Department of
Industry and Resources

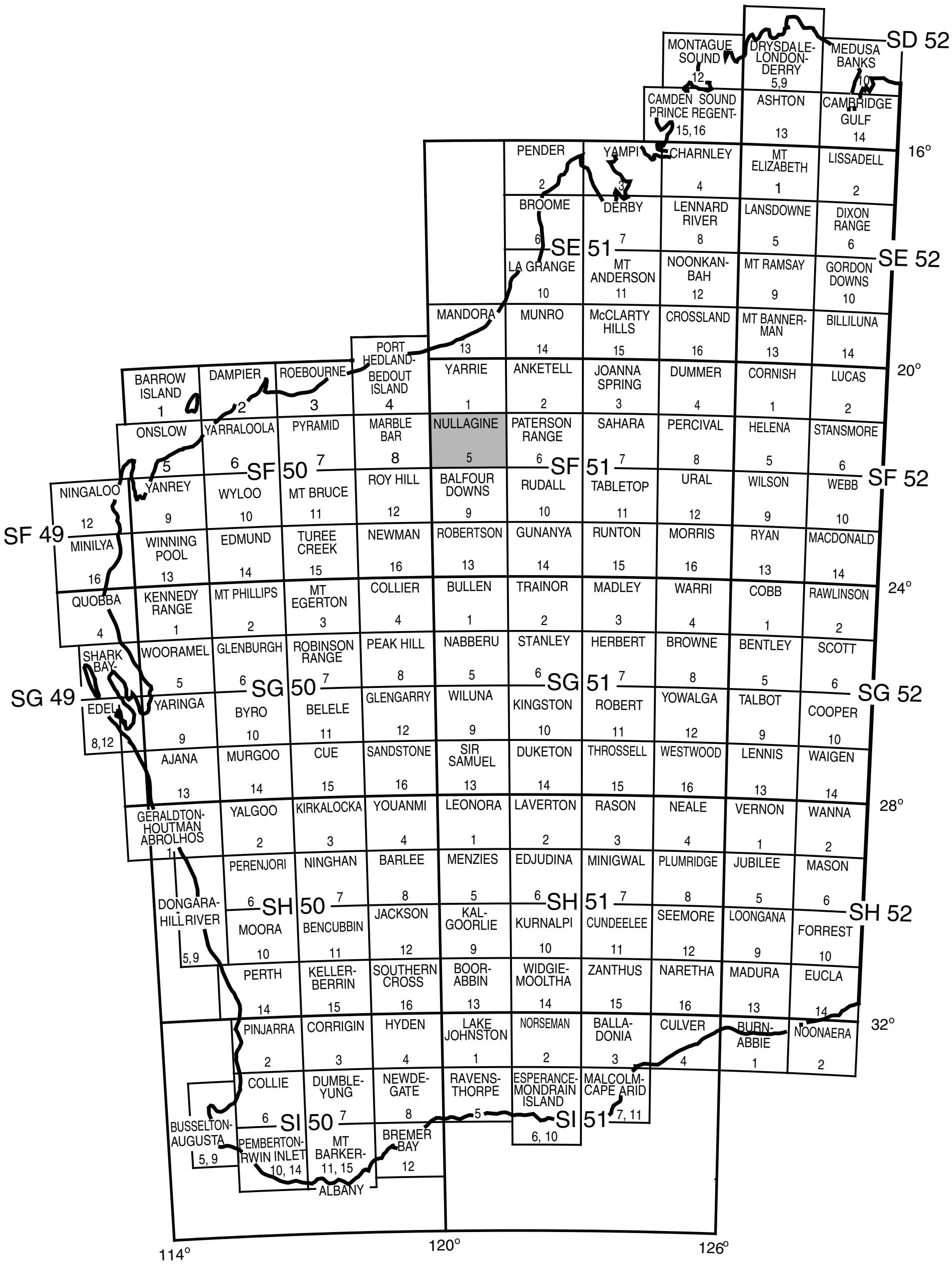
EXPLANATORY NOTES

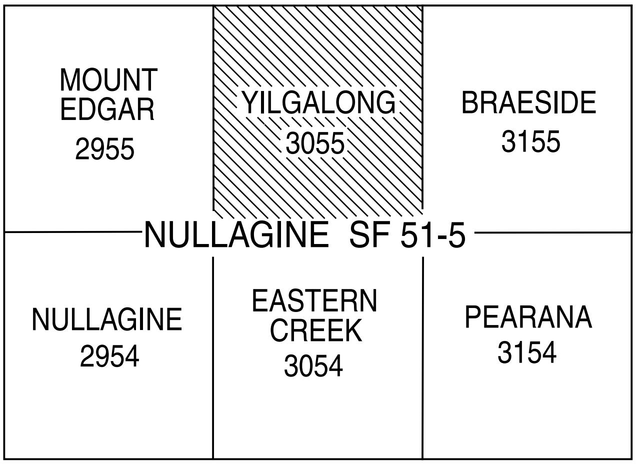
GEOLOGY OF THE YILGALONG 1:100 000 SHEET

by I. R. Williams

1:100 000 GEOLOGICAL SERIES

Geological Survey of Western Australia





IRW195

07.05.07

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE YILGALONG 1:100 000 SHEET

by
I. R. Williams

Perth 2007

MINISTER FOR RESOURCES
Hon. Francis Logan MLA

DIRECTOR GENERAL, DEPARTMENT OF INDUSTRY AND RESOURCES
Jim Limerick

EXECUTIVE DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
Tim Griffin

REFERENCE
The recommended reference for this publication is:
WILLIAMS, I. R., 2007, Geology of the Yilgalong 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 45p.

National Library of Australia Card Number and ISBN 978-1-74168-101-7

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

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

Published 2007 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/publications.
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/publications

Cover photograph:
Constructive travertine falls, 2.5 m high, composed of calcium carbonate flowstone deposited in a small creek incised in Carawine Dolomite, southwest Ripon Hills (MGA 261106E 7443607N)

Contents

Appendices

Figures

Tables

Geology of the Yilgalong 1:100 000 sheet

by

I. R. Williams

Abstract

The Yilgalong 1:100 000 sheet lies towards the eastern margin of the Archean Pilbara Craton. The East Pilbara Terrane is exposed only in the southwest corner of Yilgalong, and elsewhere is unconformably overlain by Neoarchean volcanic and sedimentary rocks of the Fortescue and Hamersley Group in the Northeast Pilbara Sub-basin of the Hamersley Basin. On Yilgalong the East Pilbara Terrane is represented by part of the Kelly Group of the Pilbara Supergroup, and by the northern half of the Yilgalong Granitic Complex. The c. 3.35 Ga Kelly Group is locally composed of metamorphosed mafic rocks of the Euro Basalt. A small area of mafic schist and metachert exposed on the eastern margin of the Yilgalong Granitic Complex may also belong to this formation. The Yilgalong Granitic Complex is predominantly composed of gneissic to strongly foliated tonalite and granodiorite belonging to the 3.32 – 3.29 Ga Emu Pool Supersuite. It is intruded by small, weakly foliated monzogranite and trondhjemite bodies of the 3.27 – 3.22 Ga Cleland Supersuite.

The. 2.77 – 2.63 Ga Fortescue Group and the disconformably overlying c. 2.54 Ga Carawine Dolomite of the Hamersley Group are distributed around a major D_7 fold — the Oakover Syncline. The Carawine Dolomite includes a distinctive microtektite and microkrystite spherule-bearing megabreccia marker horizon interpreted to be an asteroid impact-triggered tsunami deposit. The Paleoproterozoic Pinjian Chert Breccia unconformably overlies and is restricted to the Carawine Dolomite. Small areas of epiclastic sedimentary rock, correlated with the Mesoproterozoic Manganese Group of the Bangemall Supergroup, unconformably overlie the Carawine Dolomite and Pinjian Chert Breccia. Both the Pinjian Chert Breccia and overlying sedimentary rock succession are intruded by c. 523 Ma (Lower Cambrian) dolerite sills.

Deformation events recognized on Yilgalong include the 3.32 – 3.29 Ga D_2 deformation of the East Pilbara Terrane, and the D_6 (2.77 – 2.75 Ga) and D_7 (<2.50 Ga) events of the Hamersley Basin. Large transpressional, steep reverse, and related faults post-date the D_7 structures and are assigned to D_8 (1.83 – 1.76 Ga Yapungku Orogeny). Some of these structures may have been further reactivated during later Proterozoic events (>678 Ma Miles Orogeny and c. 550 Ma Paterson Orogeny).

The Archean and Proterozoic rocks are unconformably overlain by the fluvioglacial Carboniferous–Permian Paterson Formation. The formation is largely restricted to the north-northwesterly trending Wallal Embayment of the Canning Basin that transects the eastern half of Yilgalong. The current survey discovered a feature interpreted to be a recent impact structure 13.7 km west of Carawine Pool.

Recorded mineral production on Yilgalong is restricted to local manganese mining of residual and supergene deposits that overlie the Pinjian Chert Breccia and Carawine Dolomite in the Ripon Hills area. Alluvial gold workings are north and south of Elsie Creek in the southwest corner, and copper mineralization was explored 4 km west of Mopoke Well.

KEYWORDS: Archean, Proterozoic, Kelly Group, Yilgalong Granitic Complex, Fortescue Group, Hamersley Group, Paterson Formation, Pilbara Craton, regional geology, geochronology, structure, mineralization.

Introduction

The Yilgalong* 1:100 000 sheet (SF 51-5, 3055) occupies the central-northern part of the Nullagine 1:250 000 sheet (SF 51-5). The area is bound by latitudes 21°00'S and 21°30'S and longitudes 120°30'E and 121°00'E, and lies close to the northeastern margin of the Pilbara Craton (Fig. 1). Yilgalong falls within the Marble Bar District of the Pilbara Mineral Field. It derives its name from Yilgalong Creek, a north-northeasterly flowing tributary of the Oakover River.

There are no settlements, pastoral homesteads or current mining activity on Yilgalong. The Warrawagine pastoral (cattle) lease extends southeastwards from Warrawagine to cover the broad Oakover and Nullagine river valleys north, east, and southeast of the Ripon Hills (Fig. 2). The adjoining and abandoned Meentheena

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

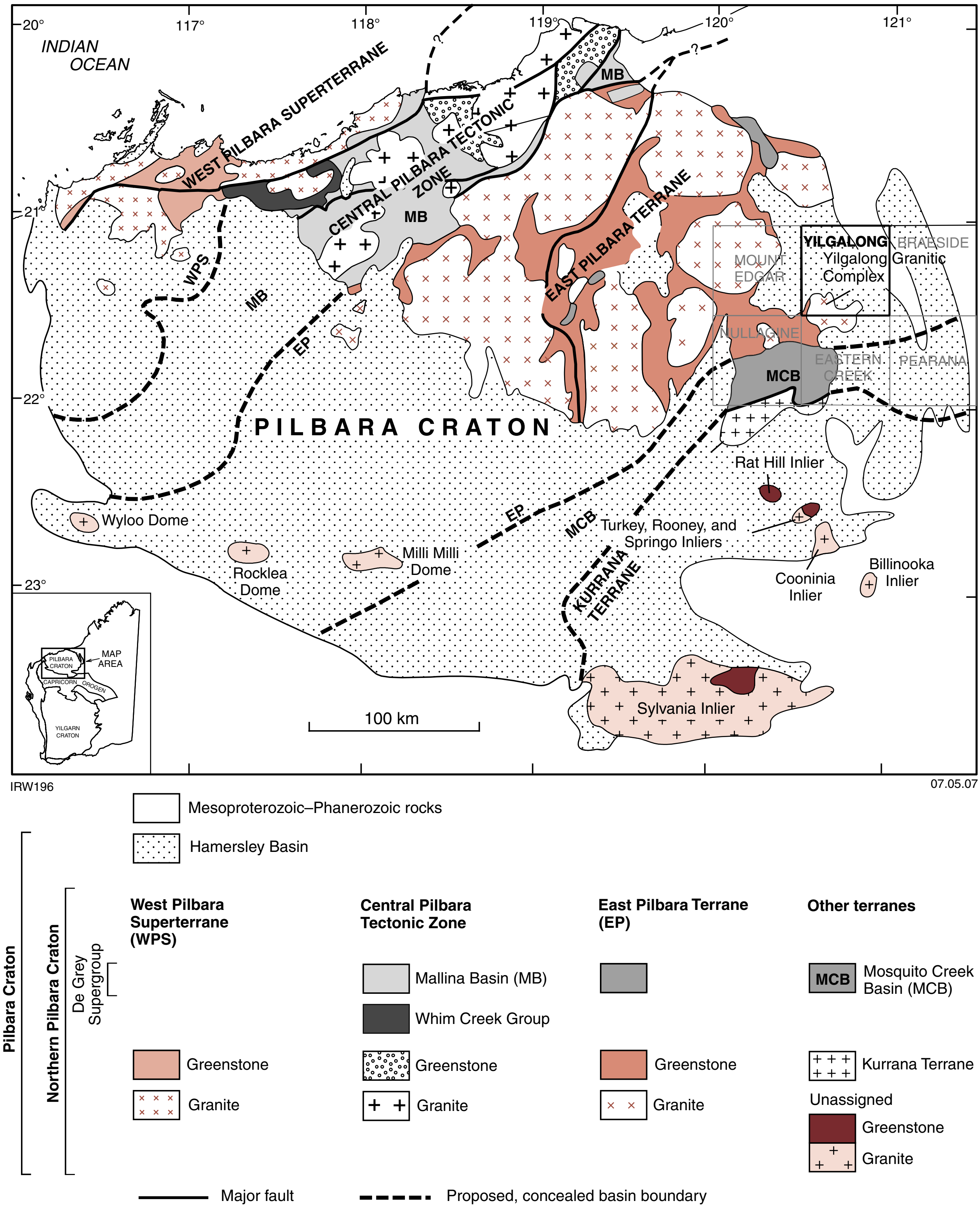


Figure 1. Regional geological setting of YILGALONG

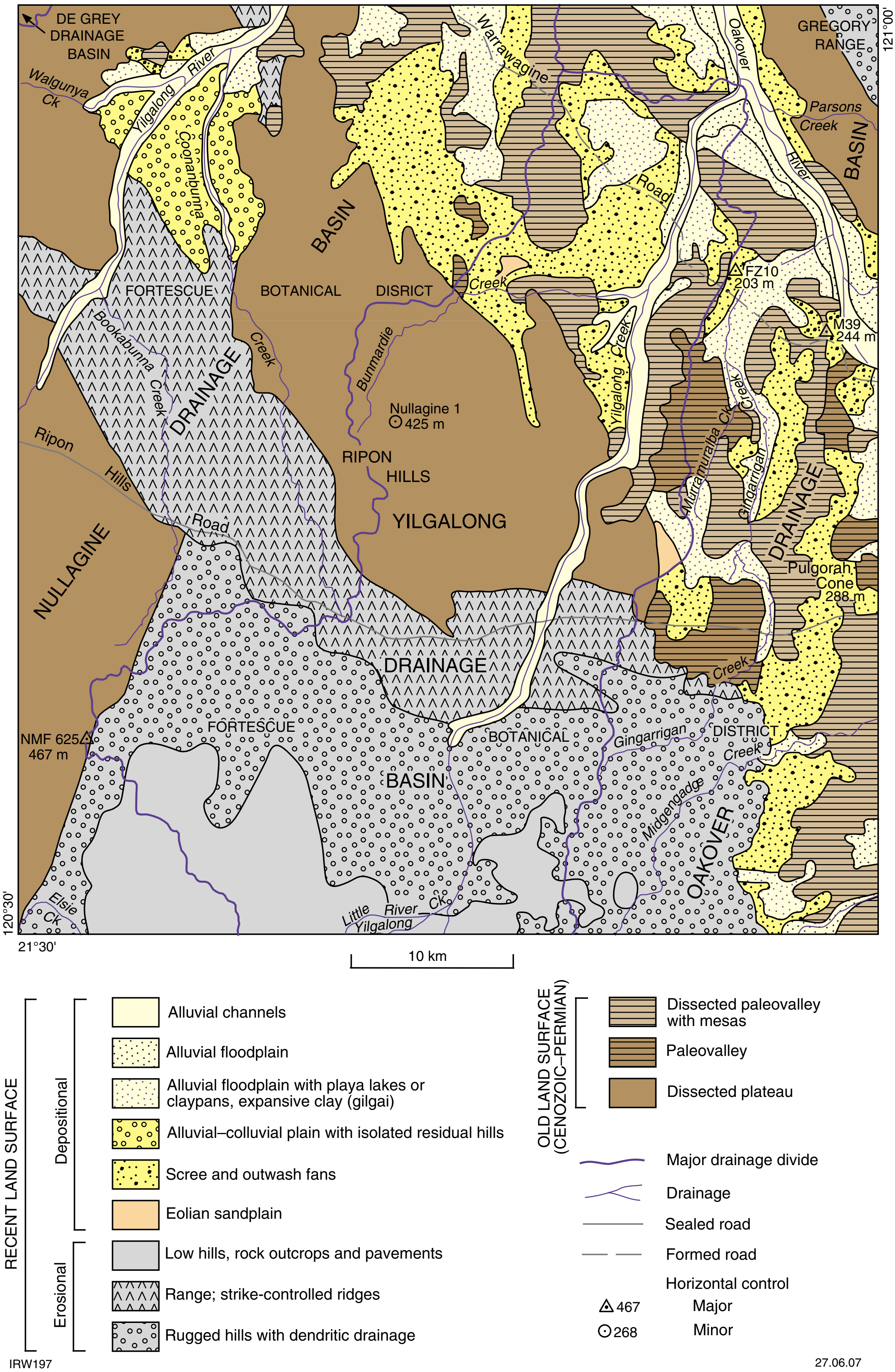


Figure 2. Physiography and drainage map of Yilgalong

pastoral lease that previously occupied the rough hilly country west and southwest of the Ripon Hills is now under the jurisdiction of the Department of Environment and Conservation. The Ripon Hills and elevated country to the south-southeast, which separate the Warrawagine and Meentheena pastoral leases, are Crown Land.

The Ripon Hills road, which services the Telfer gold, Woodie Woodie manganese, and Nifty copper mines, transects YILGALONG from west to east, skirting the southern side of the Ripon Hills (Fig. 2). The old Port Hedland – Woodie Woodie road, now designated the Warrawagine road, diagonally crosses the northeast quarter of the sheet. A new road, constructed along the drainage divide between Yilgalong and Gingarrigan creeks, links the Warrawagine road with the Ripon Hills road. Pastoral tracks give reasonable access to the valleys of the Oakover and Nullagine rivers. Old and more recent mining exploration tracks, many severely degraded, give some access to the abandoned manganese mines in the rugged Ripon Hills area and to alluvial gold and base metal exploration areas along the southwest margin of YILGALONG south of the Ripon Hills road. The remaining trackless, rugged hill country in the headwaters of the Midgengadge and Gingarrigan creeks, along tributaries of the Yilgalong Creek south of the Ripon Hills road, and along the Bookabunna and Coonanbunna creeks west of Ripon Hills, is roughly accessible to four-wheel drive vehicles.

Previous investigations

The first recorded description of the YILGALONG countryside can be found in F. T. Gregory's 1861 exploration journal (Gregory and Gregory, 1884; Feeken et al., 1970). The expedition travelled down the Nullagine River from MOUNT EDGAR to a point about 2 km north of the junction with Bookabunna Creek from where they resumed an east-southeasterly course towards the Ripon Hills. They crossed the northern part of the rugged Ripon Hills with difficulty. Continuing eastwards, Gregory recorded a northeast-trending sandy stream '50 yards wide', now called Yilgalong Creek, before reaching a broad sandy river lined with Cadgeput (paperbark) trees. Gregory subsequently named it the Oakover River. The expedition continued south-southeast upstream passing onto the adjoining BRAESIDE sheet. On the return journey, one and half months later, the expedition followed the Oakover River downstream across the northeast corner of YILGALONG and on to WARRAWAGINE. They continued down the Oakover River to its junction with the De Grey River, which they then followed to the northwest Pilbara coast.

As a direct consequence of Gregory's positive report on the pastoral potential for the De Grey region, the first settlement in the northwest, the De Grey Station, was taken up in 1863 near the mouth of the De Grey River. Over the next 32 years, sheep and later cattle leases were taken up along the De Grey and Oakover river valleys, including the eastern parts of YILGALONG.

Although YILGALONG was included in the Pilbarra (sic) Goldfields proclaimed in July 1889 (Woodward, 1894), the first geological sketch map of the area accompanied a report on the probability of finding artesian water for pastoral purposes along the upper reaches of the De Grey and adjoining Oakover river valleys (Smith, 1898). Maitland (1906) presented the first regional geological coverage of the area in a map of the Pilbara Goldfield. Over the next 50 years successive publications showed only minor changes to the regional geology, with the stratigraphic age of the successions being the main concern. The first specific regional mapping project to cover YILGALONG took place in the late 1950's and is presented in Geological Survey of Western Australia (GSWA) Bulletin 115 (Noldart and Wyatt, 1962). Around the same time (1956) the Commonwealth Government introduced export permits for a percentage of new manganese ore reserves and, in consequence, the Ripon Hills manganese deposits were discovered in 1957 (O'Driscoll, 1958; de la Hunty,1960, 1963). This was the first officially recorded mineralization on YILGALONG. A comprehensive report on the Ripon Hills manganese deposits was published by Denholm (1977).

Similar economic interest in the region followed the lifting of the iron ore export embargo in 1960 by the Commonwealth Government. The subsequent regional mapping projects, undertaken by the GSWA throughout the Pilbara region, established the broad stratigraphic framework for the newly recognized Hamersley Basin. This stratigraphy included the Fortescue and Hamersley Groups that make up the bulk of rocks exposed on YILGALONG (MacLeod et al., 1963).

Further stratigraphic and structural data from the YILGALONG area were recorded in the NULLAGINE 1:250 000 sheet and Explanatory Notes (Hickman, 1978) and GSWA Bulletin 127 (Hickman, 1983). Reconnaissance geophysical work for NULLAGINE (1:250 000) that involved total magnetic intensity (Bureau Mineral Resources, 1987) and regional gravity survey mapping (preliminary Bouguer anomalies; Bureau Mineral Resources, undated) also covered the YILGALONG area.

Renewed interest in the geology of YILGALONG arose in the early 1980s as part of broader regional studies of Fortescue Group rocks. Such studies developed in two directions. Blake (1984), the first to recognize the role of intra-Fortescue Group unconformities and discrete depositional basins within the Fortescue Group, proposed a sequence-based stratigraphic approach for the Fortescue Group. This concept was later extended to cover all the Mount Bruce Supergroup (Blake, 1993). The alternative descriptive lithostratigraphic format, initiated in earlier GSWA publications, was used in a more recent overview of the Fortescue Group (Thorne and Trendall, 2001). As part of this program the Gregory Range component of YILGALONG, lying east of the Oakover River, was mapped at 1:100 000 scale (Trendall, 1991).

The first detailed research studies pertaining to specific geology on YILGALONG commenced in the second half of the 1980s. This research was directed towards sedimentological studies of the Carawine Dolomite in the Ripon Hills areas (Simonson and Jarvis, 1993; Simonson et al., 1993b). These studies led to the discovery of a spherule-bearing dolomixtite, interpreted to be a dolomitic debris-flow deposit. The origin of the glassy spherules was attributed to a major bolide impact (Simonson, 1992). Further research (Simonson and Hassler, 1997) showed that as well as microtektites, many of the spherules were microkrystites (spherulitic silicate-melt condensates and droplets) and that such debris-flow material may be connected to an impact-generated tsunami in a deep oceanic environment (Simonson et al., 1998, 2004; Hassler et al., 2000; Hassler and Simonson, 2001). The recognition and timing of this impact event has led to further and ongoing research, debate, and discussion (Simonson et al., 2000, 2002; Glikson, 2004; Rasmussen and Koeberl, 2004; Rasmussen et al., 2005; Glikson and Vickers, in prep.).

There has also been some research on the sulfide-bearing shales of the Fortescue Group in connection with their importance in understanding the Archean sulfur cycle and early life forms. Samples have been collected and worked on from drillcore intersecting the Carawine Dolomite and Jeerinah Formation in the Ripon Hills area (Ono et al., 2003; Eigenbrode and Freeman, 2003).

Overall, there have only been a limited number of research projects on YILGALONG in comparison with adjoining map sheet areas. This may partly be attributed to its remoteness and, prior to the construction of the Ripon Hills road, difficulty in accessing the sheet area, and partly to a perceived paucity of economically interesting granite–greenstone terranes in the region.

Fieldwork for mapping YILGALONG was undertaken between June 2002 and August 2003. The sheet was compiled from 1:25 000-scale colour aerial photographs flown in April 1999. Samples for geochronology were collected from the Yilgalong Granitic Complex and the Kylena Formation. All GSWA geochronological data referenced in this publication are available on CD (Geological Survey of Western Australia, 2006).

Climate, vegetation, and physiography

The climate on YILGALONG is classified as arid (Beard, 1975), and more recently as hot desert–winter drought (Stern et al., 2004). Very hot summers with mean maximum temperatures in the low forties (°C) are followed by mild winters with mean minimum temperatures around 11–12°C (Sturman and Tapper, 1996). The mean annual rainfall is around 270 mm, and the region has an average annual evaporation rate of over 3700 mm. However, rainfall is erratic with most precipitation falling during the cyclone or monsoon period, commonly between December and early April. The heaviest rain is associated with decaying, south- to southeast-tracking cyclones and monsoonal thunderstorms. Sometimes more general light to moderate rains fall in the late autumn and early winter months (May–June). This rain is the product of the northwest Australian cloud band weather systems interacting with the southern frontal systems (Tapp and Barrell, 1984).The remainder of the season is dry and drought conditions may exist at any time of the year.

YILGALONG lies close to the northeastern margin of the Fortescue Botanical District of the Eremean Botanical Province (Beard, 1980). Hummock grassland (spinifex) is a ubiquitous groundcover for the shrub and tree steppes that cover rugged hills, dissected plateau, and strike-controlled ranges in the western half of YILGALONG and in the Gregory Range in the northeast. Kanji (*Acacia inaequilatera*), together with sparsely scattered Grevillea, Hakea, and various smaller Acacias are the main floral varieties. Occasional snappy gum (*Eucalyptus brevifolia*) and desert bloodwood (*Corymbia dichromorphloia*) have also been noted in the hilly basalt country southwest and south of the Ripon Hills and in the Gregory Range. The groundcover consists primarily of soft spinifex (*Triodia pungens*), but is mixed with buck spinifex (*Triodia wiseana*) in the northern half of YILGALONG, including the Gregory Range. The tree steppe, confined to the rocky Ripon Hills, consists of scattered snappy gum (*Eucalyptus brevifolia*) and a groundcover of soft and buck spinifex (*Triodia pungens*, *Triodia brizoides*).

The broad Oakover River valley, transecting the eastern half of YILGALONG, carries a sparse shrub steppe of *Acacia bivenosa* and groundcover of buck spinifex (*Triodia brizoides).* In addition, three florally limited units are restricted to specific landforms within the Oakover valley. The first unit covers small treeless grass alluvial plains that are developed over swelling-clay (gilgai) and gravelly sandy flats. The former carries Roebourne Plains grass (*Erogrostis setifolia*) together with other annual and perennial grasses, and the latter soft spinifex (*Triodia pungens*). The second unit consists of narrow strips of riverain sclerophyll woodland. It is found along the margins of the major alluvial channels and on adjacent overbank levees. The woodland comprises red river gum (*Eucalyptus camaldulensis)* and paperbarks (*Melaleuca leucodendron*). This unit is characteristic of the Oakover and Nullagine rivers and the lower parts of Yilgalong Creek. The third unit corresponds to the tops of mesas and small tablelands that roughly parallel the western side of Oakover River. These mesa landforms are remnants of the Oakover Formation and are characterized by a sparse cover of buck spinifex (*Triodia wiseana*) and are almost completely devoid of shrubs (Beard, 1975).

The physiographic schema adopted for YILGALONG is based on earlier proposals (Hickman, 1983; Williams, 1999, 2001) that have been subsequently modified and expanded to cover the whole Pilbara region (Hickman, 2004). It is formulated on the recognition of old (Cenozoic to Permian) and Holocene land surfaces. The Holocene land surfaces are, in turn, subdivided into erosional and depositional units (Fig. 2).

YILGALONG is situated towards the eastern margin of the Pilbara Natural Region (Beard, 1975). Twelve physiographic units are recognized, comprising six recent depositional land surface units, three recent erosional land surface units, and three eroded older (Cenozoic–Permian) land surface units (Fig. 2). The six recent depositional and two of the older land surface units are confined, for the most part, to a large paleovalley occupying about a third of the area, forming the most prominent physiographic feature on YILGALONG. This broad, northwest-trending valley, between 20 and 25 km wide, is now occupied by the present-day Oakover River. The paleovalley is bordered by the dissected plateau unit, represented by the Ripon Hills and Gregory Range Inlier (Williams, 2001) and by rugged hills with dendritic drainage in the headwater region of the Midgengadge Creek along the southwest margin of the valley. These units rise abruptly 60–100 m above the present valley floor, increasing to more than 200 m in the Ripon Hills. The paleovalley contains ferruginized Permian fluvioglacial deposits overlain by remnants of Neogene lacustrine Oakover Formation now preserved as scattered buttes, mesas, and dissected small tablelands. These landforms may rise 70 m above the current thalweg. This paleovalley lies towards the southern end of the Wallal Embayment, which is a tectonic unit of the Canning Basin (Hocking et al., 1994; Williams, 2003).

The present-day Oakover River occupies incised alluvial channels within the broad paleovalley and is bordered by alluvial floodplains, some carrying numerous claypans and broad tracts of expansive clays (gilgai or crabhole). Similar units are also present in the lower parts of the Nullagine River northwest of the Ripon Hills where an older alluvial–colluvial plain with isolated residual hills is incised by the river. The margins of the Oakover paleovalley and smaller areas adjacent to the mesas and tablelands in the central parts of the valley are covered with the coarse scree and outwash fans unit. Small areas of the eolian sandplain lie towards the western edge of the Oakover River valley. These deposits are probably derived from the sandy alluvial units adjacent to the major drainages and redistributed by the prevailing easterly winds.

The remaining two-thirds of YILGALONG is subdivided between the three recent erosional land surfaces and the dissected plateau, which is an older land surface postulated to be a correlate of the Hamersley Surface (Campana et al., 1964). The recent erosional land surfaces exhibit a strong relationship to the underlying bedrock. The low hills, rock outcrop, and pavement unit is restricted to the Yilgalong Granitic Complex. The range and strike-controlled ridge unit is developed over moderately dipping, Fortescue Group rocks of mixed lithology southwest of the Ripon Hills. The rugged hills with dendritic drainage unit is formed over shallow-dipping, mainly basaltic rocks of the Fortescue Group, particularly along the northern margin of the Yilgalong Granitic Complex.

The dissected plateau unit is particularly well developed in the Ripon Hills area where relief is over 200 m, and along the western margin of the sheet area. In the Ripon Hills the dissected plateau corresponds to a large exposure of erosion-resistant Pinjian Chert Breccia overlying the Carawine Dolomite of the Hamersley Group. The dolomite contains some widely spaced, collapsed dolines and sinkholes, some already known (Webb, 1994), others located during the current project.

The highest elevations attained on YILGALONG are within the dissected plateau unit. These elevations reach 467 m above mean sea level (AMSL) at the NMF 625 Trig Point* in the southwest corner and 425 m AMSL at the NULLAGINE 1 Trig Point in the Ripon Hills. The drainage divide between the Oakover River and Yilgalong Creek reaches 400 m AMSL at the southern border between YILGALONG and EASTERN CREEK.

The drainage on YILGALONG is dominated by the large north-northwesterly flowing Oakover River and the north-northeasterly flowing Nullagine River and associated tributaries. However, for most of the sheet area the two drainages are separated by the Yilgalong Drainage Basin, which is a large north-northeasterly flowing tributary of the Oakover River (Fig. 2). Although all drainages on YILGALONG are ephemeral, the Oakover and Nullagine rivers and Yilgalong Creek may flow for some time after heavy or prolonged rains. Semipermanent rockholes are scattered through the Ripon Hills and in rugged hilly country, as for example in the headwaters of Midgengadge Creek.

Regional geological setting

The regional geological setting for YILGALONG is shown in Figure 1, and the simplified bedrock geology and major structural elements in Figure 3. A total magnetic intensity image (GSWA, 2005a)† is given in Figure 4. Geochronological data are presented in Table 1 and the geological history for YILGALONG is summarized in Table 2.

Pilbara Craton

The YILGALONG 1:100 000 sheet was not included in the 1995–2000 joint National Geoscience Mapping Accord (NGMA) project for the reassessment of the northern Pilbara Craton (Blewett et al., 2001). This joint project had involved the Australian Geological Survey Organisation (AGSO, now renamed Geoscience Australia, GA) and GSWA.

YILGALONG is close to the northeastern margin of the Pilbara Craton (Fig. 1; Trendall, 1990). The oldest exposed units, components of the Paleoarchean Mount Elsie greenstone belt and Yilgalong Granitic Complex, are confined to the southwest quarter of the sheet. These units belong to the 3530–3170 Ma East Pilbara Terrane — the oldest component of five terranes and five basins recognized in the northern Pilbara Craton (Van Kranendonk et al., 2006).

The granite–greenstone components of the East Pilbara Terrane on YILGALONG are also basement for the unconformably overlying Neoarchean Fortescue Group and Carawine Dolomite of the Hamersley Group (Thorne and Trendall, 2001; Blake et al., 2004; Trendall et al., 2004). This widespread succession is deposited in the Northeast Pilbara Sub-basin of the Hamersley Basin. In addition, over half of the area occupied by the Hamersley Basin succession on YILGALONG is unconformably overlain by Proterozoic, Carboniferous–Permian, and Cenozoic rocks, including unconsolidated superficial deposits.

* The MGA coordinates (GDA94) of all place names used in these Explanatory Notes are listed in Appendix 1.

† From the north Paterson airborne geophysical survey, 2005. Available for download, free of charge, from <http://www.ga.gov.au/gadds>.

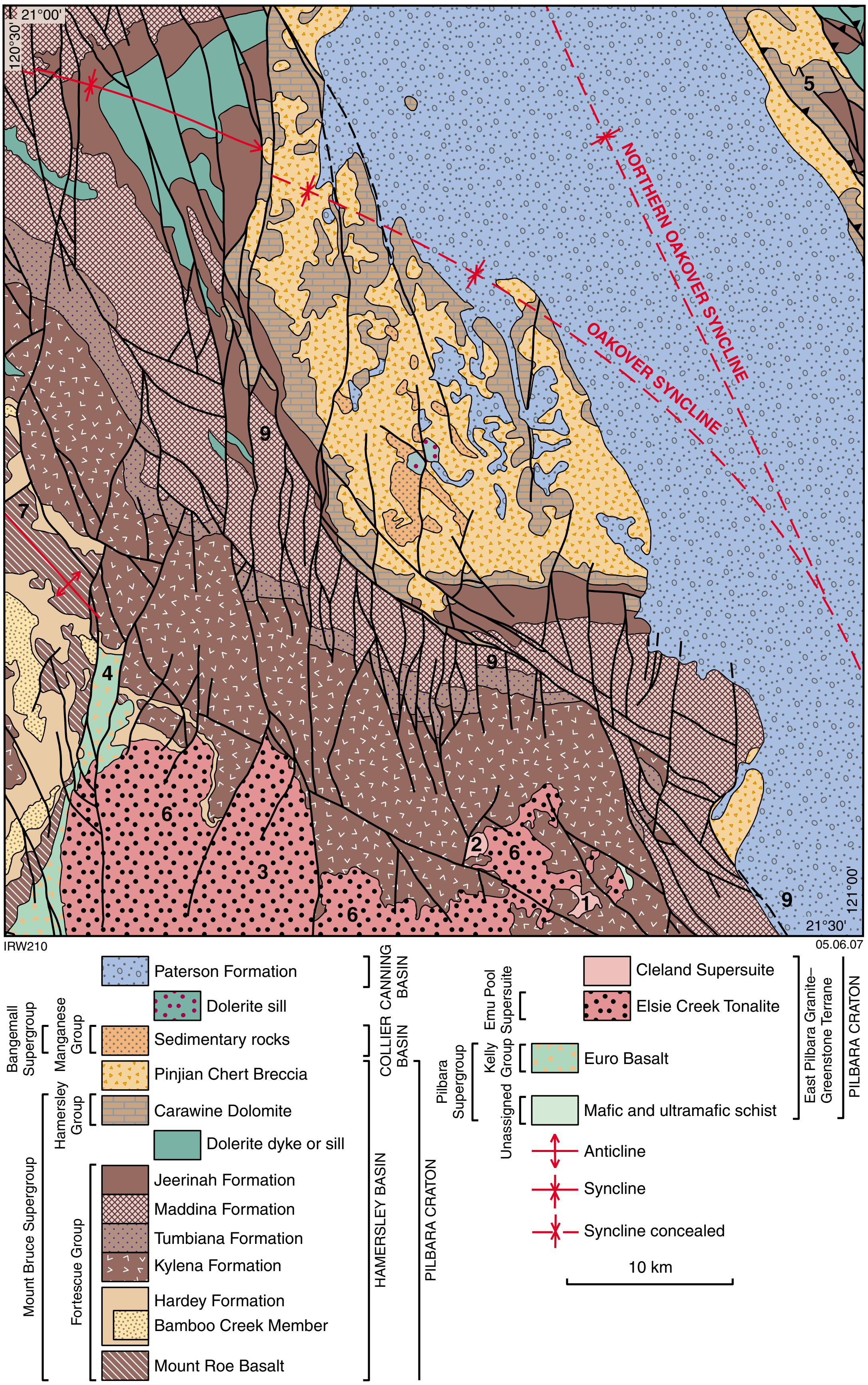


Figure 3. **Simplified bedrock geology and tectonic features of YILGALONG. 1 = Midgengadgi Monzogranite, 2 = Little River Trondhjemite, 3 = Elsie Creek Tonalite, 4 = Mount Elsie greenstone belt, 5 = Gregory Range Inlier, 6 = Yilgalong Granitic Complex, 7 = Miningarra Anticline, 8 = Meentheena Centrocline, 9 = Pearana Southwest Fault**

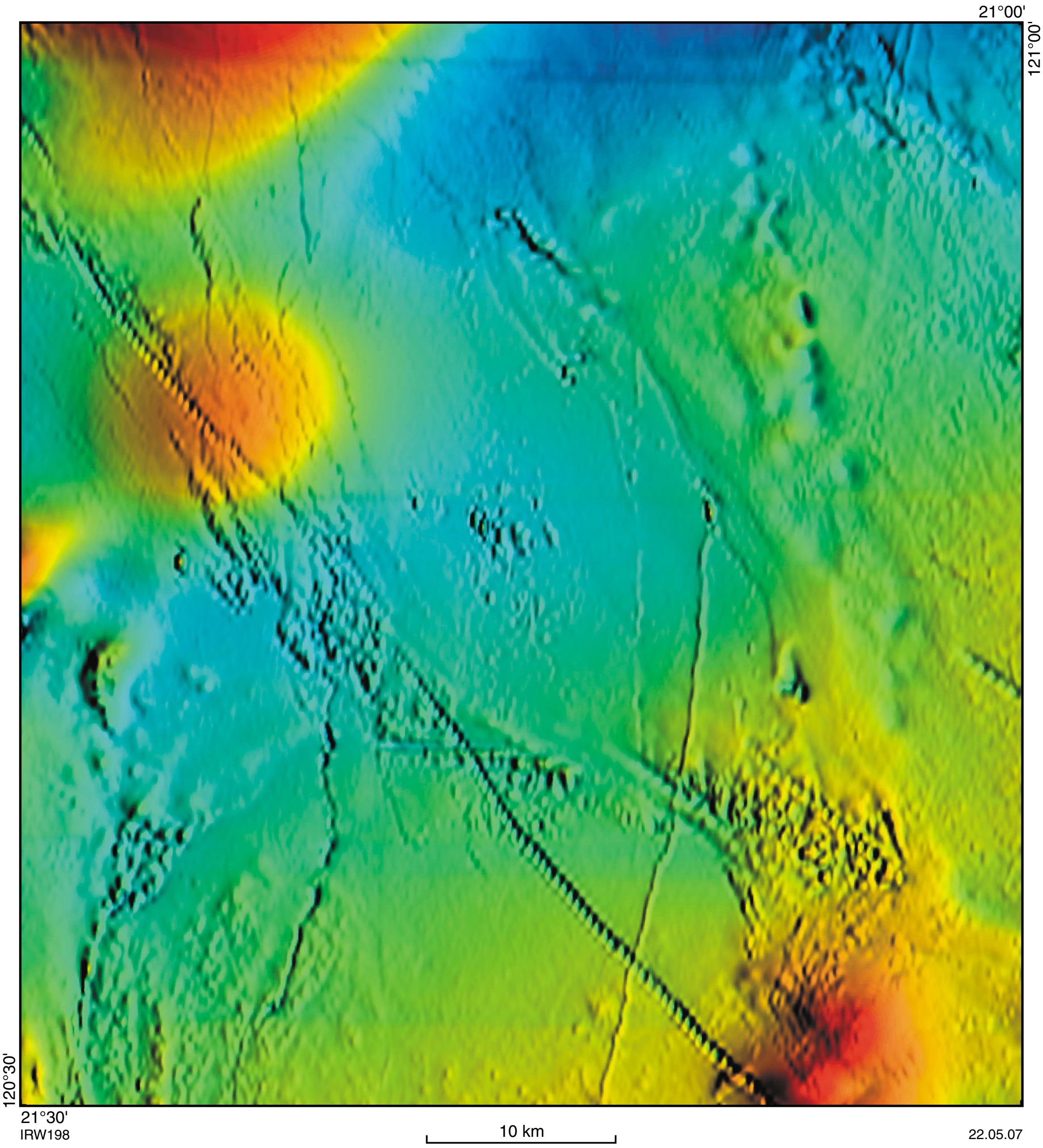


Figure 4. Total magnetic intensity (TMI) image for Yilgalong (GSWA, 2005a)

East Pilbara Terrane

The lithotectonic characteristics of the East Pilbara Terrane, characterized by broad granitic domes separated by synformal greenstone belts of the Pilbara Supergroup, have been described in detail and comprehensively reviewed in a number of recent publications (Van Kranendonk et al., 2002, 2004b, 2006; Hickman, 2004; Hickman and Van Kranendonk, 2004). On Yilgalong the exposed part of the East Pilbara Terrane is restricted to the southwest corner where the terrane occupies about 9% of the sheet area. The exposed East Pilbara Terrane in this area consists of the Mount Elsie greenstone belt (Hickman, 1983), which occupies about 4% of the area, and the northern half of the Yilgalong Granitic Complex (cf. Yilgalong Granite; Hickman, 1983), which occupies the remainder.

The Mount Elsie greenstone belt is a narrow, north-northeasterly trending belt in the southwest corner of Yilgalong. The belt, extending 17 km northwards from the Eastern Creek boundary, is sandwiched between the unconformable Mount Roe Basalt of the Fortescue Group to the west and a sheared intrusive contact with the Elsie Creek Tonalite to the east. Only the Euro Basalt has been identified in the Mount Elsie greenstone belt on Yilgalong. A small area of schistose mafic and ultramafic rocks 35 km to the east is also intruded by the

Table 1. Summary of geochronology samples collected from Yilgalong

Sample number	MGA coordinate Easting	Northing	Rock description	Age (Ma)	Method	Reference
178090	274361	7624961	Tuffaceous volcaniclastic sandstone, Kylena Formation; Dingo Well	2735 ± 6	SHRIMP U–Pb zircon	Bordokos et al., 2006b
178086	278939	7623973	Porphyritic dacite, Kylena Formation; Carawine Pool	2749 ± 5	SHRIMP U–Pb zircon	Nelson et al., 2006
178089	276390	7623252	Leucocratic monzogranite, Midgengadgi Monzogranite; Dingo Well	3274 ± 5	SHRIMP U–Pb zircon	Bordokos et al., 2006a
169260	256340	7627380	Foliated biotite tonalite; Bullyarrie Well	3277 ± 6 3308 ± 5	SHRIMP U–Pb zircon	Nelson, 2005s
169263	244390	7623250	Tonalite gneiss, Elsie Creek Tonalite; Bullyarrie Well	3290 ± 4	SHRIMP U–Pb zircon	Nelson, 2005d
169261	252440	7627290	Gneissic tonalite, Elsie Creek Tonalite; Bullyarrie Well	3291 ± 4	SHRIMP U–Pb zircon	Nelson, 2005b
169262	247570	7626520	Foliated biotite granodiorite, Elsie Creek Tonalite; Bullyarrie Well	3291 ± 4	SHRIMP U–Pb zircon	Nelson, 2005c
144682	244910	7621670	Foliated biotite tonalite, Baroona Hill	3299 ± 10	SHRIMP U–Pb zircon	Nelson, 2004a

Yilgalong Granitic Complex. This greenstone material is the easternmost exposure of the East Pilbara Terrane on Yilgalong.

Unassigned Pilbara Supergroup rocks (*API-xmbs-mus*, *API-mc*)

A small unnamed greenstone belt, 2 km long and 500 m wide comprising mafic and ultramafic schist (*API-xmbs-mus*) and metachert (*API-mc*), lies 19 km east-southeast of Dingo Well on the eastern margin of the Yilgalong Granitic Complex (Fig. 3). It is intruded by the Elsie Creek Tonalite and unconformably overlain by felsic units (*AFOk-xfa-spv*) of the Kylena Formation of the Fortescue Group.

The mafic and ultramafic schists (*API-xmbs-mus*) consist of schistose fine-grained amphibolite interlayered with chlorite–tremolite schist and amphibolitic schist with deformed ocelli indicative of komatiitic basalt parentage. The schistose fine-grained amphibolite consists of darker layers of almost pure hornblende alternating with light-coloured layers of plagioclase, hornblende, and quartz. Much of the plagioclase is sericitized, with patches of epidote and clinozoisite and very minor titanite. Poorly defined, crosscutting veins contain quartz, albite, and actinolite (Purvis, 2003c; GSWA 169291).

Thin, but persistent, metachert beds (*API-mc*) are interlayered with the mafic and ultramafic schists. Petrographically, the rock is predominately recrystallized quartz with minor muscovite and carbonaceous matter, traces of cloudy albite, and rare pyrite (Purvis, 2003c; GSWA 169290). In outcrop the metachert is faintly banded and strongly lineated. The banding is compositional with thin (<2 mm), coarse-grained, quartz-rich layers alternating with thicker (<8 mm), finer grained layers of quartz, microcrystalline schistose muscovite, and disseminated carbonaceous matter. Zircon is absent, which suggests a chert rather than a quartzite progenitor.

The mafic–ultramafic succession in this area is strongly foliated and intruded lit-par-lit by numerous foliated granitic and microgranitic dykes.

Figure 4, a total magnetic intensity image, used in combination with Figure 3, shows that the buried northern edge of the domal Yilgalong Granitic Complex, which is nonconformably overlain by the Fortescue Group succession, is traceable from the Mount Elsie greenstone belt contact in the west to the area of mafic and ultramafic schists just described. This would support a proposal that the Mount Elsie greenstone belt may wrap around the northern edge of the Yilgalong Granitic Complex and that the mafic and ultramafic schists in the area described are probably a continuation of this belt. Such a proposal is supported by the similarity in the petrography and structural fabrics of the two greenstone areas.

Kelly Group

The newly defined Kelly Group (Van Kranendonk et al., 2004b) encompasses an age range from 3420 to 3315 Ma (Van Kranendonk et al., 2006). Although the Kelly Group comprises the basal Strelley Pool Chert, Euro Basalt, Wyman Formation, and Charteris Basalt, on Yilgalong only the Euro Basalt is exposed in the Mount Elsie greenstone belt.

Euro Basalt (AKEe-xmbks-mbs, AKEe-bk, AKEe-mh, AKEe-bb, AKEe-ml, AKEe-cc)

The Euro Basalt (Hickman, 1977; Van Kranendonk et al., 2004b) is the sole greenstone unit in the Mount Elsie greenstone belt and the oldest exposed formation on Yilgalong. The formation can be traced continuously southwards onto Eastern Creek (Farrell, 2006) and southwestwards onto Nullagine (Bagas, 2005) where it is overlain by the felsic c. 3315 Ma Wyman Formation (GSWA, 2006; GSWA 144681).

Table 2. Summary of the geological history on Yilgalong

Age (Ma)	*Geological events*
Pre-3500	No evidence for older crustal material within the Yilgalong Granitic Complex on Yilgalong
3500–3400	Granite–greenstone material for this period is not exposed on Yilgalong
3350–3325	Voluminous eruption of mafic–ultramafic lavas of the Euro Basalt in the Mount Elsie greenstone belt; attributed to mantle plume activity
3325–3290	D_2: Beginning of major doming within the East Pilbara Terrane, such as expressed in the signature granitic domes surrounded by synclinal greenstone belts; on Yilgalong this is reflected in the initial moderate dips away from the developing dome of the Yilgalong Granitic Complex and faulting (both normal and steep reverse) of the Euro Basalt
3299–3290	Intrusion of the Euro Basalt by the Elsie Creek Tonalite (Emu Pool Supersuite); contact metamorphic aureoles in greenstone belts adjacent to intrusive granitic bodies
3290–3274	D_{2B}: After intrusion of the Elsie Creek Tonalite, late D_2 involved renewed uplift (doming) of the granitic material that produced the strongly sheared margins both within the greenstones and adjacent granitic rocks
3274–3240	Renewed mantle plume activity and doming (D_3); intrusion of monzogranite, granodiorite, trondhjemite (Cleland Supersuite) into the Yilgalong Granitic Complex; this event may be connected to the strong shearing at the margins both in the greenstones and adjacent granitic rocks (Elsie Creek Tonalite); uplift and erosion
3200–2775	Deformation ($D_{4–5}$) structures not recognized on Yilgalong; uplift, erosion, and weathering of the Yilgalong Granitic Complex and Mount Elsie greenstone belt
2775–2766	Onset of an extensional regime related to marginal cratonic rifting; outpouring of the Mount Roe Basalt, basal unit of the Fortescue Group on the western side of the Yilgalong Granitic Complex; coeval growth faulting, mild folding and local erosion
2766–2752	Deposition of epiclastic–volcaniclastic Hardey Formation in the western parts of Yilgalong; effusive and explosive eruption (including synvolcanic intrusions) of the c. 2766–2760 Ma Bamboo Creek Member; continuation of local growth faulting and mild folding; erosion; structures developed in the c. 2775–2752 Ma period assigned to D_6
2749–2730	Renewed mostly subaerial and local subaqueous basaltic and komatiitic fissure eruptions of the Kylena Formation; a pause in volcanic activity marked by the thin lacustrine stromatolitic carbonate Mopoke Member in the lower third of the formation
2727–2719	Deposition of phreatomagmatic volcaniclastic and volcanogenic sedimentary rocks with minor basaltic lavas of the c. 2727–2721 Ma Mingah Member and c. 2719 Ma lacustrine stromatolitic carbonate Meentheena Member of the Tumbiana Formation
2718–2713	Subaerial fissure eruptions of basalt and andesite lavas of the Maddina Formation, including the deposition of the c. 2713 Ma volcaniclastic Kuruna Member
2690–2629	Deposition of the marine sedimentary and mafic volcanic Jeerinah Formation
2741–2629	Intrusion of consanguineous mafic sills throughout the Fortescue Group
c. 2548	Deposition of the Carawine Dolomite, Hamersley Group; evidence for distal impact of an asteroid in an oceanic environment in a chaotic spherule-bearing megabreccia in the lower part of the formation
c. 2500	Deposition of Pinjian Chert Breccia concordant with the weathering and karstification of the Carawine Dolomite
<2500	Fortescue and Hamersley Groups broadly folded and faulted by episodic mild readjustments between sinking older greenstone belts and adjacent rising domal granitic complexes; this D_7 deformation represented by the major Oakover and Meentheena Synclines; Fortescue and Hamersley Group rocks subjected to very low grade greenschist-facies burial metamorphism
>1070	Deposition of fluvial and marine sedimentary rocks of the Manganese Group over the eastern margin of the Pilbara Craton; preserved in the Ripon Hills
1830–550	Brittle normal faulting with downthrow to west and east (?reactivated basement faults), later dextral and sinistral transpressional and steep reverse faulting with small tight folds on eastern side of the compressional faults; postulated to be connected to the Paleoproterozoic to Neoproterozoic convergent tectonics initiated by the collision between the West Australian Craton and the North Australian Craton (Yapungku Orogeny), and reactivated during the Miles (>678 Ma) and Paterson (550 Ma) Orogenies; assigned to D_8
c. 755	Intrusion of Round Hummock Dolerite Suite
c. 523	Intrusion of dolerite sills (Kalkarindji large igneous province)
304–284	Carboniferous–Permian ice cap and subsequent melting, erosion, and deposition of the fluvioglacial Paterson Formation
95–20	Ferruginous duricrusts (laterites) developed
c. 5–2	Deposition of the lacustrine Oakover Formation

The lower part of the formation is extensively intruded by granitic rocks of the 3292–3255 Ma Yilgalong Granitic Complex that borders the eastern side of the Mount Elsie greenstone belt. The upper parts of the formation to the west and north are unconformably overlain by units of the Fortescue Group. Overall, the Euro Basalt dips steeply to moderately west and northwest away from the Yilgalong Granitic Complex. Thickness estimates are difficult to calculate due to strong shearing and faulting, but the succession would appear to be at least 2000 m thick. The succession, shown from field relationships to be older than the 3299–3255 Ma Yilgalong Granitic Complex, has not been directly dated on YILGALONG. However, depositional ages between 3395 and 3332 Ma have been proposed (Van Kranendonk et al., 2002) and more recently a volcaniclastic sandstone within the Euro Basalt yielded a date of 3350 ± 3 Ma (GSWA, 2006; GSWA 178042).

The Euro Basalt, adjacent to the Yilgalong Granitic Complex, consists mainly of mafic schists derived from komatiitic and tholeiitic basalts (*AKEe-xmbks-mbs*). The schist component, marginal to the Yilgalong Granitic Complex contact, varies in width between 400 and 1000 m. The schists are mostly brown-weathering, grey-green, fine-grained rocks containing variable proportions of chlorite, actinolite, tremolite, epidote, microcrystalline quartz, altered plagioclase (albite), carbonate, leucoxene, and accessory opaque minerals (Purvis, 2003a; GSWA 169250). A pervasive planar foliation is present throughout together with several generations of quartz and quartz–carbonate veining. Zones of pervasive carbonate alteration are also associated with the komatiitic component of the schist. Ultramafic talc–carbonate and tremolite–chlorite schist are a minor component in the schist unit. Overall, most primary textures have been destroyed. Thin granitic and microgranitic dykes lit-par-lit intrude the schists adjacent to the Yilgalong Granitic Complex. The regional configuration of the schists and their associated metamorphic grade (upper greenschist facies) suggest that there was an initial contact metamorphism followed by strong shearing between the intrusive granitic rocks and the host Euro Basalt.

Metamorphosed, green-grey, fine-grained komatiitic basalt (*AKEe-bk*) is the thickest unit on YILGALONG. It overlies the mafic schist derived from komatiitic and tholeiitic basalts (*AKEe-xmbks-mbs*) and is overlain by the psammopelitic schist (*AKEe-mh*). The komatiitic basalt is more subdued in outcrop than the tholeiitic basalt (*AKEe-bb*), and is best exposed in the areas south of Elsie Creek and 8.5 km northeast of Salvation Well. The komatiitic basalt consists of actinolite, epidote, altered feldspar (albite), carbonate, quartz, accessory leucoxene, and opaque minerals. The komatiitic basalt is distinguished by common ocelli texture (Ashwal, 1991) towards the margins and larger varioles in the central cores of the deformed pillow structures. The regional deformation has commonly flattened the ocelli to elliptical lenses up to 30 mm long, 8 mm wide, and 2–3 mm long (Purvis, 2003c; GSWA 169254). The ocelli contain randomly oriented albite, epidote, amphibole, carbonate, leucoxene, and opaque minerals. The ocelli lack the radiating structure associated with the varioles. Feathery (amphibole after pyroxene) and rare platy spinifex texture (after olivine) have been found in less deformed areas.

Metasedimentary rocks are a minor intercalated component within the basaltic succession of the Euro Basalt on YILGALONG. Most outcrops are weathered and commonly ferruginized, making identification of the parent material difficult. A thick northwest-dipping band of variably red-brown ferruginized and silicified psammopelitic schist (*AKEe-mh*) lies 3 km south-southwest of Mopoke Well. The band forms a prominent topographic high with cliffs marked by rock overhangs and small caves eroded in the weathered metasedimentary rocks. A thinner horizon of the psammopelitic schist (*AKEe-mh*), 5 km south of Mopoke Well, appears to be a faulted continuation of this unit. Similar rocks have been recorded from EASTERN CREEK (Farrell, 2006) where they are described as interbedded metamorphosed siltstone and fine- to medium-grained sandstone.

Adjacent to the Yilgalong Granitic Complex a second metasedimentary horizon is intercalated with the mafic schists derived from komatiitic and tholeiitic basalts (*AKEe-xmbks-mbs*). This is a fine-grained, weathered pale greenish-grey pelitic rock (*AKEe-ml*) consisting mainly of quartz and chlorite, minor leucoxene, and limonite after pyrite. The fabric in thin section is schistose as outlined by the chlorite, but most of the quartz is recrystallized. The protolith of this horizon is unclear. Local thin metachert and thick white, grey, and blue-black banded metachert beds (*AKEe-cc*) are part of this horizon. These are particularly prominent 5 km northeast of Salvation Well. Such beds can be traced continuously over several kilometres. They commonly exhibit local mesoscale contorted fold patterns. Massive grey and pale-green quartzites are also locally developed in the metasedimentary horizon. Some quartzites carry green micaceous layers (fuchsite), leucoxene, and limonite clots probably after pyrite.

Metamorphosed, mostly pillowed tholeiitic basalt, minor massive dolerite and gabbro, and komatiitic basalt (*AKEe-bb*) is the youngest unit in the Euro Basalt on YILGALONG. Good but limited exposures are restricted to areas 2.5 km southwest and 4.5 km south of Mopoke Well adjacent to the overlying Fortescue Group. The tholeiitic basalt is a grey-green, fine-grained rock comprising altered feldspar, actinolite, epidote, quartz, and minor carbonate, leucoxene, and accessory opaque minerals. Partly deformed pillow structures with vesicles congregated towards the top of the pillows indicate way-up to the north and northwest. Small lenses of medium-grained dolerite and coarse-grained gabbro intercalated within the basalt pile are probably subvolcanic sills consanguineous with the basalts.

Emu Pool Supersuite (3325–3290 Ma)

Almost the entire Yilgalong Granitic Complex on YILGALONG is made up of the 3299–3290 Ma Elsie Creek Tonalite (Appendix 2; Table 2), a large intrusive body belonging to the Emu Pool Supersuite (Van Kranendonk et al., 2006). The Yilgalong Granitic Complex has a semiconcordant, variously deformed intrusive contact with the Euro Basalt on the western side and with the unassigned mafic–ultramafic schist (*API-xmbs-mus*) on the eastern side (Fig. 3). The complex is nonconformably overlain to the north and east by rocks of the Fortescue Group. Two small, related granitic inliers, surrounded by Fortescue Group rocks, are exposed in the headwaters of Midgengadge Creek adjacent to the northeast margin of the Yilgalong Granitic Complex.

The Elsie Creek Tonalite is intruded by small granitic bodies and dykes belonging to the 3275–3225 Ma Cleland Supersuite (Table 2). These include the newly named Midgengadgi Monzogranite and Little River Trondhjemite (Appendix 2).

Elsie Creek Tonalite (AEMel-mgtn)

The Elsie Creek Tonalite (*AEMel-mgtn*; Appendix 2; Table 2) underlies 99% of the area occupied by the Yilgalong Granitic Complex on YILGALONG, including the two small inliers along the northeastern margin of the complex. A weathered Archean paleosurface is preserved on the Yilgalong Granitic Complex, particularly along the northern margin adjacent to the Fortescue Group nonconformity, and on the higher parts of rugged hills that lie towards the southern boundary of the sheet. This weathered paleosurface is broadly undulating with relief in excess of 100 m. In consequence, fresh granitic rocks are best preserved in the broad valleys as scattered tors and sheets or along the sides of the more incised drainages in the hilly country.

On YILGALONG the Elsie Creek Tonalite is strongly deformed throughout the Yilgalong Granitic Complex. The deformation intensity increases towards the moderately steep intrusive contact with the adjacent greenstone belts. Protomylonitic tonalite and granodiorite gneiss, exhibiting low amphibolite-facies metamorphism, are exposed adjacent to the contact with the greenstone belts along the western margin of the Yilgalong Granitic Complex, particularly in the Elsie Creek area. Such rocks are grey to speckled white, finely laminated, and have complex foliation patterns suggestive of an S–C fabric. Some gneisses contain single or small clusters of plagioclase augen up to 6 mm in size. Away from the sheared contact the rocks are fine- to medium-grained, and locally coarse-grained, foliated to gneissic grey-green metatonalite, with minor pinkish-grey metagranodiorite and local metamonzogranite (*AEMel-mgtn*). Close to the margin such rocks have been described as tonalite and granodiorite gneiss (Purvis, 2003a; GSWA 169247, 169249, and 169252).

The assemblages consist predominately of plagioclase (andesine–oligoclase and myrmekite), quartz, microcline, biotite, and muscovite. Opaque minerals, titanite, apatite, allanite, and zircon are accessory. The biotite–muscovite flakes in most areas define a variable S–C fabric. Plagioclase can be saussuritized or irregularly replaced by sericite and carbonate. Biotite is partly replaced by chlorite. The mineral assemblages suggest that a low-temperature alteration has been superimposed on an earlier amphibolite-facies metamorphism (Purvis, 2003b; GSWA 169260 and 169261).

Pegmatite zones and dykes and microgranite (aplite) dykes are common throughout the Elsie Creek Tonalite. Various ages are evident, with the oldest dykes exhibiting similar foliations to the host gneisses, whereas other dykes post-date these foliations.

Seven kilometres northwest of Bullyarrie Well and adjacent to the Fortescue Group nonconformity, a 1 km^2 area of the Elsie Creek Tonalite is characterized by numerous mafic and ultramafic xenoliths and rafts (*AEMel-jmgtn-mw*). This would suggest that the area is close to the northern edge of the Yilgalong Granitic Complex, which, in this area, must be buried beneath the Fortescue Group rocks.

Four samples of the Elsie Creek Tonalite, collected across a distance of 10 km in the western half of the Yilgalong Granitic Complex, yielded sensitive high-resolution ion microprobe (SHRIMP) U–Pb dates ranging from 3299 ± 10 Ma (Nelson, 2005a; GSWA 144682) to 3290 ± 4 Ma (Nelson, 2005e; GSWA 169263). The remaining two samples yielded identical dates of 3291 ± 4 Ma (Nelson, 2005c,d; GSWA 169261 and 169262). All the dates are within error and indicate that the Elsie Creek Tonalite is c. 3291 Ma in age. A similar date of 3292 ± 4 Ma (Nelson, 2005f; GSWA 178008) was obtained from foliated biotite–muscovite tonalite, 6 km north of Mount Elsie in the southwestern corner of the Yilgalong Granitic Complex on EASTERN CREEK (Farrell, 2006).

Cleland Supersuite (3275–3225 Ma)

Intrusions assigned to the Cleland Supersuite are more common in the eastern half of the Yilgalong Granitic Complex on YILGALONG. Although the composition ranges from monzogranite to tonalite, monzogranite is more common. Intrusive bodies belonging to the Cleland Supersuite consist of widely separated, small (<4 km^2) stocks and microgranitic dykes, many of which are too small to register on the map sheet.

Biotite monzogranite (ACE-gmm)

Biotite monzogranite (*ACE-gmm*) outcrops at the eastern margin of the Yilgalong Granitic Complex, 17 km southeast of Dingo Well. On NULLAGINE (1:250 000) Williams and Hickman (in prep.) named this unit the Midgengadgi Monzogranite (*ACEmi-gm*), which is also defined in Appendix 2. The monzogranite forms an appendage to the main Yilgalong Granitic Complex and is almost completely surrounded by high ridges of nonconformably overlying Kylena Formation of the Fortescue Group. Fresh exposures of the monzogranite are found in flat sheets together with large tors and boulders.

The monzogranite is unfoliated, seriate to porphyritic, medium to coarse grained, and leucocratic. It consists of plagioclase (andesine–oligoclase), quartz, microcline, biotite, minor muscovite, and accessory opaque-oxide minerals and zircon. Myrmekite is abundant in places and commonly enclosed in microcline. Poikilitic microcline can be up to 8 mm long. Plagioclase is widely altered to sericite, epidote, chlorite, and carbonate minerals and biotite is commonly replaced by chlorite, epidote, and minor leucoxene (Purvis, 2003b; GSWA 178089).

A sample of the monzogranite yielded a SHRIMP U–Pb zircon date of 3274 ± 5 Ma, which is interpreted to be the age of igneous crystallization (Bodorkos et al., 2006a; GSWA 178089).

Leucocratic trondhjemite and tonalite (*ACE-gtl*)

Leucocratic trondhjemite and tonalite (*ACE-gtl*) originally described as an albite granite (Hickman, 1978) lies 10 km southeast of Dingo Well on the eastern side of Yilgalong Creek. Williams and Hickman (in prep.) named this unit the Little River Trondhjemite (*ACElr-gtl*), which is also defined in Appendix 2. The trondhjemite intrudes the Elsie Creek Tonalite and is nonconformably overlain to the south, west, and north by the Kylena Formation. The intrusion is not well exposed and is restricted to scattered, weathered boulder-strewn outcrops and water-eroded sheets along the eastern edge of Yilgalong Creek.

The trondhjemite is a massive, fine- to medium-grained, pale-pink (leucocratic) granite. It comprises about 70% albite (albitized plagioclase), 30% quartz, minor sericite, accessory rutile, and rare zircon. K-feldspar is absent, although albite has also replaced large poikilitic crystals that may have been K-feldspar. These poikilitic crystals enclose albitized plagioclase.

The petrography suggests that the granite is an albtized and weakly sericitized, undeformed leucocratic trondhjemite with low-temperature alteration (Purvis 2003a; GSWA 169272 and 169277).

A weakly foliated biotite tonalite, collected 3.3 km west-southwest of Bullyarrie Well, yielded a SHRIMP U–Pb zircon date of 3277 ± 6 Ma for the time of igneous crystallization and zircon xenocrysts dated at 3308 ± 5 Ma (Nelson, 2005b; GSWA 169260). The tonalite is part of a small, irregular-shaped body intruding the strongly foliated Elsie Creek Tonalite. Thick dykes of unfoliated porphyritic microgranodiorite and micromonzogranite, 8 km south of Mopoke Well (MGA 247872E 7631109N) and 13 km east-southeast of Dingo Well (MGA 273970E 7628375N), are assigned to the Cleland Supersuite.

Structure of the East Pilbara Terrane on Yilgalong

Regional structural relationships developed in the granite–greenstones of the East Pilbara Terrane have been widely discussed in the literature (Hickman, 1983, 2004; Hickman and Van Kranendonk, 2004; Van Kranendonk et al., 2002; Blewett, 2002). The structural data from Yilgalong can be linked to data from Eastern Creek (Farrell, 2006), and to the regional structural development of the East Pilbara Terrane.

Because the oldest rocks exposed on Yilgalong are c. 3350 Ma in age, this area preserves no evidence for older deformation events recorded elsewhere in the East Pilbara Terrane. However, to describe the structural history of Yilgalong within a regional context, the deformation events are, where possible, correlated with regional events described by Van Kranendonk et al. (2002).

D_2 (3325–3290 Ma)

The earliest structures on Yilgalong are preserved in the Kelly Group of the Mount Elsie greenstone belt. On Eastern Creek Farrell (2006) assigned these old structures — a metamorphic foliation, mineral lineations, and various minor folds — to 'D_{EP1}'. He reported that these structures must be older than the Elsie Creek Tonalite (3299–3290 Ma) because the oldest structures in that unit (D_{EP2}) are superimposed on the D_{EP1} structures. On Yilgalong this conclusion is supported by the observation that early folding of the Euro Basalt was prior to intrusion of the formation by the Elsie Creek Tonalite. Within the Kelly Group the Euro Basalt is conformable with the overlying 3325–3315 Ma Wyman Formation, requiring the age of the first deformation to be less than 3325 Ma. Accordingly, the first deformation event in the Mount Elsie greenstone belt correlates with the regional D_2 event (Hickman, 1983, 1984), which Van Kranendonk et al. (2002) related to intrusion of granitic rocks now assigned to the 3325–3290 Ma Emu Pool Supersuite (Van Kranendonk et al., 2006).

The first observable structural event on Yilgalong was folding of the Euro Basalt, with development of a regional, west-dipping, north-northwesterly to north-northeasterly trending foliation and tight, small-scale recumbent, north-plunging folds in chert 6 km northeast of Salvation Well (MGA 247400E 7631300N). Such structures are best preserved away from the contact with the Elsie Creek Tonalite, which was sheared by later deformation. The primary layering in the Mount Elsie greenstone belt, mainly in mafic and ultramafic volcanic rocks interbedded with chert and metasedimentary rocks, dips to the west and north-northwest away from the Yilgalong Granitic Complex. Pillow structures indicate way-up to the west and northwest. This part of the Mount Elsie greenstone belt is presumed to be the eastern limb of a regional D_2 syncline, the western limb of which lies buried beneath the overlying Fortescue Group to the west.

D_{2B} (3290–3274 Ma)

The second deformation event on Yilgalong produced a strong tectonic foliation in the 3299–3290 Ma Elsie Creek Tonalite and a parallel, moderate to steeply dipping metamorphic foliation in the Euro Basalt. Both foliations are parallel to the western contact of the Yilgalong Granitic Complex, as in most other granitic domes of the East Pilbara Terrane (Hickman, 1983, 1984). Within the Euro Basalt the regional foliation exhibits local small tight folds, crenulation kinks, and steep intersection and mineral lineations that plunge to the south and north in the contact metamorphic zone adjacent to the Yilgalong Granitic Complex. These foliations are best preserved in mafic and ultramafic schists (*AKEe-xmbks-mbs*), which are also host to arcuate high-strain zones that parallel the granitic contact. The 3299–3290 Ma contact metamorphism in the Euro Basalt is interpreted to have reached at least amphibolite facies. The internal fabric of the Yilgalong Granitic Complex adjacent to the contact with Mount Elsie greenstone belt is a protomylonite in which the regional foliation in the granitic gneiss is parallel to that developed in the mafic and ultramafic schists. This protomylonite is related to doming of the Yilgalong Granitic Complex, and must be syn- or post-3290 Ma.

Farrell (2006) recorded that this event (D_{EP2} on EASTERN CREEK) pre-dated 3274 Ma, the age of the Midgengadgi Monzogranite, which on YILGALONG intruded the tectonic deformation of the second deformation. In the Yilgalong Granitic Complex the Emu Pool Supersuite is 5–10 m.y. younger than in granitic complexes of the central East Pilbara Terrane, suggesting that in the southeast East Pilbara Terrane D_2 doming, accompanying and following granitic intrusion, probably continued for some time after 3290 Ma. Van Kranendonk et al. (2006) concluded that D_2 doming, metamorphism, and subsequent erosion probably continued to c. 3270 Ma.

D_3 (*3274–3240 Ma*)

On EASTERN CREEK Farrell (2006) recorded a third deformation event (D_{EP3}) that resulted in large-scale shear folds in the centre of the Mount Elsie greenstone belt and along the southwestern contact of the Yilgalong Granitic Complex. He noted that these structures truncated D_{EP2} structures, which he interpreted to indicate a post-3274 Ma age. Porphyritic monzogranite dykes of Cleland Supersuite age intrude the Mount Elsie greenstone belt on EASTERN CREEK (Farrell, 2006), and small populations of c. 3250 Ma zircons are recorded in samples of the Elsie Creek Tonalite. On the eastern margin of the Yilgalong Granitic Complex the strongly foliated Elsie Creek Tonalite is intruded by two unfoliated granitic intrusions of the Cleland Supersuite, Little River Trondhjemite, and Midgengadgi Monzogranite. The lack of any deformation fabrics in these intrusions indicates no significant post-3274 Ma deformation on the eastern side of the complex.

Elsewhere in the Pilbara Craton, D_3 was a tectonothermal event during intrusion of the 3275–3225 Ma Cleland Supersuite and deposition of the 3270–3235 Ma Sulphur Springs Group (D_3 of Van Kranendonk et al., 2002).

Later Archean deformation events

Later Archean deformations (D_4, D_5) are neither preserved nor expressed in the Mount Elsie greenstone belt and Yilgalong Granitic Complex on YILGALONG (cf. Williams and Bagas, in prep.).

Subsequent brittle faulting that disrupts the contact between the Mount Elsie greenstone belt and Yilgalong Granitic Complex is probably Neoarchean to Proterozoic because these faults also displace the Fortescue Group rocks. This faulting is probably D_8 (see **Structure of the Fortescue and Hamersley Groups**).

Hamersley Basin

Lithostratigraphic units of the Northeast Pilbara Sub-basin of the Hamersley Basin occupy over 60% of the sheet area. Such units, in decreasing order of exposed abundance, are the weakly metamorphosed volcanic and sedimentary Neoarchean Fortescue Group and the Neoarchean Carawine Dolomite of the Hamersley Group, which are components of the Mount Bruce Supergroup, and the Paleoproterozoic Pinjian Chert Breccia. The latter is controlled by the distribution of the Carawine Dolomite. The Hamersley Basin succession is unconformably overlain by scattered outliers of Mesoproterozoic sedimentary rocks, assigned to the Manganese Group of the Bangemall Supergroup (Martin et al., 2005), in the Ripon Hills area and by Permian fluvioglacial sedimentary rocks (Williams, 2001) in the region now occupied by the Oakover River valley.

Fortescue Group

Following the cratonization of the Pilbara Craton the onset of a regional extensional regime (rifting) triggered the deposition of the thick volcanic and sedimentary succession of the Fortescue Group. This regime finally led to the breakup of the craton and its eventual evolution into a subsiding passive continental margin (Blake, 1984, 1993; Tyler and Thorne, 1990; Blake and Barley, 1992; Thorne and Trendall, 2001). A historical comparative stratigraphic chart for the Fortescue Group is given in Table 3.

The complete Fortescue Group succession of the Mount Roe Basalt and the Hardey, Kylena, Tumbiana, Maddina, and Jeerinah Formations (Thorne and Trendall, 2001) occupies parts of a 16 km-wide zone that extends from near the southeast corner of YILGALONG (Fig. 3) diagonally across to the northwest corner. This zone lies to the west and south of the Ripon Hills and is the southwestern limb of the regional southeast-plunging Oakover Syncline (Hickman, 1983). Basal formations of the Fortescue Group extend south along the western border of YILGALONG. The Jeerinah Formation at the top of the Fortescue Group is also exposed in the far northeast corner, where it constitutes part of the Gregory Range Inlier (Williams and Trendall, 1998a). Altogether the Fortescue Group accounts for more than 60% of the Hamersley Basin succession exposed on YILGALONG, and is about 5.6 km thick.

The Fortescue Group unconformably overlies the Pilbara Supergroup and the Yilgalong Granitic Complex of the East Pilbara Terrane. The group is disconformably overlain by the Carawine Dolomite of the Hamersley Group in the Ripon Hills, Midgengadge Creek area, and northeast of the Oakover River in the northeast corner. Permian fluvioglacial sedimentary rocks unconformably overlie the Fortescue Group southeast of the Ripon Hills.

There is an approximately 500 m.y. gap between the emplacement of 3277–3274 Ma intrusions of the Cleland Supersuite in the Yilgalong Granitic Complex (Bodorkos et al., 2006a; GSWA 178089), which is the last recorded event in the East Pilbara Terrane on YILGALONG, and the initial deposition of fluvial deposits at the base of the c. 2775 Ma Mount Roe Basalt, which is the lowermost unit of the Fortescue Group (Hickman, 1983; Arndt et al., 1991). This hiatus corresponds to a long period of erosion and weathering, which is particularly evident in the granitic rocks of the Yilgalong Granitic Complex. The paleotopography is also considerable (>1000 m) in

Table 3. Fortescue Group stratigraphic correlation chart — a historical comparison for YILGALONG

NULLAGINE 1:250 000 *Hickman (1978)*	*YILGALONG 1:100 000* *Williams (this report)*	*Sequence stratigraphy* *Blake et al. (2004)*
Lewin Shale (*Ᵽfl*)	Jeerinah Formation (*AFOj-sk*)	Mount Jope Supersequence (2)
	Baramine Member (*AFOjb-bnth*)	
Maddina Basalt (*Ᵽfm*)	Maddina Formation (*AFOm-b*)	
Kuruna Siltstone (*Ᵽfs*)	Kuruna Member (*AFOmk-bntt*)	
Nymerina Basalt (*Ᵽfn*)	Maddina Formation (*AFOm-b*)	
Tumbiana Formation (*Ᵽft*)	Tumbiana Formation (*AFOt-xb-k*)	Mount Jope Supersequence (1)
Meentheena Carbonate Member (*Ᵽftc*)	Meentheena Member (*AFOtm-kts*)	
Mingah Tuff Member (*Ᵽftt*)	Mingah Member (*AFOti-bntt*)	
Kylena Basalt (*Ᵽfk*)	Kylena Formation (*AFOk-bng*)	Nullagine Supersequence
	Mopoke Member (*AFOkm-kts*)	
	Kylena Formation (*AFOk-xbb-bk*)	
Hardey Sandstone (*Ᵽfh*)	Hardey Formation (*AFOh-xs-f*)	
Quartz–plagioclase porphyry (*Ᵽp*)	Bamboo Creek Member (*AFOhb-fr*)	
Mount Roe Basalt (*Ᵽfr*)	Mount Roe Basalt (*AFOr-bbg*)	

that the basal Mount Roe Basalt, Hardey Formation, and lower units of the Kylena Formation are missing from the Fortescue Group where it nonconformably overlies the Yilgalong Granitic Complex along its northern and eastern contacts. However, the Mount Roe Basalt and Hardey Formation unconformably overlie with moderate dip the Euro Basalt of the Mount Elsie greenstone belt, which lies west of the Yilgalong Granitic Complex. This indicates that the Yilgalong Granitic Complex was a basement high during the early depositional stages of Fortescue Group.

Mount Roe Basalt (AFOr-scp, AFOr-bbg)

The Mount Roe Basalt (Kriewaldt, 1964; Thorne and Trendall, 2001) is confined to the southwest margin of YILGALONG, where it unconformably overlies the Euro Basalt of the Kelly Group. Farther east the Mount Roe Basalt is absent above the Fortescue Group unconformity with the Yilgalong Granitic Complex. The formation is unconformably overlain by the Hardey Formation and faulted against the younger Kylena Formation. The formation outcrops on the eastern rim of the Meentheena Centrocline (Blake, 1993) and in the core of the Miningarra Anticline (Fig. 3).

A small area of moderately dipping polymictic pebble conglomerate, sandstone, grey siltstone, and shale (*AFOr-scp*), unconformably overlying the Euro Basalt, underlies a thick (600 m) basalt succession 4.3 km south-southwest of Salvation Well. This sedimentary succession appears to be a representative of the fluvial deposits locally known elsewhere to exist at the base of the Mount Roe Basalt (Thorne and Trendall, 2001; Williams and Bagas, in prep.).

The Mount Roe Basalt consists mainly of massive, porphyritic, vesicular, and amygdaloidal subaerial basaltic lavas with some local pillowed subaqueous basaltic flows (*AFOr-bbg*). The basalts are dark grey to greenish-grey and consist dominantly of plagioclase with fresh or altered clinopyroxene, and skeletal or dendritic opaque oxides set in a quenched or fine-grained groundmass. Anatase is accessory. Porphyritic basalt flows contain thin platy plagioclase phenocrysts that in some areas aggregate to form glomeroporphyritic textures popularly known as Chinese writing stone (Bevan et al., 1999). These flows tend to lie in the upper parts of the formation.

The amygdales and vesicles are filled or partly filled with microcrystalline quartz, carbonate (calcite), chlorite, and the occasional sulfide bleb. Individual flows can be identified by scoriaceous, amygdale-rich, and vesiculated flow tops. A small area of ocelli-bearing dark-grey metabasalt, 3.5 km west of Mopoke Well, on the floor of a deep valley beneath a thick sequence of Mount Roe Basalt, may belong to the underlying older Euro Basalt. However, the rubbly nature of this exposure makes the spatial relationships between the basalts difficult to ascertain. The metabasalt is a carbonate–chlorite–albite–quartz assemblage. The ocelli are circular, elliptical or slightly amoeboid. The ocelli are now altered to carbonate and minor chlorite pseudomorphing stubby crystals that may have been clinopyroxene (Purvis, 2003c; GSWA 192002).

In the core of the Miningarra Anticline, and particularly in the area around 8 km east of Meentheena Homestead (MGA 237155E 7643350N on MOUNT EDGAR), the basalts are strongly altered and intersected by numerous quartz and laminated or banded chalcedony veins and dykes. Ferruginous gossans are associated with some of the quartz veins. The basalts are characterized by extensive carbonate (ferroan dolomite), silica (quartz), sericite, clay, chlorite, and leucoxene alteration. The carbonate alteration may be pervasive or restricted to thin veins.

The Mount Roe Basalt has not been dated on YILGALONG, but a SHRIMP U–Pb zircon date of 2775 ± 10 Ma has been obtained elsewhere (Arndt et al., 1991).

Hardey Formation (AFOh-scp, AFOhb-fr, AFOhb-frp, AFOh-sg, AFOh-spa, AFOh-sfv)

The mixed epiclastic and felsic volcanic Hardey Formation (Thorne et al., 1991; previously called Hardey Sandstone, MacLeod et al., 1963) is restricted to the southwestern quarter of YILGALONG. Although the formation is up to 800 m thick along the southwestern margin, where it unconformably overlies the Mount Roe Basalt and locally the Euro Basalt of the East Pilbara Terrane, it thins rapidly eastwards across the sheet area. Seven kilometres south of Mopoke Well the Hardey Formation rests nonconformably on the Yilgalong Granitic Complex with a considerably reduced thickness of about 300 m. The formation disappears altogether from the nonconformity about 6 km south of Bullyarrie Well. From this locality eastwards the overlying Kylena Formation rests nonconformably on the Yilgalong Granitic Complex.

The Hardey Formation can be subdivided into five distinct units or successions, similar to those described on MOUNT EDGAR (Williams and Bagas, in prep.). These are a basal coarse- to fine-grained clastic sedimentary succession, the felsic volcanic Bamboo Creek Member, a thin-bedded, coarse- to fine-grained clastic sedimentary succession restricted to the Salvation Well area, a feldspathic coarse- to fine-grained clastic sedimentary succession, and an uppermost clastic sedimentary to volcaniclastic succession. All units are discontinuous on YILGALONG and vary considerably in thickness.

The basal polymictic, matrix-supported cobble to boulder conglomerate, sandstone, siltstone and local shale (*AFOh-scp*) is up to 300 m thick and has been deposited on a pre-existing eroded surface developed on top of the Mount Roe Basalt or Yilgalong Granitic Complex. The matrix-supported polymictic conglomerate, containing a high proportion of clasts derived from the underlying Mount Roe Basalt, is found in outcrops on the western margin of YILGALONG 3 km south of the Ripon Hills Road, and 8 km west of Bookabunna Well. The proportion of basalt clasts decreases in outcrops farther south around the eastern margin of the Meentheena Centrocline and are absent from equivalent basal conglomerates overlying the Yilgalong Granitic Complex farther east. The basal Hardey Formation unit overlying the Yilgalong Granitic Complex disappears around 8 km south-southeast of Mopoke Well. Conglomerates unconformably overlying the Yilgalong Granitic Complex 12 km further to the southeast and 6 km south of Bullyarrie Well are now correlated with the uppermost epiclastic–volcaniclastic unit of the Hardey Formation (cf. Williams, 2005). The basal unit near Salvation Well is mainly dark-grey to blue-grey siltstone and shale with interbedded thin sandstone and pebble conglomerate. Locally, thick units of dark-grey (carbonaceous) shale and micaceous siltstone overlie the polymictic conglomerates, as in the area west of the Meentheena copper prospect.

Bamboo Creek Member (AFOhb-fr, AFOhb-frp)

The Bamboo Creek Member (*AFOhb-fr*; Thorne and Trendall, 2001; cf. Bamboo Creek Porphyry, Noldart and Wyatt, 1962; Hickman, 1983) is exposed in three lenticular bodies extending onto YILGALONG from adjoining MOUNT EDGAR (Williams and Bagas, in prep.). These include a small outcrop (<1 km^2) on the west side of the Nullagine River, 1 km north of the Ripon Hills road, a felsic succession more than 300 m thick and over 11 km long, which lies west and southwest of the Meentheena copper prospect, and a third body (up to 300 m thick and 7 km long) that extends from north of Salvation Well to the southwest margin. A small area (around 1 km^2) of the Bamboo Creek Member also lies 3 km west of Mopoke Well, where it is faulted against the Kylena Formation.

The Bamboo Creek Member consists mainly of red-brown weathering, dark-grey to black, fine- to coarse-grained, porphyritic rhyolite, rhyodacite, and dacite (*AFOhb-fr*). The phenocrysts are quartz, greenish sodic plagioclase, pink alkali feldspar (orthoclase) and rare altered biotite, amphibole, and pyroxene. Such porphyritic rocks in the past have been called quartz–feldspar porphyries or porphyry complexes (Hickman, 1983; Blake, 1993). The medium- to coarse-grained porphyritic rocks are commonly in the thicker successions, suggesting that they may be subvolcanic intrusions. Thin-section petrography shows that most felsic rocks of the Bamboo Creek Member have alteration assemblages of quartz, albite, carbonate, sericite, chlorite, and leucoxene.

A porphyritic dacite, 3.2 km west of Mopoke Well (MGA 245380E 7638264N), contains unusual orbicular or accretionary structures up to 25 mm in diameter. The shells of the orbicules are composed of massive fine-grained chlorite between 0.5 and 1.5 mm wide. The shells are interrupted by, and post-date, the plagioclase and quartz phenocrysts. The groundmass outside the orbicular chlorite shells is rich in quartz and sericite and has a flow texture defined by leucoxenized microlites. Internally, the chlorite shells contain abundant granular and microgranular quartz, minor to abundant chlorite, and microcrystalline leucoxene that is not elongate or oriented. Lenses of chalcedony and sometimes sparry carbonate are also present within the orbicules. The orbicular structures resemble expanded spherulites and seem to have formed during the crystallization or devitrification of the groundmass (Purvis, 2003a; GSWA 169232). Welded ignimbrite, volcanic breccia, and accretionary lapilli in resedimented pyroclastic deposits have been locally recorded elsewhere in the Bamboo Creek Member (Williams and Bagas, in prep.).

Although the Bamboo Creek Member has not been dated on YILGALONG, the same horizon on adjacent MOUNT EDGAR has yielded a SHRIMP U–Pb zircon date of 2766 ± 7 Ma from a cutting on the Ripon Hills road 3.5 km west-northwest of King Rockhole (Nelson, 2004b; GSWA 169037).

A number of coarse- to fine-grained dacite, rhyodacite, and rhyolite dykes (*AFOhb-frp*) intrude the Mount Roe Basalt in the core of the Miningarra Anticline 9 km west of Bookabunna Well. The dykes are generally less than a kilometre long and trend west-northwest. A similar trending dyke on MOUNT EDGAR intruded in the Mount Roe Basalt and in close proximity to the YILGALONG dykes, yielded a conventional zircon U–Pb date of 2765 ± 2 Ma (Thorne and Trendall, 2001).

A prominent porphyritic quartz–K-feldspar–plagioclase rhyodacite dyke intrudes the Elsie Creek Tonalite, 11 km southeast of Dingo Well. The quartz and feldspar phenocrysts are set in an altered microspherulitic groundmass. The K-feldspar may also rim some of the plagioclase phenocrysts. Petrographically, the dyke shows many features identical to the Bamboo Creek Member feeder dykes previously described from MOUNT EDGAR (Williams and Bagas, in prep.) to which this dyke has been correlated. The dyke is unconformably overlain by the Kylena Formation.

Conglomerate and sandstone unconformably overlying the Bamboo Creek Member (AFOh-sg)

The Bamboo Creek Member is unconformably overlain to the west and north of Salvation Well by a lenticular unit up to 120 m thick of thin-bedded conglomerate and sandstone, with local interbedded minor wacke and siltstone (*AFOh-sg*). The clasts in the conglomerate are mostly quartz pebbles and the associated medium- to coarse-grained sandstones are commonly feldspathic. Similar rocks have been described from MOUNT EDGAR, where it can be shown that much of the clastic material in this unit was probably eroded from the underlying Bamboo Creek Member (Williams and Bagas, in prep.).

Several thick units of red- to purple-weathering, blue-grey laminated siltstone lie 1.5 km northwest of Salvation Well. The siltstone is interbedded with thin quartz-pebble conglomerate and medium- to coarse-grained feldspathic sandstone beds. A number of exploratory costeans, up to 50 m long, have been excavated in the siltstone units. Overall, this succession is upward fining.

An almost continuous succession of feldspathic sandstone, pebbly sandstone, and conglomerate with minor fine-grained sandstone and siltstone (*AFOh-spa*), up to 250 m thick, can be traced around the southeast portion of the Meentheena Centrocline. West of Salvation Well this unit disconformably overlies the thin-bedded conglomerate, sandstone, local wacke, and siltstone unit (*AFOh-sg*), whereas 5 km north of Salvation Well the unit unconformably overlies the Bamboo Creek Member. This latter relationship is also present on the western margin, 1.5 km north of the Ripon Hills road. The discontinuous nature of the epiclastic units within the Hardey Formation is exemplified in exposures 6 km west of Bookabunna Well, where the feldspathic sandstone, pebbly sandstone, and conglomerate with minor fine-grained sandstone and siltstone succession (*AFOh-spa*) lies disconformably on the basal conglomerate, sandstone, siltstone, and local shale succession (*AFOh-scp*).

Conglomerate clasts in the feldspathic sandstone, pebbly sandstone, and conglomerate succession (*AFOh-spa*) are mostly quartz with minor coloured chert. The sandstone beds become finer grained towards the top of the unit. Tabular and trough cross-beds have been observed in the sandstone.

The youngest succession of the Hardey Formation is also the most laterally widespread unit. Although discontinuous in outcrop (Williams and Bagas, in prep.) the scattered nature of the outcrop on YILGALONG is probably due to erosion prior to deposition of the overlying Kylena Formation. The succession consists of sandstone, siltstone, shale, local pebbly sandstone and conglomerate interbedded with volcaniclastic sandstone, accretionary lapilli beds, and minor thin carbonate beds (*AFOh-sfv*).

The youngest succession (*AFOh-sfv*) is continuously exposed around the eastern side of the Meentheena Centrocline (Fig. 3) northwest of Salvation Well in the southwest corner of the sheet area, where it is commonly less than 200 m thick. Here, the youngest succession conformably overlies the feldspathic sandstone, pebbly sandstone, and conglomerate with minor fine-grained sandstone and siltstone succession (*AFOh-spa*). On the western boundary of YILGALONG, 10 km north of Salvation Well, the succession unconformably overlies the older Bamboo Creek Member. This relationship is also recorded 3 km west of Mopoke Well. At this locality the youngest succession extends from the Bamboo Creek Member disconformably onto the adjacent underlying basal polymictic, matrix-supported cobble to boulder conglomerate, sandstone, siltstone, and local shale succession (*AFOh-scp*) The youngest succession also disconformably overlies the basal succession of the Hardey Formation (*AFOh-scp*) 6 km south of Mopoke Well. It also unconformably overlies the Elsie Creek Tonalite of the Yilgalong Granitic Complex 8 km southeast of Mopoke Well. The youngest succession continues to thin eastwards and is absent from the Fortescue Group unconformity with the Yilgalong Granitic Complex about 6 km south-southeast of Bullyarrie Well, where the overlying Kylena Formation rests directly on the Yilgalong Granitic Complex. These relationships support the proposal that the Yilgalong Granitic Complex was a basement high during the deposition of the Hardey Formation.

The epiclastic component of the uppermost succession consists of red-brown- to brown-weathering, fine-grained to pebbly sandstone and pebbly conglomerate with quartz and felsic volcanic clasts interbedded with flaggy, yellow-weathering grey siltstone and shale. Volcaniclastic tuffaceous siltstone, shale, sandstone, and reworked lapilli-bearing tuffaceous rocks are more common in the upper parts of the succession. Thin-section studies show that the tuffaceous lithic–crystal sandstone contains carbonate- and microcrystalline chlorite-altered mafic shards that may form up to 35% of the rock (Purvis, 2003a; GSWA 169240). Rare thin-bedded grey carbonate lenses are interspersed through the succession.

A felsic tuffaceous horizon interbedded with terrigenous fluvial deposits in the upper part of the Hardey Formation on NULLAGINE has a SHRIMP U–Pb zircon date of 2752 ± 5 Ma (Blake et al., 2004).

Kylena Formation (AFOkm-kts, AFOk-xfa-spv, AFOk-xbb-bk, AFOk-bng)

The Kylena Formation (Kojan and Hickman, 1998; Thorne and Trendall, 2001) occupies a broad zone that stretches from the southern margin of YILGALONG, 14 km west of the southeast corner, northwest to the Nullagine River area and central parts of the western margin (Fig. 3). The formation is well exposed throughout and reaches a maximum thickness of about 1800 m between Mopoke and Mishap Wells. The Kylena Formation is predominantly composed of tholeiitic basalt with lesser komatiitic basalt, basaltic andesite, and dacite. However, the lower portion of the formation contains a widespread and distinctive carbonate marker horizon — the Mopoke Member (*AFOkm-kts*). Locally, beneath the Mopoke Member, there is also an unnamed succession of andesite, basaltic andesite, and dacite flows and associated volcaniclastic material (*AFOk-xfa-spv*). The Mopoke Member separates the Kylena Formation into two chemically distinct basaltic successions.

Succession beneath the Mopoke Member

The lower succession of the Kylena Formation (*AFOk-xbb-bk*) that lies beneath the Mopoke Member is unconformably transgressive on the underlying Hardey Formation in the southwest corner of the sheet area. From 5 km north-northwest of Bullyarrie Well to an area 16 km southeast of Dingo Well the lower succession noncomformably overlies the Elsie Creek Tonalite of the Yilgalong Granitic Complex. This lower succession reaches a maximum thickness of around 500 m in the Mopoke Well area. From here it progressively thins to the east where it overlies a basement high composed of the Yilgalong Granitic Complex. At the eastern end of the Yilgalong Granitic Complex exposure, between 10 and 19 km southeast of Dingo Well, the lower basaltic succession of the Kylena Formation disappears altogether and the unnamed felsic component of the lower succession (*AFOk-xfa-spv*), the Mopoke Member (*AFOkm-kts*), and the upper succession of the Kylena Formation (*AFOk-bng*) all nonconformably overlie parts of the Yilgalong Granitic Complex. At the base of all these units there is a thin veneer of conglomerate, containing quartz and granitic clasts, mixed with pebbly arkosic sandstone and feldspathic sandstone. This material may be grus eroded from the granitic rocks prior to deposition of the Kylena Formation.

The lower succession consists of multiple thick flows of massive, fine-grained to vesicular and amygdaloidal, grey-blue basalt and greenish-grey komatiitic basalt (*AFOk-xbb-bk*). Locally, well-exposed pillow structures indicate subaqueous conditions, probably lacustrine, because most flows appear to be subaerial as shown by columnar jointing and scoriaceous flow tops. In thin section the primary plagioclase–clinopyroxene–feldspathic mesostasis of the basalt show albite–sericite–prehnite–pumpellyite–leucoxene–chlorite alteration. Amygdales contain varying amounts of chlorite, pumpellyite, carbonate, and prehnite. Fine-grained pyroxene-spinifex textures have been noted in the komatiitic basalts.

The lower basalt succession has a distinctive radiometric (K, Th) pseudocolour signature that indicates low potassium and thorium when compared to the upper basalt succession (high K and Th) of the Kylena Formation. These signatures were first identified on Eastern Creek (Farrell, 2006) and later confirmed on Mount Edgar (Williams and Bagas, in prep.).

The lower basalt succession is overlain in the area 11 to 19 km southeast of Dingo Well by massive, porphyritic, and amygdaloidal andesite, basaltic andesite, and dacite interlayered with volcaniclastic conglomerate, sandstone, siltstone, shale, accretionary lapilli, and felsic tuffaceous beds (*AFOk-xfa-spv*). This latter succession also unconformably overlies granitic rocks of the Yilgalong Granitic Complex and directly underlies the Mopoke Member where present. The andesitic and dacitic flows and volcaniclastic rocks are commonly pale to dark grey and greenish-grey. Phenocrysts are commonly plagioclase, but some altered mafic phenocrysts, probably clinopyroxene or amphibole, are also locally present. Small elliptical amygdales contain quartz, carbonate, chlorite, and sulfides — generally pyrite, but also some sphalerite. The groundmass is commonly an altered assemblage of albite, K-feldspar, chlorite, sericite, leucoxene, carbonate, and quartz.

The volcaniclastic material includes mixtures of lithic clasts, mainly granitic material, quartz, and microcline, with reworked accretionary lapilli and glassy shards, now mainly chlorite. Some of the material may be phreatomagmatic in origin. Layered, finer grained tuffaceous siltstone and sandstone contain mixed assemblages of chlorite, clay, albite, leucoxene, and altered lithic and glassy fragments together with grains of quartz, plagioclase, and microcline.

Two samples were collected from the mixed mafic–felsic volcanic and volcaniclastic succession (*AFOk-xfa-spv*) for SHRIMP U–Pb zircon dating. A fine-grained, dark-grey dacite, collected from the northeastern side of a low rocky hill 17 km west of Carawine Pool was dated at 2749 ± 5 Ma (Nelson et al., 2006; GSWA 178086). Fine-grained, dark greenish-grey tuffaceous volcaniclastic sandstone, collected from the top of a rocky hill 12.6 km east-southeast of Dingo Well, yielded a date of 2735 ± 6 Ma. This is interpreted as the age of igneous crystallization of the tuffaceous component of the volcaniclstic sandstone (Bodorkos et al., 2006b; GSWA 178090). This sample also contained a high proportion of detrital zircons, incorporated into the volcaniclastic sandstone via sedimentary processes, which yielded dates ranging from c. 2781 to c. 3391 Ma. These dates agree with an 2741 ± 3 Ma age obtained from mafic tuffaceous material and collected from the near the base of the Kylena Formation on Nullagine (Blake et al., 2004).

Mopoke Member (AFOkm-kts)

The Mopoke Member (*AFOkm-kts*, Appendix 2) is a discontinuous, but distinctive, carbonate marker bed lying between two chemically distinguishable basaltic successions of the Kylena Formation. This chemical distinction, shown by the radiometric (K, Th) pseudocolour image, can be used to separate the lower basaltic succession with low K and Th from the upper succession with moderate to high K and Th when the Mopoke Member is absent (Williams and Bagas, in prep.).

Within the Kylena Formation the Mopoke Member is particularly useful in identifying the stratigraphic position of the component basaltic rocks where the formation is disrupted by later faults. The Mopoke Member unconformably overlies the Little River Trondhjemite 9.5 km southeast of Dingo Well (Fig. 5) and

IRW199 06.06.07

Figure 5. Mopoke Member (dark colour) nonconformably overlying the Little River Trondhjemite (light colour; MGA 269362E 7627124N)

the Midgengadgi Monzogranite of the Yilgalong Granitic Complex 17 km southeast of Dingo Well. In both areas the carbonate is underlain by thin beds of calcareous pebble conglomerate and calcareous feldspathic sandstone. The clasts in the conglomerate are quartz and locally derived granitic material.

The Mopoke Member consists of cliff-forming, silicified blue-grey carbonates, mostly limestone or dolomitic limestone, up to 5 m thick. The carbonates are interbedded and overlain by thin-bedded, grey to cream siltstone, shale, and fine-grained sandstone (*AFOkm-kts*). The siltstone and shale beds are sometimes calcareous and tuffaceous. Wave-based ripple marks of up to 1 cm amplitude are locally present. The carbonate is partly silicified, particularly where stromatolites and microbial laminations are present (Fig. 6). Stromatolites are more plentiful in the upper parts of the member and range from centimetre-scale flat-laminated, columnar and cumulate forms to large low-profile domes 1–2 m across in the thicker beds. Thin blue chert beds are locally present.

The Mopoke Member appears to be a lacustrine deposit similar, but on a smaller scale, to the overlying Meentheena Member of the Tumbiana Formation. Although not directly dated, the Mopoke Member is younger than the underlying mafic–felsic volcanic and volcaniclastic succession (*AFOk-xfa-spv*) dated around 2749–2735 Ma.

Succession above the Mopoke Member

The upper succession of the Kylena Formation makes up the bulk of the area occupied by the formation on YILGALONG, and is up to 1700 m thick in the Dingo Well area. Two small faulted inliers of the upper succession lie within the Maddina Formation 15 km east and 18 km east-southeast of Dingo Well. Field mapping indicates that the succession consists mainly of massive, amygdaloidal, and vesicular fine- to coarse-grained, grey and bluish-grey basalt and basaltic andesite (*AFOk-bng*). Radiometric data (GSWA, 2005b) show the succession to become increasingly potassic upwards, although a geochemical traverse immediately south of YILGALONG indicated that the most felsic rocks are andesites (Glikson et al., 1986). Individual flows are up to 15 m thick and commonly exhibit scoriaceous flow-tops. Columnar jointing is locally developed. Some rare large pillow structures 4 km northwest of Bookabunna Well in a road cutting on the Ripon Hills Road (MGA 247408E 7646985N) are associated with stacked subaerial flows 2 to 3 m thick, suggesting that the pillow lavas are local and limited to shallow-water conditions. Both flow forms carry amygdales and vesicles.

The basalts consist of partly altered plagioclase and clinopyroxene set in a mesostasis of chlorite, K-feldspar, opaque minerals, and accessory apatite. Alteration products include albite, sericite, chlorite, patchy quartz, carbonate, pumpellyite, and smectite. Amygdales can be ovoid or irregular in shape and filled with carbonate, chlorite, and quartz, including chalcedony.

On YILGALONG the upper basalt succession in the Kylena Formation is alkali enriched (Blake et al., 2004), as first described in the west Pilbara (Kojan and Hickman, 1998). This observation is supported by the ternary radiometric image for the NULLAGINE 1:250 000 sheet (GSWA, 2005b).

Tumbiana Formation (AFOti-bntt, AFOtm-kts, AFOt-bbg)

The Tumbiana Formation (Lipple, 1975; Thorne and Trendall, 2001) is continuously exposed over a distance of 46 km. The formation extends from the western margin, 9.5 km north of the Ripon Hills road, southeastwards to

IRW200 06.06.07

Figure 6. Silicified stromatolitic dolomite, Mopoke Member (MGA 246377E 7641976N)

where it is truncated by a regional strike-slip fault, 13.5 km east of Dingo Well. In addition, three small faulted inliers containing the Mingah Member lie between 6 and 8 km south-southeast of this easternmost outcrop. There are no further exposures on YILGALONG. The next outcrops are recorded 25 km to the south on EASTERN CREEK (Farrell, 2006). The formation ranges in thickness from 500 m in the northwest to about 300 m in the southeast exposures. On YILGALONG the Tumbiana Formation is composed of the lower Mingah Member (*AFOti-bntt*) and upper Meentheena Member (*AFOtm-kts*). South of the Ripon Hills road these two members are separated by a thick vesicular amygdaloidal and massive basaltic unit (*AFOt-bbg*). This unit consists of lenticular subaerial basaltic flows up to 250 m thick. Amygdales contain quartz, banded chalcedony (agate), and epidote. North of the Ripon Hills road the Tumbiana Formation is intruded by multiple dolerite sills and dykes (*AFO-od*). The Tumbiana Formation conformably or disconformably overlies the Kylena Formation.

Mingah Member (AFOti-bntt)

The Mingah Member (*AFOti-bntt*; Thorne and Trendall, 2001; cf. Mingah Tuff Member, Lipple, 1975) is the basal member of the Tumbiana Formation on YILGALONG. It is less prominent than on adjoining MOUNT EDGAR (Williams and Bagas, in prep.) and is between 350 m thick in the northwest to 190 m thick in the southeast. The Mingah Member is not well exposed and is characterized by low strike ridges of the more resistant coarser volcaniclastic and epiclastic beds.

The Mingah Member is composed of basaltic to andesitic volcaniclastic grey-green sandstone and siltstone, commonly interbedded with accretionary lapilli beds, local quartz sandstone, shale and thin lenticular stromatolitic carbonate units (*AFOti-bntt*). Accretionary lapilli beds are up to 1 m thick with individual lapilli ranging from 2 to 10 mm in size. Such beds are well exposed on the northern side of the Ripon Hills road 2.5 km northwest of Bookabunna Well. The closely packed accretionary lapilli beds show normal, reverse, and nongraded layers indicating primary pyroclastic fall deposits (Boulter, 1987; Thorne and Trendall, 2001). Such deposits may represent the products of phreatomagmatic eruptions (McPhie et al., 1993).

The Mingah Member has yielded SHRIMP U–Pb zircon dates ranging from 2727 ± 5 to 2721 ± 4 Ma from WARRIE (Blake et al., 2004).

Meentheena Member (AFOtm-kts)

The Meentheena Member (*AFOtm-kts*; Thorne and Trendall, 2001; cf. Meentheena Carbonate Member, Lipple, 1975) is a distinctive, commonly cliff-forming upper unit of the Tumbiana Formation. The member thins gradually from 250 m in the northwest to around 100 m in the southeast. The unit is absent from the faulted inliers farther south. The Meentheena Member appears to conformably overlie the tuffaceous Mingah Member north of the Ripon Hills road and the unnamed basalt unit (*AFOt-bbg*) south of the road.

The Meentheena Member is composed of lenticular units of stromatolitic, dark-grey siliceous limestone and dolomite within laterally variable sequences of volcaniclastic sandstone and siltstone, including accretionary lapilli beds, together with calcareous sandstone, carbonaceous shale, local quartz sandstone, and conglomerate (*AFOtm-kts*). The characteristic low cliff-lines in this member are exclusively carbonate, whereas the volcaniclastic and classic material underlie the scree slopes. The limestone and dolomite units are up to 15 m thick and the first thick carbonate unit (1–2 m) marks the base of the Meentheena Member.

The carbonate units locally carry abundant stromatolites with a broad range of morphological types. These include extensive tabular and domed biostromes, domed bioherms, and individual turbinate and bulbous columns and local oncolites. Good exposures of several stromatolitic forms are on the western end of a prominent hill 2 km east of Bookabunna Well on the northern side of the Ripon Hills road. Nonstromatolitic carbonate beds may be micritic, oolitic, laminated, and fenestrated.

A variety of sedimentary structures are found in the carbonates and interbedded volcaniclastic and epiclastic material. These include cross-bedding, wave and current ripple marks, including climbing ripple sets over stromatolitic bioherms, edgewise breccias, desiccation cracks, tepee structures, and pseudomorphs of evaporate minerals (Packer, 1990; Awramik and Buchheim, 1997, 2001; Thorne and Trendall, 2001). Although some workers favour sublittoral to supralittoral coastal conditions adjacent to shallow-marine shelf-facies deposits (Packer, 1990; Thorne and Trendall, 2001), other workers suggested that lacustrine deposition was more likely (Buick, 1992; Awramik and Buchheim, 1997, 2001).

Samples collected elsewhere from volcaniclastic rocks in the upper part of the Tumbiana Formation (Meentheena Member) have yielded dates between c. 2719 and 2715 Ma (Arndt et al., 1991; Nelson, 2001; GSWA 168935).

Maddina Formation (AFOm-bb, AFOmk-bntt)

The Maddina Formation (Kojan and Hickman, 1998; cf. Maddina Basalt, MacLeod and de la Hunty, 1966) is continuously exposed from near Boodalyerri Creek in the southeast corner diagonally across YILGALONG to the northwest corner where it occupies the core of the large Oakover Syncline (Fig. 3). From here it can be traced a further 13 km eastwards along the northern boundary of YILGALONG where the formation is exposed in the northern limb of the Oakover Syncline. The Maddina Formation is more than 1000 m thick where it is intersected by the Nullagine River. However, south of the Ripon Hills road it is difficult to estimate thicknesses due to extensive later faulting. The Maddina Formation conformably overlies the Tumbiana Formation in the western half of the sheet area, but east of Yilgalong Creek a large transpressional fault juxtaposes the Maddina Formation against the underlying Kylena Formation.

The Maddina Formation (*AFOm-bb*) is made up of stacked, massive, amygdaloidal, and vesicular, fine- to coarse-grained basalt flows. The thin to thick flows (2 to

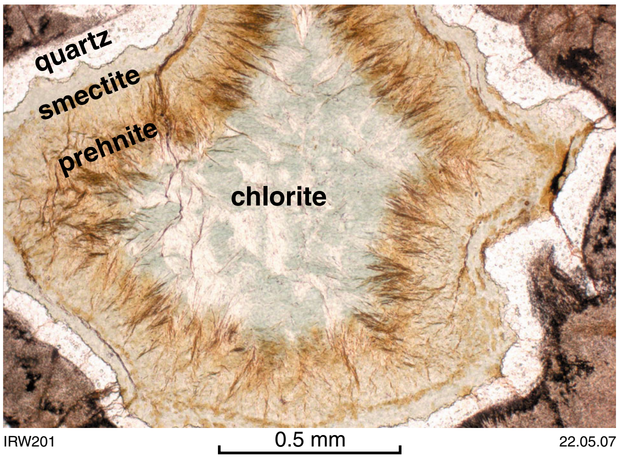


Figure 7. Thin section of zoned amygdale in the Maddina Formation (GSWA 169287; MGA 281671E 7623044N)

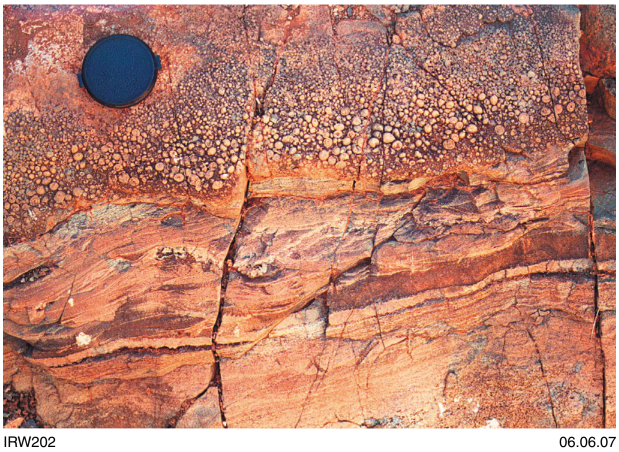


Figure 8. Interbedded siltstone and accretionary lapilli beds showing graded bedding, Kuruna Member (MGA 245467E 7664613N)

50 m thick) are intercalated with comagmatic, medium- to coarse-grained dolerite sills and local thin tuffaceous volcaniclastic horizons. Rough, silicified scoriaceous flow-tops, sometimes with quartz–epidote veining, mark the individual flows. Vesicles and amygdales generally congregate towards the top of the flows. Large irregular-shaped gas cavities up to 25 cm have been observed in some flow-tops. Amygdales are generally spherical or elliptical in shape and contain quartz, banded chalcedony (agate including pink carnelian), carbonate, chlorite, prehnite, opaque minerals, and leucoxene (Fig. 7). Locally, pipe amygdales are found towards the base of some flows. Thick basalt flows towards the top of the formation are locally columnar jointed.

The primary mineralogy of calcic plagioclase and clinopyroxene (pigeonite and augite) is variably altered to albite–chlorite–epidote–prehnite–pumpellyite–carbonate–sericite–quartz–leucoxene assemblages (Thorne and Trendall, 2001; Purvis, 2003a).

The Maddina Formation has yielded dates elsewhere ranging from 2718 to 2713 Ma (Nelson, 1998; GSWA 144993; Blake et al., 2004).

Kuruna Member (AFOmk-bntt)

The Kuruna Member (Thorne and Trendall, 2001; cf. Kuruna Siltstone, MacLeod and de la Hunty, 1966) forms a prominent marker horizon in the upper part of the Maddina Formation throughout most of its distribution on Yilgalong, apart from in the southeastern corner. The last significant exposure of the Kuruna Formation lies 10.5 km southwest of Pulgorah Cone. Possible scattered remnants of the Kuruna Member are within and overlying (as small mesa-like hills) faulted blocks of the Maddina Formation around 18 km southwest of Pulgorah Cone. The Kuruna Member is up to 150 m thick 6.5 km north of Mount Ian Well in the central parts of Yilgalong. From here the member thins to the southeast to less than 100 m and to the northwest to less than 60 m. Thick, lenticular, coarse-grained dolerite sills (*AFO-od*) locally intrude the Kuruna Member, particularly northwest of the Nullagine River.

The Kuruna Member (*AFOmk-bntt*) consists of fine- to medium-grained volcaniclastic rocks of basaltic and andesitic parentage, commonly including accretionary lapilli, khaki-brown- to olive-brown-weathering siltstone, shale, and fine-grained sandstone, with local stomatolitic carbonate. The stromatolitic carbonate tends to lie towards the top of the member and resembles the dolomite and limestone in the underlying Tumbiana Formation. Good exposures lie 6.7 km south of Walgunya Well on the western side of the Nullagine River where three carbonate horizons are separated by volcaniclastic siltstone, accretionary lapilli beds, fine-grained sandstone, and shale. The carbonates are partly silicified, particularly the stromatolitic horizons that include flat domal bioherms up to 2 m. The interbedded accretionary lapilli horizons are normally graded and the fine-grained sandstone is ripple marked (Fig. 8).

Jeerinah Formation (AFOj-xcl-kd, AFOjb-bnth)

Shale, chert, and dolomite (*AFOj-xcl-kd*) of the Jeerinah Formation (MacLeod et al., 1963) was previously mapped as Lewin Shale in this area (Hickman, 1978) and later assigned to the Jeerinah Formation (Hickman, 1983). This subunit of the Jeerinah Formation is exposed in the central and northwestern parts of Yilgalong along the southern and western margins of the Ripon Hills. Further exposures are in the far northeast corner east of the Oakover River valley in the Gregory Range Inlier (Williams and Trendall, 1998a). The exposures rimming the Ripon Hills area are strongly disrupted by complex faulting and folding. Farther north along the Nullagine River valley the formation is intruded by thick, coarse-grained dolerite sills (*AFO-od*). A similar situation exists in the Gregory Range Inlier where the Jeerinah Formation is intruded by thick dolerite sills and intersected by several steep reverse faults. In addition, thick lenticular bodies of the mafic volcanic Baramine Member (*AFOjb-bnth*) are found in both areas. The complex faulting and later mafic intrusions make it difficult to calculate the thickness of the formation. East of Yilgalong Creek and around 17 km west-southwest of Pulgorah Cone, a north-dipping succession of the Jeerinah

Formation is at least 500 m thick. About 5 km farther north of this locality and on the west bank of Yilgalong Creek an exploratory diamond drillhole (RHDH2A; MGA 274508E 7644780N) in Carawine Dolomite terminated in Jeerinah Formation after intersecting 246 m of the unit (Richards, 1985). The Jeerinah Formation disconformably overlies, or is faulted against, the underlying Maddina Basalt.

Shale, chert, and dolomite of the Jeerinah Formation (*AFOj-xcl-kd)* includes shale, siltstone, fine- to medium-grained sandstone, coloured and banded cherts, dolomite, and local stromatolitic limestone. The basal disconformity with the underlying Maddina Formation is well exposed to the south and west of the Ripon Hills. Some exposures of the uppermost Maddina Formation are ferruginized, suggesting possible weathering prior to deposition of the Jeerinah Formation.

North of the Nullagine River the basal unit is red-brown-weathering, grey to grey-blue, blocky, fine-grained quartz sandstone. This sandstone is commonly ripple marked with both current and wave-based ripples. Progressing to the southeast the basal sandstone unit changes to silicified dark-grey siltstone and shale. South of the Ripon Hills the basal sandstone is overlapped by blue-grey limestone. This latter unit, which includes brown, orange, and grey dolomite elsewhere, consistently overlies the basal sandstone and siltstone when these lithologies are present, particularly in the northwest. The carbonates, both limestone and dolomite, locally carry microbial laminations and stromatolites that exhibit small columnar and low domal forms. The carbonates are thin to medium bedded and commonly overlain by ripple-marked fine-grained sandstone. This sandstone is overlain by interbedded multicoloured chert, banded black, blue, and white chert, siltstone, thin-bedded carbonate, and shale. Scattered framboidal pyrite (marcasite) balls (now goethite) weather from the shale and chert units. The upper sections of the Jeerinah Formation consist mostly of white-weathering, black and grey carbonaceous and pyritiferous shale with thin interbeds of siltstone and coloured and banded chert beds. More than 20 m of carbonaceous shale are exposed in Parsons Creek 6 km east of Little River Well in the Gregory Range Inlier.

Geochronological samples were not collected from the Jeerinah Formation during the present survey. Samples collected from a tuffaceous band close to the top of the Jeerinah Formation (from the Roy Hill Shale Member, just beneath the Marra Mamba Formation on the NEWMAN 1:250 000 sheet) yielded a SHRIMP U–Pb date of 2629 ± 5 Ma (Trendall et al., 2004).

Baramine Member (*AFOjb-bnth*)

The Baramine Member (*AFOjb-bnth*; previously defined as the Baramine Volcanic Member, Hickman, 1983; redefined in Williams and Trendall, 1998c) is exposed in a number of localities. It is unclear whether this distribution is a structural artifice or reflects a primary lenticular distribution within the Jeerinah Formation. A continuous outcrop over 12.5 km lies along the southern margin of the Ripon Hills where it occupies the central part of the Jeerinah Formation. The thickness varies between 100 and 250 m in this area. Smaller faulted areas lie 9 km north-northeast of Bookabunna Well, 9 km east-southeast of Walgunya Well, and in the northeast corner in the Gregory Range Inlier.

The Baramine Member consists of massive, amygdaloidal, and vesicular dark-grey to grey-green basalt and basaltic andesite, interlayered with basaltic volcanic sandstone and siltstone, and local accretionary lapilli beds (*AFOjb-bnth*). Pillowed basalts are locally developed in Coonanbunna Creek 7.5 km northwest of Nullagine 1 Trig Point. Thin-bedded, grey-blue silicified mudstone is also locally interbedded with the basalts. The basaltic rocks are composed of plagioclase, clinopyroxene, and opaque minerals, including titanomagnetite and ilmenite. Feathery quenched textures are sometimes preserved in carbonate-altered mesostasis. Thin carbonate veins are locally common. Altered olivine has also been recorded. Vesicles contain carbonate, quartz, and local sulfide. Albite–sericite–carbonate–leucoxene–clay alteration is present throughout the succession.

The volcaniclastic component of the Baramine Member appears to be a mixture of resedimented syneruptive volcaniclastic deposits and volcanogenic sedimentary deposits (McPhie et al., 1993). Very fine to coarse-grained banded dark-grey and speckled white, volcanic labile sandstones are grain supported. These are dominated by basalt clasts altered to albite, chlorite, clay, leucoxene, and local carbonate. Minor quartz grains are also present. Most bedding is planar, but some grading and cross-bedding have been noted (Purvis, 2003a; GSWA 169227). Other volcaniclastic rocks have a large component of reworked pyroclastic material, including accretionary lapilli, shards, and tuffaceous vitric, lithic, and crystal grains.

The components of the Baramine Member on YILGALONG appear to be more distal from volcanic centres than those described on adjacent WARRAWAGINE, BRAESIDE, and ISABELLA (Williams, 2001; Williams and Trendall, 1998a, 1998c). In these areas many of the bedforms resemble pyroclastic surge deposits associated with phreatomagmatic eruptions, and debris-flow deposits generated from the collapse of volcanic edifices (McPhie et al., 1993).

Mafic intrusive rocks in the Fortescue Group (*AFO-od*)

Thick dolerite sills and associated dykes (*AFO-od)* preferentially intrude the Mopoke, Mingah, Meentheena, and Kuruna Members, which are volcaniclastic and carbonate members intercalated within the largely basaltic pile, and the uppermost sedimentary–volcanic Jeerinah Formation of the Fortescue Group on YILGALONG. Such sills are most numerous in the Jeerinah Formation around the core of the Oakover Syncline in the Nullagine River valley area, and in the extreme northeast corner. In the lower members of the Fortescue Group such sills are up to 150 m thick, whereas in the Jeerinah Formation they may exceed 300 m in thickness, although such estimates are made difficult by the poor outcrop.

The dolerite sills are dark-green to grey-green, fine- to coarse-grained, altered granular to ophitic rocks. Rare patches of granophyric texture have been noted in thicker dolerite sills intruded into the Jeerinah Formation. The primary assemblage includes plagioclase, clinopyroxene, and accessory skeletal titanomagnetite, titanite, and apatite. All dolerite sills exhibit varying degrees of alteration similar to the Fortescue Group basaltic rocks. Such alteration takes the form of clay-altered and prehnite-altered interstitial material and albite–prehnite–pumpellyite–chlorite–clay–carbonate–epidote–leucoxene assemblages partly replacing the primary mineralogy.

These thick dolerite sills are probably subvolcanic intrusions consanguineous with the Fortescue Group basalts.

Hamersley Group

Exposed Hamersley Group rocks account for only 10% of the area occupied by the Hamersley Basin on YILGALONG and this succession is represented solely by the Carawine Dolomite.

Carawine Dolomite (AHAc-kds, AHAc-kdx)

The Carawine Dolomite (*AHAc-kds*; Noldart and Wyatt, 1962; Hickman, 1983) is almost continuously exposed along the southern and western margins of the high dissected plateau of the Ripon Hills in the central-north of YILGALONG. The formation is also widely exposed in scattered outcrops along gorges in the northeastern half of the Ripon Hills, and also along the western side of the Gregory Range Inlier to the east of the Oakover River valley in the northeast corner of YILGALONG. Two other very small outcrops are found at Cave Bore and 17 km south-southwest of Pulgorah Cone. The restricted exposure of the formation in most areas is due to the overlying erosion-resistant and spatially related Pinjian Chert Breccia.

The thickness of the Carawine Dolomite is difficult to estimate due to the irregular contact with the overlying Pinjian Chert Breccia that unconformably overlies and infills a pre-existing karst topography dissolved and eroded within the dolomite (Fig. 9). An exploratory diamond drillhole RHDH2A on the west bank of Yilgalong Creek, 17.5 km west of Pulgorah Cone, intersected about 185 m of Carawine Dolomite before entering the underlying Jeerinah Formation (Richards, 1985). A second hole, RHDH1, 11.5 km west of Pulgorah Cone, spudded in Permian Paterson Formation 1 km northeast of exposed Carawine Dolomite failed to intersect the Carawine Dolomite. This hole intersected 158 m of Permian Paterson Formation, 85 m of dolerite (probably a sill), and 134 m of the Jeerinah Formation (Richards, 1985). On nearby PEARANA to the southeast an exploratory drillhole intersected 500 m of Carawine Dolomite (Williams and Trendall, 1998b).

IRW203 06.06.07

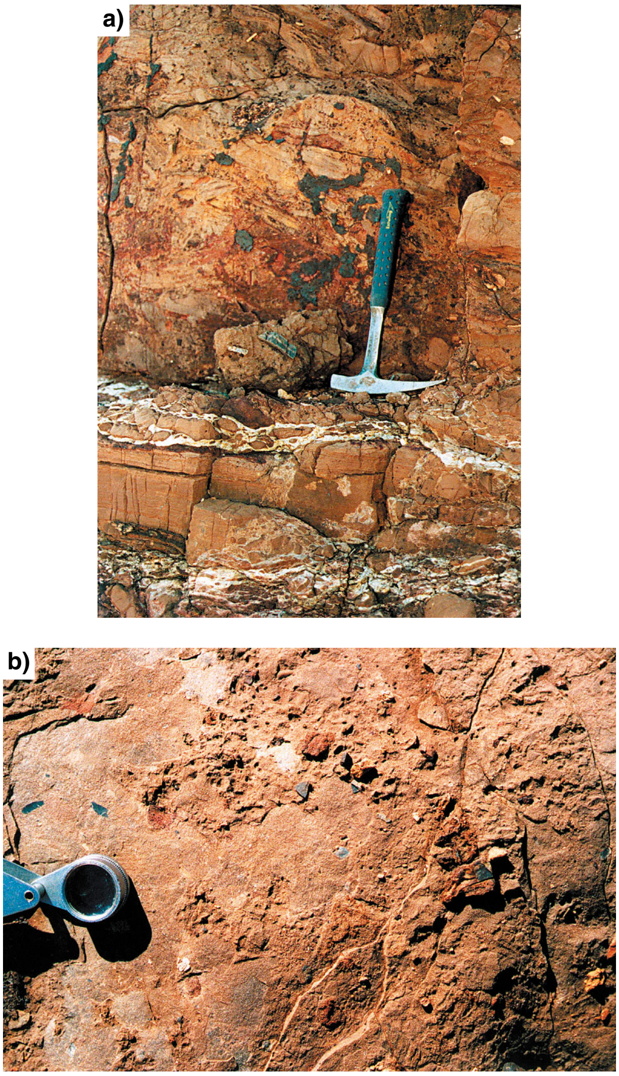
Figure 9. Remnant of the Carawine Dolomite enclosed within the Pinjian Chert Breccia, western side of the Ripon Hills (MGA 261142E 7645673N)

The contact between the Carawine Dolomite and underlying Jeerinah Formation is either disconformable or faulted. The disconformity is positioned by the first appearance of dolomite above a thick succession of shale, most of which is carbonaceous and tuffaceous. The Marra Mamba Iron Formation that separates the Carawine Dolomite from the underlying Jeerinah Formation on BALFOUR DOWNS more than 100 km to the south is absent on YILGALONG (cf. Williams and Trendall, 1998b).

The Carawine Dolomite on YILGALONG can be divided into two facies: a lower deep-water basinal deposit and an upper, evaporite- and stromatolite-bearing shallow-water platform deposit (cf. Simonson and Hassler, 1997). In the Ripon Hills region a distinctive marker horizon composed of a chaotic spherule-bearing megabreccia (*AHAc-kdx*) lies within the lower basinal facies. The western and southern margins of the Ripon Hills are dominated by the cliff-forming basinal facies of the Carawine Dolomite. This is mostly brown-weathering, grey to blue, recrystallized massive and laminated dolomite, intercalated with thin-bedded blue chert and minor shale and siltstone. The dolomite averages about 20% MgO and is commonly low in silica (Jahn and Simonson, 1995).

The scattered exposures of the Carawine Dolomite in the central, eastern, and northeastern parts of the Ripon Hills, and particularly in the Gregory Range Inlier, mostly belong to the upper shallow-water platformal facies of the Carawine Dolomite. The dolomite in the upper facies is a brown-weathering, grey recrystallized dolomite with greater variations in bedding thickness. Thin blue chert, shale, and siltstone interbeds are locally present. The dolomite in the upper facies is characterized by a wide range of sedimentary features indicative of shallow-water deposition. These include oolites, wave ripples, reverse-graded pisolites, oncolitic flat-pebble conglomerate, dololaminites, stromatolites, oncolites, and evaporitic crystal pseudomorphs after aragonite, gypsum, and halite (Simonson et al., 1993b; Simonson and Jarvis, 1993).

Stromatolite horizons are commonly silicified. Small columnar forms, larger discrete hemispherical forms up to a metre in size, and laterally linked hemispherical stromatolites have been recorded. Well-exposed stromatolitic dolomite lies along the north bank of Parsons Creek, 6 km east of Little River Well in the Gregory Range Inlier. Stromatolitic dolomite is also common in outcrops along the margins of a narrow, north-trending



IRW204 22.05.07

Figure 10. Carawine Dolomite: a) contact between the base of the chaotic spherule-bearing megabreccia and the lower basinal facies of the Carawine Dolomite (hammer head resting on contact), southwest side of the Ripon Hills (MGA 261330E 7643717N); b) close-up of the upper part of the chaotic spherule-bearing megabreccia showing scattered spherules, some spherules circled in red

Permian glacial valley 5.5 km southwest of Bunmardie Well on the eastern side of the Ripon Hills. On the western margin of the Ripon Hills stromatolitic dolomite is 3.7 km southwest of Nullagine 1 Trig Point about 100 m above the megabreccia marker horizon.

A chaotic spherule-bearing megabreccia containing angular, coarse- to fine-grained dolomite and chert clasts with a microkrystite- and microtectite-rich matrix (*AHAc-kdx*; Simonson 1992; Glikson and Vickers, in prep.; also referred to as the Spherule-bearing Tsunami Marker, SBM; Fig. 10a,b) can be traced almost continuously for more than 38 km along the southern and western margins of the Ripon Hills. The SMB extends from a point 13.2 km west-southwest of Pulgorah Cone northwest to a point 12.5 km southeast of Walgunya Well where it is truncated by faulting (Glikson and Hickman, 2005). The SBM can be cliff-forming or occupy recessive scree slopes between cliffs of bedded dolomite. This distinctive marker horizon is in the lower basinal facies of the Carawine Dolomite. It is positioned from about 30 m above the base of the Carawine Dolomite along the southern margin to about 150 m above the base along Coonanbunna Creek on the western margin of the Ripon Hills. The SBM was not found in the Gregory Range Inlier succession even though dolomites corresponding to basinal facies are present beneath stromatolitic dolomite in Parsons Creek. This supports observations recorded in Glikson and Vickers (in prep.) that the SMB has not yet been identified north of Mount Sydney in the Gregory Range Inlier.

The chert and dolomite clasts and megaclasts are mostly autochthonous, although some banded chert clasts resemble lithologies in the underlying Jeerinah Formation. The megabreccia unit varies between 10 and 30 m in thickness. The base of the SBM is generally eroded into the underlying dolomitic strata. This is shown by local dislodgement of metre-scale blocks of dolomite and chert. The fractures between the blocks are, in turn, injected by fine- to medium-grained breccia, which is also found as sheets, veins, tongues, and wedges below the base of the main SBM unit (Glikson and Vickers, in prep.).

The association of sand-sized spherules of K-feldspar within the distinctive megabreccia unit (SBM) in the Ripon Hills was first identified by Simonson (1992) who also recognized their connection to silicate melt generated by a bolide impact. These melt droplets, later referred to as microkrystites (Glass and Burns, 1988), and associated microtectites (Simonson and Glass, 2004), are common in the fine-grained to microbreccia components of the SBM, particularly in the uppermost parts of the megabreccia pile. They are also sparsely scattered in deeper levels of the megabreccia pile, mainly in breccia veins injected into fractures between dolomite and chert blocks (Glikson and Vickers, in prep.). Thin-bedded layered carbonates conformably overlie the megabreccia. Detailed petrographic descriptions and geochemical studies of the microkrystites and microtectites are given in Simonson and Glass (2004) and Glikson and Vickers (in prep.).

There has been the gradual recognition that the microkrystite- and microtectite-bearing megabreccia is the product of an asteroid impact in an oceanic environment. The resultant tsunami-wave effect produced erosion and resedimentation of the deep-water Carawine Dolomite. In addition the fallout of ejecta material (silicate spherules) from the asteroid impact cloud became incorporated in the disrupted Carawine Dolomite (Hassler and Simonson, 2001; Hassler et al., 2000; Glikson and Vickers, in prep.).

Detailed descriptions of the SMB, the nature and origin of the microkrystites and microtectites, and the possible correlation with similar horizons in the Wittenoom Dolomite and Jeerinah Formation elsewhere can be found in numerous publications over the last 14 years (Simonson, 1992, 2003; Simonson and Harnik, 2000; Simonson and Hassler, 1997; Simonson and Glass, 2004; Simonson and Jarvis, 1993; Simonson et al., 1998, 2000, 2004; Glikson, 2002, 2004; Glikson and Vickers, in prep.; Rasmussen et al., 2005).

There has been considerable discussion as to the age of the Carawine Dolomite and its stratigraphic relationship to the Wittenoom Formation in the Hamersley Ranges (Simonson et al., 1993a). Jahn and Simonson (1995) obtained a Pb–Pb isochron age of 2541 ± 32 Ma. Somewhat later a carbonate Pb–Pb date of 2548 +26/–29 Ma was obtained for the Carawine Dolomite and a 2541 +18/–15 Ma date for the SBM unit (Woodhead et al., 1998). The Bee Gorge Member of the Wittenoom Formation has yielded SHRIMP U–Pb zircon dates of 2561 ± 8 Ma for a crystal-rich tuffaceous shale (Trendall et al., 1998) and 256olomite there has to be some doubt as to whether the dated tuffaceous dolomite came from the Carawine Dolomite, as claimed (Rasmussen et al., 2005), or from dolomitic beds in the underlying Jeerinah Formation, which would agree with the isotopic date. In this area the Jeerinah Formation consists of interbedded tuffaceous and calcareous shale, siltstone, and dolomite.

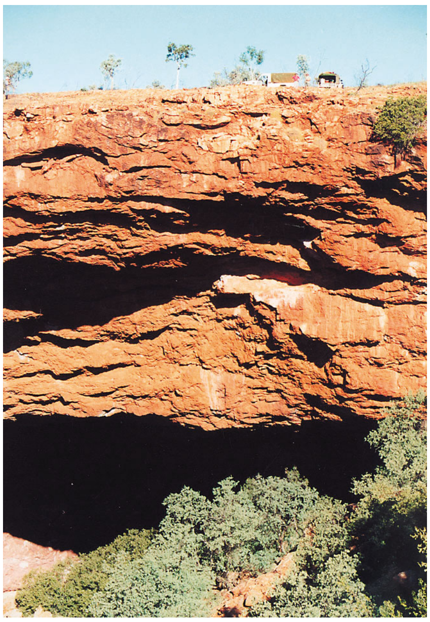
Pinjian Chert Breccia *(Æpj-ccx)*

The Pinjian Chert Breccia (*Æpj-ccx*; Noldart and Wyatt, 1962) is widely distributed throughout the Ripon Hills and northward to the east bank of the Nullagine River, 7 km west of Outcamp Bore. Further outcrops lie east of the Oakover River in the Gregory Range Inlier and along a high ridge 16.5 km south-southwest of Pulgorah Cone on the western margin of the Oakover River valley. In all localities the Pinjian Chert Breccia is closely associated with Neoarchean Carawine Dolomite. It is a strongly outcropping unit characterized by spinifex-covered high rounded hills. The breccia has a highly irregular unconformable contact with the underlying Carawine Dolomite. This contact surface is postulated to be a paleokarst topography (Hickman, 1978; Williams, 1989; Williams and Trendall, 1998b). The paleokarst surface can be observed at the contact with the dolomite where the breccia can be seen to fill fissures, caves, and dolines. The karst development appears to be ongoing or episodic throughout the Proterozoic and Phanerozoic. This is supported by the apparent underlying control in the sediment distribution shown by overlying Proterozoic and sometimes Permian sedimentary rocks in blind valleys (poljes) and the development of recent caves, collapsed dolines, and sinkholes, both in the Carawine Dolomite and Pinjian Chert Breccia.

The Pinjian Chert Breccia consists of randomly mixed angular fragments of chert and banded chert that are chaotically or crudely bedded. The initial deposition occurred in the early Paleoproterozoic soon after the deposition of the Carawine Dolomite and consisted of bedded, coloured, and banded cherts. An example of this chert bedding is preserved in a cliff-line 4 km southeast of the Nullagine 1 Trig Point. On commencement of the karstification processes in the underlying Carawine Dolomite, the overlying Pinjian Chert began to collapse into the growing voids within the dolomite. In addition, thin chert beds and silicified dolomite components were released during dissolution of the dolomite and contributed further chert fragments to the growing breccia piles infilling the cavities. The chert breccia was later resilicified during Cenozoic times. Further weathering during this time saw the development of secondary breccias and karstification. This process has continued up to the present time where the remaining Carawine Dolomite is continuing to dissolve, creating further collapse of the Pinjian Chert Breccia into the new cavities. Locally, the breccia is enriched in iron and manganese oxides, derived from the dissolution of the Carawine Dolomite.

The Pinjian Chert Breccia in the Ripon Hills is host to deep sinkholes and collapsed dolines, four of which are recorded on YILGALONG (Williams, 2005). The largest, known locally as 'The Crater' (MGA 260695E 7651365N) lies on the western edge of the plateau, 2.8 km west of the Nullagine 1 Trig Point. This is a collapsed, oval-shaped doline 132 m (north–south axis) by 100 m (east–west axis) and is 55 m deep to a sandy floor in the middle of the doline (Fig. 11). A cave beneath the overhanging western side of the doline slopes steeply down to 70 m below the surface (Webb, 1994).

The doline and caves at this locality are developed entirely within the Pinjian Chert Breccia. It would appear that a large cave in the Carawine Dolomite beneath the doline had collapsed and subsequently stoped its way through the overlying Pinjian Chert Breccia to the present-day surface. The doline post-dates a pre-existing incised valley in the Pinjian Chert Breccia thus emphasizing that the doline is not a sinkhole. The cave entrance lies about 380 m AMSL and 140 m above the large Coonanbunna Creek, 3.4 km to the west. A second deep sinkhole (MGA 262107E 7656582N), 5.4 km north-northeast of 'The Crater', is developed at the contact between the Carawine Dolomite and Pinjian Chert Breccia.



IRW205 06.06.07

Figure 11. Eastern rim of 'The Crater' doline, Ripon Hills (MGA 260695E 7651365N)

Structure of the Fortescue and Hamersley Groups

Fortescue and Hamersley Group rocks on YILGALONG lie on the eastern side of the Northeast Pilbara Sub-basin of the Hamersley Basin and along the western edge of the Gregory Range Inlier (Thorne and Trendall, 2001). The current distribution of these rocks in both areas is controlled by the large Oakover Syncline (Hickman, 1978). Numerous northwest- to north-trending faults transect YILGALONG, and include normal, steep reverse, and transpressional faults.

D_6 deformation (2775–2750 Ma)

Unlike the Mount Edgar Granitic Complex to the northwest there are no exposed ring faults (Hickman, 1984; Collins 1989; Van Kranendonk et al., 2004a) or evidence for reactivation of such faults intersecting Fortescue Group rocks on YILGALONG (cf. Williams and Bagas, in prep.). However it is evident from the distribution of the Mount Roe Basalt, Hardey Formation, and the overlying Kylena Formation that the Yilgalong Granitic Complex was a basement high during their deposition. All Fortescue Group rocks dip away from the Yilgalong Granitic Complex to the west and north. The bedding is generally steeper in the Mount Roe Basalt than in the younger Kylena Formation.

Although there is no direct evidence on YILGALONG for folding and faulting (D_6) of the basal Mount Roe Basalt prior to the deposition of the Hardey Formation, the high percentage of locally derived basalt clasts in the overlying basal Hardey Formation points to uplift and erosion of the Mount Roe Basalt. This activity has been attributed to syndepositional growth faults on MARBLE BAR (Van Kranendonk, 2003) and MOUNT EDGAR (Blake, 1993; Williams and Bagas, in prep.).

D_7 deformation (<2500 Ma, ?Opthalmian Orogeny)

The regional configuration of the Fortescue and Hamersley Group rocks on YILGALONG is dominated by the large Oakover Syncline, the southeast-plunging axis of which extends from MOUNT EDGAR in the northwest corner of the sheet area east-southeasterly to the Oakover River valley (Fig. 3). This axis is postulated to curve south-southeastwards down the Oakover River valley between the Ripon Hills and Gregory Ranges (Gregory Range Inlier) beneath Permian Paterson Formation cover (Hickman, 1983). However, it is also possible that the synclinal axis postulated to occupy the Oakover River valley may instead extend north-northwest onto WARRAWAGINE. If this were the case the north-northwest synclinal axis underlying the Oakover River valley (Northern Oakover Syncline, Fig. 3) may either truncate the east-southeasterly plunging axis previously mentioned, which would make the Oakover River valley axis younger or, more likely, the Oakover River valley axis may bifurcate into a west-northwesterly and north-northwesterly trending axes. In this situation it would indicate coeval development. The west-northwest–east-southeast Oakover Synclinal axis that passes through the northwest corner of the sheet area was previously called the Northwest Oakover Syncline (Blake, 1993).

The southeast margin of the Meentheena Centrocline (Blake, 1993) unconformably abuts the Mount Elsie greenstone belt in the southwest corner of YILGALONG. The Miningarra Anticline (Williams and Bagas, in prep.) that separates the Oakover Syncline from the Meentheena Centrocline is truncated by a north-trending fault (east-side down), 4 km northwest of Mopoke Well. Small synclines and anticlines in the Mount Roe Basalt and Hardey Formation parallel the Miningarra Anticline in the area around the Meentheena copper prospect, 4.5 km west of Mopoke Well.

As recorded elsewhere (Williams and Bagas, in prep.), the Fortescue and Hamersley succession regionally dips away from the pre-existing granitic domes. This also applies to the Yilgalong Granitic Complex where the Kylena Formation offlaps the granitic complex with low to moderate dips to the north and east. Gravity and TMI data (Blewett et al., 2000; Wellman, 2000) show that synclines containing the Fortescue and Hamersley Group successions preferentially overlie Paleoarchean to Mesoarchean synformal greenstone belts.

This common coincidence of Paleoarchean, Mesoarchean, and Neoarchean to Paleoproterozoic synclines was first pointed out by Kriewaldt (1964), and suggests that D_7 folding in the northeast Hamersley Basin included reactivation of underlying older structures (Hickman, 1983; Van Kranendonk et al., 2004a).

Unassigned quartz veins (*Æzq*) and dolerite or gabbro dykes (*Æo*)

Prominent quartz veins (*Æzq*) are scattered throughout the Yilgalong Granitic Complex, particularly towards the sheared western margin. These range from short (<1 km) to long (~8 km) strike ridges up to 20 m high and 50 m wide. Many short veins trend between 290° and 310°, whereas larger veins trend between 030° and 350°.

The larger veins link to large faults that cut the Neoarchean Fortescue Group, which may indicate reactivated basement faulting during the Proterozoic. Such faults within the Fortescue Group are also marked by single or en echelon quartz ridges up to 5 km long.

Most quartz veins are massive to faintly banded, cryptocrystalline white quartz with local brecciation and later siliceous annealing.

The Yilgalong Granitic Complex is intruded by a number of fine- to coarse-grained, massive, homogeneous dolerite and gabbro dykes (*Æo*). Such dykes are short, being less than 3 km long and trend between 040° and 310°, roughly parallel to nearby quartz veins. The dolerite and gabbro dykes are generally weathered and outcrops are low and rubbly.

Collier Basin

The Mesoproterozoic Collier Basin (Martin and Thorne, 2001; Martin et al., 2005) is the younger of two basins replacing the extensive Bangemall Basin (Muhling and Brakel, 1985). Small areas of unmetamorphosed sedimentary rocks in the Ripon Hills and the Gregory Range Inlier on YILGALONG are postulated to be possible correlates of the Manganese Group.

Manganese Group

The Mesoproterozoic Manganese Group occupies a northeasterly trending sub-basin of the older-than-1070 Ma Collier Basin (Tyler and Hocking, 2002). The Manganese Group unconformably borders the southeastern part of the Pilbara Craton and the Northeast Pilbara Sub-basin of the Hamersley Basin. Units of the Manganese Group (Muhling and Brakel, 1985; Williams, 1989) can be traced to within 4 km south of the Pearana Rockhole on PEARANA (Williams and Trendall, 1998b). This siliciclastic and carbonate succession of the Manganese Group, part of the Woblegun Formation (Williams, 1989), lies about 95 km southeast of the Ripon Hills.

Unassigned sedimentary rocks (ᵽMN-ss, ᵽMN-sh, ᵽMN-sgp, ᵽMN-sl, ᵽMN-st)

Scattered paleo-interior valleys or poljes in the central parts of the Ripon Hills surrounding the Nullagine 1 Trig Point contain mixed siliciclastic sedimentary successions very similar to those described from the Mesoproterozoic Manganese Group on PEARANA to the southeast (Williams and Trendall, 1998b). Similar small outcrops of mixed siliciclastic sedimentary material are also found between 4 and 6 km north of Gingarrigan Well in the Gregory Ranges east of the Oakover River. The base of the interior valleys in the Ripon Hills can be more than 140 m below the surrounding hilltops of Pinjian Chert Breccia.

The sedimentary successions all dip moderately off the Pinjian Chert Breccia and towards the centre of the depositional basins, that is, the interior valleys. Modern-day drainage has subsequently broached the interior valleys. Intact remnants of the sedimentary succession suggest that it was more than 200 m thick. In all areas the sedimentary succession unconformably overlies eroded and previously weathered Paleoproterozoic Pinjian Chert Breccia.

Previous work assigned these sedimentary rocks to the Waltha Woora Formation, which was at that time part of the Bangemall Group (Hickman, 1978). Subsequent remapping of PEARANA and BRAESIDE showed that the Waltha Woora Formation was a westward extension of the younger Tarcunyah Group (Williams and Trendall, 1998a). Nevertheless, the current study tentatively supports correlation of the sedimentary succession in the Ripon Hills with the Woblegun Formation (Williams, 1989), which was originally part of the superseded Bangemall Group and now part of the Collier Group.

The basal units of the sedimentary succession are variable. Successions include interbedded fine- to coarse-grained red and brown sandstone, red, brown, and grey siltstone, and local micaceous siltstone (*ᵽMN-ss*); purple-, red-, grey- to white-weathering shale, including ferruginous and manganiferous shale, and local, thinly interbedded, brown to grey siltstone and sandstone (*ᵽMN-sh*); and interbedded poorly sorted, granule and pebble polymictic conglomerate, with coarse- to medium-grained, grey-white to brown lithic and quartz sandstone (*ᵽMN-sgp*). The last described conglomerate and sandstone succession is the most widespread basal unit. It is found in many of the smaller, more peripheral outcrops in the Ripon Hills and in the Gregory Ranges north of Gingarrigan Well. The conglomerates are matrix supported and contain poorly sorted, subangular clasts of coloured and banded chert, jasper, and vein quartz. The sandstone and conglomerate are locally ferruginous. Cross-bedding and ripple marks are present in some sandstone units. The basal assemblages appear to be fluvial deposits.

The basal units in the largest exposure, 4 km south-southeast of the Nullagine 1 Trig Point, are overlain and overlapped in places by green to grey-green mudstone and siltstone, both locally micaceous (*ᵽMN-sl*). The green mudstone is massive, with a conchoidal fracture. The rock is largely composed of clay, quartz, minor detrital muscovite, and rare brown and green biotite. Patchy carbonate cement is also present and a single patch of barite was observed in thin section (Purvis, 2003a; GSWA 169228).

In the same area the green mudstone and siltstone unit (*ᵽMN-sl*) is overlain by fine- to coarse-grained, red-brown-weathering, blue-grey lithic and quartz sandstone (*ᵽMN-st*). The mixed sandstones form low rubbly cliffs. Medium- to coarse-grained sandstones locally carry abundant greenish clay pellets, probably smectite, that are similar to glauconite pellets found in greensands. It is postulated that the pellets are possibly derived from the alteration of glauconite. Shale intraclasts are also common within the sandstone succession.

Glauconite is recorded from a number of localities on BALFOUR DOWNS (Williams, 1989) to the south. Both the basal Coondoon and Woblegun Formations of the Manganese Group that onlaps the Pinjian Chert Breccia in this area contain glauconitic sandstone. In both cases the glauconitic sandstone lies towards the top of the exposed succession. The glauconitic sandstone and associated siltstone and shale were interpreted to indicate shallow-marine conditions (Williams, 1989). The glauconite-bearing succession in the Ripon Hills is down-faulted on the eastern side against the Pinjian Chert Breccia, which may help to explain its preservation in this area.

These observations indicate that the Mesoproterozoic Collier Basin was much more extensive than previously interpreted. The disappearance of the thick succession that appears to have blanketed the eastern Pilbara may be due to later Permian glaciation, evidence for which is still preserved on the surface of the Pinjian Chert Breccia.

Unassigned Proterozoic dolerite intrusions

The contact between the Jeerinah Formation and the Carawine Dolomite is intruded by a fresh, fine-grained dolerite (*Ꝑod*) along the eastern side of Coonanbunna Creek and west of Ripon Hills. The mineralogy consists of plagioclase, clinopyroxene, altered olivine, and orthopyroxene with very minor quartz and carbonate. Skeletal opaque minerals are accessory. The olive phenocrysts are altered to carbonate and a pale-green phyllosilicate, possibly phlogopite. The orthopyroxene is fresh (Purvis, 2003a; GSWA 169216). This sill is displaced by later faulting.

A number of fresh to very weakly altered dolerite dykes (*Ꝑod*) up to 30 km long intersect the Yilgalong Granitic Complex, Fortescue Group, Carawine Dolomite, and Pinjian Chert Breccia. The dykes trend roughly north, west, and northwest and exhibit strong negative magnetic anomalies. The surface expression ranges from fresh bouldery outcrops in the Yilgalong Granitic Complex to weathered dolerite occupying joints, fractures, and valley floors in the Fortescue Group, Carawine Dolomite, and Pinjian Chert Breccia. The dykes post-date most fault lines on YILGALONG.

The fresh dolerite is massive and dark grey with ophitic and subophitic textures. Fresh or partly sericitized zoned plagioclase (labradorite to andesine) and clinopyroxene (both augite and pigeonite) are the primary minerals. Rare brown hornblende and biotite partly rim the pyroxenes. Small and scattered interstitial patches of clay, including chlorite–smectite and ferrostilpnomelane are present. Needles of apatite and opaque minerals are accessory. Some dykes carry interstitial granophyre.

Proterozoic Round Hummock Dolerite Suite (*ꝐRH-od*, *ꝐRH-og*)

Several medium- to coarse-grained unmetamorphosed dolerite dykes (*ꝐRH-od*) and an unusual totally altered gabbro dyke (*ꝐRH-og*) belonging to the Round Hummock Dolerite Suite (Hickman, 1983) intrude the Fortescue Group and Yilgalong Granitic Complex in the southwest corner of YILGALONG. The linear dykes are up to 15 m wide, trend northwest to west-northwest, and extend onto adjacent MOUNT EDGAR (Williams and Bagas, in prep.). They post-date the folding and most faulting in the Fortescue Group.

The gabbro dyke is a coarse-grained, pale-grey granular rock with an altered assemblage, but with good textural preservation. The plagioclase, up to 2 mm in grain size, is mostly replaced by carbonate. Very coarse grained, large prismatic and ophitic pyroxene grains are largely altered and replaced by irregular aggregates of highly clouded, orange-brown quartz. Interstitial areas are filled with chlorite and rare carbonate. Euhedral titanomagnetite is leucoxenized (Purvis, 2003a; GSWA 169243). Copper mineralization in the Meentheena copper prospect is in quartz veins within the sheared margins of this gabbro dyke (Purvis, 2003a; GSWA 169243).

Because of mutual interference, Hickman (1983) proposed that the Round Hummock Dolerite Suite might be a conjugate set with the north-northeasterly trending 755 ± 3 Ma Mundine Well Dolerite Suite (Wingate and Giddings, 2000).

Paleoproterozoic to Neoproterozoic deformation

D_8 deformation (<1830 Ma)

The large D_7 folds in the Fortescue and Hamersley Groups are intersected by numerous west-northwesterly to north-northeasterly trending faults. The oldest are north-trending, vertical-dipping, brittle normal faults with downthrow to the east or west. Such faults correspond in places to large recrystallized quartz ridges in the Yilgalong Granitic Complex, suggesting that they may, in some cases, be reactivated basement faults. They appear to be related to west-northwest trending faults that displace them or are displaced by them. All of these faults intersect the Fortescue and Hamersley Group successions as well as the Oakover Synclinal axis. Such faults are easily recognized where they displace the Tumbiana Formation. They are also present, but less obvious in the overlying Carawine Dolomite and Pinjian Chert Breccia.

A second series of faults are arcuate transpressional with both dextral and sinistral strike-slip movements. These faults trend from west-northwest around to north and are concentrated along the southwestern and western margins of the Ripon Hills. On a regional setting these transpressional fault extend southeastwards across EASTERN CREEK to link up with a major sinistral transpressional fault that diagonally transects PEARANA, where it also displaces Hamersley and Fortescue Group rocks (Williams and Trendall, 1998b, Williams, in prep.).

The arcuate fault on southwestern margins of the Ripon Hills has juxtaposed the Carawine Dolomite against the Kuruna Member of the Maddina Formation 6 km east of Mount Ian Well. Although initially this juxtaposition appears to be a normal fault with a northeast-block-down movement, the presence of numerous small folds axes, up to 5 km long, parallel or slightly oblique to these faults on the northeast and east side of the faults lines and their absence from the southwest side points to southwesterly directed compression. This in turn suggests that faults have a thrust movement to the southwest. This is further borne out by small strike-slip displacements along the faults, which tend to be sinistral in the southeast and dextral on the northern extensions of the faults. Many of the older north-trending faults in this region terminate against the transpressional faults, although some also displace them, suggesting later reactivation.

Faults truncating the Jeerinah Formation, Carawine Dolomite, and Pinjian Chert Breccia in the Gregory Range Inlier are transpressional, steep reverse faults with movements similar to those described from the southwestern and western sides of the Ripon Hills. These have been described in detail by Trendall (1991) and Williams and Trendall (1998a–c).

All the faults described above are Proterozoic. The allocation of these faults to specific events related either to the initial 1830–1765 Ma Paleoproterozoic collision of the West Australian Craton with the North Australian Craton (the Yapungku Orogeny; Myers et al., 1996; Bagas, 2004), or to the later older-than-678 Ma Neoproterozoic Miles Orogeny (Bagas, 2004) and c. 550 Ma Paterson Orogeny (Bagas, 2004) — events in the adjacent Paterson Orogen — remains a matter of conjecture.

Phanerozoic rocks

Unassigned dolerite intrusions (*Єod*)

A cluster of fine- to medium-grained dolerite sills and dykes (*Єod*) intrude the Pinjian Chert Breccia and sedimentary rocks correlated with the Manganese Group. They occupy an area of about 15 km^2 in the central parts of the Ripon Hills centred 3.5 km southeast of Nullagine 1 Trig Point.

The primary minerals in the dolerite consist of plagioclase and partly ophitic augite and pigeonite. Disseminated K-feldspar was identified in the fine-grained groundmass together with patchy, but locally common, granophyre. There is minor magmatic quartz, minor to rare green and brown hornblende and biotite, and rare olivine. Opaque minerals and apatite are accessory and zircon, zirconolite, and baddeleyite have been recorded (Purvis, 2003a; GSWA 169230 and 169231; Rasmussen and Fletcher, 2004). Contact metamorphic hornfels have been formed in green-grey mudstones intruded by a thin dolerite sill 4 km south of the Nullagine 1 Trig Point.

Rasmussen and Fletcher (2004) reported mean zircon, zirconolite, and baddeleyite $^{207}Pb/^{206}Pb$ and $^{238}U/^{206}Pb$ ages of about 524 and 510 Ma respectively for the large dolerite sill intruded into Manganese Group sedimentary rocks, 2.9 km southeast of Nullagine 1 Trig Point (T. S. Blake in conjunction with Consolidated Minerals Ltd, 2004, written comm.).

These results are consistent with the sills belonging to the Kalkarindji large igneous province (Glass, 2002; Glass and Phillips, 2006). These are the first recorded Cambrian ages from the Pilbara Craton.

Canning Basin

The eastern half of YILGALONG is crossed by the southern extension of the Wallal Embayment of the Canning Basin (Hocking et al., 1994). The embayment, covering about 30% of the sheet area, contains fluvioglacial Carboniferous–Permian rocks of the Paterson Formation, mesoform remnants of the overlying lacustrine Neogene Oakover Formation, and superficial Cenozoic deposits. The embayment on YILGALONG is floored by Fortescue and Hamersley Group rocks of the Northeast Pilbara Sub-basin of the Hamersley Basin, which, in turn, overlies the eastern margin of the Pilbara Craton.

Paterson Formation (*CPpa-sgpg*)

Scattered exposures of the Carboniferous–Permian Paterson Formation (*CPpa-sgpg*; Traves et al., 1956; Hickman, 1983; Stevens and Apak, 1999; Haines et al., 2004) in the Oakover River valley are limited to low mesas and breakaways, rubble-covered low hills, and locally eroded stream banks along the Oakover River, and Gingarrigan and Murramuralba creeks. Locally, the Paterson Formation is disconformably overlain by mesas of the Neogene Oakover Formation. Most of these exposures lie in the southeast quarter of YILGALONG.

Noldart and Wyatt (1962) had divided the Permian succession in the Oakover River valley into a basal tillite, called the ‘Braeside Tillite’ (Clapp, 1925), and the overlying fluvioglacial sandstone, grit, conglomerate, and shale, called the ‘Bunmardie Beds’. The type area for the ‘Braeside Tillite’ (the diamictite component of the Paterson Formation) was about 7.5 km south of Gingarrigan Well on the west side of the Oakover River. The ‘Bunmardie Beds’ were named after good exposures along Bunmardie Creek. Both of these terms are no longer in use (Hickman, 1983).

Remnants of the fluvioglacial Paterson Formation are also preserved in ice-scoured basins, channels, and U-shaped valleys in the central and eastern parts of the Ripon Hills where the formation unconformably overlies the Carawine Dolomite and Pinjian Chert Breccia. An ice-scoured valley in Pinjian Chert Breccia containing Paterson Formation is also 16 km south-southwest of Pulgorah Cone, south of Midgengadge Creek. At this locality the Pinjian Chert Breccia is faulted against the Maddina Formation. In general, the ice-scoured basins and valleys, containing Paterson Formation or the residual ‘boulder beds’ (*R1tpa*) derived from weathered Paterson Formation, are elongated in a north-northwest direction. A particularly good example of this style of linear valley lies 6.5 km southwest of Bunmardie Well.

Polished striated pavements have been recorded from several localities on YILGALONG. All indicate a north-northwesterly to north-northeasterly directed movement of the overlying ice cover. Striated pavements on YILGALONG were first recorded by Forman (1960) in the Ripon Hills, 2.5 km east-southeast of Nullagine 1 Trig Point. During the present survey striated pavements were recorded on unassigned Proterozoic sandstone overlying Pinjian Chert Breccia 5 km north of Gingarrigan Well and on Pinjian Chert Breccia in the floor of a north-northeasterly trending valley 16.2 km south-southwest of Pulgorah Cone in the Midgengadge Creek area (Figs 12 and 13). The pavements are highly polished and exhibit ice striae, grooves, pitting, and chatter marks. The Pulgorah Cone and Ripon Hills localities contain rock drumlins.

The total thickness of the Paterson Formation on YILGALONG is unknown. An exploratory drillhole, RHDH1, just east of the Ripon Hills, intersected 158 m of interbedded clayey shale, siltstone, poorly sorted dirty sandstone, and local pebble beds. This succession was assigned to the Paterson Formation (Richards, 1985). A shallow rotary chip and corehole intersected 91.4 m of claystone and mudstone interpreted to be ‘Braeside Tillite’

IRW206 06.06.07

Figure 12. Ice-polished south-facing ramp on western margin of ice-scoured valley. Residual boulders weathered from diamictites of the Carboniferous–Permian Paterson Formation in foreground, Midgengadge Creek area (MGA 283813E 7628878N)

IRW207 06.06.07

Figure 13. Ice-polished pavements on a 'roche moutonnée'. Ice movement was to the north away from the viewer; Midgengadge Creek area (MGA 284448E 7629206N)

(diamictite) 4.5 km east of Outcamp Bore (Kempton, 1976). On Warrawagine to the north exploratory stratigraphic holes intersected up to 259 m of Paterson Formation.

Associated seismic refraction lines suggest depth to Archean basement to be around 661 m in the centre of the Oakover River valley west of Chukuwalyee Well (MGA 277136E 7693462N; Sentinel Mining Company, 1967; Williams, 2001).

The Paterson Formation consists of diamictite, mudstone, siltstone, sandstone, and conglomerate (*CPpa-sgpg*). Exposures within the Ripon Hills are confined to small elongate depressions or linear valleys mainly surrounded by Pinjian Chert Breccia and locally by Carawine Dolomite. The configuration of the clastic material, which includes moderate dips away from the valley sides and towards the depression or valley centre, shows that the preserved successions are not always continuous between outcrops in adjoining valleys.

The succession in the Ripon Hills is commonly coarser grained towards the base with polymictic conglomerate and pebbly sandstone passing up to interbedded sandstone, siltstone, and white claystone. Cross-bedding is common in the sandstones. The clasts in the conglomerate are commonly allochthonous quartzite, sandstone, and chert, but with little local input from the surrounding Pinjian Chert Breccia. The latter, after erosion, was probably transported northward by the ice movement. Diamictites are found in some of the more extensive outcrops such as those along the track to the abandoned Ripon Hills manganese mines 4 km northeast of the Nullagine 1 Trig Point. Here, the diamictite contains polished and faceted boulders of assorted granitic rocks, basalt, quartzite, sandstone, and chert.

The Paterson Formation in the Oakover River valley is more weathered, locally lateritized, and overlain by the Neogene Oakover Formation. Exposures of the basal diamictite, locally weathered to boulders, cobbles, and pebbles in clay, silt, and sand (*R1tpa*), are found 13 km west-southwest of Pulgorah Cone and 6 km south-southwest of 20 Mile Well along the eastern margin of the Ripon Hills, and on the western bank of the Oakover River, 7 km south of Gingarrigan Well. The basal diamictite is overlain by interbedded matrix-supported pebble and cobble conglomerate, pebbly sandstone, grey to brown coarse- to fine-grained sandstone, siltstone, shale, and claystone. The finer grained units carry the occasional cobble and small boulder dropstones. Sandstones are commonly planar and trough cross-bedded. Such successions are probable fluvioglacial deposits.

The Paterson Formation has been assigned to depositional Sequence Pz5 (Middleton, 1990) covering the Early Permian (Sakmarian–Asselian age) and Late Carboniferous period (Mory and Backhouse, 1997; Stevens and Apak, 1999; Haines et al., 2004). Palynology studies of material obtained from shallow drillholes (Kempton, 1976) between Warrawagine Homestead and Mount Sydney Creek (on Braeside) along the Oakover River valley suggested a Late Sakmarian age for the Paterson Formation on Yilgalong (Backhouse, 1976).

Recent reviews of the Permo-Carboniferous glaciation in Western Australia (Playford, 2001, 2002) have concluded that new evidence from the preserved glacial landforms, particularly those from the Oakover River valley region, indicate major wet-based ice sheets, several kilometres thick. These probably extended across all or most of Australia. The ice cap, moving away from the polar regions, moved north-northwest across Western Australia. This differs from earlier suggestions and interpretations of the more restricted glaciated valley environments (Traves et al., 1956; Noldart and Wyatt, 1962).

Regolith

Cenozoic deposits

Cenozoic deposits cover around 40% of YILGALONG and of these deposits more than 90% are in the Oakover River valley. The remaining Cenozoic deposits in the Ripon Hills and adjacent areas to the southwest, and in the Gregory Range Inlier, are mostly Quaternary or older alluvium and colluvium associated with drainage systems.

The Cenozoic deposits can be allocated to five main categories on YILGALONG: eroded residual deposits including laterite that pre-date the Oakover Formation; the lacustrine Oakover Formation and associated colluvium; pre-Quarternary consolidated and eroded colluvial, alluvial, and residual deposits; Quaternary semiconsolidated and unconsolidated, recent or currently active colluvial, low-slope, alluvial, and residual deposits; and recent lacustrine and eolian deposits.

Residual or relict units (*$R3c_bv_b$*, *$R3_rf$*)

Residual and sheetwash clay and silt with a gilgai (expansive clay) surface (*$R3c_bv_b$*) is exposed along elevated divides between north-flowing streams southeast of Rocky Pool in the Nullagine River valley. This unit overlies dolerite (*AFO-od*), fragments of which are mixed with the clay and silt. A similar elevated area of gilgai-surfaced clay and silt deposit surrounds Cave Bore on the northeast side of the Ripon Hills. In this area the unit is adjacent to exposed Carawine Dolomite and underlies the Oakover Formation. Dolerite fragments were not found in this locality.

Small patches of massive, pisolitic, and nodular ferricrete or laterite (*$R3_rf$*) overlie remnants of the Paterson Formation in the Ripon Hills area. These are remnants of a previously extensive, but now dissected, laterite that overlies a pallid weathered horizon mainly developed on the underlying Paterson Formation. This ferruginous duricrusted surface is more widespread in the Oakover River valley, particularly along the high ground marking the drainage divide between Yilgalong and Murramuralba creeks. Similar deposits lie in the upper reaches of the Gingarrigan Creek, and around Pulgorah Cone. Laterite remnants in the form of low breakaways also overlie the Paterson Formation. The ferruginized duricrusted surface pre-dates the Oakover Formation.

Colluvial unit (*C3*)

Widespread aprons of consolidated colluvial sands, silt, and gravel (*C3*) rim major bedrock exposures along the margins of the Oakover River valley and, to a lesser extent, the Nullagine River valley and larger subsequent streams such as Coonanbunna Creek. The colluvium slopes gently upward to bedrock where there is an abrupt change of slope. These colluvial pediments are well developed along the northeast margin of the Ripon Hills. They are dissected by numerous shallow streams and are commonly covered with a scattered veneer of small pebbles. The uniform and widespread dissection of this surface indicates an older land surface that can be seen to pre-date the lacustrine Oakover Formation. The flat-lying, residual clay and silt unit with gilgai surface (*$R3c_bv_b$*) is contained within or overlies the colluvial unit (*C3*).

Oakover Formation (*NOA-ktzl*, *NOA-ktpl*)

The Oakover Formation (Noldart and Wyatt, 1962) is scattered throughout the Oakover River valley and in widely spaced outliers in the Nullagine River valley north and northeast of Rocky Pool. The widespread distribution of the remnant outcrops shows that at one time it covered the entire Oakover River valley between the Ripon Hills and Gregory Ranges. The formation is now preserved in a series of distinctive cliffed tablelands, mesas, buttes, and scarps roughly parallel to, and mostly on the western side of, the present-day Oakover River. These landforms rise to 70 m above the present-day Oakover River bed. Similar, but less dramatic, exposures line the eastern side of Yilgalong Creek northeast of the Ripon Hills and the upper reaches of the Tanguin Creek (Williams, 2001) between Outcamp Bore and 20 Mile Well. The Tanguin Creek drainage lies between the Nullagine River and Yilgalong Creek.

Regional mapping in the early 1990s distinguished an upper unit of vuggy, white to grey opaline silica, silicified carbonate rock, and minor calcareous sandstone (*NOA-ktzl*). This distinctive siliceous unit overlies a more-widespread lower unit of blue, grey, and fawn limestone, calcareous sandstone, and packstone (*NOA-ktpl*; Williams and Trendall, 1998a,b). Although some silica replacement of pre-existing carbonate is evident in the upper unit, much of the silica (opaline) appears to be directly precipitated from solution.

The lower unit intertongues with colluvium (*C2*) eroded from the adjacent bedrock on the valley margins. The unit also overlies lateritized Paterson Formation and abuts or overlies the Pinjian Chert Breccia, Carawine Dolomite, and Jeerinah Formation. The upper siliceous unit is only ever observed overlying the lower carbonate unit. The upper siliceous cliff-forming unit (*NOA-ktzl*) varies from 3 to 10 m thick, whereas the lower carbonate unit (*NOA-ktpl*) is up to 45 m thick on YILGALONG.

Although the Oakover Formation is mentioned in many earlier publications (see table 3 in Williams and Trendall, 1998a) its genesis remains unclear. The general consensus supports a lacustrine environment (Towner and Gibson, 1983; Middleton, 1990; Williams and Trendall, 1998a,b) developed during a stillstand event that included stagnant drainage with little or no detrital input into the valley. The Oakover Formation has much in common with the carbonates of the Lawford Formation (Kimberly area) and Nadarra Formation (Carnarvon Basin; Hocking et al., 2005).

Undiagnostic ostracods have been recorded from the Oakover Formation (Veevers and Wells, 1961, p. 197) and fossiliferous oolitic limestone has been described from the base of the Oakover Formation near the abandoned Braeside Homestead on the western margin of BRAESIDE. The latter gave a Miocene–Holocene age range (Cockbain, 1978). A precise age of deposition for the formation is still under review due to paucity of diagnostic palynology and paleontology. However, more recently, a growing understanding of regolith stratigraphy and climatic changes from the Mesozoic to the present-day period places the Oakover Formation in the Pliocene (Hocking et al., 2005).

Residual or relict unit (*R2k*)

Partly silicified sheets of dissected, secondary carbonate or residual calcrete, comprising massive, nodular, and cavernous, white to grey limestone (*R2k*), is locally exposed along Coonanbunna Creek adjacent to or overlying the Carawine Dolomite and Jeerinah Formation. Similar dissected calcrete overlies weathered komatiitic and carbonate-rich basalts of the Euro Basalt 5 km south of Mopoke Well. In both areas adjacent or underlying carbonate-rich rocks are the source of the calcrete deposits. The development of pedogenic calcretes appears to be related to increasing desiccation during a prevailing continental climate in Pliocene times and is possibly coeval with the lacustrine Oakover Formation (Hocking et al., 2005).

Alluvial units (*A2t, A2k*)

Dissected consolidated alluvial gravel, sand, and silt, locally with carbonate cement (*A2t*) is widespread along the margin of the Oakover and Nullagine rivers and Yilgalong Creek. The cemented alluvium is locally cliff forming where undergoing current erosion. The unit is crudely bedded and gravel beds exhibit current imbrication, supporting an alluvial genesis.

Several low calcrete mesas, consisting of silicified massive, nodular, and cavernous limestone (*A2k*) trace out a probable earlier course of Midgengadge Creek 14 km southwest of Pulgorah Cone. The calcrete overlies the Maddina Formation and is up to 15 m above the bed of the present-day Midgengadge Creek with which it intertwines.

Low dissected mesas of alluvial calcrete also lie parallel to and west of the Nullagine River 6.5 km south-southwest of Rocky Pool. This calcrete has a white crumbly upper surface. However, it is possible that these exposures are outliers of the Oakover Formation, which lies 10.5 km to the north.

Colluvial units (*C2, C2f*)

Remnants of partly consolidated colluvial sand, silt, and gravel (*C2*) are dissected older proximal outwash fans, scree, and talus. The unit is mostly confined to the Oakover River valley where it overlies or is eroded from the Oakover Formation. It is common along Gingarrigan Creek, but most exposures are limited in area by overlying recent colluvial deposits.

Dissected consolidated ferruginous colluvium of sand, silt, clay, and rock fragments (*C2f*), mostly reworked pisolites, laterite and ferruginous duricrust, is confined to the Oakover River valley. In most areas the unit lies adjacent to or is near ferruginous duricrust ($R3_rf$) outcrops. The ferruginous colluvium is well exposed along Gingarrigan Creek 2 km west of Barbilgunyah Hill.

Residual or relict units ($R1gp_g$, *R1tpa*)

A small area of residual quartzofeldspathic sand, with a thin veneer of quartz and granitic rock fragments ($R1gp_g$), overlies the contact between the Elsie Creek Tonalite and Midgengadgi Monzogranite 16 km southeast of Dingo Well.

Residual boulders, cobbles, and pebbles in clay, silt, and sand, including locally transported material (*R1tpa*) form a distinctive eluvial deposit that invariably overlies weathered Permian fluvioglacial Paterson Formation. The unit includes allochthonous, sometimes faceted and striated, boulders and cobbles of mixed granitic rocks, basalt, quartzite, and chert enclosed in unconsolidated clay, silt, and sand. Jumbled, disoriented, and very large broken boulders of the chaotic spherule-bearing megabreccia (*AHAc-kdx*), covering an area of about 10 m^2, overlie north-dipping Jeerinah Formation rocks, 13.6 km west-southwest of Pulgorah Cone on the southern side of the Ripon Hills road. The megabreccia is postulated to be a glacial erratic. The boulders lie at the western edge of the residual 'boulder bed' unit (*R1tpa*) and are more than 500 m south of the nearest in situ occurrence of the megabreccia. This position, south of known outcrops, and the orientation of the boulders in relation to the underlying Jeerinah Formation suggest local ice-transport.

Alluvial units ($A1_c$, $A1_b$, $A1_f$, $A1_fc_b$, $A1_i$, $A1_v$)

YILGALONG has a well-developed drainage system (Fig. 2). Sand, silt, and gravel in active drainage channels within bedrock areas and clay, silt, and sand in poorly defined drainage courses on floodplains ($A1_c$) are widespread. Such units tend to be narrow and linear in the bedrock areas of the hilly southwest portion and broader and more meandering in the flatter areas of the Oakover River valley. The large Oakover, Nullagine, and Little rivers, Yilgalong Creek, and the lower reaches of Boondalyerri, Walgunya, and Coonanbunna creeks are occupied with broad, active, anastomosing channels filled with unconsolidated sand, silt, and gravel ($A1_b$). Such channels can carry point bars up to 2 m high. The unconsolidated material is confined within well-defined channels with banks incised into finer grained overbank and floodplain deposits of silt, sand, and gravel ($A1_f$) or older alluvium (*A2t*).

Some parts of the Oakover River valley floodplain, including broad valleys between outcrops of the Oakover Formation, carry a distinctive unit of sand, silt, and clay with gilgai (crabhole) surface in areas of expansive clay ($A1_fc_b$). This unit is well developed 4 km east of Outcamp Bore, 3 km east of Cave Bore, 2 km south and west of New 20 Mile Well, north and south of Gap Well, and 8 km west-southwest of Barbilgunyah Hill. A second distinctive floodplain unit is characterized by numerous small claypans. This is a mixed floodplain deposit of sand, silt, and clay ($A1_i$). It is generally close to major drainage lines and locally fringes or is close to the gilgai unit ($A1_fc_b$). An example of the latter lies 4.7 km east of Outcamp Bore. Other exposures are scattered along the lower reaches of Yilgalong Creek, and 1.5 km west of Yilgalong Pool, 2 km south of Little River Well, and 6.7 km southwest of Barbilgunyah Hill.

Recent well-developed alluvial fans consisting of pebbly silt and sand ($A1_v$) lie along the base of the west-facing scarp of an eroded low (20 m) tableland of Oakover Formation, 5.5 km east of Outcamp Bore. The pebbly material is mostly opaline silica from the upper siliceous unit of the Oakover Formation.

Low-gradient slope units (*W1*, *W1f*)

A few widely scattered areas of silt, sand, and pebbles on distal sheetwash fans (*W1*) are found in the Oakover River valley and on the margins of the Nullagine River valley 4.5 km north and 3 km northeast of Rocky Pool. Larger areas lie 3 km west of Outcamp Bore on the northern boundary of the sheet area, and 7 km south-southwest of Pulgorah Cone where the unit is surrounded by low cliffs of the Oakover Formation. The sheetwash has a distinctive striping of alternating bare and vegetation-rich (generally *Acacia* sp.) bands. The banding, called ‘tiger bush’ (Wakelin-King, 1999), is developed at right angles to the general sheetwash flow. The bare silty and sandy areas have a thin veneer of opaline silica and quartz pebbles.

Ferruginous sheetwash deposits of silt, sand, and ferruginous nodules (pisolites) in distal outwash fans (*W1f*) are marginal to ferruginous duricrust and low laterite ridges in the Murramuralba Creek area southwest of Gap Well. The unit is similar to the previously described sheetwash unit except that the thin veneer is almost exclusively of pisolitic nodules with minor quartz pebbles.

Colluvial units (*C1*, *C1q*)

Small areas of unconsolidated colluvial sand, silt, and gravel (*C1*) in scree and talus in proximal mass-wasting deposits are scattered throughout the southwestern half of YILGALONG and in the Gregory Range. More extensive scree areas and outwash fans surround and abut many of the Oakover Formation mesas and tablelands in the Oakover River valley. A colluvial apron of quartz debris in sand, silt, and clay (*C1q*) surrounds a large quartz ridge occupying a major fault line 13 km south of Walgunya Well on the southeastern side of the Nullagine River.

Eolian unit (*E*)

Several small areas of light to dark-red eolian sand (*E*) lie close to the northeast margin of the Ripon Hills. Similar eolian sand is found in the southeast corner where it is banked up against scarps of the Oakover Formation. The eolian sand along the edge of the Ripon Hills is derived from Yilgalong Creek and adjacent floodplains and is indicative of the prevailing easterly winds. The sand in the southeast corner is derived from the Oakover River that lies 2.5 km to the east on BRAESIDE.

Lacustrine unit (L_pc_b)

A small claypan of lacustrine clay and silt with gilgai surface and sparse samphire vegetation (L_pc_b) lies 6.6 km west-northwest of the New 20 Mile Well. Unlike the numerous claypans that occupy floodplains adjacent to the major drainages ($A1_i$), this discrete claypan occupies a slight depression in a plateau of Oakover Formation that forms the major divide between the Nullagine and Oakover River drainage basins (Fig. 2).

Probable impact site

An investigation of a probable meteorite impact crater was carried out during fieldwork in July 2003. The crater was initially recognized during preliminary aerial photograph interpretation carried out prior to fieldwork.

The impact crater is on the northeast-facing slope of an east-draining tributary of the Oakover River (MGA 281672E 7623041N; Figs 14 and 15). The site is 23 km south-southwest of Pulgorah Cone in fresh amygdaloidal and vesicular medium-grained basalt of the Maddina Formation. Large amygdales are filled with quartz, chalcedonic quartz (agate), smectite, prehnite, chlorite, and traces of copper mineralization (malachite). In general, the basalt resembles the flowtop component of a basalt flow. No impact structures such as shatter cones were identified on the exposed host rock. The rim is rubbly and broken on the surface, but appears to be intact beneath this surface. The actual crater is filled with sand and rock rubble, some of which appears to have fallen in from the sides. A shallow pit (~0.5 m) dug in the lowest part of the crater met with compacted, but broken or shattered, basalt.

IRW208 06.06.07

Figure 14. Probable meteorite impact crater on YILGALONG, viewed from 800 m to the north. Low hills in the background are Maddina Formation (MGA 281672E 7623041N)

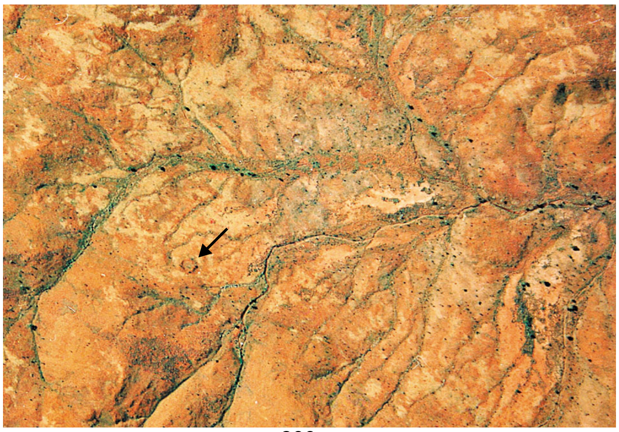


Figure 15. Aerial photograph view of probable meteorite impact crater on YILGALONG (MGA 281672E 7623041N)

The crater is slightly elliptical in shape with outer north–south dimensions totalling 27 m and east–west dimensions of 36.3 m. The internal crater-floor dimensions are 18.2 m north–south and 17.5 m east–west. A crater rim higher than the crater floor is developed on the northern, western, and southern sides, but is absent from the eastern side. Here, because of the primary northeast hill slope the rim spills down the slope. The western rim is the highest and widest, rising 1.75 m above the crater floor and extending 12.1 m in width. The general orientation of the crater suggests a steep descent from the northeast for the impact body.

The dimensions of the Yilgalong crater, apart from the shallow depth, are similar to those of the well-known Dalgaranga crater (25 m) in the Murchison region of Western Australia (Bevan and McNamara, 1993).

A thorough search of the crater and surrounding areas did not reveal any recognizable meteoritic material or metal artefacts suggestive of a bomb crater, which is another possible explanation for the crater. The exposed Neoarchean Maddina Formation basalt at the impact site is weathered to the same extent as all the surrounding basalts in the area, suggesting that it pre-dates the current weathering cycle. The possible age of the impact is unknown. Kanji (*Acacia inaequilatera*) growing on the crater rim is up to 4 m high.

Economic geology

Mineral exploration and prospecting on YILGALONG has, up to the present time, only yielded minor manganese-ore production, mainly for metallurgical and beneficiation testing, from the Ripon Hills area and scattered alluvial gold workings with unrecorded production from the Elsie Creek area in the southwest corner. The previously unrecorded Meentheena copper prospect is reputed to have been found in the early part of last century and the YILGALONG area in general would have been explored for base metals around the same time because of its proximity to the Braeside lead field in the Gregory Ranges (Finucane, 1938; Williams and Trendall, 1998a). However, it was not until the 1950s, during the so-called 'manganese rush' triggered by a sudden increase in price for manganese on the U.S. markets, that serious exploration was undertaken in the region. The first recorded mineralization on YILGALONG — the Ripon Hills manganese deposits — was discovered in 1957 (O'Driscoll, 1958). Over the next 50 years there was ongoing, but mostly low key, mineral exploration and prospecting by large international companies, mining syndicates, and individual prospectors with little positive results. This work has been directed towards manganese, iron, base metals, nickel, gold, diamond, and coal exploration.

An overview of the economic mineral potential, production, and mineral occurrences for the east Pilbara, which covers YILGALONG, is presented in Ferguson and Ruddock (2001). Additional information covering company exploration data for YILGALONG is available from the Western Australian mineral exploration (WAMEX) open-file system held in the Department of Industry and Resources' (DoIR) library (Appendix 3). Current information for all mines, deposits, and process plants, with the exception of petroleum and gas, for Western Australia is recorded in the Western Australian mines and mineral deposition information (MINEDEX) database, available on CD (Cooper et al., 2002).

The description of mineral deposits and occurrences in these notes follows the format outlined in Ferguson and Ruddock (2001) and is adopted on the accompanying YILGALONG map sheet (Williams, 2005). Western Australian mineral occurrence (WAMIN) database reference numbers* (Ferguson and Ruddock, 2001) are shown in brackets next to the deposit or prospect.

Vein and hydrothermal mineralization

Precious metal — gold

The Euro Basalt in the Elsie Creek greenstone belt, in the southwest corner of YILGALONG, has been explored for gold. During the current survey several old shallow shafts sunk on quartz-reef-bearing shear zones and associated alluvial patches were located north and south of Elsie Creek between 3.3 and 7.7 km south-southwest of Salvation Well. Old alluvial workings surround a shallow shaft at Elsie Creek 3 (*17671*). Recent bulldozing at the Elsie Creek diggings (*17673*) and Elsie Creek 2 (*17672*) indicate ongoing metal-detecting activity of alluvial ground alongside drainage lines on what appears to be older workings.

A deep shaft, located during recent exploratory work and pinpointed on airphotos in the current survey, is presumed to be following up gold indicators. This shaft is 6.4 km south-southwest of Mopoke Well in sheared Euro Basalt (Yilgalong IRW 6; *17676*)

* Operating status of sites are denoted as follows: 5224 = mineral deposit; *5224* = mineral occurrence or prospect.

Five bulldozed costeans spread over a strike distance of 675 m (Salvation Well NW, *17674*) intersect the interbedded quartz-pebble conglomerate, sandstone, wacke, and grey-blue to purple siltstone unit (*AFOhb-frp*) of the Hardey Formation 1.5 km northwest of Salvation Well. The costeans lie towards the base of this unit where it unconformably overlies the Bamboo Creek Member. Some thin quartz veinlets were noted in the costeans, but there was no obvious gossanous material.

A sixth large costean cuts the basal polymictic, matrix-supported cobble to boulder conglomerate, sandstone, siltstone, and local shale (*AFOh-scp*) unit of the Hardey Formation 4.7 km north-northeast of Salvation Well. The lithology exposed in this costean is mostly thin-bedded, grey micaceous siltstone. Local, thin crosscutting veins of a sky-blue mineral were identified as turquoise with a small amount of an admixed impurity, suspected to be berlinite ($AlPO_4$; R. M. Clarke, W.A. Chemistry Centre, 2002, written comm.).

The nature and type of mineralization explored for at these localities is unclear and no supporting documents have been identified. However, the basal Hardey Formation is known to carry gold mineralization (Hickman, 1983; Bagas, 2005).

Base metal — copper

The previously unrecorded and recently rediscovered Meentheena copper prospect (*17677*) lies 4 km west of Mopoke Well. The prospect consists of a series of shallow pits (<1.5 m deep) sunk on a series of small en echelon gossanous quartz veins, striking about 290° and dipping steeply (70° to 80°) to the south-southwest. The quartz veins occupy sheared contacts between the Mount Roe Basalt and a dolerite – altered gabbro dyke belonging to the Proterozoic Round Hummock Dolerite Suite. Mineralization has been found in the sheared contact on both sides of the dyke, which is up to 6 m wide.

The main copper mineralization can be traced intermittently over a distance of 250 m, mostly on the northern side of the dyke. It is represented by patchy malachite and probable chrysocolla in vuggy gossanous quartz and thin patinas of green copper minerals along joint and fracture planes in the sheared basalt and dolerite adjacent to the quartz veins. It is doubtful if any copper ore was removed from the prospect.

Mineralization in regolith

Precious mineral — diamond

Loam sampling along the southern side of Yilgalong Creek where it flows out of the Ripon Hills, an area singled out by airborne and ground magnetic anomalies, returned a single macrodiamond and a few chromites (Knight, 1994). Follow-up sampling failed to find further diamonds or indicator minerals. It was concluded that the previous samples may have been derived from remnant Permian fluvioglacial rocks that outcrop in the area (Home, 1995).

Steel industry metal — manganese

The geological aspects and metallurgical properties of manganese mineralization, centred in the Ripon Hills on YILGALONG, have been previously documented (O'Driscoll, 1958; Muskett, 1960; de la Hunty, 1960, 1963, 1965; Noldart and Wyatt, 1962; Longreach Metals NL, 1974; Denholm, 1977; Hickman, 1983; Ferguson and Ruddock, 2001). The main mineralized area in the Ripon Hills is about 14 km^2, lying between 2 km east and 4 km northeast of Nullagine 1 Trig Point. This area encompasses 10 manganese prospects designated A to J (Denholm, 1977), which are given WAMIN database numbers of 5219, 5220, 5221, 5222, 5223, 5224, 5225, 3503, 5226, 5227 respectively (Williams, 2005). A further five prospects are scattered throughout the remaining parts of the Ripon Hills: prospect K (5228), 2.5 km northwest of the Nullagine 1 Trig Point; Ripon Hills southeast prospect (*5231*), 8.3 km south-southwest of Little River Spring Bore; Ripon Hills south prospect (*5232*), 5.7 km south of Mount Ian; Little River Spring prospect (*17678*), 1.8 km west-northwest of Little River Spring Bore; and Cave Bore SW prospect (*17680*), 10.5 km southwest of Cave Bore. A manganese occurrence, Midgengadge Creek S (*17679*) was also noted overlying Pinjian Chert breccia, 15 km south-southwest of Pulgorah Cone.

Overall production figures are difficult to extract. Apart from large bulk samples collected for beneficiation and metallurgical tests (Williams, 1958, 1960), production appears to have been bulked with ore mined from other areas (Hickman, 1983). A combined drill-proven, indicated and inferred resource is estimated at 56 000 000 tonnes with average grade of 19.4% Mn and 25.9% Fe, using a 15% Mn cutoff (Denholm, 1977). These resource figures are reduced to 12 000 000 tonnes if a cutoff grade of 20% is used to produce an average grade 24.6% Mn and 23% Fe. The average depth of the orebody in this case would be 8 m (Denholm, 1977).

Unlike the high-grade deposits (>45%) in the Woodie Woodie area (Williams and Trendall, 1998b), the main Ripon Hills deposits are of much lower grade with an iron content up to 25% and manganese less than 40% (Denholm, 1977).

The area where the main ferruginous manganese mineralization is developed is underlain by Pinjian Chert Breccia. The mineralization is confined to a broad shallow north–south-trending depression, partly faulted on the eastern side and along the southwestern margin. Such depressions may have a karst genesis as observed elsewhere in the Ripon Hills. The manganese mineralization overlies or replaces remnants of shale (*EMN-ss*) belonging to the Proterozoic Manganese Group. In some areas the ferruginous manganese ore overlaps the shale to lie directly on or replace the Pinjian Chert Breccia (Denholm, 1977). All the rocks in this region show remnant effects of ferruginization (lateritization) and supergene enrichment in post-Permian times (Late Cretaceous – Early Miocene; Hocking et al., 2005).

The higher grade manganese ores have a dark bluish colour with a botryoidal appearance, whereas the ferruginous manganese is coated with brownish-orange limonite–goethite. The main manganese mineral is very fine grained pyrolusite (manganese oxide) intergrown with hematite, with local bixbyite (iron–manganese oxide) and braunite (manganese silicate). The main gangue minerals are kaolin and diaspore (Denholm, 1977).

The manganese prospect K (5228) is similar to that found in the main mineralized areas east of Nullagine 1 Trig Point in that it is associated with Manganese Group sedimentary rocks. All the other localities in the Ripon Hills and at Midgengadge Creek are small and associated with the Pinjian Chert Breccia.

References

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.

ASHWAL, L. D., 1991, Two Cratons and an Orogen — Excursion Guidebook and Review Articles for a Field Workshop through Selected Archaean Terranes of Swaziland, South Africa and Zimbabwe, IGCP Project 280: Johannesburg, South Africa, University of Witwatersrand, Dept. of Geology, p. 128–131.

AWRAMIK, S. M., and BUCHHEIM, H. P., 1997, A large Late Archaean lake: Meentheena Carbonate member, Tumbiana Formation (Fortescue Group), Pilbara region, Western Australia: A stromatolite and lithofacies sequence analysis approach: Geological Society of America, Abstracts with Program, v. 29(6), p. 466–467.

AWRAMIK, S. M., and BUCHHEIM, H. P., 2001, Late Archaean lacustrine carbonates, stromatolites, and transgressions, *in* 4th International Archaean Symposium 2001, Extended Abstracts *edited by* K. F. CASSIDY, J. M. DUNPHY, and M. J. VAN KRANENDONK: Canberra, AGSO–Geoscience Australia, Record 2001/37, p. 222–223.

BACKHOUSE, J., 1976, Palynology of the Oakover River Boreholes: Western Australia Geological Survey, Palaeontology Report No. 6/1976 (unpublished).

BAGAS, L., 2004, Proterozoic evolution and tectonic setting of the northwest Paterson Orogen, Western Australia: Precambrian Research, v. 128, p. 475–496.

BAGAS, L., 2005, Geology of the Nullagine 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

BEARD, J. S., 1975, The vegetation of the Pilbara area: Vegetation Survey of Western Australia 1:1 000 000 Vegetation Series, Explanatory Notes to Sheet 5: Perth, University of Western Australia Press, 120p.

BEARD, J. S., 1980, A new phytogeographic map of Western Australia: Western Australian Herbarium Research Notes, no. 3, p. 37–58.

BEVAN, A., DOWNS, P., and BEVAN, J., 1999, Australian Chinese writing stone; an appraisal of a decorative porphyritic basaltic rock from Western Australia: Australian Gemmologist, v. 20, p. 178–181.

BEVAN, A., and McNAMARA, K., 1993, Australia's meteorite craters: Western Australian Museum, 27p.

BLAKE, T. S., 1984, The lower Fortescue Group of the northern Pilbara Craton — stratigraphy and palaeogeography, *in* Archean and Proterozoic basins of the Pilbara — 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. 123–143.

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.

BLAKE, T. S., and BARLEY, M. E., 1992, Tectonic evolution of the Late Archaean and Early Proterozoic Mount Bruce Megasequence Set, Western Australia: Tectonics, v. 11, p. 1415–1425.

BLAKE, T. S., BUICK, R., BROWN, S. J. A., and BARLEY, M. E., 2004, Geochronology of a Late Archean flood basalt province in the Pilbara Craton, Australia: constraints on basin evolution, volcanic and sedimentary accumulation, and continental drift rates: Precambrian Research, v. 133, p. 143–173.

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., HUSTON, D. L., and CHAMPION, D. C., 2001, North Pilbara National Geoscience Mapping Accord project (1995–2000): AGSO Research Newsletter, May 2001, p. 25–28.

BLEWETT, R. S., WELLMAN, P., RATAJKOSKI, M., and HUSTON, D. L., 2000, Atlas of North Pilbara geology and geophysics, 1:1.5 million scale: Canberra, Australian Geological Survey Organisation, Record 2000/04, 36p.

BODORKOS, S., LOVE, G. J., and NELSON, D. R., and WINGATE, M. T. D., 2006a, 178089: leucocratic monzogranite, Dingo Well; Geochronology dataset 632, *in* Compilation of geochronology data, March 2006 update: Western Australia Geological Survey.

BODORKOS, S., NELSON, D. R., LOVE, G. J., and WINGATE, M. T. D., 2006b, 178090: tuffaceous volcaniclastic sandstone, Dingo Well; Geochronology dataset 633, *in* Compilation of geochronology data, March 2006 update: Western Australia Geological Survey.

BUICK, R., 1992, The antiquity of oxygenic photosynthesis: Evidence from stromatolites in sulphate-deficient Archaean lakes: Science, v. 255, p. 74–77.

BOULTER, C. A., 1987, Subaqueous deposition of accretionary lapilli: significance for palaeoenvironmental interpretations in Archaean greenstone belts: Precambrian Research, v. 34, p. 231–246.

BUREAU OF MINERAL RESOURCES, 1987, Preliminary total magnetic intensity map, Nullagine, W.A. Sheet SF 51-5: Canberra.

CAMPANA, B., HUGHES, F. E., BURNS, W. G., WHITCHER, I. G., and MUCENIEKAS, E., 1964, Discovery of the Hamersley iron deposits (Duck Creek – Mt Pyrton – Mt Turner area): The Australasian Institute of Mining and Metallurgy, Proceedings, no. 210, p. 1–30.

CLAPP, F. G., 1925, A few observations on the geology and geography of north-west and desert basins, Western Australia: The proceedings of the Linnean Society of New South Wales for the year 1925, v. 1(2), no. 201, p. 60–61.

COCKBAIN, A. E., 1978, Fossiliferous oolitic limestone from the Oakover Beds: Western Australia Geological Survey, Palaeontology Report No. 42/1978 (unpublished).

COLLINS, W. J., 1989, Polydiapirism of the Archaean Mt Edgar batholith, Pilbara Block, Western Australia: Precambrian Research, v. 43, p. 41–62.

COOPER, R. W., FLINT, D. J., and SEARSTON, S. M., 2002, Mines and mineral deposits of Western Australia: digital extract from MINEDEX — an explanatory note, 2002 update: Western Australia Geological Survey, Record 2002/19, 20p.

DENHOLM, L. S., 1977, Investigation of the ferruginous manganese deposits at Ripon Hills, Pilbara Manganese Province, Western Australia: The Australasian Institute of Mining and Metallurgy, Proceedings, no. 264, p. 9–7.

de la HUNTY, L. E., 1960, Summary report on some manganese deposits in the Pilbara and West Pilbara Goldfields: Western Australia Geological Survey, Bulletin 114, Miscellaneous Reports for 1957, no. 7, p. 45–49.

de la HUNTY, L. E., 1963, The geology of the manganese deposits of Western Australia: Western Australia Geological Survey, Bulletin 116, p. 44–52.

de la HUNTY, L. E., 1965, Manganese ore deposits of Western Australia, *in* Geology of Australian ore deposits *edited by* J. McANDREW: 8th Commonwealth Mining and Metallurgical Congress, 1965, Melbourne, Victoria, p. 140–146.

EIGENBRODE, J. L., and FREEMAN, K. H., 2003, Late Archean shallow- and deepwater sulfur cycles: Molecuar (sic) and isotopic evidence: 13th Annual V. M. Goldschmidt Conference, 2003, Kurashiki, Japan, Abstracts; Special Supplement to Geochimica et Cosmochimica Acta, v. 67, no. 18 (S1), p. A85.

FARRELL, T. R., 2006, Geology of the Eastern Creek 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

FEEKEN, E. H. J., FEEKEN, G. E. E., and SPATE, G. H. K., 1970, The discovery and exploration of Australia: Sydney, New South Wales, Nelson Press, 318p.

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., 1938, The Braeside lead field, Pilbara District: Aerial, Geological and Geophysical Survey of Northern Australia, Western Australia Report 24, p. 3–9.

FORMAN, D. J., 1960, Glaciated pavement in the Ripon Hills, Western Australia: Royal Society of Western Australia, Journal, v. 43(4), p. 123–125.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 2005a, 1:100 000 Total magnetic intensity image, *in* North Paterson airborne geophysical survey, 2005: Western Australia Geological Survey, (unpublished) Available for online download, free-of-charge, from <http://www.ga.gov.au/gadds>.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 2005b, Ternary radiometric image (KTU as RGB), *in* North Paterson airborne geophysical survey, 2005: Western Australia Geological Survey, (unpublished) Available for online download, free-of-charge, from <http://www.ga.gov.au/gadds>.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA, 2006, Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

GLASS, B. P., and BURNS, C. A., 1988, Microkrystites; a new term for impact-produced glassy spherules containing primary crystallites: Proceedings of the Lunar and Planetary Science 18th, p. 455–458.

GLASS, L. M., 2002, Petrogenesis and geochronology of the North Australian Kalkarindji low-Ti continental flood basalt province: Canberra, The Australian National University, PhD thesis (unpublished).

GLASS, L. M., and PHILLIPS, D., 2006, The Kalkarindji continental flood basalt province: A new Cambrian large igneous province in Australia with possible links to faunal extinctions: Geology, v. 34(6), p. 461–464.

GLIKSON, A. Y., 2002, Two and a half billion year-old asteroid impact deposits in the Pilbara, Western Australia: Meteorite, February 2002, p. 24–28.

GLIKSON, A. Y., 2004, Early Precambrian asteroid impact-triggered tsunami: Excavated seabed, debris flows, exotic boulders, and turbulence features associated with 3.47–3.47 Ga-old asteroid impact fallout units, Pilbara Craton, Western Australia: Astrobiology v. 4, no. 1, p. 1–32.

GLIKSON, A. Y., DAVY, R., and HICKMAN, A. H., 1986, Geochemical data files of Archaean volcanic rocks, Pilbara Block, Western Australia: Australia Bureau of Mineral Resources, Record 1986/14, 10p.

GLIKSON, A. Y., and HICKMAN, A. H., 2005, Asteroid impact signatures of the Pilbara Craton (1:1 000 000 scale), *in* Archean to early Proterozoic asteroid impact fallout units and tsunami deposits, Pilbara Craton, Western Australia (in prep.) *by* A. Y. GLIKSON and J. VICKERS: Western Australia Geological Survey, Report 102, Plate 1.

GLIKSON, A. Y., and VICKERS, J., in prep., Archean to early Proterozoic asteroid impact fallout units and related tsunami deposits, Pilbara Craton, Western Australia: Western Australia Geological Survey, Report 102.

GREGORY, A. C., and GREGORY, F. T., 1884, Journals of Australian exploration (facsimile edition 1981): Perth, Western Australia, Hesperian Press, p. 78–79.

HAINES, P. W., MORY, A. J., STEVENS, M. K., and GHORI, K. A. R., 2004, GSWA Lancer 1 Well completion report (basic data) Officer and Gunbarrel Basins, Western Australia: Western Australia Geological Survey, Record 2004/10, 39p.

HASSLER, S. W., ROBEY, H. F., and SIMONSON, B. M., 2000, Bedforms produced by impact-generated tsunami, ~2.6 Ga Hamersley Basin, Western Australia: Sedimentary Geology, v. 135, p. 283–294.

HASSLER, S. W., and SIMONSON, B. M., 2001, The sedimentary record of extraterrestrial impacts in deep-shelf environments: Evidence from the Early Precambrian: Journal of Geology, v. 109, p. 1–19.

HICKMAN, A. H., 1977, New and revised definitions of rock units in The Warrawoona Group, Pilbara Block: Western Australia Geological Survey, Annual Report 1976, p. 53.

HICKMAN, A. H., 1978, Nullagine, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 22p.

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

HICKMAN, A. H., 1984, Archaean diapirism in the Pilbara Block, Western Australia, *in* Precambrian Tectonics Illustrated *edited by* A. KRÖNER and R. GREILING: Stuttgart, Germany, Schweizerbarts'che Verlagsbuchhandlung, p. 113–127.

HICKMAN, A. H., 2004, Geology of the Cooya Pooya 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 25p.

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 in Precambrian time *edited by* P. G. ERIKSSON, W. ALTERMANN, D. R. NELSON, W. U. MUELLER, and O. CATUNEANU: Elsevier, Developments in Precambrian Geology, v. 12, p. 118–139.

HOCKING, R. M., LANGFORD, R. L., THORNE, A. M., SANDERS, A. J., MORRIS, P. A., STRONG, C. A., GOZZARD, J. R., and RIGANTI, A., 2005, A classification system for regolith in Western Australia — an update: Western Australia Geological Survey, Record 2005/10, 19p.

HOCKING, R. M., MORY, A. J., and WILLIAMS, I. R., 1994, An atlas of Neoproterozoic and Phanerozoic basins of Western Australia, *in* The sedimentary basins of Western Australia *edited by* P. C. PURCELL and R. R. PURCELL: Petroleum Exploration Society of Australia Symposium, Perth, Western Australia, 1994, Proceedings, p. 21–43.

HOME, D. P., 1995, Final report on exploration completed within exploration licence E45/1439 (Carawine 1) Nullagine 1:250 000 mapsheet, Western Australia, CRA Exploration Pty Limited: Western Australia Geological Survey, Statutory mineral exploration report, A43403 (unpublished).

JAHN, B. M., and SIMONSON, B. M., 1995, Carbonate Pb–Pb ages of the Wittenoom Formation and Carawine Dolomite, Hamersley Basin, Western Australia (with implications for their correlation with the Transvaal Dolomite of South Africa): Precambrian Research, v. 72, p. 247–261.

KEMPTON, N. H., 1976, Relinquishment Report, Temporary reserves 5984H–5988H Western Australia: Western Australia Geological Survey, Statutory mineral exploration report, A35830 (unpublished).

KNIGHT, B. K., 1994, Annual report on exploration completed within exploration licence E45/1439 (Carawine 1) for the period ending October 1994, Nullagine 1:250 000 mapsheet, Western Australia, CRA Exploration Pty Limited: Western Australia Geological Survey, Statutory mineral exploration report, A43323 (unpublished).

KOJAN, C. J., and HICKMAN, A. H., 1998, Late Archaean volcanism in the Kylena and Maddina Formations, Fortescue Group, west Pilbara: Western Australia Geological Survey, Annual Review 1997–98, p. 43–53.

KRIEWALDT, M., 1964, The Fortescue Group of the Roebourne region, North-West Division: Western Australia Geological Survey, Annual Report 1963, p. 30–34.

LIPPLE, S. L., 1975, Definitions of new and revised stratigraphic units of the eastern Pilbara Region: Western Australia Geological Survey, Annual Report 1974, p. 58–63.

LONGREACH METALS NL., 1974, Ripon Hills manganese/iron exploration, 1971–1974: Western Australia Geological Survey, Statutory mineral exploration report, A3973, A5053 (unpublished).

MacLEOD, W. N., and de la HUNTY, L. E., 1966, Roy Hill, W.A. (1st edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 27p.

MacLEOD, W. N., de la HUNTY, L. E., JONES, L. E., and HALLIGAN, R., 1963, A preliminary report on the Hamersley Iron province, North-West Division: Western Australia Geological Survey, Annual Report 1962, p. 44–54.

MAITLAND, A. G., 1906, Third report on the geological features and mineral resources of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 23, 92p.

MARTIN, D. McB., SHEPPARD, S., and THORNE, A. M., 2005, Geology of the Maroonah, Ullawarra, Capricorn, Mangaroon, Edmund, and Elliot Creek 1:100 000 sheets: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 65p.

MARTIN, D. McB., and THORNE, A. M., 2001, New insights into the Bangemall Supergroup: Western Australia Geological Survey, Record 2000/5, p. 1–2.

McPHIE, J., DOYLE, M., and ALLEN, R., 1993, Volcanic textures — a guide to the interpretation of textures in volcanic rocks: University of Tasmania, Centre for Ore Deposit and Exploration Studies, 189p.

MIDDLETON, M. F., 1990, Canning Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 425–457.

MORY, A. J., and BACKHOUSE, J., 1997, Permian stratigraphy and palynology of the Carnarvon Basin, Western Australia: Western Australia Geological Survey, Report 51, 41p.

MUHLING, P. C., and BRAKEL, A. T., 1985, Geology of the Bangemall Group — the evolution of an intracratonic Proterozoic basin: Western Australia Geological Survey, Bulletin 128, 266p.

MUSKETT, G. H., 1960, Beneficiation of manganese ores from Balfour Downs and Ripon Hills, Pilbara, W. A.: Australia CSIRO and the School of Mines of Western Australia, Kalgoorlie, Ore-dressing Investigations Report No. 710, 11p.

MYERS, J. S., SHAW, R. D., and TYLER, I. M., 1996, Tectonic evolution of Proterozoic Australia: Tectonics, v. 15, no. 6, p. 1431–1446.

NELSON, D. R., 1998, 144993: dacite, Booloomba Pool, *in* Compilation of geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, p. 133–135.

NELSON, D. R., 2001, 168935: volcaniclastic sandstone, Sophie Tank, *in* Compilation of geochronology data, 2000: Western Australia Geological Survey, Record 2001/2, p. 175–177.

NELSON, D. R., 2004a, 144682: foliated biotite tonalite, Baroona Hill; Geochronology dataset 274, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2004b, 169037: porphyritic rhyolite, King Rockhole; Geochronology dataset 152, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005a, 169260: foliated biotite tonalite, Bullyarrie Well; Geochronology dataset 569, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005b, 169261: gneissic tonalite, Bullyarrie Well; Geochronology dataset 570, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005c, 169262: foliated biotite granodiorite, Bullyarrie Well; Geochronology dataset 571, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005d, 169263: tonalite gneiss, Bullyarrie Well; Geochronology dataset 572, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005e, 178008: biotite–muscovite tonalite gneiss, Mount Elsie; Geochronology dataset 548, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., LOVE, G. J., BODORKOS, S., and WINGATE, M. T. D., 2006, 178086: porphyritic dacite, Carawine Pool; Geochronology dataset 631, *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NOLDART, A. J., and WYATT, J. D., 1962, The geology of portion of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 115, 199p.

O'DRISCOLL, D., 1958, Report on the inspection of manganese deposits in Western Australia. September, 1957: Australia Bureau of Mineral Resources, Record 1958/7a, 19p.

ONO, S., EIGENBRODE, J. L., PAVLOV, A. A., KHARECHA, P., RUMBLE III, D., KASTING, J. F., and FREEMAN, K. H., 2003, New insights into Archean sulfur cycle from mass-independent sulfur isotope records from the Hamersley Basin, Australia: Earth and Planetary Science Letters, v. 213, p. 15–30.

PACKER, B. M., 1990, Palaeontology, sedimentology, and stable isotope geochemistry of selected formations in the 2.8 Ga old Fortescue Group: Los Angeles, U.S.A., University of California, PhD thesis (unpublished).

PLAYFORD, P. E., 2001, The Permo-Carboniferous glaciation of Gondwana: its legacy in Western Australia: Western Australia Geological Survey, Record 2001/5, p. 15–16.

PLAYFORD, P. E., 2002, Palaeokarst, pseudokarst, and sequence stratigraphy in Devonian reef complexes of the Canning Basin, Western Australia, *in* The sedimentary basins of Western Australia 3 *edited by* M. KEEP and S. J. MOSS: Petroleum Exploration Society of Australia, Symposium, Perth, W.A., 2002, Proceedings, p. 763–793.

PURVIS, A. C., 2003a, Mineralogical Report No. 8318: Kent Town, South Australia, Pontifex & Associates Pty. Ltd., 93p.

PURVIS, A. C., 2003b, Mineralogical Report No. 8331: Kent Town, South Australia, Pontifex & Associates Pty. Ltd., 81p.

PURVIS, A. C., 2003c, Mineralogical Report No. 8414: Kent Town, South Australia, Pontifex & Associates Pty. Ltd., 26p.

RASMUSSEN, B., BLAKE, T. S., and FLETCHER, I. R., 2005, U–Pb zircon age constraints on the Hamersley spherule beds: Evidence for a single 2.63 Ga Jeerinah-Carawine impact ejecta layer: Geology, v. 33(9), p. 725–728.

RASMUSSEN, B., and FLETCHER, I. R., 2004, Zirconolite: A new U–Pb chronometer for mafic igneous rocks: Geology, v. 32(9), p. 785–788; Correction to text, Geology, v. 32, p. 892.

RASMUSSEN, B., and KOEBERL, C., 2004, Iridium anomalies and shocked quartz in a Late Archean spherule layer from the Pilbara craton: New evidence for a major asteroid impact at 2.63 Ga: Geology, v. 32(12), p. 1029–1032.

RICHARDS, M. N., 1985, Final report on exploration completed within exploration licences Ripon Hills north 45/63, Ripon Hills south 45/64, Gingarrigan Creek 45/05, Nullagine SF 51-5, Western Australia: Western Australia Geological Survey, Statutory mineral exploration report, A15932 (unpublished).

SENTINEL MINING COMPANY, 1967, 1967 Report, TRs, 4102–4107H Warrawagine Basin, TR 4090H Mt Cecelia: Western Australia Geological Survey, Statutory mineral exploration report, A1153 (unpublished).

SIMONSON, B. M., 1992, Geological evidence for a strewn field of impact spherules in the early Precambrian Hamersley Basin of Western Australia: Geological Society of America, Bulletin, v. 104, p. 829–839.

SIMONSON, B. M., 2003, Petrographic criteria for recognizing certain types of impact spherules in well-preserved Precambrian successions: Astrobiology v. 3, no. 1, p. 49–65.

SIMONSON, B. M., BYERLY, G. R., and LOWE, D. R., 2004, The early Precambrian stratigraphic record of large extraterrestrial impacts: *in* The Precambrian Earth: Tempos and Events in Precambrian Time *edited by* P. G. ERIKSSON, W. ALTERMANN, D. R. NELSON, W. U. MUELLER, and O. CATUNEANU: Elsevier, Developments in Precambrian Geology, 12, p. 27–45.

SIMONSON, B. M., DAVIES, D., WALLACE, M., REEVES, S., and HASSLER, S. W., 1998, Iridium anomaly but no shocked quartz from Late Archean microkrystite layer: Oceanic impact ejecta?: Geology, v. 26, p. 195–198.

SIMONSON, B. M., and GLASS, B. P., 2004, Spherule layers — Records of ancient impacts: Annual Review Earth and Planetary Sciences, v. 32, p. 329–361.

SIMONSON, B. M., and HARNIK, P., 2000, Have distal impact ejecta changed through geologic time?: Geology, v. 28, p. 975–978.

SIMONSON, B. M., and HASSLER, S. W., 1997, Revised correlations in the Early Precambrian Hamersley Basin based on a horizon of resedimented impact spherules: Australian Journal of Earth Sciences, v. 44, p. 37–48.

SIMONSON, B. M., HASSLER, S. W., and SCHUBEL, K. A., 1993a, Lithology and proposed revisions in stratigraphic nomenclature of the Wittenoom Formation (Dolomite) and overlying formations, Hamersley Group, Western Australia: Western Australia Geological Survey, Report 34, Professional Papers, p. 65–79.

SIMONSON, B. M., HASSLER, S. W., SMIT, J., and SUMNER, D., 2002, How many Late Archaean impacts are recorded in the Hamersley Basin of Western Australia?, Abstracts, 33rd Lunar and Planetary Science Conference, Houston, Texas, 2002: Oberlin College Geology, Ohio, Abstract no. 1772.

SIMONSON, B. M., HORNSTEIN, M., and HASSLER, S. W., 2000, Particles in Late Archean Carawine Dolomite (Western Australia) resemble Muong Nong-type tektites, *in* Impacts and the early Earth; proceedings of the first workshop of the European Science Foundation Scientific Program on the response of the earth system to impact processes *edited by* I. GILMOUR and C. KOEBERL: Heidelberg, Springer-Verlag, p. 81–213.

SIMONSON, B. M., and JARVIS, D. G., 1993, Microfabrics of oolites and pisolites in the early Precambrian Carawine Dolomite of Western Australia, *in* Carbonate microfabrics *edited by* R. REZAK and D. LAVAI: New York, Springer–Verlag, p. 227–237.

SIMONSON, B. M., SCHUBEL, K. A., and HASSLER, S. W., 1993b, Carbonate sedimentology of the early Precambrian Hamersley Group of Western Australia: Precambrian Research, v. 60, p. 287–335.

SMITH, R. N., 1898, The probability of obtaining artesian water between the Pilbara Goldfields and the Great Sandy Desert: Western Australia Geological Survey, Bulletin 1, part 2, p. 24–27.

STERN, H., de HOEDT, G., and ERNST, J., 2004, Objective classification of Australian climates: Commonwealth of Australia 2004, Bureau of Meteorology, viewed 22 April 2005, <http://www.bom.gov.au/climate/environ/other/koppen_explain.shtml.>

STEVENS, M. K., and APAK, S. N., (compilers), 1999, GSWA Empress 1 and 1A well completion report, Yowalga Sub-basin, Officer Basin, Western Australia: Western Australia Geological Survey, Record 1999/4, 110p.

STURMAN, A. P., and TAPPER, N. J., 1996, The weather and climate of Australia and New Zealand: United Kingdom, Oxford University Press, 476p.

TAPP, R. G., and BARRELL, S. L., 1984, The northwest Australian cloud band: climatology, characteristics and factors associated with development: Journal of Climatology, v. 4, p. 411–424.

THORNE, A. M., and TRENDALL, A. F., 2001, Geology of the Fortescue Group, Pilbara Craton, Western Australia: Western Australia Geological Survey, Bulletin 144, 249p.

THORNE, A.M., TYLER, I. M., and HUNTER, W. M., 1991, Turee Creek, W.A. (2nd edition); Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 29p.

TOWNER, R. R., and GIBSON., D. L., 1983, Geology of the onshore Canning Basin, Western Australia: Australia Bureau of Mineral Resources, Bulletin 215, 51p.

TRAVES, D. M., CASEY, J. N., and WELLS, A. T., 1956, The geology of the southwestern Canning basin, Western Australia: Australia Bureau of Mineral Resources, Report 29, 74p.

TRENDALL, A. F., 1990, Pilbara Craton — introduction, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 128.

TRENDALL, A. F., 1991, Progress report on the stratigraphy and structure of the Fortescue Group in the Gregory Range area of the eastern Pilbara Craton: Western Australia Geological Survey, Record 1990/10, 38p.

TRENDALL, A. F., COMPSTON, W., NELSON, D. R., de LAETER, J. R., and BENNETT, V. C., 2004, SHRIMP zircon ages constraining the depositional chronology of the Hamersley Group, Western Australia: Australian Journal of Earth Sciences, v. 51, p. 621–644.

TRENDALL, A. F., NELSON, D. R., de LAETER, J. R., and HASSLER, S. W., 1998, Precise zircon U–Pb ages from the Marra Mamba Iron Formation and Wittenoom Formation, Hamersley Group, Western Australia: Journal of Earth Sciences, v. 45, p. 137–142.

TYLER, I. M., and HOCKING, R. M., 2002, A revision of the tectonic units of Western Australia: Western Australia Geological Survey, Annual Review 2000–01, p. 33–44.

TYLER, I. M., and THORNE, A. M., 1990, The northern margin of the Capricorn Orogen, Western Australia — an example of an early Proterozoic collision zone: Journal of Structural Geology, v. 12, p. 685–701.

VAN KRANENDONK, M. J., 2003, Stratigraphic and tectonic significance of eight local unconformities in the Fortescue Group, Pear Creek Centrocline, Pilbara Craton, Western Australia: Western Australia Geological Survey, Annual Review 2001–02, p. 70–79.

VAN KRANENDONK, M. J., COLLINS, W. J., HICKMAN, A. H., and PAWLEY, M. J., 2004a, Critical tests of vertical vs. horizontal tectonic models for the Archaean East Pilbara Granite–Greenstone Terrane, Pilbara Craton, Western Australia: Precambrian Research, v. 131, p. 173–211.

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

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

VAN KRANENDONK, M. J., SMITHIES, R. H., HICKMAN, A. H., BAGAS, L., WILLIAMS, I. R., and FARRELL, T. R., 2006, Revised lithostratigraphy of Archean supracrustal and intrusive rocks in the northern Pilbara Craton, Western Australia: Western Australia Geological Survey, Record 2006/15, 63p.

VEEVERS, J. J., and WELLS, A. T., 1961, The geology of the Canning Basin, Western Australia: Australia Bureau of Mineral Resources, Bulletin 60, p. 197.

WAKELIN-KING, G. A., 1999, Banded mosaic (‘tiger bush’) and sheetflow plains: a regional mapping approach: Australian Journal of Earth Sciences, v. 46, p. 53–60.

WEBB, R., 1994, A new caving area — East Pilbara (EP): W.A. Speleological Group, The Western Caver, v. 34, p. 51–53.

WELLMAN, P., 2000, Upper crust of the Pilbara Craton, Australia; 3D geometry of a granite/greenstone terrain: Precambrian Research, v. 104, p. 175–186.

WILLIAMS, I. R., 1989, Balfour Downs, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 38p.

WILLIAMS, I. R., 1999, Geology of the Muccan 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

WILLIAMS, I. R., 2001, Geology of the Warrawagine 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

WILLIAMS, I. R., 2003, Yarrie, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 84p.

WILLIAMS, I. R., 2005, Yilgalong, W.A. Sheet 3055 (Version 1, June 2005): Western Australia Geological Survey, 1:100 000 Geological Series.

WILLIAMS, I. R., in prep., Nullagine, W.A. Sheet SF 51-5 (Version 1): Western Australia Geological Survey, 1:250 000 Geological Series.

WILLIAMS, I. R., and BAGAS, L., in prep., Geology of the Mount Edgar 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

WILLIAMS, I. R., and TRENDALL, A. F., 1998a, Geology of the Braeside 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.

WILLIAMS, I. R., and TRENDALL, A. F., 1998b, Geology of the Pearana 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

WILLIAMS, I. R., and TRENDALL, A. F., 1998c, Geology of the Isabella 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 24p.

WILLIAMS, K. L., 1958, Manganese ore from Rippon (sic) Hills, Western Australia: Australia CSIRO, Mineragraphic Investigations, Report No. 747, 4p.

WILLIAMS, K. L., 1960, Manganese ore from Ripon Hills, Western Australia: Australia CSIRO, Mineragraphic Investigations, Report No. 825, 11p.

WINGATE, M. T. D., and GIDDINGS, J. W., 2000, Age and paleomagnetism of the Mundine Well dyke swarm, Western Australia: implications for an Australia–Laurentia connection at 755 Ma: Precambrian Research, v. 100, p. 335–357.

WOODHEAD, J. D., HERGT, J. M., and SIMONSON, B. M., 1998, Isotopic dating of an Archean bolide impact horizon, Hamersley Basin, Western Australia: Geology, v. 26, p. 47–50.

WOODWARD, H. P., 1894, Mining Handbook to the Colony of Western Australia, Written especially for Prospectors and Strangers to the colony who are interested in mining, by authority of The Commissioner of Crown Lands: Perth, Western Australia, Government Printer, 68p.

Appendix 1

Gazetteer of localities for YILGALONG

Locality	MGA coordinates Easting	Northing
Barbilgunyah Hill	288891	7648165
Bookabunna Well	250773	7644502
Bullyarrie Well	259368	7628908
Carawine Pool (BRAESIDE 1:100 000)	303080	7615893
Cave Bore	264918	7670602
Dingo Well	262196	7633614
Gap Well	283597	7655635
GingarriganWell	290248	7673531
Little River Spring Bore	277894	7651067
Little River Well	283482	7671072
Meentheena copper prospect	244790	7638975
Mishap Well	253810	7636096
Mopoke Well	248661	7638951
Mount Ian	266422	7646424
Mount Ian Well	258398	7640701
New 20 Mile Well	279115	7669495
NMF 625 Trig Point	245210	7632292
Nullagine 1 Trig Point	263456	7651701
Outcamp Bore	264580	7674802
Pearana Rockhole (PEARANA 1:100 000)	317186	7576390
Pulgorah Cone	291892	7643893
RHDH1 (borehole)	280266	7642601
RHDH2A (borehole)	274508	7644780
Rocky Pool	248883	7669618
Salvation Well	243171	7627058
20 Mile Well	269086	7665917
Walgunya Well	245866	7670850
Yilgalong Pool	283611	7674744

Appendix 2

Definition of new stratigraphic names on YILGALONG

Midgengadgi Monzogranite (*ACEmi-gm*)

Derivation of name: Midgengadge Creek, a northeasterly flowing tributary of the Oakover River (MGA 286100E 7632000N).

Distribution: A small intrusion of unknown shape unconformably overlain by Fortescue Group rocks, exposed dimensions are roughly 2 km northeast by 2 km northwest, lies on the southeastern margin of the exposed part of the Yigalong Granitic Complex. Possibly further small unfoliated tonalite, microgranodiorite and micromonzogranite intrusions and dykes scattered through the Yigalong Granitic Complex belong to the Cleland Supersuite

Type areas: Well exposed tor-covered sheets (around MGA 276390E 7623252N), 17.5 km southeast of Dingo Well.

Lithology: Nonfoliated, seriate to porphyritic, medium- to coarse-grained leucocratic biotite monzogranite.

Relationships: Belongs to the Cleland Supersuite, intruded into Elsie Creek Tonalite, unconformably overlain by the lower and upper successions of the Kylena Formation including the Mopoke Member.

Age: Main body has a sensitive high-resolution ion microprobe (SHRIMP) zircon U–Pb date of 3274 ± 5 Ma (GSWA 178089; Bordokos et al., 2006). A weakly foliated biotite tonalite gave a SHRIMP zircon U–Pb date of 3277 ± 6 Ma (GSWA 169260; Nelson, 2005a). This sample also contained five zircon xenocrysts that have a SHRIMP zircon U–Pb date of 3308 ± 5 Ma.

Little River Trondhjemite *(ACElr-gtl)*

Derivation of name: Little River, a northeasterly flowing tributary of Yilgalong Creek (MGA 262300E 7622000N).

Distribution: A faulted (western edge) semicircular intrusion, unconformably overlain by Fortescue Group rocks, lies on the northern margin towards the eastern end of the exposed Yigalong Granitic Complex.

Type areas: In water-worn sheets along the eastern side of Yilgalong Creek, 9.9 km southeast of Dingo Well (MGA 268987E 7626599N).

Lithology: Massive, fine- to medium-grained leucocratic quartz trondhjemite.

Relationships: Probably belongs to the Cleland Supersuite; intruded into Elsie Creek Tonalite; unconformably overlain by the lower and upper successions of the Kylena Formation including the Mopoke Member.

Age: Post-Elsie Creek Tonalite, therefore younger than c. 3290 Ma.

Elsie Creek Tonalite (*AEMel-mgtn*)

Derivation of name: Elsie Creek, a west flowing tributary of the Nullagine River (MGA 244000E 7622000N).

Distribution: Apart from the Midgengadgi Monzogranite and Little River Trondhjemite, it occupies the remainder of the Yigalong Granitic Complex that lies along the southern margin of YILGALONG in the southwest corner.

Type areas: In gorges along the western margin of the Yilgalong Granitic Complex 150 to 200 m east of the contact with the Mount Elsie greenstone belt: a) in unnamed creek (MGA 244390E 7623250N); b) on south bank of Elsie Creek (MGA 244910E 7621670N).

Lithology: Gneissic to foliated, fine- to medium-grained biotite tonalite and granodiorite, minor monzogranite, tonalite gneiss; protomylonitic at the margin with Mount Elsie greenstone belt.

Relationships: Belongs to the Emu Pool Supersuite, has a sheared intrusive contact with the Euro Basalt of the Mount Elsie greenstone belt on the western side and unassigned amphibolites on the eastern edge on the Yigalong Granitic Complex, and is unconformably overlain by the Hardey and Kylena Formations of the Fortescue Group along the northern margin.

Age: Five SHRIMP zircon U–Pb dates have been obtained from the Elsie Creek Tonalite: a) 3299 ± 5 Ma (GSWA 144682; Nelson, 2004); b) 3291 ± 4 Ma (GSWA 169262; Nelson, 2005c); c) 3291 ± 4 Ma (GSWA 169261; Nelson, 2005b); d) 3290 ± 4 Ma (GSWA 169263; Nelson, 2005d).

Mopoke Member

Derivation of name: Mopoke Well (MGA 248661E 7638951N).

Distribution: Exposed discontinuously across the southwest quarter of YILGALONG; lies in the lower third of the Kylena Formation between 5 km north of the Ripon Hills road on the western edge and the southern edge of the sheet area, 17 km southeast of Dingo Well.

Type areas: Prominent low cliff-lines (2–3 m high) of Mopoke Formation on southern side of Ripon Hills road (MGA Zone 51 244521E 7648675N), 7.5 km northwest of Bookabunna Well; small cliffed cuesta (3 m high) of stromatolitic dolomite, interbedded chert and ripple-marked, fine-grained sandstone and siltstone (MGA Zone 51 246377E 7641976N), 3.8 km northwest of Mopoke Well; a rubbly cliffed exposure (3 m high) of dolomite and calcareous, pebbly sandstone resting nonconformably on Little River Trondhjemite (Yilgalong Granitic Complex; MGA 269362E 7627124N), 9.6 km southeast of Dingo Well.

Lithology: Cliff-forming, silicified blue-grey carbonates, mostly limestone or dolomitic limestone, up to 5 m thick, interbedded and overlain by thin-bedded, grey to cream, calcareous and tuffaceous siltstone and shale, ripple-marked fine-grained sandstone and thin blue chert beds; partly silicified carbonates locally carry stromatolites and microbial laminations.

Relationships: A discontinuous marker bed in the lower third of the Kylena Formation. It separates the lower succession of grey-blue tholeiitic basalt and greenish-grey komatiitic basalt from the upper succession of grey and bluish-grey basalt and basaltic andesite, both successions have distinctive radiometric signatures; it locally overlies a mixed mafic–felsic volcanic and volcaniclastic succession 16.5 km southeast of Dingo Well; has been recognized on the adjoining EASTERN CREEK and MOUNT EDGAR sheets.

Age: The Mopoke Member has not been dated directly; however, it is younger than the mafic to felsic volcanic and volcaniclastic succession dated at c. 2749–2735 Ma of the Kylena Formation and older than the overlying c. 2727 Ma Mingah Member of the Tumbiana Formation.

References

BODORKOS, S., LOVE, G. J., and NELSON, D. R., and WINGATE, M. T. D., 2006, 178089: leucocratic monzogranite, Dingo Well; Geochronology dataset 632, *in* Compilation of geochronology data, March 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2004, 144682: foliated biotite tonalite, Baroona Hill; Geochronology dataset 274 *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005a, 169260: foliated biotite tonalite, Bullyarrie Well; Geochronology dataset 569 *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005b, 169261: gneissic tonalite, Bullyarrie Well; Geochronology dataset 570 *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005c, 169262: foliated biotite granodiorite, Bullyarrie Well; Geochronology dataset 571 *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

NELSON, D. R., 2005d, 169263: tonalite gneiss, Bullyarrie Well; Geochronology dataset 572 *in* Compilation of geochronology data, June 2006 update: Western Australia Geological Survey.

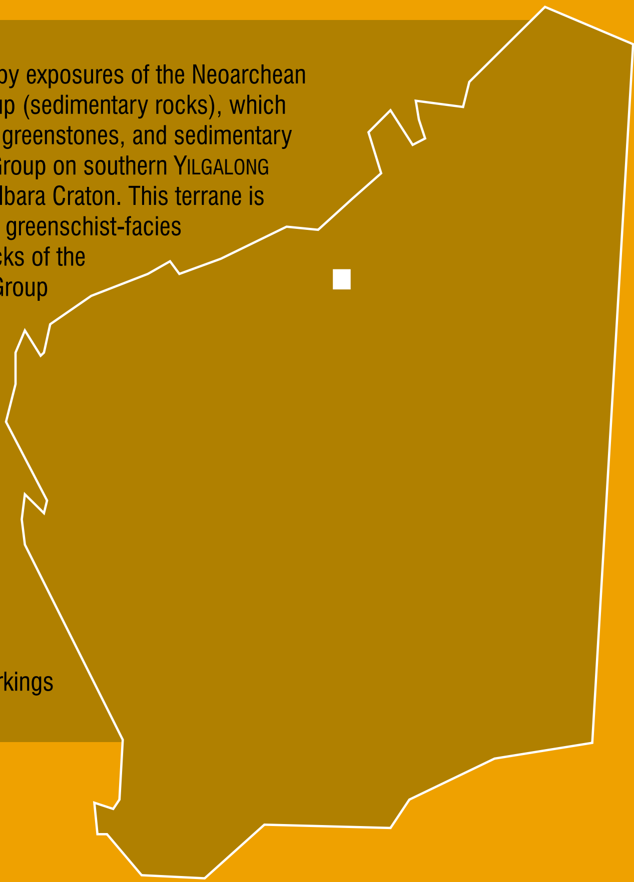
Appendix 3

Company data on GSWA WAMEX open file for YILGALONG

*WAMEX Item no.**	*Duration*	*Exploration title*	*Company*
965	1965–1966	Spinaway copper–zinc exploration	CRA Exploration
2275	1965–1970	Reedy Creek copper exploration	Conwest Australia
1957	1966–1968	Cookes Creek copper–molybdenum–tungsten	D.F.D. Rhodes
1840	1966–1973	Nullagine and Balfour Downs iron–manganese	Goldsworthy Mining, Sentinel Mining
966	1969–1972	Ragged Hills copper/lead	Western Mining Corporation
3279	1970–1973	Yarrie nickel–copper/copper–molybdenum	Woodreef Mines, Australian Anglo American, Kitchener Mining
3018	1970–1976	East Pilbara nickel–copper	Mogul Mining
4146	1971–1974	Ripon Hills manganese/iron	Longreach Metals
6348	1974–1979	Woodie Woodie manganese	Broken Hill Pty, Dampier Mining
3224	1974–1982	Ragged Hills lead	Hancock & Wright Prospecting
11530	1975–1975	Shaw River/Oakover River coal	Shell Australia
3194	1982–1983	Rocky pool/Coonanbunna Creek lead–zinc	CRA Exploration
2345	1982–1984	Bamboo Creek gold	Carpentaria Exploration
4148	1982–1985	Woodie Woodie manganese	Preussag Australia
2655	1983–1984	Ripon Hills lead–zinc	CRA Exploration
6734	1986–1987	Baroona Hill gold exploration	Intercontinental Gold and Minerals
12777	1989–2000	Ripon Hills/Woodie Woodie manganese	Valient Consolidated, Valient Manganese
5851	1990–1991	Carawine gold/base metals	MIM Exploration
6948	1993–1993	Outcamp Bore West manganese	Valient Consolidated
8015	1993–1994	Carawine diamond	CRA Exploration
7504	1993–1994	Ripon Hills manganese	Valient Consolidated
8855	1993–1996	Gingarrigan Well manganese	Valient Consolidated
8875	1993–1996	Nullagine River base metals	Normandy Exploration, Ocean Resources
9193	1993–1997	Gingarrigan Well manganese	Valient Consolidated
12043	1993–1998	Baroona Hill/Meentheena gold	Mr M. G. Creasey
10015	1993–1998	Meentheena gold	Normandy Exploration
10470	1993–1999	Gingarrigan Well manganese	Consolidated Minerals, Valient Consolidated
13250	1993–2000	Baroona Hill/Meentheena gold	Mr M. G. Creasey
8321	1994–1995	Yilgalong gold	Mr R. J. Watson
9525	1994–1997	Yilgalong gold	Mr R. J. Watson
11770	1994–2002	Yilgalong gold/nickel	Mr B. J. O'Brien, Plenty River Corporation, Plenty River Gold Mines, Plenty River Mining
11427	1994–2002	Yilgalong gold/base metals	Plenty River Mining
10191	1997–1999	Mount Elsie gold	Darkdale Pty, Minair Exploration
10990	1999–2000	Warrawagine diamond	Stockdale Prospecting
11225	1999–2001	Warrawagine diamond	De Beers Australia Exploration
11923	2000–2002	Haoma Nullagine diamond	Haoma Mining
11841	2000–2003	Yilgalong diamond	Douglass Mitchell

NOTES: WAMEX: Western Australian mineral exploration database containing statutory mineral exploration reports as submitted to the GSWA
* Information available from Department of Industry and Resources Library, Mineral House, 100 Plain Street, East Perth, W.A. 6004

The geology of the YILGALONG 1:100 000 sheet is dominated by exposures of the Neoarchean Fortescue Group (mainly basaltic rocks) and Hamersley Group (sedimentary rocks), which unconformably overlie Paleoarchean–Mesoarchean granites, greenstones, and sedimentary basins of the Pilbara Craton. Deep erosion of the Fortescue Group on southern YILGALONG has exposed a small part of the East Pilbara Terrane of the Pilbara Craton. This terrane is locally composed of the c. 3350 Ma Kelly Group (dominantly greenschist-facies metabasalt) and 3320–3220 Ma metamorphosed granitic rocks of the Emu Pool and Cleland Supersuites. Overlying the Fortescue Group the Hamersley Group is represented by the c. 2540 Ma Carawine Dolomite, which includes remarkably well preserved asteroid impact deposits. Younger Proterozoic units are the Pinjian Chert Breccia, which is a residual deposit on the Carawine Dolmoite, and the Manganese Group. All the Precambrian rocks are unconformably overlain by the fluvioglacial Carboniferous–Permian Paterson Formation. YILGALONG records a long tectonic history, in which deformation after c. 1830 Ma was related to collision between the Pilbara Craton and the Paterson Orogen. Mineral production on YILGALONG has been restricted to manganese deposits along the Carawine Dolomite – Pinjian Chert Breccia unconformity, and small-scale gold workings along shear zones in the Euro Basalt.



These Explanatory Notes are published in digital format (PDF) and are available online at: www.doir.wa.gov.au/GSWA/publications. 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/publications

WILLIAMS

Geology of the Yilgalong 1:100 000 sheet

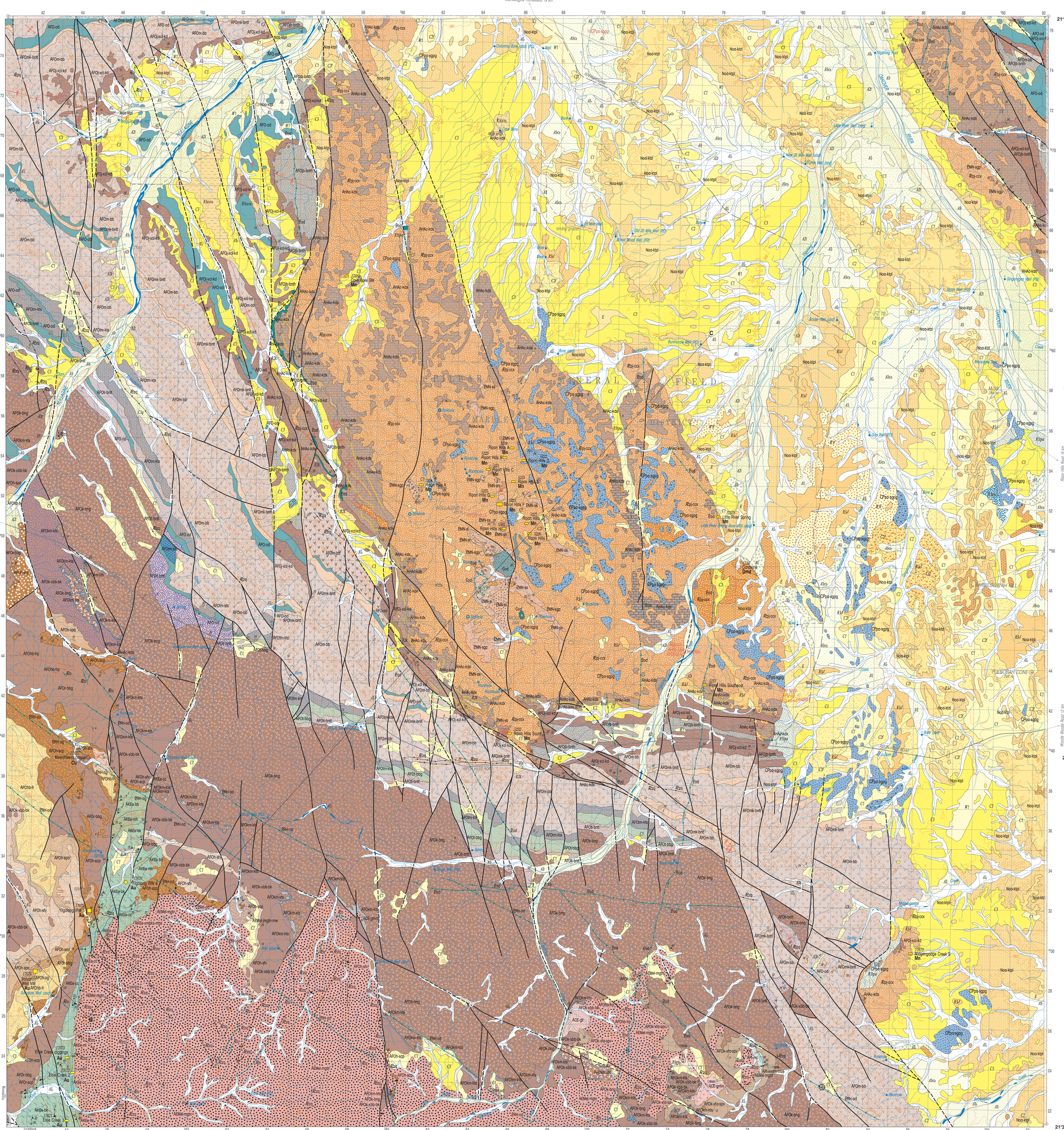
EXPLANATORY NOTES

YILGALONG

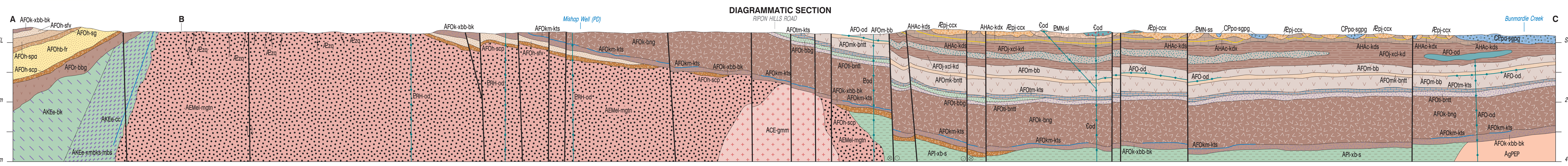
AUSTRALIA 1 : 100 000 GEOLOGICAL SERIES

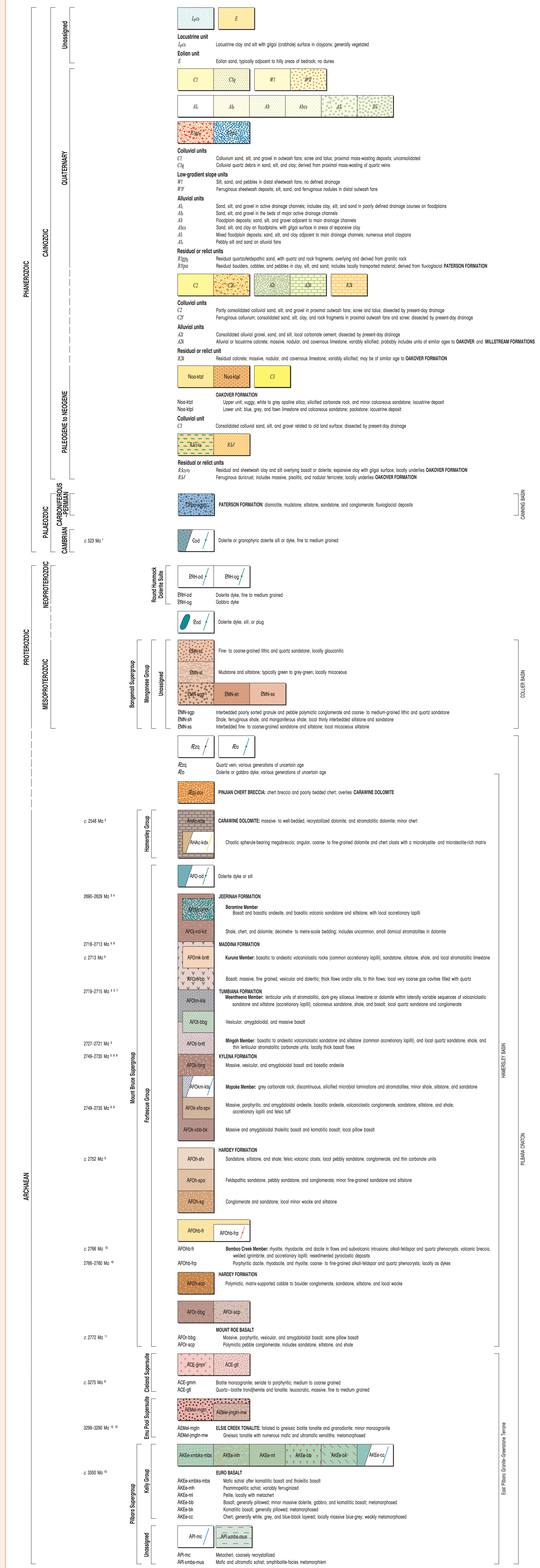
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

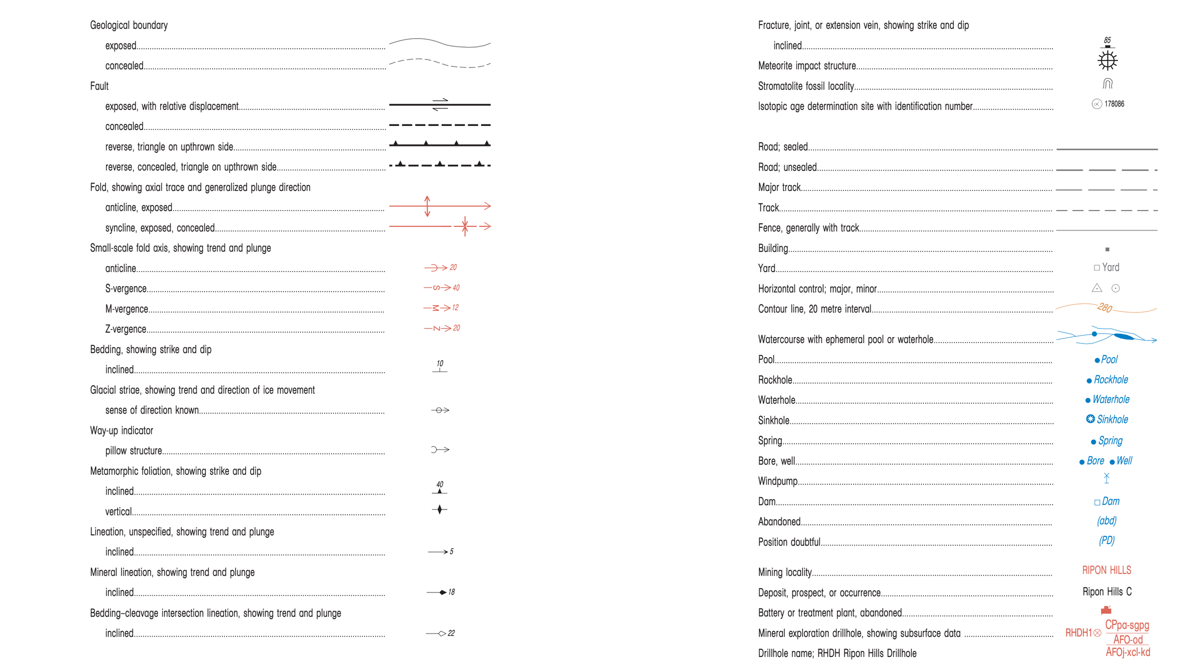
SHEET 3055



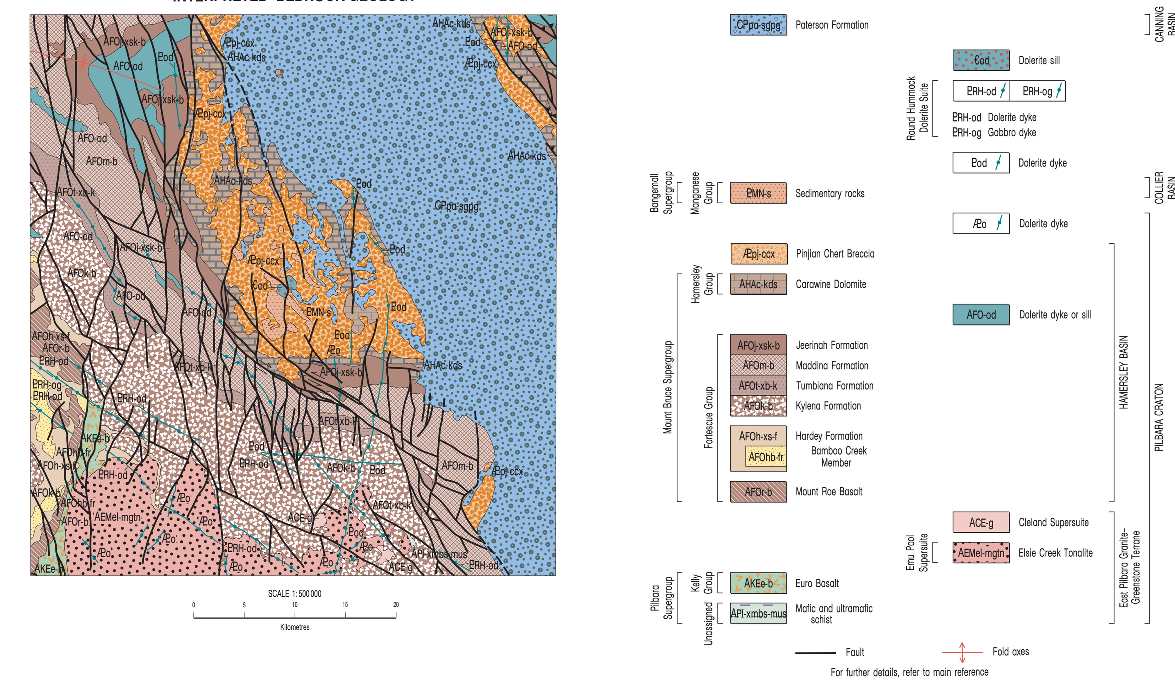
DIAGRAMMATIC SECTION







INTERPRETED BEDROCK GEOLOGY



MINERAL OCCURRENCES

MINERALIZATION STYLES *

- Vein and hydrothermal
- Stratabound sedimentary and/or sedimentary banded iron-formation
- Regolith hosted

MINERAL AND ROCK COMMODITY GROUPS

- Precious mineral
- Precious metal
- Steel industry metal
- Base metal

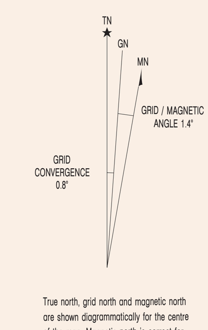
MINERAL AND ROCK COMMODITIES

Copper.......... Cu
Diamond.......... Dmd
Gold.......... Au
Manganese.......... Mn

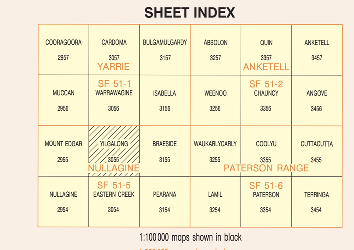
OPERATING STATUS AND SITE IDENTIFICATION NUMBER

Mineral deposit e.g. 5224
Mineral occurrence or prospect e.g. *5231*

Mineral occurrences and numbers are from the GSWA WAMIN database.
*Larger symbols represent mines or deposits also in the DoIR MINEDEX database.



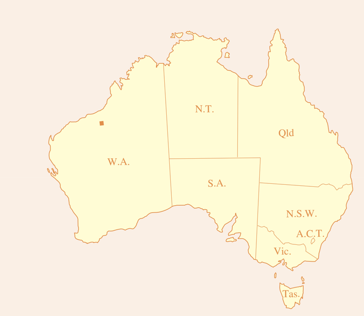
SHEET INDEX



DATA DIRECTORY

Theme	Data Source	Data Currency	Agency
Geology	GSWA	2002–2003	Dept of Industry and Resources
Structural data	WAROX	AUG 2004	Dept of Industry and Resources
Mineral occurrences (non-confidential)	MINDEX*	JUN 2005	Dept of Industry and Resources
	WAMIN*	JUN 2005	Dept of Industry and Resources
Cadastre	TENGRAPH	APR 2004	Dept of Industry and Resources
Horizontal control	GESMAR	AUG 2004	Dept of Land Information
Topographic nomenclature	GEONOMA	2004	Dept of Land Information
Topography	DLI and GSWA field survey	2004	Dept of Land Information

* GSWA and DOIR databases can be viewed online (www.doir.wa.gov.au/aboutus/geoview launch.asp) or can be downloaded from GSWA Data and Software Centre (www.doir.wa.gov.au/GSWA/downloadcentre)



Compiled by I. R. Williams 2003–2004

Geology by I. R. Williams 2002–2003

Geochronology by:

(1) B. Rasmussen and I. R. Fletcher, 2004, Geology, v. 32, p. 785–788.
(2) J. D. Woodhead et al., 1998, Geology, v. 26, p. 47–50.
(3) N. T. Arndt et al., 1991, Australian Journal of Earth Sciences, v. 38, p. 261–281.
(4) D. R. Nelson et al., 1999, Precambrian Research, v. 97, p. 165–189.
(5) T. S. Blake et al., 2004, Precambrian Research, v. 133, p. 143–173.
(6) D. R. Nelson, 1998, GSWA geochronology dataset, GSWA 144993.
(7) D. R. Nelson, 2001, GSWA geochronology dataset, GSWA 168935.
(8) D. R. Nelson, et al., in prep., GSWA geochronology dataset, GSWA 178086.
(9) S. Bodorkos et al., in prep., GSWA geochronology dataset, GSWA 178090, 178089.
(10) D. R. Nelson, in prep., GSWA geochronology dataset, GSWA 169037, 169033, 169043, 169260, 169261, 169262, 169263, 178042.
(11) M. T. D. Wingate, 1999, Australian Journal of Earth Sciences, v. 46, p. 493–500.
(12) D. R. Nelson, 2004., GSWA geochronology dataset, GSWA 144682.

Edited by C. Strong and G. Loan

Cartography by D. Ladbrook and K. Greenberg

Published by the Geological Survey of Western Australia. Digital and hard copies of this map are available from the Information Centre, Department of Industry and Resources, 100 Plain Street, East Perth, WA, 6004. Phone (08) 9222 3459, Fax (08) 9222 3444
Web www.doir.wa.gov.au Email geological.survey@doir.wa.gov.au

The recommended reference for this map is:
WILLIAMS, I. R., 2005, Yilgalong, W.A. Sheet 3055: Western Australia Geological Survey, 1:100 000 Geological Series.

Department of Industry and Resources

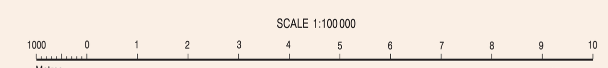
ALAN CARPENTER, M.L.A.
MINISTER FOR STATE DEVELOPMENT

JIM LIMERICK
DIRECTOR GENERAL

Geological Survey of Western Australia

TIM GRIFFIN
DIRECTOR

SCALE 1:100 000



UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Map Grid Australia Zone 51

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

YILGALONG

SHEET 3055 **FIRST EDITION 2005**

Version 1.0 — June 2005