproducts of these mining operations. The Wodgina main lode produced 0.402 Mt of tantalum ore at 1283 ppm Ta_2O_5 and about 211 ppm Nb_2O_5, whereas West Wodgina produced 44 000 t of tantalum ore at 1000 ppm Ta_2O_5 (Sweetapple, 2000). The Mount Cassiterite mine in the Wodgina district has produced 4.37 Mt of ore at 525 ppm Ta_2O_5 and 292 ppm SnO_2 containing about 240 t of Ta (Sweetapple, 2000). The recently discovered Mount Cassiterite East deposit contains an inferred resource estimated at 28 Mt of ore at 415 ppm Ta_2O_5 (Louthean, 1998). Tantalum has also been produced as a common byproduct of alluvial tin mining, where tantalum minerals form microinclusions in cassiterite.

At Pilgangoora pegmatite dykes up to 600 m long and 300 m wide intrude probable Warrawoona Group amphibolite and mafic schist. Hickman (1983) noted that these are sparsely mineralized and that most of the tantalum was extracted from the alluvium and colluvium.

Alluvial diggings are in all the tin–tantalum districts, with cassiterite samples up to 36 kg in the Wodgina area (Blockley, 1980).

Copper

Minor amounts of copper have been mined on WODGINA. In the East Strelley greenstone belt the shallow Hazelby workings are on gently south-dipping, south-plunging folds of black chert and chlorite–actinolite schist. Mineralization consists of a limonitic band containing malachite and azurite, which can be traced along strike to the west, where three shallow exploration pits were excavated and the area drilled by Esso in 1974 and 1975 (Ferguson and Ruddock, 2001). Marston (1980) reported production of 10.81 t of ore at 7.5% Cu from Hazelby, and 23.36 t of cuprous ore from Crown Land in the East Strelley greenstone belt in 1964.

In the southwest of the Wodgina greenstone belt the Stannum West copper prospect contains thin veinlets and disseminated geothite, malachite, and chrysocolla along a 200 m-long by 10 m-wide zone of chlorite schist and amphibolite (Marston, 1980). Four shallow pits yielded 3.71 t of cupreous ore at 6.25% Cu. Drilling by Pancontinental Mining Ltd in 1974 was unsuccessful, and the prospect is considered uneconomic (Marston, 1980). The Stannum Northeast prospect in the centre of the Wodgina greenstone belt contains rare 'feeble' copper staining associated with kaolinitized rock.

The Mount Francisco deposit is 1 km south of Mount Francisco, and in 1957 produced 4.23 t of ore at 4.23% Cu (Marston, 1980). Bassests, a small prospect 1.3 km south-southeast of Kangan Homestead, contains disseminated malachite along the length of a 250 m-long by 2 m-wide quartz vein in granite of the Yule Granitoid Complex (Marston, 1980).

Lead

Fine granular galena was reported from a 1.5 m quartz vein in granite at West Wodgina, and is consider uneconomic (Blockley, 1971a). Southeast of Wodgina, very coarse grained galena assayed 74.6% Pb, 64.94 g/t Ag, and 0.82 g/t Au (Blockley, 1971a). Small prospects of lead, zinc, and fluorite are noted in the northern East Strelley greenstone belt. Abeysinghe and Fetherston (1979) described veins at McPhees, and Blockley (1971b) described veins at Water Right 115, Pilgangoora, that assayed 3.74% Cu, 1.38% Pb, 0.24% Zn, and 258.14 g/t Ag. At Greens Well galena with cerussite, anglesite, and blende in a gangue of fluorite and quartz assayed 44.76% Pb with no silver or gold (Blockley, 1971b).

Gemstone pegmatites

Hickman (1983) described emerald-bearing pegmatites in the Pilgangoora and Wodgina pegmatite districts. Occurrences of emerald in the Wodgina pegmatite district were noted to be minor and of poor quality (Simpson, 1948).

Minor potential for other pegmatite-related gemstones exists in the Pilbara region. The main mineral is tourmaline, the black (schorl) variety being widespread throughout the Pilbara region, and the blue (indicolite) variety being reported in the Wodgina district (Hickman, 1983). Topaz has been reported in the Mount Francisco (Hickman, 1983) and Wodgina pegmatite districts (Simpson, 1952).

Other minerals

There has been minor production of cesium (as a byproduct of beryl mining at Wodgina) and emeralds (at McPhees Hill and Coffin Bore in the Pilgangoora pegmatite district) from a number of pegmatite bodies in the Pilbara Craton (Sweetapple, 2000). The principal source of beryl in the Pilbara region was the 'Tantalite Lode' at Wodgina. Hickman (1983) noted that total production of contained BeO amounted to 106 t at Wodgina, 0.266 t at Pilgangoora, and more than 31 t at Mount Francisco.

Spodumene-bearing pegmatite veins 1.5 km north of Mount York in the East Strelley greenstone belt contain probable reserves estimated at 1.6 Mt of pegmatite containing 1.2% LiO_2 (Hickman 1983). Simpson (1912) described small concentrations of uneconomic radioactive minerals (uranium) from the Wodgina district. Baxter (1979) reported minor scheelite (W) from quartz veins in the adjacent mica schist from Kingston's scheelite lease at Wodgina.

Tertiary pisolitic iron deposits on the tops of the Wodgina and Pincunah ranges were described by de la Hunty (1961). Blockley (1971b) estimated that the Wodgina deposit contained about 1 Mt of iron ore averaging 56% Fe.

References

ABEYSINGHE, P. B., and FETHERSTON, J. M., 1979, Barite and fluorite in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 17, 97p.

ARNDT, N. T., NELSON, D. R., COMPSTON, W., TRENDALL, A. F., and THORNE, A. M., 1991, The age of the Fortescue Group, Hamersley Basin, Western Australia, from ion microprobe zircon U–Pb results: Australian Journal of Earth Sciences, v. 38, p. 261–281.

BAKER, D. E. L., SECCOMBE, P. K., and COLLINS, W. J., 2000, Geodynamic framework and characterization of mineralising fluids and the McPhees gold deposit, Pilbara Craton, Western Australia: Geological Society of Australia, Abstracts, v. 59, p. 13.

BAKER, D. E. L., SECCOMBE, P. K., and COLLINS, W. J., 2002, Structural history and timing of gold mineralization in the northern East Strelley Belt, Pilbara Craton, Western Australia: Economic Geology, v. 97, p. 775–785.

BAXTER, J. L., 1979, Molybdenum, tungsten, vanadium and chromium in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 11, 140p.

BICKLE, M. J., BETTENAY, L. F., BARLEY, M. E., CHAPMAN, H. J., GROVES, D. I., CAMPBELL, I. H., and de LAETER, J. R., 1983, A 3500 Ma plutonic and volcanic calc-alkaline province in the Archean East Pilbara Block: Contributions to Mineralogy and Petrology, v. 84, p. 25–35.

BICKLE, M. J., BETTENAY, L. F., CHAPMAN, H. J, GROVES, D. I., McNAUGHTON, N. J., CAMPBELL, I. H., and de LAETER, J. R., 1989, The age and origin of younger granitic plutons of the Shaw batholith in the Archean Pilbara Block, Western Australia: Contributions to Mineralogy and Petrology, v. 101, p. 361–376.

BLAKE, T. S., 1993, Late Archean crustal extension, sedimentary basin formation, flood basalt volcanism and continental rifting: the Nullagine and Mount Jope Supersequences, Western Australia: Precambrian Research, v. 60, p. 185–241.

BLEWETT, R. S., 2000, North Pilbara 'Virtual' Structural Field Trip: Australian Geological Survey Organization, Record 2000/45.

BLEWETT, R. S., 2002, Archaean tectonic processes: a case for horizontal shortening in the North Pilbara Granite–Greenstone Terrane, Western Australia: Precambrian Research, v. 113, p. 87–120.

BLEWETT, R. S., CHAMPION, D. C., SMITHIES, R. S., VAN KRANENDONK, M. J., FARRELL, T. R., and THOST, D., 2001, Wodgina, W.A. Sheet 2655: Western Australia Geological Survey, 1:100 000 Geological Series.

BLEWETT, R. S., WELLMAN, P., RATAJKOSKI, M., and HUSTON, D. L., 2000, Atlas of North Pilbara geology and geophysics (1:1.5M scale): Geoscience Australia, Record 2000/04, 36p.

BLOCKLEY, J. G., 1971a, Geology and mineral resources of the Wodgina district: Western Australia Geological Survey, Annual Report 1970, p. 38–42.

BLOCKLEY, J. G., 1971b, The lead, zinc, and silver deposits of Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 9, 234p.

BLOCKLEY, J. G., 1980, Tin deposits of Western Australia, with special references to associated granites: Western Australia Geological Survey, Mineral Resources Bulletin 12, 184p.

BROWN, D. A., CAMPBELL, K. S. W., and COOKE, K. A. W., 1968, The geological evolution of Australia and New Zealand: Oxford, United Kingdom, Pergamon Press, 409p.

BUICK, R., THORNETT, J. R., McNAUGHTON, N. J., SMITH, J. B., BARLEY, M. E., and SAVAGE, M., 1995, Record of emergent continental crust ~3.5 billion years ago in the Pilbara Craton of Australia: Nature, v. 375, p. 574–577.

CHAMPION, D. C., and SMITHIES, R. H., 2000, The geochemistry of the Yule Granitoid Complex, East Pilbara Granite–Greenstone Terrane; evidence for early felsic crust ; Western Australia Geological Survey, Annual Review 1999–2000, p. 42–48.

DAWES, P. R., SMITHIES, R. S., CENTROFONTI, J., and PODMORE, D. C., 1994, Unconformable contact relationships between the Muccan and Warrawagine batholiths and the Archaean Gorge Creek Group in the Yarrie mine area, northeast Pilbara: Western Australia Geological Survey, Record 1994/3, 23p.

de la HUNTY, L. E., 1961, Report on some limonitic iron ore deposits in the vicinity of Port Hedland, Pilbara goldfield, W.A.: Western Australia Geological Survey, Annual Report 1960, p. 15–21.

ERIKSSON, K. A., 1981, Archaean platform-to-trough sedimentation, East Pilbara Block, Australia: Geological Society of Australia, Special Publication, v. 7, p. 235–244.

FERGUSON, K. M., and RUDDOCK, I., 2001, Mineral occurrences and exploration potential of the east Pilbara: Western Australia Geological Survey, Report 81, 114p.

FINUCANE, K. J., 1935, McPhees Patch area, Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report No.1, 2p.

FINUCANE, K. J., and TELFORD, R. J., 1939, Tantalite deposits of the Pilbara Goldfield: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report No 46, 8p.

HICKMAN, A. H., 1983, Geology of the Pilbara Block and its environs: Western Australia Geological Survey, Bulletin 127, 268p.

HICKMAN, A. H., 1990, Geology of the Pilbara Craton, *in* Third International Archaean Symposium, Perth, 1990, Excursion Guidebook no. 5: Pilbara and Hamersley Basins *edited by* S. E. HO, J. E. GLOVER, J. S. MYERS, and J. R. MUHLING: University of Western Australia, Geology Department and University Extension, Publication no. 21, p. 2–13.

HICKMAN, A. H., 2001, Geology of the Dampier 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

HICKMAN, A. H., 2004, Two contrasting granite–greenstone terranes in the Pilbara Craton, Australia: evidence for vertical and horizontal tectonic regimes prior to 2900 Ma: Precambrian Research, v. 131, p. 153–172.

HICKMAN, A. H., and LIPPLE, S. H., 1975, Explanatory notes on the Marble Bar 1:250 000 Geological Sheet, W.A.: Western Australia Geological Survey, Record 1974/20, 90p.

HICKMAN, A. H., and LIPPLE, S. H., 1978a, Marble Bar, W.A. Sheet SF 50-8: Western Australia Geological Survey, 1:250 000 Geological Series.

HICKMAN, A. H., and LIPPLE, S. H., 1978b, Marble Bar, W.A.: Western Australia Geological Survey 1:250 000 Geological Series Explanatory Notes, 24p.

HICKMAN, A. H., and VAN KRANENDONK, M. J., 2004, Diapiric processes in the formation of Archaean continental crust, East Pilbara Granite–Greenstone Terrane, Australia, *in* The Precambrian Earth: Tempos and Events *edited by* P. G. ERIKSSON, W. ALTERMANN, D. R. NELSON, W. U. MUELLER, and O. CATUNEANU: Amsterdam, The Netherlands, Elsevier, p. 54–75.

HOFMAN, H. J., GREY, K., HICKMAN, A. H., and THORPE, R., 1999, Origin of 3.45 Ga coniform stromatolites in the Warrawoona Group, Western Australia: Geological Society of America, Bulletin v. 3, p. 1256–1262.

HORWITZ, R. C., 1990, Palaeogeographic and tectonic evolution of the Pilbara Craton, northwestern Australia: Precambrian Research, v. 48, p. 327–340.

HUSTON, D. L., BLEWETT, R. S., KEILLOR, B., STANDING, J., SMITHIES, R. H., MARSHALL, A., MERNAGH, T. P., and KAMPRAD, J., 2002, Lode gold and epithermal deposits of the Mallina – Whim Creek Basin, Pilbara Craton, Western Australia: Economic Geology, v. 97, p. 801–818.

INGRAM, P. A. J., 1977, A summary of the geology of a portion of the Pilbara Goldfield, Western Australia, *in* The Archaean, search for the beginning *edited by* G. J. H. McCALL: Stoudsburg, Pennyslvania, U.S.A., Dowden, Hutchison and Ross, p. 208–216.

KENNEDY, A. K. 1998, SHRIMP ages of apatites from Pilbara tin-bearing pegmatites, *in* Geoscience for the new millennium, 14th Australian Geological Convention, Townsville, Queensland, 1998: Geological Society of Australia, Abstracts v. 49, p. 242.

KLOPPENBURG, A., WHITE, S. H., and ZEGERS, T. E., 2001, Structural evolution of the Warrawoona greenstone belt and adjoining granitoid complexes, Pilbara Craton, Australia; implications for Archaean tectonic processes: Precambrian Research, v. 112, p. 107–147.

KRAPEZ, B., 1993, Sequence stratigraphy of the Archaean supracrustal belts of the Pilbara Block, Western Australia: Precambrian Research, v. 60, p. 1–45.

LOUTHEAN, R., 1998, Wodgina adds spice to world-class tantalite role: Paydirt, v. 1, no. 45 (November), p. 1–2.

LOWE, D. R., 1983, Restricted shallow-water sedimentation of Early Archean stromatolitic and evaporitic strata of the Strelley Pool Chert, Pilbara Block, Western Australia: Precambrian Research, v. 19, p. 239–283.

MARSTON, R. J., 1980, Copper mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 13, 208p.

McNAUGHTON, N. J., GREEN, M. D., COMPSTON, W., and WILLIAMS, I. S., 1988, Are anorthositic rocks basement to the Pilbara Craton?: Geological Society of Australia, Abstracts v. 21, p. 272–273.

McNAUGHTON, N. J., COMPSTON, W., and BARLEY, M. E., 1993, Constraints on the age of the Warrawoona Group, eastern Pilbara Block, Western Australia: Precambrian Research, v. 60, p. 69–98.

MORANT, P., 1998, Panorama zinc–copper deposits, *in* Geology of Australian and Papua New Guinean mineral deposits *edited by* D. A. BERKMAN and D. H. McKENZIE: The Australasian Institute of Mining and Metallurgy, Monograph 22, p. 287–292.

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

NELSON, D. R., 1999, Compilation of SHRIMP U–Pb zircon geochronology data, 1998: Western Australia Geological Survey, Record 1999/2, 222p.

NELSON, D. R., 2004, GSWA 178045, *in* Compilation of geochronology data, October 2004 update: Western Australia Geological Survey.

NEUMAYR, P., 1993, The nature and genesis of Archaean syn-amphibolite facies gold mineralization in the Mt York district, Pilbara Craton, Western Australia: The University of Western Australia, PhD thesis (unpublished).

NEUMAYR, P., RIDLEY, J. R., McNAUGHTON, N. J., KINNY, P. D., BARLEY, M. E., and GROVES, D. I., 1998, Timing of gold mineralization in the Mt York district, Pilgangoora greenstone belt, and implications for the tectonic and metamorphic evolution of an area linking the western and eastern Pilbara Craton: Precambrian Research, v. 88, p. 249–265.

NOLDART, A. J., and WYATT, J. D., 1958, Summary progress report on reconnaissance survey of portion of the Pilbara Goldfield, W.A.: Western Australia Geological Survey, Bulletin 113, p. 35–44.

NOLDART, A. J. and WYATT, J. D., 1962, The geology of portion of the Pilbara Goldfield covering the Marble Bar and Nullagine 4-mile map sheets: Western Australia Geological Survey, Bulletin 115, 199p.

RAMSAY, J. G., 1967, Folding and fracturing of rocks: New York, U.S.A., McGraw Hill, International Series in the Earth Planetary Sciences, 568p.

RICHARDSON, L. M., 1997, Marble Bar (Marble Bar, western Port Hedland, eastern Roebourne and northeastern Pyramid 1:250 000 sheet areas) airborne geophysical survey 1996 — operations report: Australian Geological Survey Organisation, Record 1997/63, 57p.

RYAN, G. R., 1964, A reappraisal of the Archaean of the Pilbara Block: Western Australia Geological Survey, Annual Report 1963, p. 25–28.

RYAN, G. R., 1965, The geology of the Pilbara Block: The Australasian Institute of Mining and Metallurgy, Proceedings, v. 214, p. 61–94.

SIMPSON, E. S., 1912, Radium–uranium ores from Wodgina: Western Australia Geological Survey, Bulletin 48, p. 9–21.

SIMPSON, E. S., 1948, Minerals of Western Australia, v. 1: Perth, Western Australia, Government Printer.

SIMPSON, E. S., 1952, Minerals of Western Australia, v. 3: Perth, Western Australia, Government Printer.

SMITHIES, R. H., 1998, Mount Wohler, W.A. Sheet 2455: Western Australia Geological Survey, 1:100 000 Geological Series.

SMITHIES, R. H., and FARRELL, T. R., 2000, Geology of the Satirist 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 42p.

SMITHIES, R. H., HICKMAN, A. H., and NELSON, D. R., 1999, New constraints on the evolution of the Mallina Basin, and their bearing on relationships between the contrasting eastern and western granite–greenstone terrains of the Archaean Pilbara Craton, Western Australia: Precambrian Research, v. 94, p. 11–28.

SWEETAPPLE, M. T., 2000, Characteristics of Sn–Ta–Be–Li–industrial mineral deposits of the Archaean Pilbara Craton, Western Australia: Australian Geological Survey Organisation, Record 2000/44, 54p.

SWEETAPPLE, M. T., and COLLINS, P. L. F., 1998, Tantalum–tin mineralized pegmatites at Wodgina and Mt Cassiterite, Pilbara Craton, Western Australia, *in* Geoscience for the new millennium, 14th Australian Geological Convention, Townsville, Queensland, 1998: Geological Society of Australia, Abstracts, no. 49, p. 435.

SWEETAPPLE, M. T., and COLLINS, P. L. F., 2002, Genetic framework for the classification and distribution of Archaean rare metal pegmatites in the North Pilbara Craton, Western Australia: Economic Geology, v. 97, p. 873–895.

SWEETAPPLE, M. T., CORNELIUS, H., and COLLINS, P. L. F., 2001, Tantalum mineralization of the Wodgina pegmatite district: The Wodgina and Mount Cassiterite pegmatite orebodies: Western Australia Geological Survey, Record 2000/11, p. 41–58.

THORPE, R. A., HICKMAN, A. H., DAVIS, D. W., MORTENSEN, J. K., and TRENDALL, A. F., 1992, U–Pb zircon geochronology of Archaean felsic units in the Marble Bar region, Pilbara Craton, Western Australia: Precambrian Research, v. 56, p. 169–189.

VAN KRANENDONK, M. J. 1997. Results of field mapping, 1994–1996, in the North Shaw and Tambourah 1:100 000 sheet areas, eastern Pilbara Craton, northwestern Australia: Australian Geological Survey Organisation, Record 1997/23, 44p.

VAN KRANENDONK, M. J., 1998, Litho-tectonic and structural components of the North Shaw 1:100 000 sheet, Archaean Pilbara Craton: Western Australia Geological Survey, Annual Review 1997–98, p. 63–70.

VAN KRANENDONK, M. J., 2000, Geology of the North Shaw 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 86p.

VAN KRANENDONK, M. J., 2003, Geology of the Tambourah 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 57p.

VAN KRANENDONK, M. J., HICKMAN, A. H., SMITHIES, R. H., and PIKE, G., 2002, Geology and tectonic evolution of the Archaean North Pilbara Terrain, Pilbara Craton, Western Australia: Economic Geology, v. 97, p. 695–732.

VAN KRANENDONK, M. J., and MORANT, P., 1998, Revised Archaean stratigraphy of the North Shaw 1:100 000 sheet, Pilbara Craton: Western Australia Geological Survey, Annual Review 1997–98, p. 55–62.

VAN KRANENDONK, M. J., SMITHIES, R. H., HICKMAN, A. H., BAGAS, L., WILLIAMS, I. R., and FARRELL, T. R., 2004, Event stratigraphy applied to 700 million years of Archaean crustal evolution, Pilbara Craton, Western Australia: Western Australia Geological Survey, Annual Review 2003–04, p. 49–61.

VEARNCOMBE, S., 1996, Volcanogenic massive sulfide–sulphate mineralization at Strelley, Pilbara Craton, Western Australia: The University of Western Australia, PhD thesis (unpublished).

WELLMAN, P., 1999, Interpretation of regional geophysics of the Pilbara Craton, northwest Australia: Australian Geological Survey Organisation, Record 1999/45.

WILHELMIJ, H. R., 1986, Depositional history of the middle Archaean sedimentary sequences in the Pilbara Block, Western Australia: A genetic stratigraphic analysis of the terrigenous rocks of the Pilgangoora syncline: The University of Western Australia, PhD thesis (unpublished).

WILHELMIJ, H. R., and DUNLOP, J. S. R., 1984, A genetic stratigraphic investigation of the Gorge Creek Group in the Pilgangoora syncline, *in* Archaean and Proterozoic basins of the Pilbara, Western Australia: evolution and mineralization potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: The University of Western Australia, Geology Department and University Extension, Publication no. 9, p. 68–88.

WILLIAMS, I. S., and COLLINS, W. J., 1990, Granite–greenstone terranes in the Pilbara Block, Australia, as coeval volcano–plutonic complexes; evidence from U–Pb zircon dating of the Mount Edgar batholith: Earth and Planetary Science Letters, v. 97, p. 41–53.

WILLIAMS, I. S., PAGE, R. W., FROUDE, D., FOSTER, J. J., and COMPSTON, W., 1983, Early crustal components in the Western Australian Archaean: Zircon U–Pb ages by ion microprobe analysis from the Shaw Batholith and Narryer Metamorphic Belt: Geological Society of Australia, Abstract Series v. 9, p.169.

ZEGERS, T. E., WHITE, S. H., de KEIJZER, M., and DIRKS, P., 1996, Extensional structures during deposition of the 3460 Ma Warrawoona Group in the eastern Pilbara Craton, Western Australia: Precambrian Research, v. 80, p. 89–105.

ZEGERS, T. E., NELSON, D. R., WIJBRANS, J. R., and WHITE, S. H., 2001, SHRIMP U–Pb zircon dating of Archaean core-complex formation and pan-cratonic strike-slip deformation in the Pilbara Craton: Tectonics, v. 20, p. 883–909.

Appendix 1

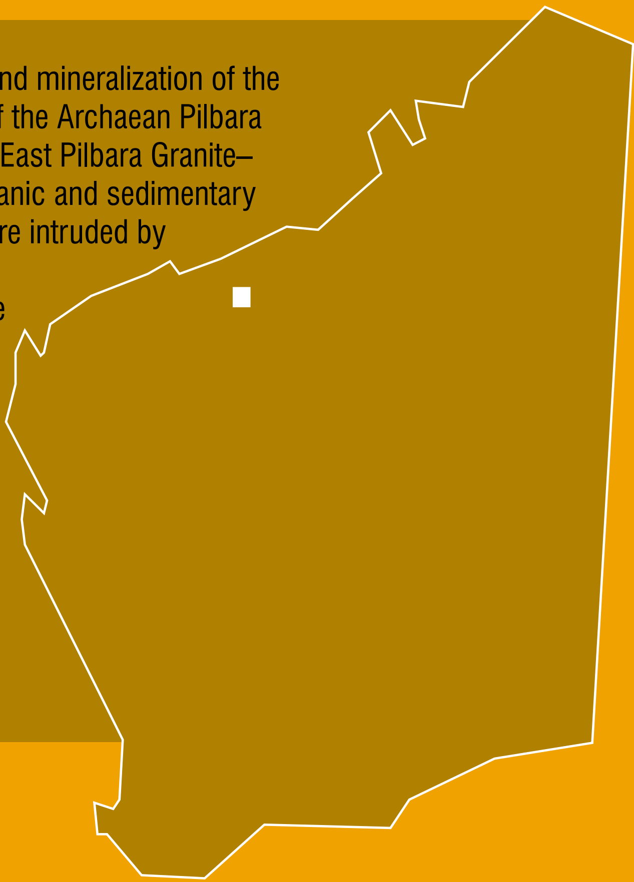
Gazetteer of localities

Place name	*MGA coordinates*	
	Easting	*Northing*
Chinnamon Creek	699500	7662000
Coffin Bore	695625	7665619
Comet gold mine (abandoned)	670630	7651940
Green Well	702700	7665350
Hazelby copper deposit	701770	7669730
Iron Stirrup gold mine (abandoned)	699500	7669200
Kangan Homestead	657450	7666010
Kingston’s scheelite lease	670200	7655500
Lynas Find gold mine (abandoned)	699950	7678500
Main Hill – Breccia Hill gold prospect	698000	7664200
McPhees gold mine (abandoned)	701400	7675800
McPhees Hill emerald mine (abandoned)	701100	7678600
McPhees Patch gold mine (abandoned)	700000	7676300
Mount Cassiterite tin mine (abandoned)	673020	7656640
Mount Cassiterite East tin mine (abandoned)	673800	7656400
Mount Francisco tin mine (abandoned)	660710	7636470
Mount Francisco cassiterite deposit	661080	7635500
Mount York	697360	7665600
Mills Find gold mine (abandoned)	667150	7647050
Numbana pegmatite minerals mine (abandoned)	669320	7639400
Old Faithful gold deposit	700840	7671200
Pilgangoora tin–tantalum mine (abandoned)	697430	7671130
Pincunah Hill	795200	7653500
Pincunah Waterhole	689400	7653900
Stannum mine tin mine (abandoned)	669480	7649300
Stannum Northeast tin prospect	666760	7651320
Stannum West copper prospect	667490	7649910
Tank Pool	696450	7658650
Todds Find gold mine (abandoned)	705450	7667420
Turner Well	689600	7650900
West Wodgina tin mine (abandoned)	670180	7658300
Wodgina tantalum mine	674000	7657000
Wodgina mining camp	674717	7656660
Wodgina (old town)	673700	7656700
Zakanaka gold mine (abandoned)	696800	7666200

These Explanatory Notes describe the geology and mineralization of the WODGINA 1:100 000 sheet in the northern part of the Archaean Pilbara Craton. The area is in the western margin of the East Pilbara Granite–Greenstone Terrane, where 3515–3000 Ma volcanic and sedimentary rocks (greenstones) of the Pilbara Supergroup are intruded by 3470–2830 Ma granitic rocks.

Granitic intrusion has fragmented the greenstone succession to such a degree that stratigraphic correlations between the area's various greenstone belts are uncertain.

The area contains a wide variety of mineral commodities, including gold (periodically mined for more than 100 years), tin, tantalum, and other pegmatite minerals such as beryl and spodumene. There has been small-scale mining of copper and lead, and gemstones include emerald and topaz.



These Explanatory Notes are published in digital format (PDF) and are available online at: www.doir.wa.gov.au/gswa/onlinepublications. Laser-printed copies can be ordered from the Information Centre for the cost of printing and binding.

Further details of geological publications and maps produced by the Geological Survey of Western Australia are available from:

Information Centre
Department of Industry and Resources
100 Plain Street
East Perth, WA 6004
Phone: (08) 9222 3459   Fax: (08) 9222 3444

www.doir.wa.gov.au/gswa/onlinepublications

BLEWETT, CHAMPION

Geology of the Wodgina 1:100 000 sheet

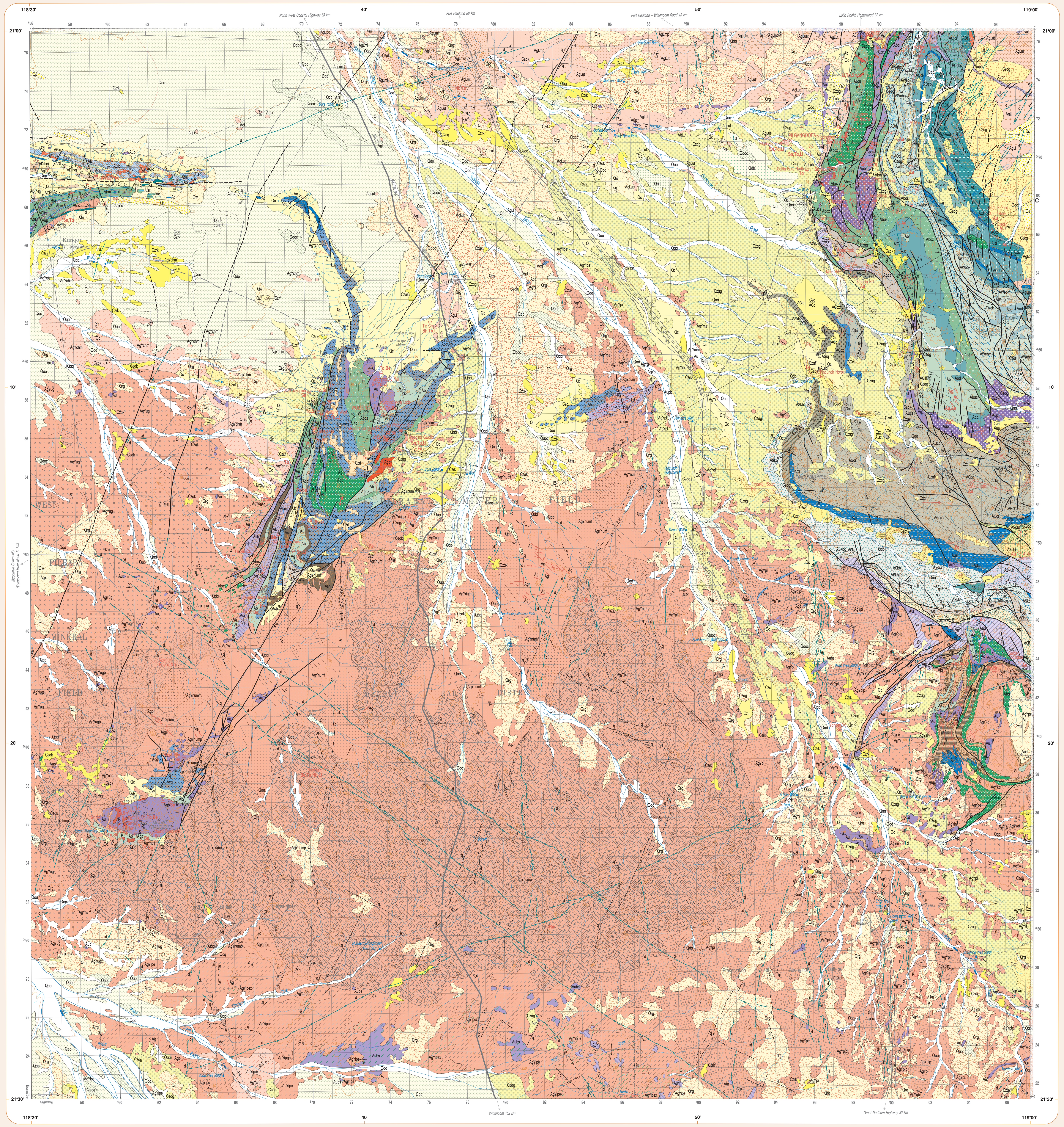
EXPLANATORY NOTES

AUSTRALIA 1:100 000 GEOLOGICAL SURVEY

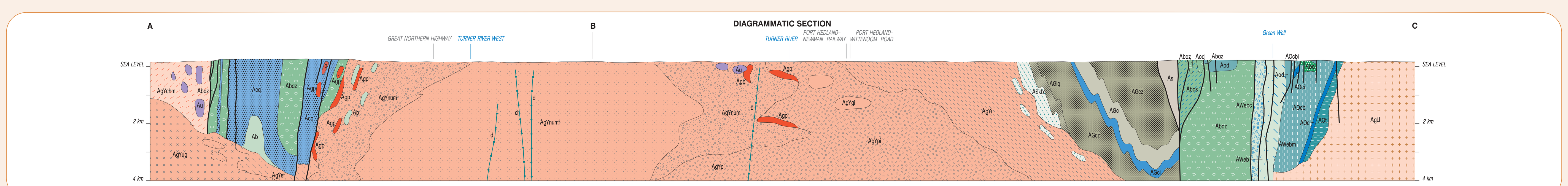
WODGINA

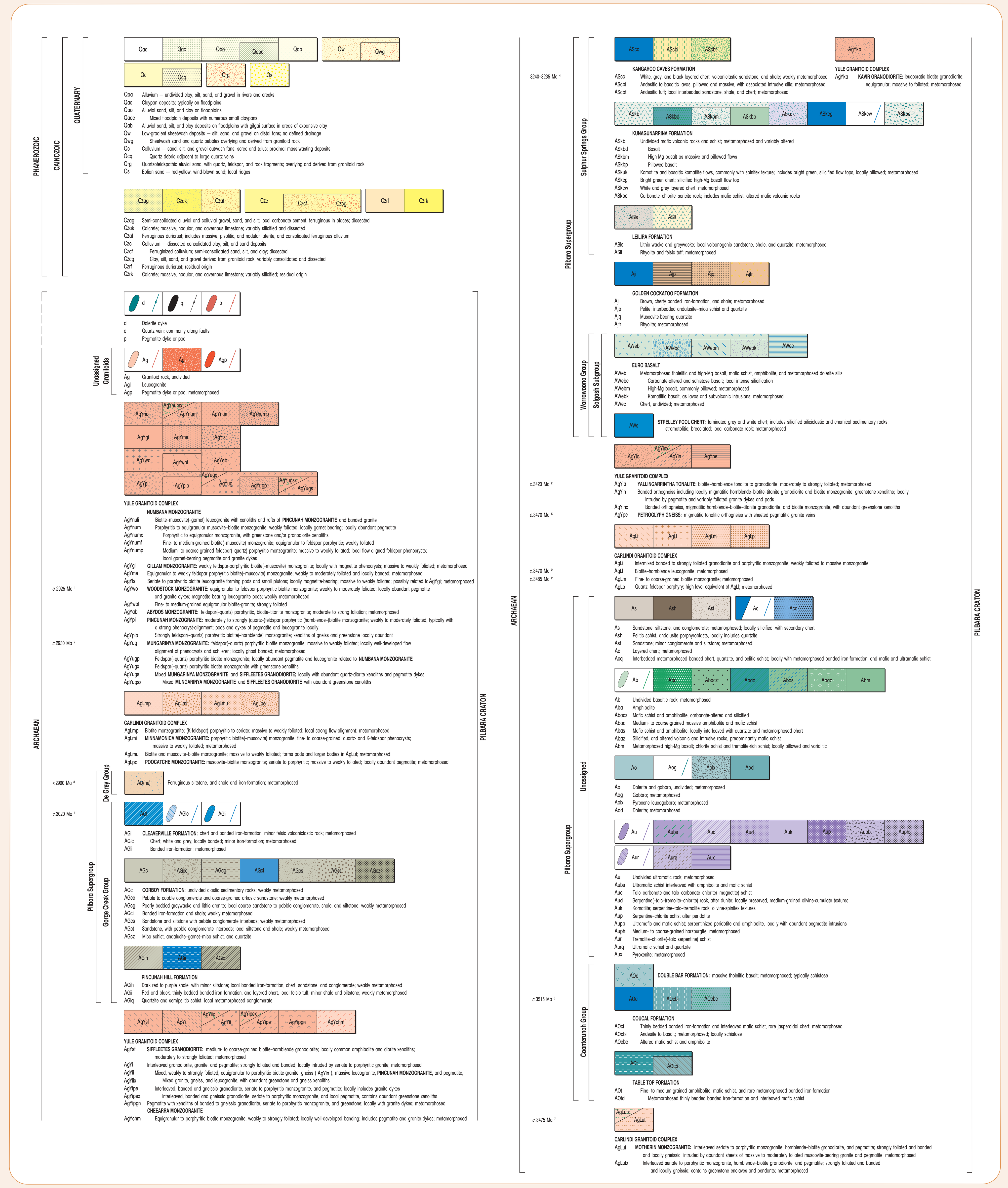
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

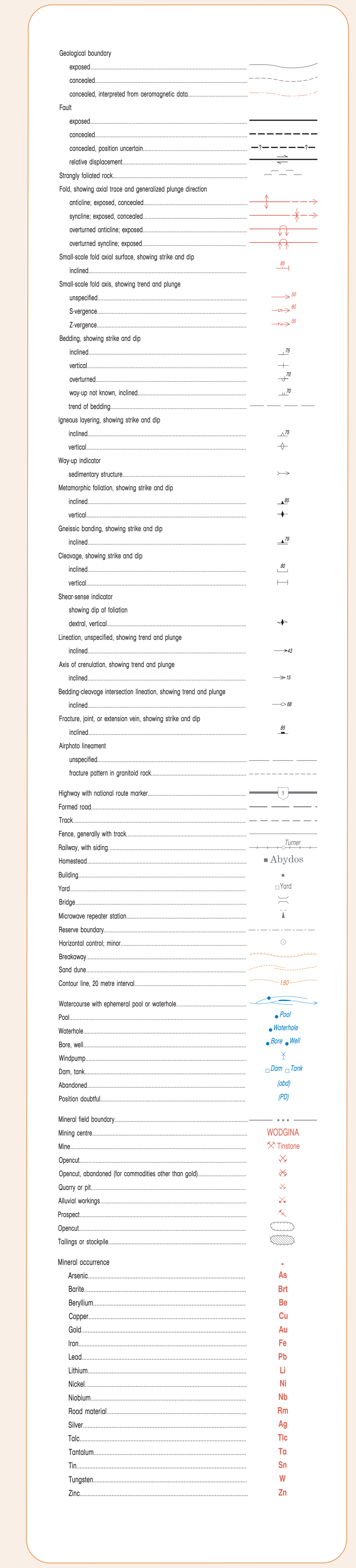
SHEET 2655



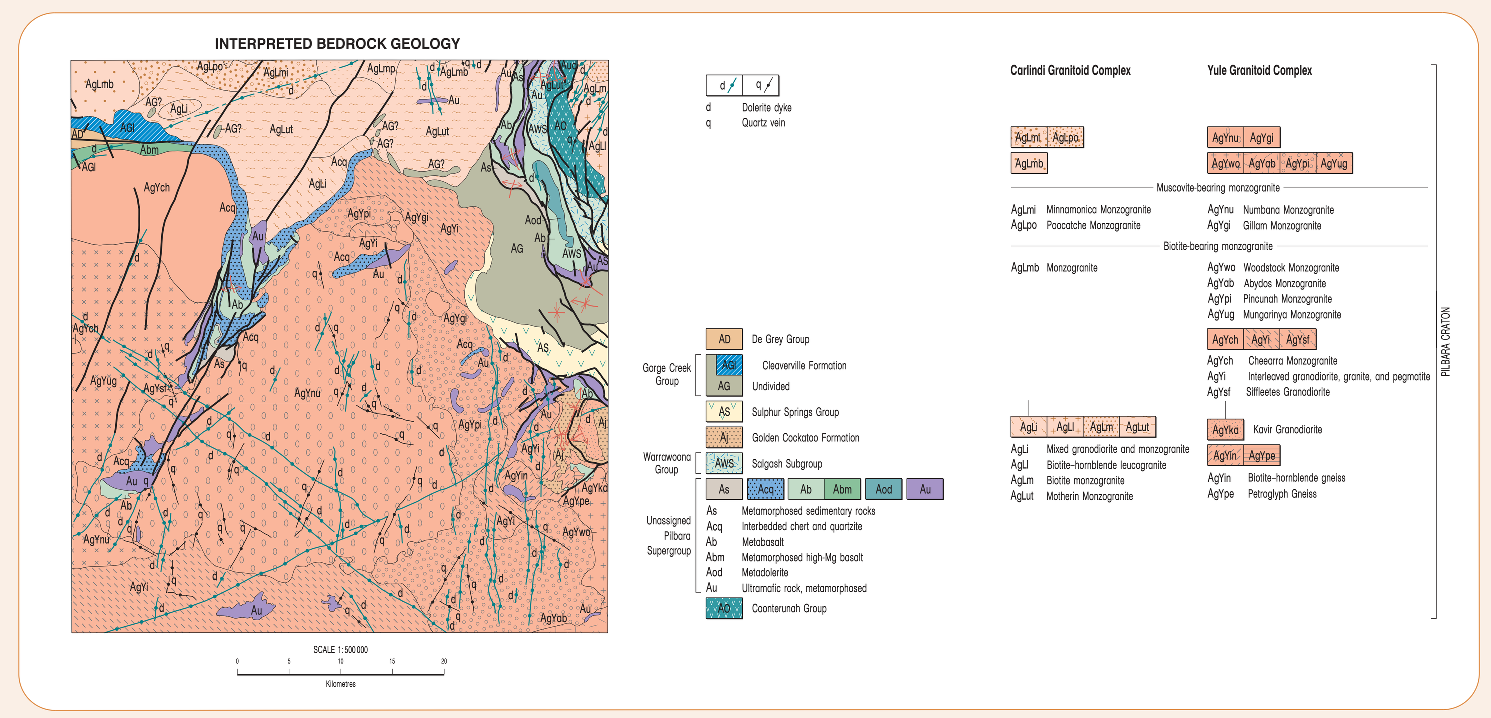
DIAGRAMMATIC SECTION



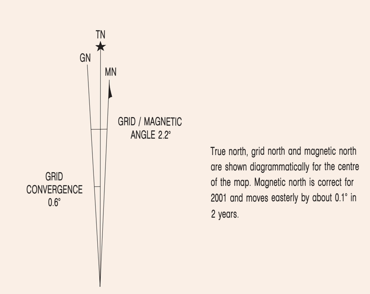




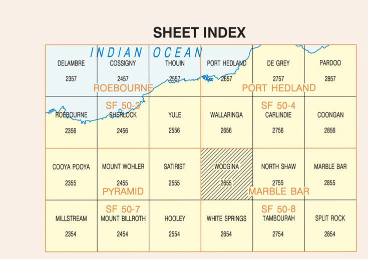
INTERPRETED BEDROCK GEOLOGY

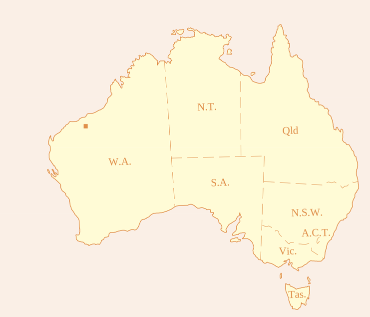


SCALE 1:500 000



SHEET INDEX





Geology by R. S. Blewett, and D. C. Champion (AGSO) 1997–1998; R. H. Smithies 1998; M. J. Van Kranendonk 1994–1997; T. R. Farrell 1998; D. Thost (AGSO) 1997

Geochronology by:

(1) D. R. Nelson, 1998, GSWA Record 1998/2, p. 52–55, 63–65, 120–122, 169–171.
(2) D. R. Nelson, 1999, GSWA Record 1999/2, p. 97–103, 163–169.
(3) D. R. Nelson, 2000, GSWA Record 2000/2, p. 93–95.
(4) C. Brauhart, 1999, University of Western Australia, PhD Thesis (unpublished).
(5) M. Van Kranendonk, 2000, written communication.
(6) R. Buick et al., 1995, Nature, v. 375, p. 574–577.
(7) D. E. L. Baker, 2001, written communication.

Edited by N. Tetlaw and G. Loan

Cartography by D. Ladbrook and B. Williams

Topography from the Department of Land Administration Sheet SF 50-8, 2655, with modifications from geological field survey

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

Printed by Land and Property Information, Bathurst, NSW

The recommended reference for this map is:
BLEWETT R. S., CHAMPION D. C., SMITHIES R. H., VAN KRANENDONK M. J., FARRELL T. R., and THOST D., 2001, Wodgina, W.A. Sheet 2655: Western Australia Geological Survey, 1:100 000 Geological Series

Department of Industry and Resources

CLIVE BROWN, M.L.A.
MINISTER FOR STATE DEVELOPMENT

JIM LIMERICK
DIRECTOR GENERAL

Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

NGA

PRODUCT OF THE NATIONAL GEOSCIENCE AGREEMENT

SCALE 1:100 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
BATHYMETRIC DATUM: LOWEST LOW SEA LEVEL

Grid lines indicate 1000 metre interval of the Map Grid Australia Zone 50

The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

Reference points to align maps based on the previous datum, AGD84, have been placed near the map corners

WODGINA

SHEET 2655

FIRST EDITION 2001

Version 2 – July 2003