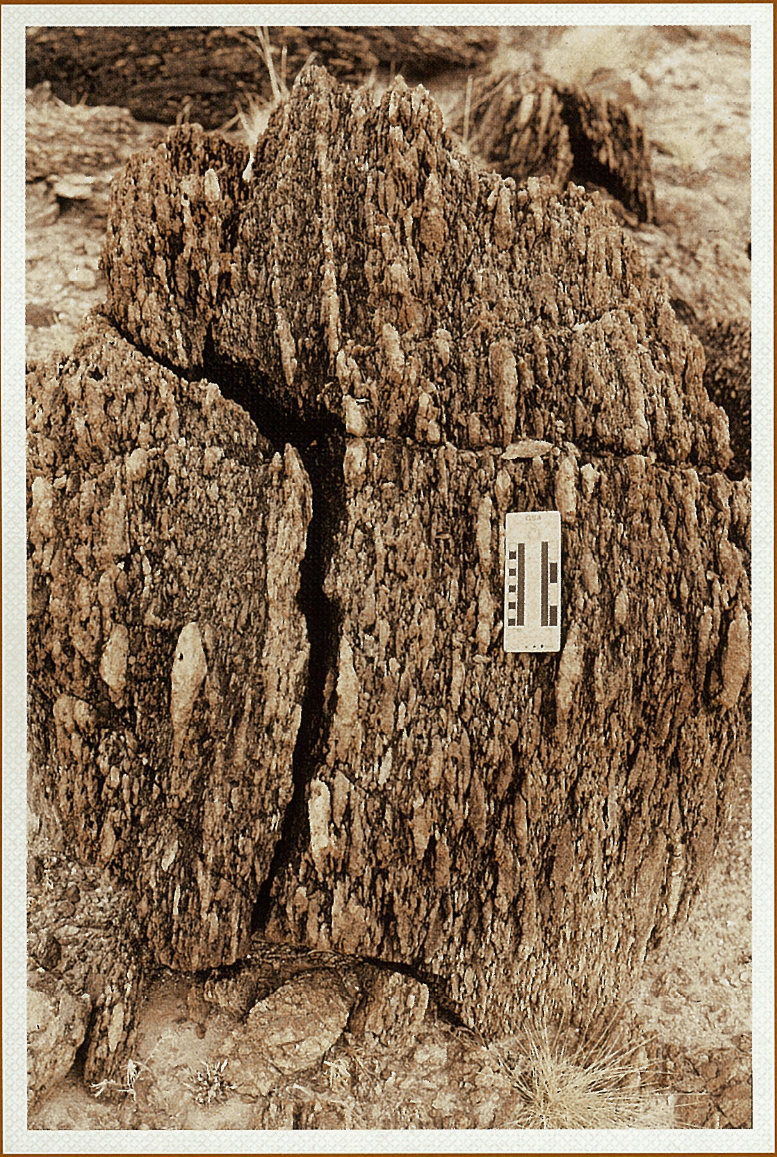
EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE DOCKRELL 1:100 000 SHEET

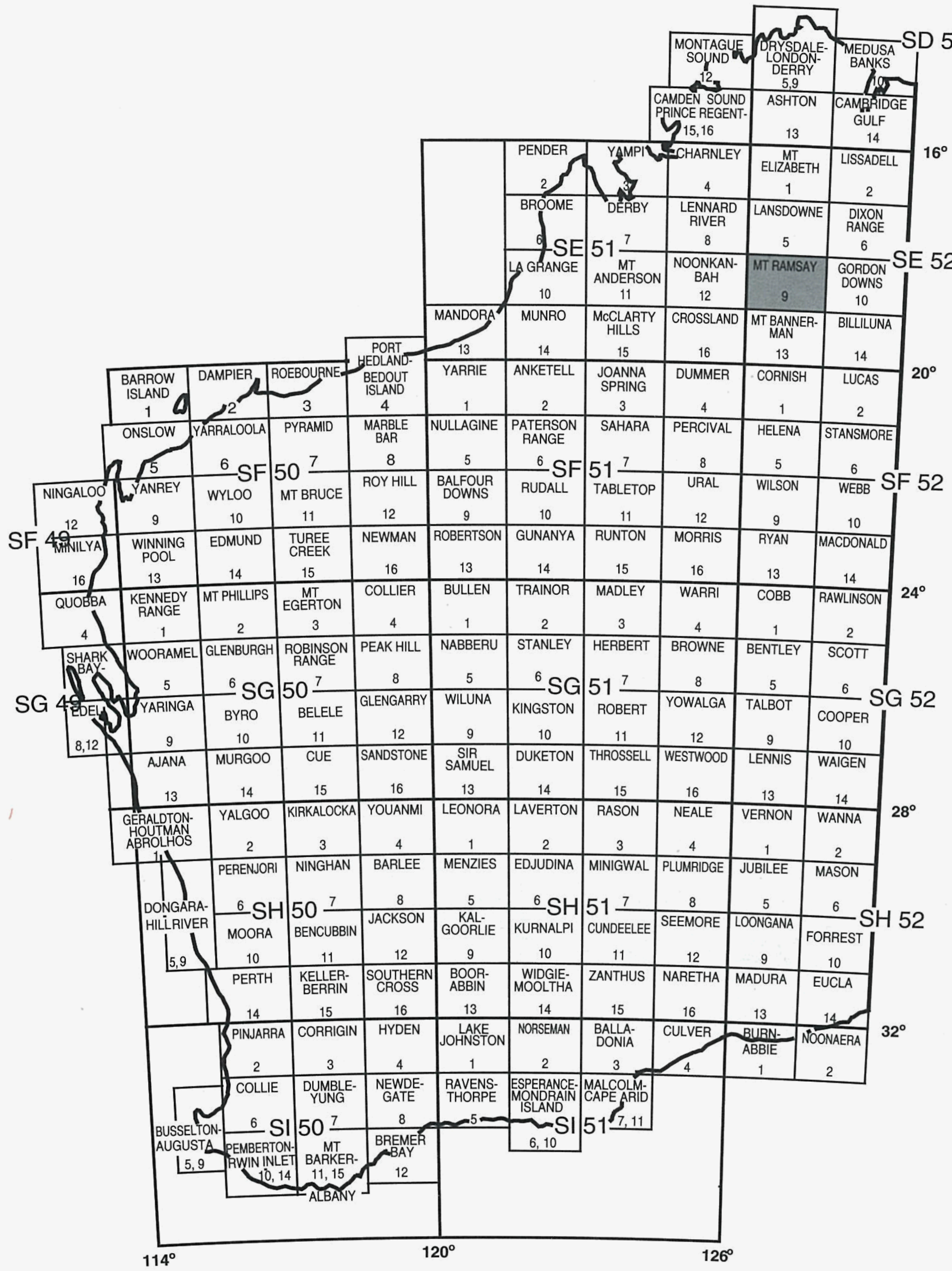
by I. M. Tyler, T. J. Griffin, and S. Sheppard

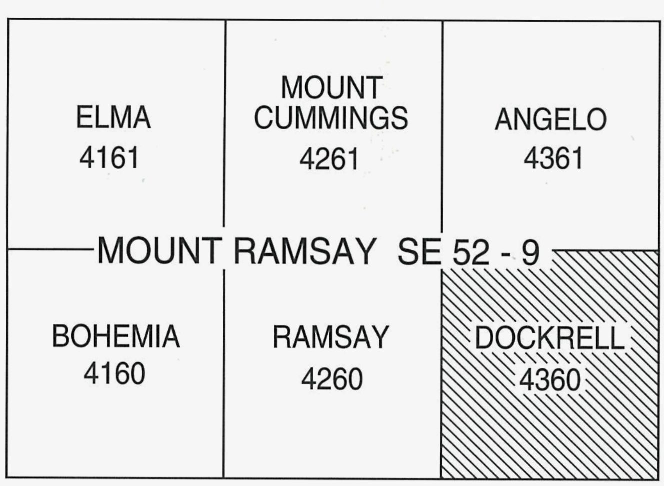
1:100 000 GEOLOGICAL SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY


MONTAGUE SOUND 12
DRYSDALE-LONDON-DERRY 5,9
MEDUSA BANKS 10
SD 52
CAMDEN SOUND PRINCE REGENT- 15,16
ASHTON 13
CAMBRIDGE GULF 14
16°
PENDER 2
YAMPI 3
CHARNLEY 4
MT ELIZABETH 1
LISSADELL 2
BROOME 6
DERBY 7
LENNARD RIVER 8
LANSDOWNE 5
DIXON RANGE 6
SE 51
SE 52
LA GRANGE 10
MT ANDERSON 11
NOONKAN-BAH 12
MT RAMSAY 9
GORDON DOWNS 10
MANDORA 13
MUNRO 14
McCLARTY HILLS 15
CROSSLAND 16
MT BANNER-MAN 13
BILLILUNA 14
BARROW ISLAND 1
DAMPIER 2
ROEBOURNE 3
PORT HEDLAND-BEDOUT ISLAND 4
YARRIE 1
ANKETELL 2
JOANNA SPRING 3
DUMMER 4
CORNISH 1
LUCAS 2
20°
ONSLOW 5
YARRALOOLA 6
PYRAMID 7
MARBLE BAR 8
NULLAGINE 5
PATERSON RANGE 6
SAHARA 7
PERCIVAL 8
HELENA 5
STANSMORE 6
SF 50
SF 51
SF 52
NINGALOO 12
YANREY 9
WYLOO 10
MT BRUCE 11
ROY HILL 12
BALFOUR DOWNS 9
RUDALL 10
TABLETOP 11
URAL 12
WILSON 9
WEBB 10
SF 49
MINILYA 16
WINNING POOL 13
EDMUND 14
TUREE CREEK 15
NEWMAN 16
ROBERTSON 13
GUNANYA 14
RUNTON 15
MORRIS 16
RYAN 13
MACDONALD 14
QUOBBA 4
KENNEDY RANGE 1
MT PHILLIPS 2
MT EGERTON 3
COLLIER 4
BULLEN 1
TRAINOR 2
MADLEY 3
WARRI 4
COBB 1
RAWLINSON 2
24°
SHARK BAY-
WOORAMEL 5
GLENBURGH 6
ROBINSON RANGE 7
PEAK HILL 8
NABBERU 5
STANLEY 6
HERBERT 7
BROWNE 8
BENTLEY 5
SCOTT 6
SG 49
SG 50
SG 51
SG 52
EDEL 8,12
YARINGA 9
BYRO 10
BELELE 11
GLENGARRY 12
WILUNA 9
KINGSTON 10
ROBERT 11
YOWALGA 12
TALBOT 9
COOPER 10
AJANA 13
MURGOO 14
CUE 15
SANDSTONE 16
SIR SAMUEL 13
DUKETON 14
THROSSELL 15
WESTWOOD 16
LENNIS 13
WAIGEN 14
GERALDTON-HOUTMAN ABROLHOS 1
YALGOO 2
KIRKALOCKA 3
YOUANMI 4
LEONORA 1
LAVERTON 2
RASON 3
NEALE 4
VERNON 1
WANNA 2
28°
PERENJORI 6
NINGHAN 7
BARLEE 8
MENZIES 5
EDJUDINA 6
MINIGWAL 7
PLUMRIDGE 8
JUBILEE 5
MASON 6
SH 50
SH 51
SH 52
DONGARA-HILL RIVER 5,9
MOORA 10
BENCUBBIN 11
JACKSON 12
KAL-GOORLIE 9
KURNALPI 10
CUNDEELEE 11
SEEMORE 12
LOONGANA 9
FORREST 10
PERTH 14
KELLER-BERRIN 15
SOUTHERN CROSS 16
BOOR-ABBIN 13
WIDGIE-MOOLTHA 14
ZANTHUS 15
NARETHA 16
MADURA 13
EUCLA 14
PINJARRA 2
CORRIGIN 3
HYDEN 4
LAKE JOHNSTON 1
NORSEMAN 2
BALLA-DONIA 3
CULVER 4
BURN-ABBIE 1
NOONAERA 2
32°
COLLIE 6
DUMBLE-YUNG 7
NEWDE-GATE 8
RAVENS-THORPE 5
ESPERANCE-MONDRAIN ISLAND 6, 10
MALCOLM-CAPE ARID 7, 11
SI 50
SI 51
BUSSELTON-AUGUSTA 5, 9
PEMBERTON-IRWIN INLET 10, 14
MT BARKER-ALBANY 11, 15
BREMER BAY 12
114°
120°
126°


ELMA 4161
MOUNT CUMMINGS 4261
ANGELO 4361
MOUNT RAMSAY SE 52 - 9
BOHEMIA 4160
RAMSAY 4260
DOCKRELL 4360

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE DOCKRELL 1:100 000 SHEET

by
I. M. Tyler, T. J. Griffin, and S. Sheppard

Perth 1998

MINISTER FOR MINES
The Hon. Norman Moore, MLC

DIRECTOR GENERAL
L. C. Ranford

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
David Blight

Copy editor: **D. D. Ferdinando**

REFERENCE

The recommended reference for this publication is:
TYLER, I. M., GRIFFIN, T. J., and SHEPPARD, S., 1998, Geology of the Dockrell 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 24p.

National Library of Australia Card Number and ISBN 0 7309 6614 3

ISSN 1321–229X

The locations of points mentioned in this publication are referenced to the Australian Geodetic Datum 1984 (AGD84)

Cover photograph: Trachyandesitic volcaniclastic breccia from the Butchers Gully Member of the Olympio Formation, Halls Creek Group, exposed in the core of the Garden Creek Anticline. The rock contains flattened scoriaceous clasts, which may be the product of lava fountaining.

Contents

Figures

Tables

Geology of the Dockrell 1:100 000 sheet

by

I. M. Tyler, T. J. Griffin, and S. Sheppard

Abstract

The DOCKRELL 1:100 000 map sheet (SE52-9, 4360) is bounded by latitudes 18°30'S and 19°00'S and longitudes 127°00'E and 127°30'E. The sheet lies entirely within the Halls Creek Orogen, a major northeasterly trending orogenic belt developed within the Proterozoic and Palaeozoic rocks of the East Kimberley region of Western Australia.

The Halls Creek Orogen initially formed during the Palaeoproterozoic between the Kimberley Craton to the northwest, and the North Australian Craton to the east. Palaeoproterozoic rocks of the c. 1910 to 1790 Ma Lamboo Complex share many features with convergent Phanerozoic plate margins associated with subduction of oceanic crust. The oldest rocks are the c. 1910 Ma Ding Dong Downs Volcanics and associated granitoid intrusions, which occur in the Eastern zone of the Lamboo Complex. They are unconformably overlain by the c. 1880 to <1847 Ma Halls Creek Group, which consists mainly of mafic and alkaline volcanic rocks and turbiditic metasedimentary rocks. These were intruded by the Woodward Dolerite. The Tickalara Metamorphics in the Central zone of the Lamboo Complex were deformed and metamorphosed at high grade during the c. 1865 to 1850 Ma Hooper Orogeny, reflecting accretion of an island arc to the edge of the Kimberley Craton. The c. 1843 Ma felsic and mafic volcanic rocks of the Koongie Park Formation, which elsewhere host significant volcanic-associated massive sulfides Zn–Pb–Cu(–Ag) deposits, also occur in the Central zone.

The Eastern, Central, and Western zones of the Lamboo Complex on DOCKRELL are intruded by granitoid and gabbroic rocks of the c. 1835 to 1805 Ma Sally Downs supersuite. Deformation and metamorphism affecting some of the granitoids and the Halls Creek Group took place during the Halls Creek Orogeny, which reflects suturing of the Kimberley and North Australian Cratons at c. 1820 Ma.

Further intrusion of granitoid took place at c. 1790 Ma, followed by pegmatite dykes at c. 1740 Ma, and associated Sn, Ta, Nb, W, Cu, Mo, and F mineralization.

Large-scale, north-northeasterly trending sinistral strike-slip faults, and associated dextral faults developed during the Mesoproterozoic Yampi Orogeny. These structures may have controlled gold mineralization.

The Lamboo Complex is unconformably overlain by c. 610 Ma Neoproterozoic glacigene rocks of the Louisa Downs Group deposited in the Louisa Basin. Sinistral reactivation of the strike-slip faults occured during the c. 560 Ma King Leopold Orogeny deforming the glacigene rocks. This was followed by the eruption of the basaltic rocks of the Antrim Plateau Volcanics in the Ord Basin. Further sinistral strike-slip faulting and associated folding took place during the c. 400 to 300 Ma Alice Spring Orogeny.

The formation of an extensive lateritized plateau surface took place between the Late Cretaceous and Early Miocene.

KEYWORDS: Halls Creek Orogen, Lamboo Complex, Louisa Basin, Ord Basin, Ding Dong Downs Volcanics, Halls Creek Group, Sally Downs supersuite, Louisa Downs Group, Antrim Plateau Volcanics, regional geology

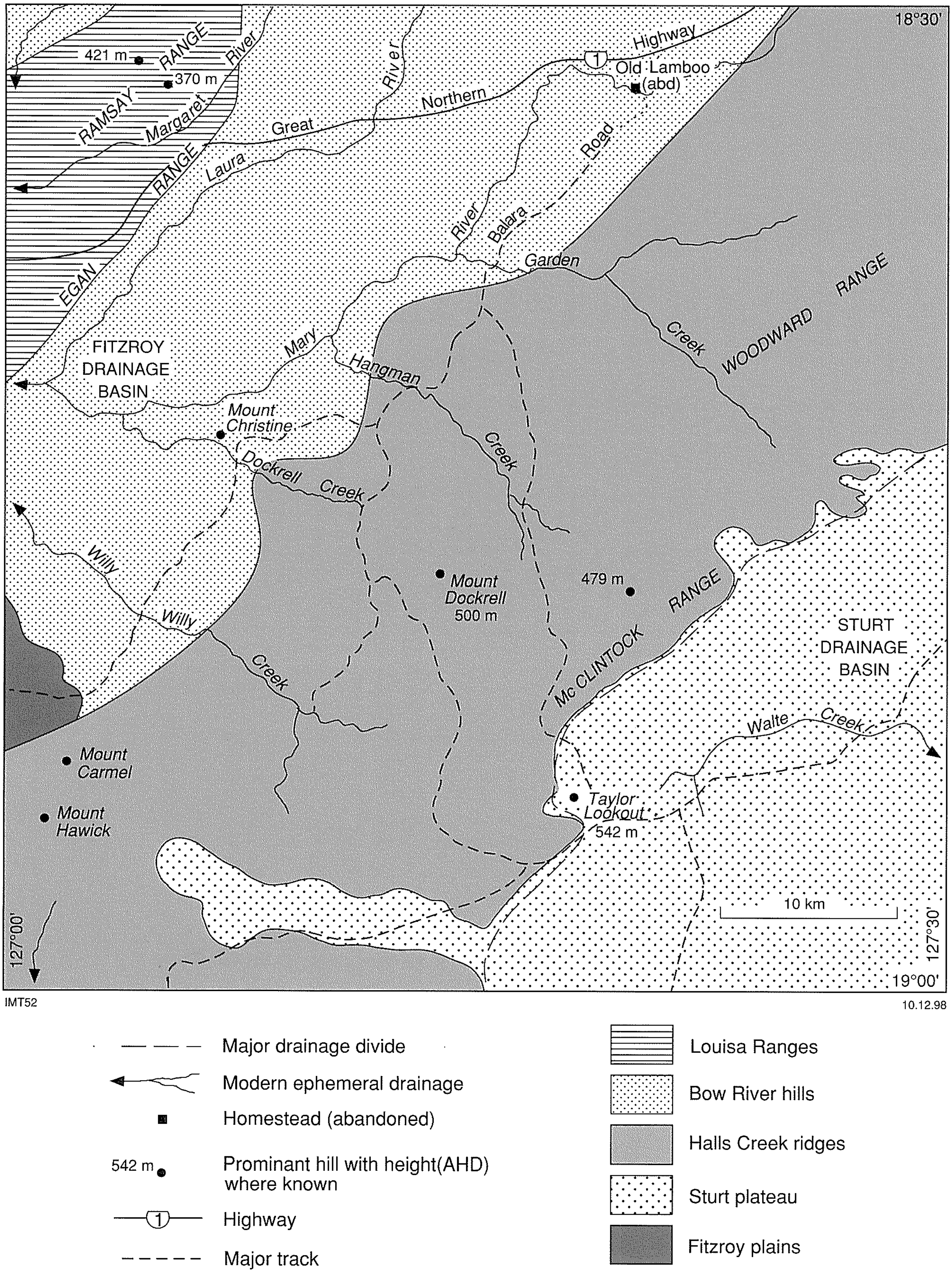


Figure 1. Physiographic and drainage sketch map of DOCKRELL

Introduction

The DOCKRELL* 1:100 000 map sheet (SE52-9, 4360) is bounded by latitudes 18°30'S and 19°00'S and longitudes 127°00'E and 127°30'E, and lies within the Kimberley region of Western Australia. Gold mining has taken place in the Mount Dockrell area, and alluvial working may still take place. Mining for tin has occurred in the McClintock Range.

Cattle grazing for beef is the main commercial activity in the Kimberley region and the Lamboo pastoral lease occupies most of the sheet, with the Ruby Plains lease extending onto the southeastern corner. Neither homestead is located on DOCKRELL, the Old Lamboo Homestead being unoccupied.

The sealed Great Northern Highway traverses the northern part of the sheet, linking Fitzroy Crossing and Halls Creek. Access within the rest of the sheet is via station tracks.

Geological investigations prior to 1968 are summarized in the explanatory notes for the first edition of MOUNT RAMSAY (Roberts et al., 1965; 1968). More recent work is referred to as appropriate in the following Notes.

This survey was carried out during the remapping of the King Leopold and Halls Creek Orogens commenced in 1986 by the Geological Survey of Western Australia (GSWA). Field work was carried out in 1990 and 1991 using 1:25 000 colour aerial photography flown in 1990 and available from the Western Australian Department of Lands Administration (DOLA). The mapping also forms part of a joint project with the Australian Geological Survey Organisation (AGSO) carried out as part of the National Geoscience Mapping Accord (NGMA) Kimberley–Arunta project.

Physiography, vegetation, and climate

DOCKRELL lies mostly within the Ordland physiographic division (Beard, 1979, fig. 7). The sheet area includes parts of the Louisa Ranges, the Bow River Hills, and the Halls Creek Ridges subprovinces of the Lamboo Hills province, together with the Sturt Plateau province (Fig. 1). The Fitzroy Plains province of the Fitzroyland physiographic division extends across the western edge of the sheet. The highest point within the sheet is Taylor Lookout (542 m AHD), and the McClintock Range forms the watershed between Wolfe Creek, which drains into Sturt Creek and the interior, and the Fitzroy drainage basin, which drains to the Indian Ocean. The watershed also marks a change from the high, gently sloping, sand-covered Sturt plateau in the southeastern part of the sheet, to the dissected plateau and low hill country of the Lamboo Hills in the northwestern and central part of the sheet.

The vegetation of the Kimberley region has been described by Beard (1979). The sand-covered plateau country in the southeastern part of DOCKRELL is covered by short grass savanna with spinifex, whereas tree steppe and low tree savanna with spinifex occurs on the dissected plateau. The low hills are covered by sparse tree steppe, and low tree savanna.

The climate is semi-arid monsoonal. Rainfall, which averages between 400 mm and 350 mm per annum, occurs mainly during the 'wet' season between November and April when temperatures are hot, often in excess of 40°C, and the humidity is high. In the 'dry' season temperatures are warm to hot, and humidities are low.

Watercourses generally only flow after prolonged heavy rain. Permanent pools occur in some of the rivers; however, water supplies for stock are provided by wells and bores.

Regional geological setting

The main tectonic features of DOCKRELL and neighbouring sheets are shown in Figure 2, and the geological history of rocks within the sheet area is summarized in Table 1. The sheet lies entirely within the Halls Creek Orogen (Fig. 2), a major northeasterly trending orogenic belt developed within the Proterozoic and Palaeozoic rocks of northern Australia (Rutland, 1981; Griffin and Grey, 1990). Three tectonic units are present on DOCKRELL (Fig. 3). In the northwestern part of the sheet, the Palaeoproterozoic (c. 1910 to 1790 Ma) Lamboo Complex is unconformably overlain by c. 610 Ma Neoproterozoic glacigene rocks deposited in the Louisa Basin. These rocks are overlain by Cambrian deposits of the Ord Basin.

The Halls Creek Orogen (Fig. 2) initially formed in the Palaeoproterozoic between the presumed Archaean and earliest Palaeoproterozoic rocks of the Kimberley Craton, underlying the Kimberley Basin to the northwest, and a composite Archaean craton to the east (Tyler et al., 1995). Earlier models for the formation of the orogen, and other belts of similar age in northern Australia, proposed extension and crustal thinning, then convergence without subduction of oceanic crust (Hancock and Rutland, 1984; Etheridge et al., 1987; Wyborn, 1988). However, Ogasawara (1988) noted the similarity of some tonalites in the Halls Creek Orogen to those formed by partial melting of basaltic rock above subduction zones. He suggested that the Halls Creek Orogen may represent the site of an Early Proterozoic convergent margin. Griffin et al. (1994), Tyler et al. (1995) and Sheppard et al. (1995; 1997a) have recently argued that the Halls Creek Orogen shares many features with convergent Phanerozoic plate margins associated with subduction of oceanic crust.

Major sinistral strike-slip faulting in a transpressive regime reactivated pre-existing fault zones, affecting rocks up to and including Palaeozoic volcanic and sedimentary successions in the Ord Basin. Thorne and Tyler (1996) suggested that most movement occurred in the latest Proterozoic and the Palaeozoic.

* Capitalized names refer to standard map sheets.

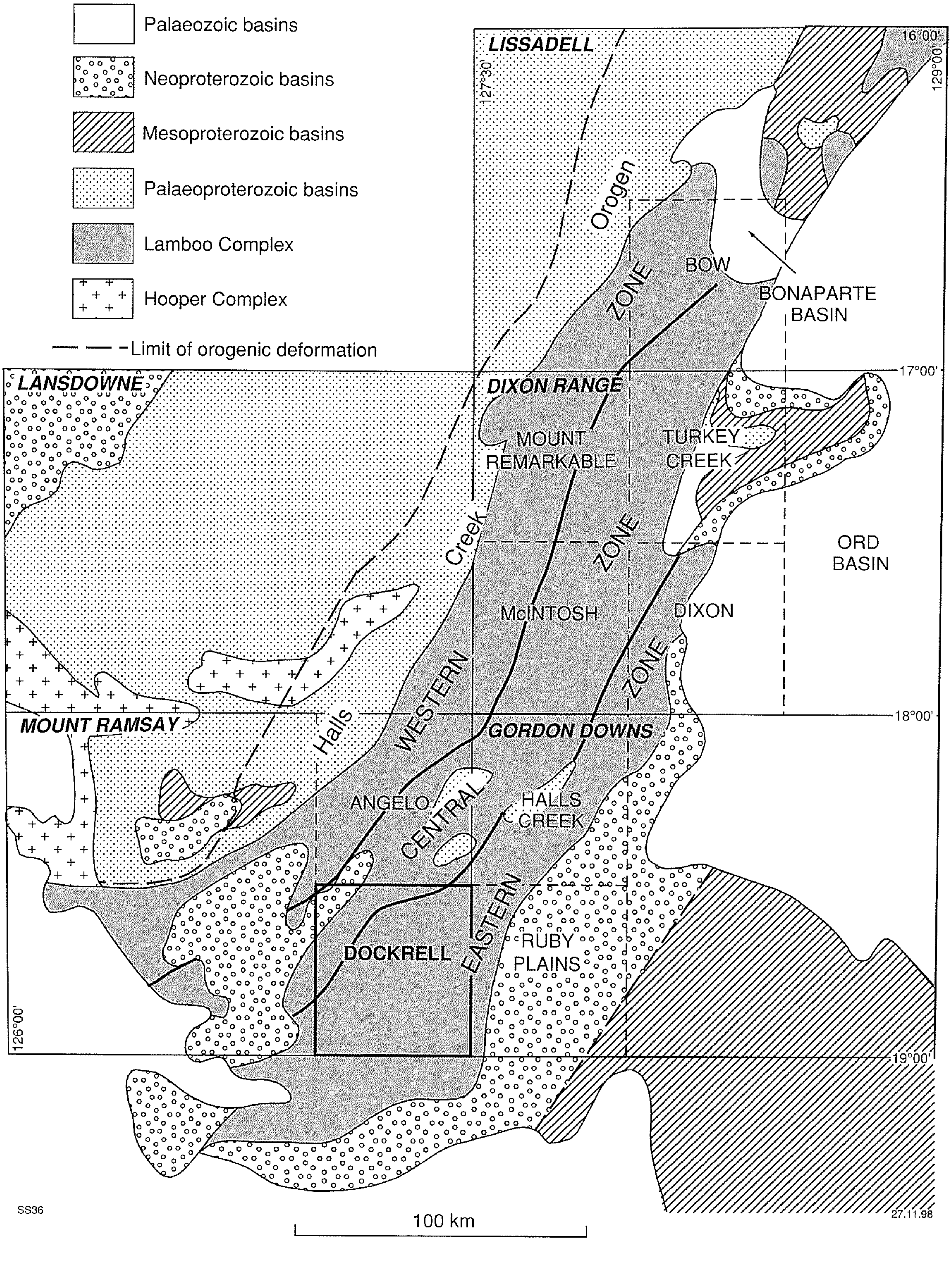


Figure 2. Location of 1:100 000 and 1:250 000 map sheets in the East Kimberley and their relationship to the tectonic zones in the Lamboo Complex

Table 1. Summary of the geological history of DOCKRELL

	Lamboo Complex		
Age (Ma)	*Western zone*	*Central zone*	*Eastern zone*
c. 1920–1910			Eruption of the Ding Dong Downs Volcanics. Intrusion of gabbroic rocks. Intrusion of Esaw Monzogranite, and Junda Microgranite
c. 1880			Uplift and erosion. Deposition of Saunders Creek Formation and Biscay Formation
c. 1865–1850	HOOPER OROGENY		
c. 1865		Deposition of protoliths to Tickalara Metamorphics	
1857–1850			Deposition of lower part of the Olympio Formation. Eruption of the Butchers Gully Member
c. 1850		Deformation and metamorphism of Tickalara Metamorphics under high T/low P metamorphic conditions (?D_2/M_2)	
c. 1845		Deposition of the Koongie Park Formation	
<1847			Deposition of upper Olympio Formation Intrusion of Woodward Dolerite
1835–1805	HALLS CREEK OROGENY		
			Layer-parallel shearing, possibly related to a southwesterly directed extension (D_3)
c. 1827		Intrusion of Loadstone Monzogranite	
c. 1820		Early phase of Mount Christine Granitoid. Shearing related to sinistral strike-slip faulting	Upright to moderately inclined, horizontally plunging, open to isoclinal folding in the Eastern zone (D_4), related to southeasterly directed thrusting. Accompanied by moderate-T/moderate-P metamorphism (M_4)
1820–1805	Intrusion of Dillinger and Grimpy Monzogranites, the late phase of Mount Christine Granitoid, and Emull Gabbro		
c. 1790			Intrusion of the San Sou Monzogranite
c. 1740			Intrusion of Sn-bearing pegmatites
	Intrusion of dolerite and lamprophyre dykes		
c. 1000	YAMPI OROGENY		
	Large-scale sinistral strike-slip faulting and associated folding (D_5). Greenschist facies metamorphism		
c. 610	Deposition of the Louisa Downs Group in the Louisa Basin during mountain glaciation from the north, followed by a marine transgression		
c. 560	KING LEOPOLD OROGENY		
	Thrusting and tight folding along the southern margin of the Halls Creek Orogen (D_6)		
c. 540 the	Deposition of the Lally Conglomerate, and eruption of the continental flood basalts of the Antrim Plateau Volcanics in Ord Basin		
400–300	ALICE SPRINGS OROGENY		
375–355	Extensional faulting on the Ramsay Range Fault		
?320	Sinistral strike-slip faulting and associated folding		
70–50	Formation of plateau surface		
20 to present	Uplift and dissection of plateau surface		

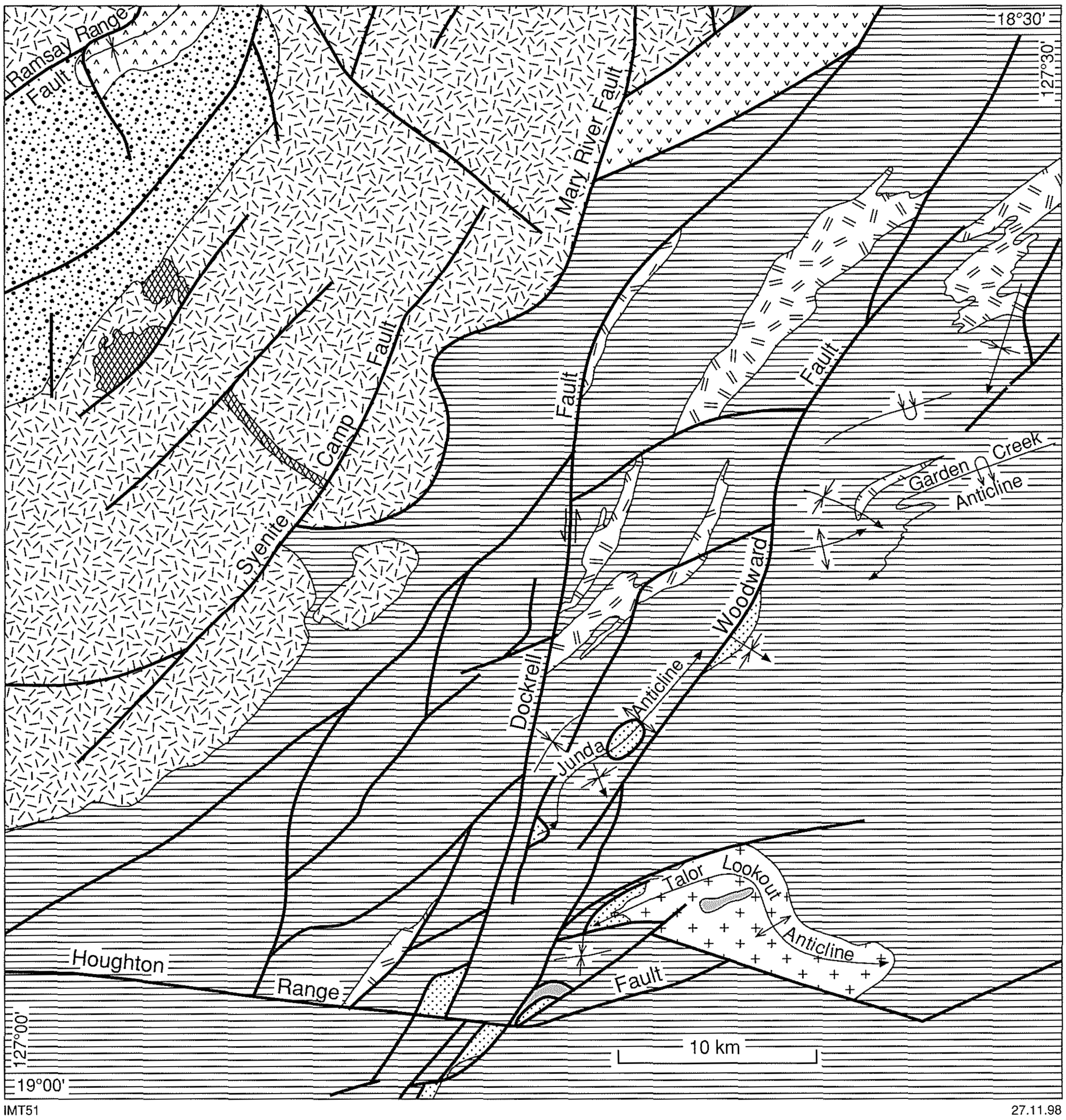


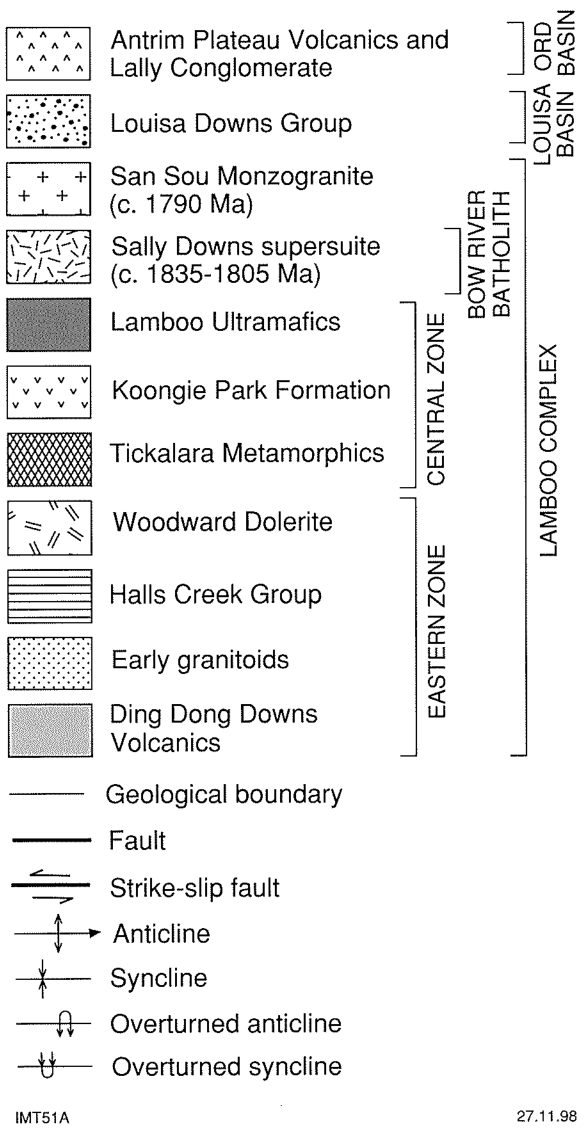
Figure 3. Simplified geological map of DOCKRELL (reference opposite)

Lamboo Complex

The Lamboo Complex on DOCKRELL consists of Palaeoproterozoic (c. 1910 Ma to c. 1790 Ma) low- to high-grade metasedimentary rocks, and mafic and felsic intrusive and extrusive igneous rocks.

Griffin and Tyler (1992) recognized three northeasterly trending zones within the Lamboo Complex: the Western, Central, and Eastern zones (Fig. 2). These correspond roughly to the subdivisions established by Hancock and Rutland (1984). The boundary between the Central and Western zones was modified by Tyler et al. (1995).

On DOCKRELL the boundary between the Central and Eastern zones is the Angelo Fault, whereas the boundary between the Central and Western zones is the Ramsay Range Fault. Granitoids of the c. 1835 to 1805 Ma Sally Downs supersuite (see below) intrude all three zones, with the Mount Christine Granitoid and Dillinger Monzogranite obscuring the Angelo Fault in the northern and western parts of DOCKRELL. The Grimpy Monzogranite outcrops to the northwest of the Ramsay Range Fault obscuring Western zone rocks. As a result, rocks that form the Western zone do not outcrop on DOCKRELL, and are not described in these Notes.



Eastern zone

Ding Dong Downs Volcanics and early granitoids

The oldest rocks within the DOCKRELL sheet area are low- to medium-grade mafic rocks, metasedimentary rocks, and associated gabbroic rocks belonging to the Ding Dong Downs Volcanics, together with the Junda Microgranite and the Esaw Monzogranite.

Page and Sun (1994) have reported SHRIMP U–Pb zircon ages of c. 1920–1910 Ma from felsic volcanic rocks within the Ding Dong Downs Volcanics on HALLS CREEK. This contrasts with SHRIMP U–Pb zircon ages of c. 1880 to 1850 Ma for volcanic units within the Halls Creek Group (Page and Hancock, 1988; Page and Sun, 1994; Blake et al., 1998). The Ding Dong Downs Volcanics was originally included within the Halls Creek Group (Dow and Gemuts, 1969), however, an unconformity is recognized between the Ding Dong Downs Volcanics and the Saunders Creek Formation around the Saunders Creek Dome on HALLS CREEK (Hancock and Rutland, 1984; Hancock, 1991; Blake et al., in press a). Although there is only minor angular discordance between the metasedimentary rock units above and below the unconformity (Hancock and Rutland, 1984), Griffin and Tyler (1992) recognized an erosional contact with the granophyric granitic rocks in the core of the Sophie Downs Dome that represents a significant time gap of some 30 million years. Griffin and Tyler (1992) proposed that the Halls Creek Group be redefined to exclude the Ding Dong Downs Volcanics.

Roberts et al. (1965, 1968) included all the granitoid rocks exposed in the southeastern part of DOCKRELL within the Sophie Downs 'Granite'. The Sophie Downs Granophyre Member of the Ding Dong Downs Volcanics is now restricted to the granitoid rocks exposed in the core of the Sophie Downs Dome on HALLS CREEK (Blake et al., in press a). Roberts et al. (1965, 1968), Dow and Gemuts (1969), and Gemuts (1971) considered that the Sophie Downs 'Granite' intruded the Halls Creek Group. However, an unconformity is present between the Sophie Downs Granophyre Member and the overlying Saunders Creek Formation of the Halls Creek Group around the Sophie Downs Dome (Griffin and Tyler, 1992; Blake et al., in press a). This relationship is supported by a SHRIMP U–Pb zircon age for the Sophie Downs Granophyre Member similar to those from the Ding Dong Downs Volcanics (Page and Sun, 1994).

The Esaw Monzogranite is exposed in the core of the Taylor Lookout Anticline (AMG* 190075), whereas the c. 1912 Ma Junda Microgranite is exposed in the Junda

Anticline (AMG 200165), and four other anticlines to the northeast and southwest (Fig. 3). Both these granitoids are overlain by the Saunders Creek Formation, and although the contacts are commonly sheared, a poorly exposed unconformity occurs to the south-southwest of Limestone Bore (AMG 112990). The c. 1790 Ma San Sou Monzogranite intrudes the Ding Dong Downs Volcanics, the Esaw Monzogranite, and the Halls Creek Group (see below).

Ding Dong Downs Volcanics (Ᵽv, Ᵽvs, Ᵽvm)

In the core of the Taylor Lookout Anticline to the northwest of San Sou Bore (around AMG 200080), amygdaloidal metabasalt, metagabbro, and meta-anorthosite, with minor calc-silicate rock (*Ᵽv, Ᵽvm*), form large areas of country rock within the San Sou Monzogranite. The rocks are typically only weakly foliated. However, they have been thoroughly recrystallized under upper greenschist to epidote–amphibolite facies metamorphic conditions, possibly within the aureole of the San Sou Monzogranite. One sample from this area is composed of the assemblage grossular garnet, clinopyroxene, calcite, and plagioclase, and may represent a carbonate-altered mafic volcanic or plutonic rock.

Amygdaloidal metabasalt consists of a fine- to medium-grained groundmass of amphibole, epidote, plagioclase, and quartz, with numerous intergrowths of epidote, sericite, plagioclase, and quartz replacing primary feldspar phenocrysts that were up to 2 mm across. Near Esaw Bore (AMG 203076), a xenolith within the Esaw Monzogranite consists of intergrowths up to 1 cm across of biotite, muscovite, quartz, and pinite after cordierite, within a weakly foliated fine- to medium-grained groundmass of biotite, muscovite, K-feldspar, plagioclase, and quartz. It may have been derived from an altered felsic igneous rock (*Ᵽvs*). Strongly foliated, medium-grained, interlayered pelite and amphibolite occurs adjacent to the contact with the overlying Saunders Creek Formation at Esaw Bore.

North of Bulara Well (AMG 154027), the Ding Dong Downs Volcanics consists of strongly foliated and layered, medium-grained amphibolite, within which quartzo-feldspathic metamorphic segregations 2–3 mm thick are developed. The rock consists of hornblende, biotite, plagioclase, and quartz, with minor epidote and sericite derived from alteration of feldspar.

Esaw Monzogranite (Ᵽges)

The Esaw Monzogranite is exposed as several small remnants, the largest of which (about 4 km^2) is to the west of Taylor Lookout. Two small exposures (<0.5 km^2) are present 4 km east of Taylor Lookout and about 5 km to the southwest, at Bulara Well. Exposures mainly consist of deeply weathered tors and bouldery hills. Most samples are weakly foliated, but a strong, subhorizontal foliation is locally present along the contact with the overlying Saunders Creek Formation. The monzogranite is composed of moderately to strongly recrystallized, leucocratic biotite–muscovite monzogranite, and garnet–muscovite monzogranite. In all samples, granular quartz, plagioclase (oligoclase–andesine), and microcline comprise at least 95% of the rock. Fine-grained biotite forms small clots accompanied by muscovite and accessory magnetite, apatite, and zircon. Garnet is probably almandine–spessartine, and forms small, rounded, and fractured crystals. A metamorphic overprint in the rocks is evident from disseminated sericite and clinozoisite alteration in plagioclase, epidote replacing magnetite, and recrystallization of quartz and feldspar to fine-grained granoblastic aggregates.

Junda Microgranite (Ᵽgju)

The Junda Microgranite is exposed in the cores of a series of structural domes in the southeastern part of DOCKRELL. The exposures, which are each between 1–3 km^2, are generally low-lying and deeply weathered; however, they form rugged hills southwest of Junda Bore (AMG 205170). A SHRIMP U–Pb zircon date of 1913 ± 5 Ma was obtained for a sample of microgranite about 1 km southwest of Junda Bore (Page, R. W., 1994, pers. comm.).

The Junda Microgranite is overlain by the Saunders Creek Formation, except in the areas 6 km northeast of Junda Bore and 8 km southwest of Junda Bore, where it is overlain by the Biscay Formation of the Halls Creek Group. Where the contacts are well exposed, they are either sheared or extensively veined by quartz. Pegmatite dykes and quartz veins cut the Junda Microgranite.

Most of the microgranite is composed of a foliated and partly recrystallized, fine-grained, leucocratic monzogranite. Narrow shear zones and closely spaced fractures are common in more massive exposures. Biotite may form small clots which, together with fine-grained mafic inclusions, are flattened in the foliation.

The microgranite is composed of fine-grained, granular quartz, plagioclase (albite–oligoclase), and microcline, with a few percent of chocolate-brown biotite in small clots. The rock also contains a very small amount of muscovite, which is commonly intergrown with biotite. Epidote, zircon, apatite, and allanite typically occur with, or are included within, biotite.

Halls Creek Group

The Halls Creek Group, as redefined by Griffin and Tyler (1992), consists of three formations: the Saunders Creek Formation, the Biscay Formation, and the Olympio Formation.

A SHRIMP U–Pb zircon age of c. 1880 Ma has been obtained from a felsic unit within the Biscay Formation

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

to the northwest of the Sophie Downs Dome on Halls Creek (Tyler et al., 1995). Page and Hancock (1988) reported a conventional U–Pb zircon age of 1856 ± 5 Ma for a 'sill' within 'Biscay Formation tuffs'. However, due to uncertainty as to whether the 'sill' dated was coeval with the surrounding tuffs, they regarded the date as a minimum age for the Halls Creek Group. Recent mapping on Halls Creek (Blake et al., in press a) indicates that the 'sill' is a lava flow, and that both the flow and the enclosing tuffs belong to the Maude Headley Member of the Olympio Formation. A SHRIMP U–Pb zircon age of 1857 ± 5 Ma was obtained from the same zircon suite, and an age of 1857 ± 2 Ma was obtained from similar rocks on McIntosh to the north (Page and Sun, 1994). A SHRIMP U–Pb age of 1847 ± 6 Ma (Blake et al., 1998) for detrital zircons from a turbiditic greywacke provides a maximum age for the deposition of the upper part of the Olympio Formation.

Saunders Creek Formation (ⱣHs)

The Saunders Creek Formation is the basal unit of the Halls Creek Group, and is exposed around the margins of a series of structural domes in the southeastern part of Dockrell. Previously it was only recognized around the Taylor Lookout Anticline, and to the north of Bulara Well (Roberts et al., 1968). Typically, contacts with the underlying Ding Dong Downs Volcanics, Esaw Monzogranite, and Junda Microgranite are strongly sheared, although, as noted above, the relationship is also unconformable. The Saunders Creek Formation is not seen overlying granitic rocks near Mount Cross (around AMG 255210), nor granitic rocks 6 km to the northwest of Esaw Bore (around AMG 160125). At these localities the Biscay Formation overlies granitoid.

The Saunders Creek Formation consists of up to 150 m of extensively recrystallized, metamorphosed, cross-laminated, medium- to coarse-grained quartz sandstone and feldspathic sandstone, with abundant heavy-mineral concentrations. Thin layers of muscovite–biotite schist are also present and may contain porphyroblasts of andalusite that have been extensively retrogressed and replaced by muscovite intergrowths. Metamorphosed quartz-pebble conglomerate units occur towards the base. The heavy-mineral concentrations typically occur on bedding surfaces and the bases of troughs and scours, and consist predominantly of magnetite.

Hancock (1991) carried out a detailed study of the sedimentology of the Saunders Creek Formation around the Saunders Creek Dome on Halls Creek. He interpreted the unit as being deposited by a braided fluvial system flowing from the northwest, with a transition to a lower energy, transitional marine environment towards the top. Page and Sun (1994) reported discrete populations of SHRIMP U–Pb ages from detrital zircons of 2450 Ma, 2600 Ma, 3300 Ma, and 3600–3500 Ma indicating an Archaean source region. Although the Saunders Creek Formation on Dockrell has less well-preserved sedimentary features, it was regarded by Hancock (1991) to represent a similar sequence of depositional environments.

Biscay Formation (ⱣHr, ⱣHrt, ⱣHrs)

The Biscay Formation conformably overlies the Saunders Creek Formation, and is dominated by metamorphosed mafic volcanic rocks, and metasedimentary rocks. The unit is well exposed around the structural domes in the southeastern part of Dockrell, where it is up to 1500 m thick, and between the Syenite Camp and Dockrell Faults, where it hosts extensive small-scale gold mineralization. Previously Roberts et al. (1968) mapped large areas of Biscay Formation as Woodward Dolerite.

Three units can be recognized within the Biscay Formation on Dockrell: lower and upper mafic volcanic units (*ⱣHrt*), and a middle metasedimentary unit (*ⱣHrs*). The complete succession is exposed at the northern margin of the Junda Anticline. This succession differs from that presented by Hancock and Rutland (1984) and Hancock (1991), who included both the Butchers Gully Member (now regarded as part of the Olympio Formation; Griffin and Tyler, 1992; Blake et al., in press a) and the Koongie Park Formation (now known to be younger than the Halls Creek Group; Page et al., 1994; Griffin et al., in prep.; Blake et al., in press a) within their succession, together with units within the Tickalara Metamorphics that are no longer considered to be equivalent to the Biscay Formation (Tyler et al., 1995; Tyler et al., in prep. a).

The lower and upper mafic volcanic units both consist of massive metabasaltic lava flows, laminated volcaniclastic deposits, and fragmental deposits that are typically characterized by a carbonate matrix. Pillow lavas may be developed locally. These rocks are interlayered with minor carbonate rocks, and pelitic and psammitic metasedimentary rocks. The middle metasedimentary unit consists of thin- to medium-bedded pelite and psammite that now form crenulated muscovite–biotite–quartz schists.

Typically the rocks within the formation are well foliated and thoroughly recrystallized, with primary igneous or sedimentary textures rarely preserved. However, some of the metabasalts contain up to approximately 10% fine-grained albite and clinozoisite pseudomorphs after plagioclase phenocrysts. Metamorphic grade varies from upper greenschist to amphibolite facies.

Olympio Formation (ⱣHo, ⱣHoq)

The Olympio Formation is presumed to conformably overlie the Biscay Formation, although where the contact is exposed it shows strong bedding-parallel shearing. The formation consists of a monotonous sequence of metamorphosed thin- to medium-bedded (up to 2 m) mudstone, siltstone, quartz wacke, greywacke, and arkosic sandstone (*ⱣHo*). Also present are thicker (2 to 4 m), coarser-grained, metamorphosed quartz sandstone units (*ⱣHoq*). These are most prominent in the Woodward Range in the northeastern part of the sheet.

Due to the lack of persistent marker horizons within the Olympio Formation, and the possibility of structural repetition, the thickness of the unit is difficult to estimate. However, Dow and Gemuts (1969) suggested that the unit was 4000 m (12 000 feet) thick (see also Hancock and Rutland, 1984; Hancock, 1991).

The rocks were extensively recrystallized under greenschist to amphibolite facies metamorphic conditions, with the mudstone and siltstone components now forming well-foliated and crenulated fine- to medium-grained (garnet–andalusite) mica schists.

The Olympio Formation has been interpreted as being deposited by turbidity currents as part of a submarine fan system (Dow and Gemuts, 1969; Hancock and Rutland, 1984; Hancock, 1991). Complete Bouma sequences are uncommon. Graded bedding is developed in most of the arenaceous units, which pass up into laminated siltstones and mudstones, representing divisions ADE of a Bouma sequence. Within the thicker, coarse-grained quartz sandstone units, siltstone and mudstone are generally absent with only repeated occurrence of Bouma sequence division A. Sedimentary structures, reported from the Olympio Formation elsewhere (Dow and Gemuts, 1969; Hancock, 1991), include bottom structures, and convolute and ripple lamination, but are rare in Olympio Formation rocks on DOCKRELL.

The scarcity of bottom structures and ripple laminations from the arenaceous units on DOCKRELL means that sediment transport directions cannot be established. Hancock (1991) tentatively reported that palaeocurrents obtained from outcrops to the northeast of Halls Creek were from the northwest. The petrography of clasts within the arenaceous units from these outcrops indicated a largely crystalline source predominantly composed of granitic rocks, with variable inputs of felsic volcanic rocks and muscovite-bearing metasedimentary rocks (Hancock, 1991). Clast compositions in rocks sampled on DOCKRELL are consistent with a predominantly granitic source.

Butchers Gully Member (ɆHob, ɆHoc)

Towards the base of the Olympio Formation a distinctive alkali volcanic unit is recognized. Griffin and Tyler (1992) named this the Butchers Gully Member and it is best developed to the east of Halls Creek where it consists of trachytic and trachyandesitic lava flows and volcaniclastic deposits, with minor basaltic lavas (Esslemont, 1990; Taylor et al., 1995 a,b; Blake et al., in press a). On DOCKRELL, its main outcrop is in the eastern part of the sheet, in the headwaters of Garden Creek, and was previously mapped as Biscay Formation (Roberts et al., 1968). It also outcrops 2.5 km to the east of Junda Bore, 3 km to the northwest of Esaw Bore, and 3 km to the northwest of Mount Hawick (around AMG 900100). The Butchers Gully Member hosts the Brockman rare-metal deposit on HALLS CREEK (Blake et al., in press a).

On DOCKRELL, the Butchers Gully Member may be up to 100 m thick, but is thickened in the headwaters of Garden Creek by two generations of tight to isoclinal folding. It consists mainly of melanocratic altered and metamorphosed volcaniclastic deposits with a carbonate matrix (*ɆHob*). The rocks are well foliated and altered; primary igneous textures and mineral assemblages are not preserved. Biotite is the main mafic mineral with lesser amounts of amphibole, chlorite, epidote, sericite, calcite, quartz, and opaque minerals, consistent with a primary alkalic, rather than a mafic tholeiitic, composition. Some fragmental volcanic rocks near the top of the Butchers Gully Member, east of the headwaters of Garden Creek, are strongly altered and silicified. The rocks consist of quartz, albite, sericite, and chlorite, with variable amounts of calcite. One sample contains about 15% prismatic tourmaline crystals, in clots up to about 3 mm in diameter, largely parallel to the foliation.

Volcaniclastic breccias, representing either agglomerates or lahar deposits, occur on DOCKRELL. However, the most distinctive unit is made up of flattened, disc-shaped scoriaceous clasts up to 20 cm in diameter, which may be the product of lava fountaining. The top of this unit is marked by a distinctive 2 to 3 m-thick ferruginous chert (*ɆHoc*).

Woodward Dolerite (*Ɇdw*)

The Woodward Dolerite intruded the Biscay Formation and the lower part of the Olympio Formation of the Halls Creek Group, forming sills up to 200 m thick. The sill or sequence of sills in the Olympio Formation in the Woodward Range (around AMG 380410) and to the northeast and southwest of Eronga Yard (AMG 186250), is structurally repeated by faulting and tight to isoclinal folding. Dow and Gemuts (1969) suggested that sills may be up to 600 m thick (2000 feet). This is not seen on DOCKRELL, and may refer to rocks that have now been identified as Biscay Formation. The intrusion of the Woodward Dolerite must be younger than the c. 1847 Ma maximum depositional age of the Olympio Formation, but pre-dates deformation and metamorphism of the Halls Creek Group as a whole.

The unit consists of medium- to coarse-grained metadolerite. Finer-grained margins of the sills are locally developed. Primary igneous layering is absent. Igneous ophitic textures are preserved, but decussate metamorphic textures are common. Mineral assemblages typically consist of either actinolite, albite, clinozoisite, and chlorite, with or without quartz, K-feldspar, and biotite; or edenitic hornblende, plagioclase, and clinozoisite, with or without quartz and biotite. These are consistent with metamorphism under upper greenschist to epidote–amphibolite facies conditions respectively. Accessory magnetite and ilmenite are rimmed by epidote and titanite respectively.

Central zone

Tickalara Metamorphics (*ɆTm, ɆTh*)

The Tickalara Metamorphics outcrops as several large areas of country rock within the Mount Christine Granitoid in the northwestern part of DOCKRELL. The Tickalara Metamorphics was previously interpreted as a medium- to high-grade equivalent of the Halls Creek Group (Dow and Gemuts, 1969; Hancock and Rutland, 1984; Allen, 1986). However, the maximum depositional age for the upper Olympio Formation of c. 1847 Ma is younger than the c. 1850 Ma age for peak granulite facies metamorphism in the Tickalara Metamorphics near Turkey Creek (Page and Hancock, 1988; Page and Sun, 1994), and the two represent different volcano-sedimentary successions (Tyler et al., 1995).

A northwesterly trending strip of interlayered migmatitic pelitic gneiss and amphibolite (*ꟼTm*) occurs to the northeast of Mount Christine (around AMG 016310). The pelitic rocks are banded, medium- to coarse-grained migmatites that consist of sillimanite, andalusite, pinite after cordierite, biotite, muscovite, chlorite, plagioclase, K-feldspar, and quartz, with minor apatite and opaque minerals. The sillimanite and K-feldspar are typically replaced by muscovite, whereas andalusite and chlorite are prograde. More siliceous layers are present, and the occurrence of altered coarse-grained cordierite gives them a distinctive spotted appearance. Veins of a foliated granitoid phase cut across the banding in the migmatites.

The amphibolites are medium-grained and well foliated, and consist of hornblende, plagioclase (now extensively replaced by fine epidote and sericite), and quartz, with minor chlorite and coarse grains of epidote. Calc-silicate layers, pods, and lenses are parallel to the foliation.

The large areas of Tickalara Metamorphics exposed to the southeast of the Egan Range are composed of well-layered, siliceous hornfelses (*ꟼTh*). Mineral assemblages and textures in these rocks are described in the section on **Contact metamorphism** below.

Hooper Orogeny

The Hooper Orogeny was first recognized in the Hooper Complex of the King Leopold Orogen (Fig. 2), and occurred between c. 1865 and 1850 Ma (Tyler and Griffin, 1993; Griffin et al., 1993; Griffin and Tyler, in press). Tyler et al. (1995), Tyler and Page (1996), and Sheppard et al. (1997a) noted similarities in the geological evolution of the Hooper Complex and the Western and Central zones of the Lamboo Complex.

Rocks of the Tickalara Metamorphics within the Central zone are affected by two phases of deformation interpreted as being related to large-scale easterly directed thrusting (Hancock and Rutland, 1984). A maximum age for the first phase is provided by the deformed c. 1863 Ma Rose Bore Granite on McINTOSH (Tyler and Page, 1996). High-grade, low to moderate pressure metamorphism reached its peak during and after the second deformation phase (Griffin and Tyler, 1992; Tyler et al., 1995; Tyler and Page, 1996). Metamorphism may reflect an underlying magmatic heat source (Thornett, 1987), possibly related to igneous underplating along an active plate margin (Tyler and Page, 1996).

Page and Hancock (1988) used conventional U–Pb zircon dating techniques to obtain an age of 1851 ± 1 Ma (recalculated by Page and Sun, 1994, assuming zero-age Pb loss) from a migmatitic gneiss on TURKEY CREEK, which they interpreted as the age of peak metamorphism. This date has been confirmed by a SHRIMP U–Pb zircon age of 1852 ± 2 Ma from the same rock (Page and Sun, 1994). Granitoids of the Dougalls suite, together with layered mafic–ultramafic intrusions were intruded between c. 1856 and 1850 Ma (Hoatson and Tyler, 1993; Hoatson, 1993; Page et al., 1995; Tyler and Page, 1996).

The Hooper Orogeny may correspond to the accretion of the Central zone, which may represent an island arc, to the edge of the Kimberley Craton (Myers et al., 1996; Sheppard et al., 1997a). From the relative position of the zones within the Lamboo Complex, subduction of oceanic crust (Ogasawara, 1988; Griffin et al., 1994; Tyler et al., 1995; Sheppard et al., 1995; 1997a) was probably to the northwest, beneath the Kimberley craton (Tyler and Page, 1996).

Deformation

The earliest deformation recognizable within the Central zone on DOCKRELL produced a layer-parallel gneissic banding/foliation within the interlayered pelitic migmatite and amphibolite that forms the strip of Tickalara Metamorphics northeast of Mount Christine. This fabric is cut by veins of granitoid, and pre-dates the intrusion of the Mount Christine Granitoid. It probably correlates with the D_2/M_2 event of Griffin and Tyler (1992) and Tyler and Page (1996).

Metamorphism

High-grade metamorphic assemblages, consisting of sillimanite, biotite, cordierite, K-feldspar, plagioclase, and quartz , developed in the migmatitic Tickalara Metamorphic rocks synchronously with deformation. Migmatitic textures are consistent with anatexis in situ (Mehnert, 1968; Ashworth, 1985), probably via the metamorphic reaction (Thompson, 1982):

$$Al_2SiO_5 + \text{biotite} + \text{quartz} = \text{cordierite} + \text{K-feldspar} + \text{melt}$$

The absence of garnet reflects the high temperature/low pressure nature of the metamorphism. Hornblende–plagioclase–quartz assemblages developed in the associated amphibolites.

Koongie Park Formation (*ꟼe*)

In the Central zone on DOCKRELL, ANGELO, and HALLS CREEK, felsic and mafic volcanic rocks and associated metasedimentary rocks were previously regarded as part of the Biscay and Olympio Formations of the Halls Creek Group (Roberts et al., 1968; Gemuts and Smith, 1967). Subsequently, Griffin and Tyler (1992) proposed that they be redefined as the Koongie Park Member, a component of the Tickalara Metamorphics. However, SHRIMP U–Pb dating of zircons from two rhyolite samples and a microgranite from HALLS CREEK gave a pooled age of 1843 ± 2 Ma (Page et al., 1994). This is about 10 Ma younger than the age of deformation and peak metamorphism of the Tickalara Metamorphics (see above). The unit is now given formation status, separate from both the older Tickalara Metamorphics, and the Halls Creek Group.

On ANGELO and HALLS CREEK, the Koongie Park Formation hosts significant stratabound volcanic-associated massive sulfide Zn–Pb–Cu(–Ag) deposits (Griffin et al., in prep.; Blake et al., in press a).

The Koongie Park Formation is intruded and metamorphosed by granitoids, and mingled gabbro–granite of the 1835–1800 Ma Sally Downs supersuite, which includes the c. 1827 Ma Loadstone Monzogranite (Blake et al., in press a; Griffin et al., in prep.; Page et al., in prep. b).

On DOCKRELL the Koongie Park Formation is very poorly exposed, but probably occupies an area of about 120 km^2 in the northeastern part of the sheet, bounded by the Highway, Angelo, and Mary River Faults. It is represented by two small exposures at Black Rock (AMG 189473), each of <0.1 km^2, and another, slightly larger one, adjacent to the Angelo Fault, on the northern edge of the map sheet (AMG 318533).

The unit consists of laminated fine-grained sandstone and siltstone, felsic volcaniclastic sandstone, chert and banded iron formation, with minor metabasalt and calc-silicate rock. To the northeast, on ANGELO and HALLS CREEK, the Koongie Park Formation includes substantial outcrop of felsic and mafic volcanic and volcaniclastic rock, and subvolcanic intrusions (Griffin and Tyler, 1992; Orth, 1997; Blake et al., in press a; Griffin et al., in prep.).

Sally Downs supersuite

The granitoids in the Halls Creek Orogen were considered by Dow and Gemuts (1967) and Gemuts (1971) to be part of a single batholith, the Bow River Granite (equivalent to the Bow River Granitoid Suite of Ogasawara, 1988). However, recent geochemical studies and SHRIMP U–Pb dating (Page and Sun, 1994; Sheppard et al., 1995, in prep.; Page et al., in prep. b) indicates that the granitoids form the 1865–1850 Ma Paperbark supersuite ('batholith' of Sheppard et al., 1995) and the 1835–1805 Ma Sally Downs supersuite ('batholith' of Sheppard et al., 1995). On DOCKRELL the Loadstone, Grimpy, and Dillinger Monzogranites, and the Mount Christine Granitoid (the c. 1820 Ma granitoids of Tyler and Griffin, 1994), are all part of the Sally Downs supersuite. The San Sou Monzogranite was emplaced about 15 to 20 Ma after the youngest rocks in the Sally Downs supersuite. It is physically separate from them, and is therefore excluded from the supersuite.

On DOCKRELL, and elsewhere in the Lamboo Complex, field relationships indicate that many of the gabbros in the Central zone, and the c. 1830–1805 Ma granitoids of the Sally Downs supersuite, are broadly coeval (Blake and Hoatson, 1993; Sheppard, 1996; Sheppard et al., 1997b). Evidence for this includes mingling relationships between many unlayered gabbros and adjacent granitoids, and mafic inclusions in granitoids with features consistent with magma-in-magma relationships (for example, Vernon, 1991). Furthermore, large areas of 'intimate mixtures of granite, gabbro and metamorphic rock' recorded on the first edition MOUNT RAMSAY (Roberts et al., 1968), DIXON RANGE (Dow and Gemuts, 1967) and GORDON DOWNS (Gemuts and Smith, 1967) 1:250 000 map sheets, have features indicative of magma mingling. These outcrops are composed of biotite gabbros, some with resorbed feldspar and quartz xenocrysts, and other hybrid rocks, cut by irregular and partly disintegrated granitoid veins. Therefore, unlayered gabbros are considered to be an integral part of the Sally Downs supersuite, although they are probably the product of a separate tholeiitic magmatic event (Sheppard, 1996).

Emull Gabbro (*Ᵽoe*)

The Emull Gabbro is a north-northeasterly trending, elongate intrusion about 15 km long by 7–8 km wide, with about two-thirds of the intrusion outcropping on ANGELO, and one-third on DOCKRELL. The intrusion consists of medium- to fine-grained gabbro and tonalite. It is extensively veined and intruded by the Dillinger Monzogranite, but the occurrence of net-veined complexes and limited hybrid rocks along the contact imply that the granite and gabbro were, in part, coeval.

Undivided gabbro and associated mafic and ultramafic rocks (*Ᵽo*)

Undivided gabbro includes a range of basic and intermediate intrusive rocks that outcrop along the northern edge of DOCKRELL (around AMG 040520), and around Dillinger Bore (AMG 102459). At Dillinger Bore mafic and intermediate rocks are exposed over an area of approximately 3 km^2. The rock types comprising this unit are porphyritic to even-textured, medium- to fine-grained gabbro, diorite, and tonalite, with minor pyroxenite and hornblendite. The tonalite comprises veins which cut and enclose gabbro and diorite. In proximity to the veins, gabbro and diorite commonly contain rounded xenocrysts of quartz and plagioclase of a similar size to those in the tonalite. All of these rock types are extensively veined by medium- to coarse-grained porphyritic biotite monzogranite of the Mount Christine Granitoid and Dillinger Monzogranite.

The gabbros and diorites have been recrystallized and metamorphosed to varying degrees. The least altered samples are medium-grained, subophitic-textured gabbro and norite with small amounts of strongly fractured, anhedral olivine, or reddish-brown biotite. Unaltered plagioclase crystals are normally zoned from cores of labradorite to rims of andesine. Medium-grained metagabbro and metadiorite samples are composed of edenitic hornblende and plagioclase, with minor quartz and biotite, and accessory apatite, titanite, and epidote. Plagioclase shows widespread sericite and clinozoisite alteration, and biotite crystals contain abundant lamellae of prehnite. Tonalite samples are also partly recrystallized and altered.

Loadstone Monzogranite (*Ᵽgst*)

The Loadstone Monzogranite is a large, poorly exposed pluton, which outcrops extensively on HALLS CREEK (Blake et al., in press a) and ANGELO (Griffin et al., in prep.). On DOCKRELL it only outcrops over a small area northeast of Sweet Water Well (around AMG 241523), where it consists of two exposures, each covering an area of less than 0.5 km^2. The intrusion is generally homogenous, consisting almost entirely of medium- to coarse-grained, weakly porphyritic biotite monzogranite and syenogranite. Most of the rocks are massive and undeformed, but in shear zones the granites are strongly recrystallized to fine-grained cataclastic rocks. The intrusion is distinguished from most others in the Sally Downs supersuite by the presence of microcline, rather than microperthite. A SHRIMP U–Pb zircon age of 1827 ± 2 has been obtained from this unit on HALLS CREEK (Page et al., in prep. b).

Grimpy Monzogranite (*Ꝑggy*)

The Grimpy Monzogranite is a large (~15 × 40 km), elongate, north-northeasterly trending intrusion, of which only a relatively small area of about 10 km^2 outcrops in the northwest corner of DOCKRELL. Most of the Grimpy Monzogranite consists of medium- to fine-grained, even-textured or weakly porphyritic biotite granodiorite and tonalite, with lesser biotite monzogranite. Most of the rocks are massive, but strongly foliated zones also occur.

The granodiorites and tonalites are composed of about 25–30% quartz, 50–60% plagioclase, 0–10% microperthite, 5–15% biotite, rare hornblende (≤1%), and accessory apatite, opaque minerals, zircon, and monazite. Phenocrysts consist of 5–10 mm long, tabular crystals of microperthite. Most samples from the Grimpy Monzogranite show sericite and clinozoisite alteration of plagioclase cores, chloritization of biotite, and epidote and titanite rimming magnetite and ilmenite respectively.

Dillinger Monzogranite (*Ꝑgdi*)

The Dillinger Monzogranite outcrops over an area of about 25 by 10 km, but it probably extends further north underneath an extensive plain of colluvium on ANGELO. The greater part of the Dillinger Monzogranite outcrops in the north of DOCKRELL, where it is exposed as low bouldery hills. The Dillinger Monzogranite is a homogenous intrusion composed of medium-grained, even-textured or weakly porphyritic, leucocratic biotite monzogranite. Fine-grained mafic inclusions are abundant near contacts with gabbros. Although the monzogranite extensively veins and intrudes the Emull Gabbro, and undivided gabbro, diorite, and tonalite, locally developed hybrid rocks and net-veined complexes suggest that it is broadly coeval with the gabbros.

The rocks consist of 0–10% microperthite phenocrysts, in a groundmass of granular (2–3 mm) quartz, microperthite, and plagioclase, with minor biotite, and accessory magnetite, apatite, zircon, and allanite. Plagioclase crystals are zoned from cores of oligoclase to rims of albite. Fine-grained, granophyric textures are widespread: they show a range from incipient development at grain boundaries to complete recrystallization of quartz and feldspars.

Mount Christine Granitoid (*Ꝑgch*)

The Mount Christine Granitoid forms an intrusion that extends for about 40–50 km in a north-northeast direction and is 20 km across. The bulk of its outcrop lies on DOCKRELL. It is exposed as low bouldery hills and scattered tors, separated by extensive areas of laterite and colluvium. Two samples from north of Mount Christine have given SHRIMP U–Pb zircon ages of 1819 ± 4 Ma and 1808 ± 3 Ma repectively (Page et al., in prep. b). The first sample was from a foliated granitoid phase which intrudes the northwesterly trending strip of migmatite and amphibolite to the northeast of Mount Christine; the second is representative of the massive monzogranite exposed all around the Mount Christine area.

The Mount Christine Granitoid intrudes the high-grade Tickalara Metamorphics on DOCKRELL. The massive monzogranite phase dated at 1808 ± 3 Ma is the only granitoid from the Sally Downs supersuite that intrudes the Halls Creek Group of the Eastern zone. On the northern edge of DOCKRELL and the southern edge of ANGELO, the Mount Christine Granitoid intrudes undivided gabbro and tonalite. It is unconformably overlain by Neoproterozoic sedimentary rocks of the Louisa Downs Group on its western margin.

The Mount Christine Granitoid is composed of a wide range of rock types, with medium- to coarse-grained biotite monzogranite, and medium-grained hornblende-biotite monzogranite and granodiorite being predominant. Minor rock types are quartz monzodiorite and quartz diorite, leucocratic biotite monzogranite and syenogranite, and two-mica monzogranite. The granitoid contains a variety of pelitic and mafic (biotite norite, biotite gabbro, and actinolite–epidote hornfels) inclusions.

Medium-grained and weakly porphyritic, or coarse-grained and strongly porphyritic biotite monzogranite is the most common rock type in the Mount Christine Granitoid. The rocks are composed of about 30% quartz, 25–35% microcline, 20–30% plagioclase, 5–8% biotite, and accessory magnetite, apatite, allanite, and zircon. Tabular microcline phenocrysts <1.5 cm long have ribbon-like microperthite exsolution, and small inclusions of plagioclase, biotite, and minor quartz. Oscillatory and normally zoned plagioclase crystals are generally inclusion-free; weakly zoned crystals have cores of andesine. Anhedral quartz phenocrysts up to 7 mm in diameter show incipient recrystallization. Accessory minerals typically occur as inclusions in biotite. Hornblende-bearing monzogranite and granodiorite contain slightly less microcline and quartz, but more plagioclase than hornblende-absent granitoids.

Quartz monzodiorite and quartz diorite are medium-grained, foliated and contain sparse microcline phenocrysts. All are weakly to moderately recrystallized and metamorphosed. Quartz monzodiorites are composed of about 10–15% quartz, 40% plagioclase, 15% microcline, 20% edenitic hornblende, and 10% brown biotite, with minor epidote and titanite, and accessory apatite, allanite, and zircon. Leucocratic biotite monzogranite and syenogranite samples are fine- to medium-grained and contain sparse microcline and quartz phenocrysts, and <5% biotite and magnetite.

Many samples of the Mount Christine Granitoid are only weakly deformed and recrystallized. Samples which have undergone deformation are typically finer grained than undeformed rocks. They also display extensive ribbon-like microperthite exsolution in microcline, and abundant quartz–K-feldspar granophyre and symplectite intergrowths. Alteration of plagioclase to sericite and clinozoisite, the occurrence of epidote, and alteration of biotite to chlorite is widespread in the Mount Christine Granitoid.

Halls Creek Orogeny

Deformation and metamorphism during the Halls Creek Orogeny (Tyler and Page, 1996) has affected the entire Lamboo Complex, including the syn-orogenic granitoids and intrusive mafic rocks of the Sally Downs supersuite. The Halls Creek Orogeny may be the result of a collision between the combined Central and Western zones, and the Eastern zone, the earliest stages of which began at c. 1835 Ma. Such a collision, reflecting suturing of the Kimberley Craton onto the North Australian Craton to the east, was completed by c. 1805 Ma.

Deformation

Griffin and Tyler (1992) established a sequence of deformation events (D_1 to D_7) for the southern part of the Halls Creek Orogen. Their nomenclature is followed here, although deformation that affected the Halls Creek Group in the Eastern zone, and was previously assigned to D_1 and D_2 on the published map sheet (Tyler and Griffin, 1994), must have occurred after c. 1847 Ma, the youngest age of detrital zircons in the upper part of the Olympio Formation. Those events are, therefore, younger than D_1 and D_2 in the Central and Western zones, which formed during the Hooper Orogeny between 1865 and 1850 Ma (Tyler et al., 1995; Tyler and Page, 1996). Thus the first two deformations in the Eastern zone probably correlate with D_3 and D_4 in the Central and Western zone, which formed during the Halls Creek Orogeny, and will be referred to as such in these notes. A minimum age for these deformations is provided by the c. 1808 Ma age for the Mount Christine Granitoid, which cuts across the trend of D_4 structures in the vicinity of Hangman Well (around AMG 110327), and Rockhole Camp (around AMG 087263).

First deformation

The first deformation to affect rocks in the Eastern zone of the Lamboo Complex (the regional D_3, Table 1) was a layer-parallel shearing event that affected both the Ding Dong Downs Volcanics and the Halls Creek Group. A penetrative foliation is well developed, but, folds that might be related to this fabric are not recognized. On McINTOSH, Warren (1994a) noted an early shear zone that removed the upper part of the Biscay Formation and the lower part of the overlying Olympio Formation, including the Butchers Gully Member. This relationship is consistent with low-angle extensional faulting. Similar structures were recognized by Hancock (1991) around the Sophie Downs Dome on HALLS CREEK, with movement thought to have been to the south.

The Ding Dong Downs Volcanics to the north of Bulara Well are intensely deformed, showing a strong, mylonitic layer-parallel foliation. Boudinage occurs parallel to the foliation, and rotation of the boudins is consistent with a northeast to southwest sense of shear.

The overlying Saunders Creek Formation is also strongly deformed at its base, with the development of mylonitic rocks in the southeastern part of DOCKRELL. Pebbles within conglomerate units, which show asymmetrical tails that are consistent with northeast to southwest movement, are well exposed near Esaw Bore. Pegmatites have intruded into the Saunders Creek Formation prior to shearing, and show boudinage and rotation, again consistent with a northeast to southwest sense of shear.

A zone of intense deformation is also developed at the contact between the Biscay and Olympio Formations.

Second deformation

The second deformation to affect the Eastern zone of the Lamboo Complex (the regional D_4, Table 1) produced pervasive open to isoclinal, east-northeasterly to northeasterly trending folds at all scales. Axial surfaces are upright to moderately inclined to the southwest. Plunges were subhorizontal, but, as the result of later refolding, now vary from near horizontal to near vertical to either the southwest or northeast. Folds generally have a good axial planar crenulation cleavage and crenulation hinge lineation. Cleavage refraction between psammitic and pelitic units is well developed in the Olympio Formation.

The Ding Dong Downs Volcanics, early granitoid rocks, and lower Halls Creek Group rocks are exposed in the cores of tight regional-scale anticlines, with the Olympio Formation exposed in the intervening tight to isoclinal synclines. The difference in fold intensity is probably the result of disharmonic folding, reflecting the more massive nature of the lower Halls Creek Group and its basement, compared with the thinner bedded Olympio Formation. Griffin and Tyler (1992) also noted that folds become tighter adjacent to the Angelo–Halls Creek Fault system, but this is best seen on HALLS CREEK. The outcrop pattern of the Woodward Dolerite defines large-scale folds within the Olympio Formation.

The Garden Creek Anticline is regarded here as a D_4 fold that was overturned to the northwest. In the nose of this fold, smaller-scale D_4 fold closures are isoclinal and S_3 and S_4 fabrics are parallel to both bedding and each other. Due to refolding, the folds either plunge steeply to the southwest, or are reclined, plunging steeply to the northeast. However, more open, small-scale D_4 folds, further to the northeast, clearly show a layer-parallel S_3 being folded by D_4, with S_4 itself being crenulated later by S_5.

In the migmatitic Tickalara Metamorphics to the north of Mount Christine, D_4 post-dates the c. 1820 Ma phase of granitoid intrusion. A shear zone is developed along the western margin of the strip of migmatite and amphibolite. The c. 1820 Ma granitoid occurs within the shear zone and shows microscopic shear-sense indicators consistent with normal, down to the southwest, movement.

Migmatitic leucosomes are isoclinally folded within the shear zone, with variations in the orientation of fold hinges suggesting the possible development of sheath folds. Strain was lower within the middle of the migmatite and amphibolite strip, and folds, which also affect granitoid veins, are open to tight and have axial plane foliation. The axial surfaces of the folds are parallel to the shear zone at the margin of the strip. A well exposed fold in amphibolite on the northern bank of the Mary River has a curved hinge and may be a sheath fold, produced by progressive simple shear within the shear zone.

Foliated c. 1820 Ma granitoids occur as xenoliths within the main coarse-grained, porphyritic phase of the Mount Christine Granitoid, implying that deformation occurred before c. 1808 Ma. The northwesterly orientation and normal sense of movement on the shear zone are consistent with it developing as a normal fault antithetic to a northeasterly trending sinistral strike-slip fault (see Wilcox et al., 1973). Deformation probably correlates with D_4.

Metamorphism

In general, rocks in the Eastern zone of the Lamboo Complex have been metamorphosed under low- to medium-grade metamorphic conditions. Dow and Gemuts (1969, fig. 4) indicated that metamorphic grade increased from greenschist to amphibolite facies conditions from the Angelo Fault southeastwards across DOCKRELL. Typically, pelitic lithologies consist of fine- to medium-grained mica schist. Porphyroblasts of chlorite, garnet, and andalusite occur in medium-grade rocks to the southeast. In mafic rocks mineral assemblages are typical of the greenschist facies and epidote–amphibolite facies. Lower grade rocks consist of actinolite, chlorite, and epidote/clinozoisite, with interstitial quartz and albite. In the higher grade rocks chlorite is absent, and the amphibole is typically a blue-green edenitic variety.

In medium-grade pelitic rocks a sequence of mineral growth is apparent that can be related to the deformation sequence. Andalusite porphyroblasts, up to 1 cm in length, typically show trails of fine inclusions. S_3 wraps the porphyroblasts; however, in some sections 'millipede' textures (Bell and Rubenach, 1980) are developed suggesting that growth was syn-D_3. Andalusite shows partial to complete replacement by fine- to medium-grained muscovite.

Garnet porphyroblasts, which can be up to 5 mm in diameter, have apparently grown during D_4. They show 'millipede' textures consistent with synchronous growth of the porphyroblasts and the S_4 crenulation cleavage that wraps them. Prograde garnet, together with coarse muscovite and biotite, locally overgrows S_3 and may occur with retrogressed andalusite porphyroblasts.

Chlorite porphyroblasts are no more than 1 mm in length and are restricted to magnesium-rich rocks. Where present they are crenulated by S_4 and probably grew during M_3 but remained stable during M_4.

The sequence of mineral growth, with assemblages comprising early andalusite, muscovite, and biotite, with or without chlorite, being replaced by garnet, muscovite, and biotite, with or without chlorite, is consistent with the metamorphic mineral reaction:

andalusite + biotite = garnet + muscovite.

Based on the petrogenetic grid of Harte and Hudson (1979, fig. 2), this would imply an anticlockwise pressure-temperature-time (P-T-t) path involving initial low pressure/moderate temperature metamorphism (M_3; 500–600°C, <3 MPa) followed by an increase in pressure to moderate pressure/moderate temperature conditions (M_4; 600°C, >3 MPa).

Contact metamorphism

In the pelitic migmatites of the Tickalara Metamorphics to the north of Mount Christine, sillimanite is replaced by muscovite, cordierite is replaced by pinite, and prograde andalusite and chlorite are developed. In the amphibolites, plagioclase is replaced by sericite and fine-grained epidote, while chlorite, and coarser-grained epidote are also developed. Given the close proximity of these rocks to the Mount Christine Granitoid, this medium-grade event is attributed to contact metamorphism. This event also produced the quartz–muscovite–biotite–cordierite hornfels in the Tickalara Metamorphics to the southeast of the Egan Range (around AMG 950360) characterized by large poikiloblastic cordierite crystals, largely altered to pinite.

Contact metamorphism against the Mount Christine Granitoid has also affected Biscay Formation rocks to the southeast of Sandy Creek Bore (around AMG 040210). There, a medium-grained pelitic hornfels consisting of quartz, K-feldspar, biotite, cordierite, and sillimanite is developed. The Woodward Dolerite, adjacent to and within the Mount Christine Granitoid, is composed of medium-grained amphibolite. Textures vary from subhedral granular to granoblastic, and mineral assemblages consist of green-brown hornblende, andesine, biotite, quartz, opaque minerals, and apatite.

San Sou Monzogranite (*Ƥgss*)

The San Sou Monzogranite is a small, poorly exposed intrusion in the southeast corner of DOCKRELL. The main approximately 3 × 9 km mass is centred on Taylor Lookout, with further exposures of about 4 km² found several kilometres to the southeast. A SHRIMP U–Pb zircon age of 1788 ± 6 Ma was determined for a sample of the monzogranite (Page and Sun, 1994). It is the only granitoid of this age known in the Lamboo Complex, but it is of a similar age to The Granites Granite in the Granites–Tanami Inlier (Page and Sun, 1994). The San Sou Monzogranite intrudes the Esaw Monzogranite and Ding Dong Downs Volcanics in the Taylor Lookout Anticline, and the Saunders Creek, Biscay, and Olympio Formations of the Halls Creek Group. Variably recrystallized, medium- to fine-grained leucocratic biotite monzogranite is the sole rock type.

Minor microcline and rare plagioclase phenocrysts, are set in a groundmass of granular quartz, microcline, and plagioclase, with minor reddish-brown biotite, and accessory allanite, apatite, and zircon. Euhedral allanite is a prominent accessory in several samples. Much of the quartz is partly recrystallized to polygonal aggregates. There is widespread sericitization of plagioclase and development of rod-like microperthite in microcline. Epidote and titanite are pseudomorphed by magnetite and ilmenite, respectively. Biotite is partly chloritized, and allanite is commonly hydrated.

Pegmatite veins and dykes *(p)* and rhyolite porphyry *(po)*

The Halls Creek Group, early granitoids, Ding Dong Downs Volcanics, and the San Sou Monzogranite are intruded by pegmatite veins and dykes which are generally about 1–5 m wide and traceable for up to 150 m along strike. A pegmatite from McClintock Range, which gave an Archaean Rb–Sr model age (Dow and Gemuts, 1969), has given a SHRIMP U–Pb zircon age of c. 1740 Ma (R. W. Page, 1992 quoted by Griffin and Tyler, 1992). Griffin and Tyler (1992) suggested that there are two ages of pegmatite dyke intrusion, because some dykes are deformed and boudinaged by an early layer-parallel deformation (D_3), whereas others, including that from which the zircon age was obtained, are cut only by S_5. The dykes are composed of microcline, albite, quartz, muscovite, and coarse-grained tourmaline, with spessartite, ilmenite, manganocolumbite, and cassiterite as accessory minerals, and, where the dykes intrude calcareous rocks, fluorite and apatite may be present (Roberts et al., 1965, 1968).

A rhyolite porphyry intrudes the Dillinger Monzogranite near the Dillinger microwave repeater station (AMG 119447).

Dolerite dykes *(d)*

Sparse dolerite dykes intrude the Tickalara Metamorphics, and c. 1835–1805 Ma granitoids and gabbros on DOCKRELL. The dykes strike between north-northeast and north-northwest, and are composed of ophitic, medium-grained dolerite, uralitized dolerite, and porphyritic quartz dolerite (Roberts et al., 1965).

Lamprophyre dykes

Several altered lamprophyre dykes intrude the Mount Christine Monzogranite around AMG 002458 (Pirajno, F., 1995, pers. comm.). The dykes, which were identified after the publication of the DOCKRELL map sheet (Tyler and Griffin, 1994), are less than 2 m wide and strike north-northwest. Contacts with the host granitoid are commonly sheared, and the granitoids may be altered up to about five metres away from the dykes. The dykes are composed of microphenocrysts of ‘olivine’ (altered to carbonate–quartz) and ‘phlogopite’ (altered to chlorite–carbonate–opaques), in a groundmass of granular chlorite, calcite, and untwinned feldspar. The groundmass also contains abundant acicular and prismatic apatite crystals (~2%), opaque minerals and zircon. Depending on whether the igneous feldspar was K-feldspar or plagioclase, the rocks were probably either minettes or kersantites (Rock, 1991).

Yampi Orogeny

Tyler and Griffin (1990) identified a deformational event in the King Leopold Orogen, in the west Kimberley, that produced large-scale shearing in the crystalline rocks of the Hooper Complex, together with northeasterly directed folding and thrusting along the southwestern margin of the Kimberley Basin. Deformation was accompanied by medium-grade metamorphism. This event was referred to as the Yampi Orogeny by Tyler and Griffin (1993) and Griffin et al. (1993).

The age of deformation was poorly constrained, taking place after intrusion of the Hart Dolerite into the Kimberley Group at c. 1800 Ma (Page and Sun, 1994), but before deposition of the Neoproterozoic glacigene rocks of the Mount House Group. Tyler and Griffin (1990) suggested that deformation and metamorphism might be linked to c. 1300 Ma events in the Paterson Orogen to the southwest. Shaw et al. (1992) obtained K–Ar ages from sheared granitoid rocks from the Hooper Complex that placed age limits of between 1475 ± 12 Ma and 999 ± 9 Ma on the Yampi Orogeny.

In the Halls Creek Orogen, large-scale, north-northeasterly trending, sinistral strike-slip faults and easterly trending dextral faults have developed after the deposition of the Kimberley Basin (Dow and Gemuts, 1969; Plumb and Gemuts, 1976; Tyler et al., 1995; Thorne and Tyler, 1996), affecting rocks as young as Devonian. However, Dow and Gemuts (1969) noted that younger rocks showed smaller displacements than older rocks suggesting that the faults have long, complex histories.

Tyler et al. (1995) suggested that the pattern of strike-slip faulting was controlled by major northeasterly trending structures that developed during the Palaeoproterozoic, and whose position is now marked by the zone boundaries within the Lamboo Complex. The current fault pattern developed first as ductile structures in the Mesoproterozoic, accompanying the northeasterly directed folding and thrusting developed during the Yampi Orogeny in the King Leopold Orogen. Later reactivations of the faults were more brittle. Griffin and Tyler (1992) referred to the initial, more ductile deformation as D_5.

Deformation

On DOCKRELL the main D_5 fault structures are the north-northeasterly trending Woodward and Dockrell Faults. The overall pattern of faulting (Fig. 3) is consistent with a sinistral fault system, with these two main faults forming synthetic sinistral structures, while east-northeasterly trending dextral faults form antithetic structures that connect the main faults (see Wilcox et al., 1973). Both the synthetic and antithetic fault sets are steep, and may be marked by large-scale quartz veining, zones of disrupted bedding up to several metres wide, and by the development of phyllonite.

Associated with the faults are a set of open to tight folds that have conjugate easterly and northwesterly to northerly trending axial surfaces, and generally moderate to steep plunges. Their orientation is also consistent with an overall sinistral strike-slip movement. An axial planar crenulation cleavage (S_5) may be developed within the Ding Dong Downs Volcanics, the early granitoids, the Halls Creek Group, and the 1740 Ma pegmatite dykes. In the vicinity of the major faults, folds and cleavages have been re-orientated subparallel to them.

Fold interference between D_4 and D_5 has developed throughout the southeastern part of DOCKRELL (Fig. 3), and the variable, conjugate nature of the orientation of D_5 has produced a range of interference patterns. The Junda Microgranite outcrops in the core of a type 1 'dome' (see Ramsay and Huber, 1987, p. 492) produced by interference between a northeasterly trending D_4 anticline and a northwesterly trending D_5 anticline. To the southwest the same D_4 fold is refolded by easterly trending D_5 folds to give type 3 'hooks'.

The Taylor Lookout Anticline is partly obscured by intrusion of the San Sou Monzogranite. However, the outcrop pattern of the lower Halls Creek Group around the dome is inconsistent with a simple dome-shaped refold structure, but resembles a type 2 'arrowhead' pattern produced by interference of a east-northeasterly trending D_4 anticline and northeasterly trending D_5 folds, with moderate plunges.

The Garden Creek Anticline is a type 3 'hook' produced by the interference of an east-northeasterly trending D_4 anticline, which was overturned to the northwest, and D_5 folds which are easterly and northwesterly trending, and easterly plunging. The northwestern limb of the D_4 anticline is overturned so that the D_5 folds are a downward facing synformal anticline–antiformal syncline pair. A southerly plunging, north-northeasterly trending D_5 syncline is present to the north of the anticline, and is associated with dextral movement on a northeasterly trending fault, making the overall structure a large-scale box fold (Fig. 3).

Metamorphism

Metamorphism associated with D_5 took place under greenschist facies conditions, and in the southeastern part of DOCKRELL is retrograde. In medium-grade pelitic mica schists the cleavage tends to form as spaced zones of recrystallization made up of finer grained mica and trails of opaque minerals. Andalusite porphyroblasts were retrogressed during M_4. However garnet, which was prograde during M_4, can be altered to either chlorite, intergrowths of muscovite and biotite, or intergrowths of biotite and opaque. Late porphyroblasts of chlorite, which overgrow S_4, may occur.

In granitoids of the Sally Downs supersuite and the San Sou Monzogranite, partial recrystallization of quartz, alteration of plagioclase cores to sericite and clinozoisite, chloritization of biotite, and the occurrence of epidote and titanite, probably occurred during M_5. The formation of granophyric textures and widespread crystallization of microperthite are also related to the M_5 event. The scarcity of igneous hornblende in these granitoids, and the abundance of granular epidote inclusions in biotite, suggests that hornblende was pseudomorphed by biotite and epidote during greenschist facies metamorphism (e.g. Wyborn and Page, 1983).

Louisa Basin

Louisa Downs Group

Neoproterozoic glacigene rocks outcrop extensively throughout the Kimberley region (Dow and Gemuts, 1969; Coates and Preiss, 1980; Plumb, 1981; Corkeran et al., 1996; Plumb, 1996). The Louisa Downs Group was deposited in the Louisa Basin, and outcrops in the northwestern part of DOCKRELL, where it unconformably overlies granitoid rocks of the Lamboo Complex. Elsewhere on MOUNT RAMSAY the Louisa Downs Group unconformably overlies the Kimberley Group, the Crowhurst Group, the Colombo Sandstone, and the Glidden Group (see Roberts et al., 1968; Tyler et al., in prep. b). West of Louisa Downs, in the Kuniandi Range, it disconformably overlies the Kuniandi Group, also regarded as a Neoproterozoic glacigene sequence (Roberts et al., 1965).

Dow and Gemuts (1969) suggested that the tillite at the base of the Louisa Downs Group succession was a subaqueous deposit from a grounded ice sheet. Plumb (1981; written communication, 1993) points out that this tillite interfingers with fluvioglacial outwash material occurring to its north and suggests that the sequence represents a glacier passing southwards into a subaqueous, marine or lacustrine environment. Ice movement was from the north. Glaciation was followed by a marine transgression.

Coates and Preiss (1980) correlated the Louisa Downs Group with the Mount House Group, and with both the Duerdin Group and the overlying Albert Edward Group, and equated all three successions with the Maranoan Glaciation in South Australia, now dated at c. 610 Ma.

Plumb (written communication, 1993; 1996) disputes this correlation, preferring to correlate the Louisa Downs Group with the Albert Edward Group, and the Mount House and Duerdin Groups with the Kuniandi Group. He regards the Louisa Downs Group as the product of a local, mountain glaciation which, although not known elsewhere in Australia, has been identified just below the base of the Cambrian elsewhere in the world. This correlation has been confirmed by the identification of the stromatolite *Tungussia julia* within the Egan Formation (Corkeran et al., 1996).

The Louisa Downs Group is divided into five formations (Table 2) that have a maximum combined thickness of some 4000 m (13 000 feet, see Roberts et al., 1965, 1968, 1972). The following descriptions are based

Table 2. Stratigraphy of the Neoproterozoic to early Palaeozoic sedimentary basins on DOCKRELL

Group/Basin	*Formation*	*Thickness (m)*	*Lithology*
ORD BASIN	Antrim Plateau Volcanics (Ꞓa)	>1500	Massive, vesicular, and amygdaloidal basalt; minor sandstone
	Lally Conglomerate (Ꞓl)	33	Medium- to coarse-grained sandstone and quartz cobble conglomerate
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ unconformity/disconformity ~ ~ ~ ~ ~ ~ ~ ~ ~ ~			
LOUISA BASIN **Louisa Downs**	Lubbock Formation (*ᵽtl*)	1 830	Medium-grained quartz wacke and siltstone
Group	Tean Formation (*ᵽtt*)	120	Fine- to medium-grained feldspathic sandstone, quartz sandstone, quartz wacke, conglomerate, siltstone, and mudstone
	McAlly Shale (*ᵽtm*)	1 500	Mudstone; minor siltstone and fine-grained sandstone
	Yurabi Formation (*ᵽty*)	125	Medium-grained sandstone, siltstone, mudstone, dolomitic siltstone, and silty or sandy dolomite
	Egan Formation (*ᵽte*)	40	Tillite, coarse-grained arkose, dolomite, algal dolomite, and siltstone

on the detailed measured sections of Roberts et al. (1965) with additional data from Coates and Preiss (1980), and Plumb (1981).

Egan Formation (ᵽLe)

The Egan Formation is the basal unit of the Louisa Downs Group, and the type area occurs on DOCKRELL where the Great Northern Highway crosses the Egan Range (AMG 999456; Roberts et al., 1965; Coates and Preiss, 1980). There the unit unconformably overlies the Mount Christine Granitoid, and is 40 m thick.

The lower part of the unit consists of coarse-grained, poorly sorted arkose, overlain by poorly bedded dolomite and dolomite breccia. This is in turn overlain by a massive, unstratified tillite, which consists of pebbles and cobbles of dolomite and quartzite in a silty to fine-grained sandy matrix. The diamictite is overlain by interbedded dolomite, showing algal lamination, and siltstone. The dolomite beds may also show irregular wavy lamination, tepee structures, intraclast breccias, and small 'overthrusts' related to dewatering.

Yurabi Formation (ᵽLy)

The Yurabi Formation on DOCKRELL is 125 m (355 feet) thick and disconformably overlies the Egan Formation (Roberts et al., 1965). The lower part of the unit is dominated by medium-grained, ripple-laminated sandstone interbedded with siltstone and mudstone. This is overlain by siltstone and mudstone, with more resistant beds of laminated dolomitic siltstone, and silty or sandy dolomite. The top of the unit consists of thinly bedded mudstone, siltstone, and fine-grained sandstone.

McAlly Shale (ᵽLm)

The McAlly Shale conformably overlies the Yurabi Formation and consists of 1500 m (5000 feet) of finely laminated mudstone, interbedded near its base with finely laminated siltstone and fine-grained sandstone.

Tean Formation (ᵽLt)

The Tean Formation conformably overlies the McAlly Shale, and is 120 m (400 feet) thick. The unit consists mainly of fine- to medium-grained feldspathic sandstone and quartz wacke, interbedded with conglomerate, fine- to medium-grained quartz sandstone, and laminated siltstone and mudstone.

Lubbock Formation (ᵽLl)

The Lubbock Formation conformably overlies the Tean Formation. It is at least 1830 m (6000 feet) thick, and consists of interbedded ?turbiditic, medium-grained quartz wacke and siltstone. The quartz wackes may show graded bedding.

King Leopold Orogeny

The King Leopold Orogeny (Tyler and Griffin, 1993; Griffin et al. 1993) produced extensive, well exposed, west-northwesterly trending folding and thrusting in the King Leopold Ranges, along the southwestern margin of the Kimberley Basin (Griffin and Myers, 1988; Tyler and Griffin, 1990), together with the reactivation of shear zones in the Hooper Complex (Tyler et al., 1991; Shaw et al., 1992). Deformation affected Late Proterozoic glacigene rocks and Shaw et al. (1992) obtained K–Ar ages of c. 560 Ma from reactivated shear zones and interpreted this date as the age of deformation. Coates and Preiss (1980) and Plumb (1981) reinterpreted the data from Bofinger (1967) and reported Rb–Sr ages of 568 Ma and 576 ± 80 Ma respectively from the McAlly Shale of the Louisa Downs Group. These ages were interpreted as reflecting a metamorphic, cleavage forming event, which was correlated by Shaw et al. (1992) with the King Leopold Orogeny. Thrusting in the West Kimberley was linked to sinistral strike-slip faulting in the East Kimberley (Tyler and Griffin, 1990; Tyler et al., 1991). Deformation occurred at about the same time as the Paterson Orogeny and the Petermann Ranges Orogeny (Myers et al., 1996).

On DOCKRELL, deformation that can be attributed to the King Leopold Orogeny (D_6) is restricted to the southern margin of the sheet, to the south of the easterly trending Haughton Range Fault. Deformation takes the form of easterly to east-northeasterly trending open to tight folds that refold D_4 and D_5 structures and produce a range of medium- and small-scale interference patterns. The Haughton Range Fault, whose position is marked by extensive quartz veining exposed within sandplain, offsets both the Woodward and Dockrell Faults. An axial planar crenulation cleavage (S_6) is developed and can be seen to crenulate S_5.

To the east of DOCKRELL, on RUBY PLAINS, the folding is seen to affect both of the Neoproterozoic Duerdin and Albert Edward Groups (Blake et al., in press b). However, the folding does not affect the unconformably overlying ?Cambrian Antrim Plateau Volcanics further to the northeast on GORDON DOWNS, consistent with it being Late Proterozoic (c. 560 Ma) in age.

Ord Basin

Cambrian deposits

Possible Cambrian strata, which consists of the Lally Conglomerate and the overlying basalts of the Antrim Plateau Volcanics, outcrop in the Ramsay Range in the northwestern corner of DOCKRELL. This sequence overlies the Lubbock Formation of the Louisa Downs Group with apparent conformity. However, this contact is regarded as a disconformity as the Lally Conglomerate overlies McAlly Shale at Mount George, to the north of the Glidden Fault on MOUNT RAMSAY, and steps down onto the Yurabi Formation to the southwest of Moola Bulla Homestead (Roberts et al., 1965; Tyler et al., in prep. b). Uplift presumably took place during the King Leopold Orogeny. This assumption sets a maximum age for the Lally Conglomerate and Antrim Plateau Volcanics of c. 560 Ma. In the Hardman Basin on DIXON RANGE the Antrim Plateau Volcanics are overlain with apparent conformity by Middle Cambrian strata (Mory and Beere, 1988).

Neoproterozoic to early Cambrian mafic volcanic rocks occur throughout central and northern Australia (Shaw et al., 1991; Walter et al., 1995), and are regarded as representing a period of widespread continental extension (Shaw et al., 1991).

Lally Conglomerate (*Ꞓl*)

The Lally Conglomerate has been described by Roberts et al. (1965, 1968). Across the Ramsay Range, the Lally Conglomerate is less than 33 m thick and consists of massive, cross-bedded, medium- to coarse-grained sandstone, with occasional lenses of quartz cobble conglomerate.

Antrim Plateau Volcanics (*Ꞓa*)

The Antrim Plateau Volcanics on DOCKRELL was described by Roberts et al. (1965, 1968). It conformably overlies the Lally Conglomerate and consists of massive, vesicular, and amygdaloidal basalt, with occasional sandstone interbeds.

Bultitude (1971) described the Antrim Plateau Volcanics from nine stratigraphic drillholes in the Victoria River District of the Northern Territory. The succession consisted of feldspar-phyric, tholeiitic olivine to quartz basalt lava flows, which averaged 36 m in thickness. The lava flows were interlayered with occasional bands of agglomerate, as well as sandstone, siltstone, limestone, and chert beds. Individual flows had a central massive, medium-grained interior grading into an altered, fine-grained, vesicular zone in the upper, and generally also the basal part. Vesicles were filled with chlorite, quartz, calcite, chalcedony, agate, prehnite, and pumpellyite.

Alice Springs Orogeny

On DOCKRELL, the Louisa Downs Group, Lally Conglomerate, and the Antrim Plateau Volcanics are folded into a large-scale, gently plunging, northeasterly trending syncline. The syncline is bounded along its northwestern side by the Ramsay Range Fault with a throw of some 3.5 to 4 km (combined thickness of Louisa Downs Group and ?Cambrian strata), down to the southeast, suggested by the juxtaposition of Antrim Plateau Volcanics against Palaeoproterozoic granitoid. The structure may have formed as a hanging-wall synform (see Ramsay and Huber, 1987, fig. 23.25) produced by local normal movement of the Ramsay Range Fault. Although Devonian rocks are not preserved within the syncline, faulting may be related to events that triggered the deposition of Late Devonian siliciclastic rocks on alluvial fans and by braided streams within the Ord Basin to the northeast (Mory and Beere, 1988; Mory, 1990; Thorne and Tyler, 1996).

The Ramsay Range Fault and the adjacent syncline are cut and displaced by northerly and northwesterly trending faults. Open to tight, medium-scale folding is associated with these faults. Both the extensional faulting and the folding may be related to sinistral strike-slip faulting that has affected Palaeozoic and older rocks throughout the Halls Creek Orogen, and represents the effects of the

Upper Devonian to Carboniferous (400 Ma–300 Ma) Alice Springs Orogeny (Shaw et al., 1992) in the East Kimberley (Tyler et al. 1995; Thorne and Tyler, 1996).

Superficial deposits

Cainozoic deposits

Laterite (Czl) consisting of massive and pisolitic, ferruginous duricrust, forms an extensive high plateau throughout the southern and western parts of DOCKRELL. The laterite is generally regarded as having formed between the Late Cretaceous and Early Miocene (Hocking and Cockbain, 1990). Colluvial and alluvial deposits (Czs), consisting of partly consolidated silt, sand, and gravel overlie the laterite and also occur on floodplains adjacent to drainage channels. Partly consolidated colluvial deposits (Czc) occur as valley-fill, and as scree and rubble overlying the Halls Creek Group in the southeastern part of the sheet.

Unconsolidated alluvium (Qa), consisting of silt, sand, and gravel, occurs along present drainage channels. Sheet-wash deposits (Qw) occur in broad drainage lines with ill-defined channels on the plateau country in the southeastern part of the sheet. An area of black soil plain (Qb) occurs to the south of Old Lamboo Homestead.

Economic geology

The following descriptions of mineral deposits and occurrences on DOCKRELL are based on a summary of both published information and information contained within open-file WAMEX reports compiled by Sanders (in prep.), that cover the whole of the East Kimberley. AMG grid references are given for occurrences that were not shown on the published 1:100 000 map sheet (Tyler and Griffin, 1994).

Gold

On DOCKRELL, historical gold production has taken place mainly in the area to the southwest of Mount Dockrell. Mineralization is associated with sulfide minerals, mainly galena, within quartz and quartz–carbonate veins. Mineralization may be related to the intersection of major north-northeasterly trending strike-slip faults with contacts between mafic rocks (such as the basaltic volcanic rocks of the Biscay Formation, or doleritic rocks of the Woodward Dolerite) and feldspathic metasedimentary rocks of the Olympio Formation (Warren, 1994b). Numerous alluvial gold workings are also present.

Several small and poorly documented gold prospects occur to the east of Garden Creek Bore, along contact zones between metasedimentary rocks of the Olympio Formation, and the Woodward Dolerite. There gold mineralization occurs in thin (up to 50 cm thick) quartz–calcite veins, which can also contain galena, sphalerite, pyrite, and rare copper carbonate. Intersection of veins can produce small-sized, pipe-shaped 'gold leaders', which reportedly consist of spectacular specimen pieces of gold, and extend to depths of 5 to 6 metres.

At the Mount Dockrell Mining Centre, mineralization at the Victoria, McNeills, and Lady Hopetoun workings is associated with thin, discontinuous, quartz veins within narrow (2–3 m wide), northerly trending zones of brittle fracturing. Alternatively, the mineralization is found within shear zones, which are developed either in relatively fresh, fine- to medium-grained amphibolite, or along the contacts between amphibolite and meta-greywacke. The quartz veins contain late carbonate, which fills cavities, chloritic segregations and fracture coatings, and occasional galena crystals. Wallrock alteration is limited to minor silicification and chloritization. Thin alteration selvages with rosettes of retrograde amphibole suggest that mineralization took place after peak metamorphism.

At the Irish Lass workings, persistent low grade mineralization is associated with a series of thin, northeasterly trending quartz–carbonate veins, which are parallel to the moderately to steeply east-dipping foliation in weathered, sheared mafic rocks of the Biscay Formation. The veins contain arsenopyrite, galena, and chalcopyrite also, with chloritic films and segregations, and have thin carbonate–chlorite–epidote alteration selvages. Retrograde amphibole (?actinolite) is relatively abundant.

At Erin go Bragh, one group of workings is developed on a 3–4 m wide zone of open stockwork quartz veining exposed in foliated north-northeasterly trending metasedimentary rocks. Shallow percussion drilling obtained a 3 m intercept grading 3.79 ppm Au. A second group of workings is developed on a narrow, northeasterly trending shear zone and associated quartz veining within a metadolerite. Some carbonate–quartz–amphibole–chlorite–limonite–(malachite) vein selvages are present. Shallow percussion drilling obtained a 3 m intercept grading 1.78 ppm Au.

To the northwest of Irish Lass, several large prospecting pits trend east-southeasterly over about 70 m, and are developed on variably silicified, chloritized, and carbonated quartz–carbonate veins in a metadolerite breccia. The quartz–carbonate veins have inner chlorite selvages and retrograde amphibole outer selvages. Fine, disseminated, and minor aggregate galena–pyrite–chalcopyrite is not uncommon in the metadolerite. Shallow percussion drilling obtained a 2 m intercept grading 8.54 ppm Au.

The Hangmans Au–Pb prospect (AMG 164246) occurs in a 6 m wide, north-northeasterly trending ferruginous quartz vein, which extends for 150 m along the contact between sheared and carbonated metadolerite of the Woodward Dolerite, and tightly folded metasedimentary rocks of the Olympio Formation of the Halls Creek Group. Gold mineralization is associated with irregularly developed galena pods within the quartz vein, which have assayed up to 11 ppm Au, and 0.53% Pb.

The East Dockrell Au–As–Pb occurrence (AMG 157218) is developed in a quartz stockwork and in massive siliceous gossans within sericite and quartz–sericite schists. Mineralization appears to be related to widespread, sporadic sulfide-bearing quartz veins, which are enriched at the surface.

Tin, tantalum, niobium, tungsten, copper, molybdenum, and fluorine

In the southern and southeastern part of DOCKRELL, pegmatite-hosted and associated skarn Sn–Ta–Nb, W–Sn, W–Sn–F, W, Cu, and Cu–Mo–Ag mineralization is present.

The Mount Heartbreak area, west-southwest of Taylor Lookout, has historically been the site of small-scale mining of alluvial deposits of Sn, with cassiterite derived from the numerous pegmatites in the area. The alluvial deposits were worked intermittently up to 1962, with recorded production of 1.31 t of Sn concentrate containing 870 kg of metallic Sn. A shaft was sunk at the Mount Cross tin mine east of Junda Bore.

The pegmatites are generally small, and while they are all enriched in Sn, Ta, and Nb, values are erratic, with rock chip assays giving values of up to 1480 ppm Sn, 350 ppm Ta and 365 ppm Nb. These small values mean that they are unlikely to form the basis for an economic deposit. They are the likely source of the skarn-forming fluids in the area.

A W–Sn skarn occurs adjacent to one of the main alluvial workings (AMG 148076). Mineralization occurs in podiform skarn developed within sheared carbonate-rich volcanic rocks forming the Butchers Gully Member of the Olympio Formation. The mineralogy of the skarn is dominated by vesuvianite (64%), with clinozoisite (25%), calcite (4%), fluorite (4%), muscovite (2%) and scheelite (1%) also present. Rock chip sampling gave results up to 1.5% W and 1,150 ppm Sn, although average results were significantly lower (10–2760 ppm W and 400–700 ppm Sn). The skarn is intruded by a number of pegmatoid phases including blue-grey quartz, quartz–feldspar, quartz–feldspar–mica, and mica-rich pegmatites, as well as quartz–albite–tourmaline rich phases.

Tungsten mineralization in the Mount Dockrell area (North Dockrell, AMG 128210; South Dockrell AMG 115205) occurs in the Olympio Formation. Scheelite occurs within stratabound epidote-bearing 'quartzites' and tourmaline-bearing 'quartzites' of probable metasomatic origin, and in cross-cutting quartz veins. The mineralization is closely associated with highly anomalous Sn–Ta and F values, and fluorite and cassiterite are present.

Disseminated and vein related Cu mineralization occurs sporadically throughout the Halls Creek Group on DOCKRELL. Skarn Cu (AMG 180081; 193087), Cu–Mo–Ag (AMG 179076), and W (AMG 192088; 196092) mineralization occurs along a carbonate unit in the Biscay Formation to the west and northwest of Taylor Lookout, and is probably related to the adjacent c. 1790 Ma San Sou Monzogranite.

Gossans occur along the carbonate unit associated with chalcopyrite and malachite. A percussion drillhole intersected a chalcopyrite-bearing quartz vein and gave a 2 m intercept assaying 1.35% Cu, 14 ppm Ag, 28 ppm Mo, 60 ppm Pb, and 470 ppm Zn.

Tungsten mineralization occurs as scheelite, forming within either thin stratiform calc-silicate or marble/calc-silicate horizons, or within vein quartz hosted by calc-silicate or mafic rocks. In each case, the scheelite mineralization is narrow and discontinuous along strike, and is low grade. Where the scheelite is hosted by carbonate or calc-silicate, small discontinuous quartz veins are the likely source of the mineralization.

References

ALLEN, R., 1986, Relationship of the thermal evolution to tectonic processes in a Proterozoic fold belt: Halls Creek mobile zone, East Kimberley, West Australia: University of Adelaide, PhD thesis (unpublished).

ASHWORTH, J. R., 1985, Migmatites: Glasgow, Blackie, 302p.

BEARD, J. S., 1979, The vegetation of the Kimberley area: Vegetation Survey of Western Australia, 1:1 000 000 Vegetation Series, Explanatory Notes to Sheet 1. University of Western Australia Press, Perth.

BELL, T. H., and RUBENACH, M. J., 1980, Crenulation cleavage development — evidence for progressive, bulk inhomogeneous shortening from millipede microstructures in the Robertson River Metamorphics: Tectonophysics, v. 68, p. T9-15.

BLAKE, D. H., and HOATSON, D. M., 1993, Granite, gabbro, and migmatite field relationships in the Proterozoic Lamboo Complex of the east Kimberley region, Western Australia: AGSO Journal of Australian Geology and Geophysics, v. 14, p. 319–330.

BLAKE, D. H., TYLER, I. M., GRIFFIN, T. J., SHEPPARD S., THORNE, A. M., and WARREN, R. G., 1998, Geology of the Halls Creek 1:100 000 Sheet (4461), Western Australia: Australian Geological Survey Organisation, 36p.

BLAKE, D. H., TYLER, I. M., and SHEPPARD, S., 1997, Geology of the Ruby Plains 1:100 000 Sheet (4460), Western Australia: Australian Geological Survey Organisation, 15p.

BOFINGER, V. M., 1967, Geochronology of the east Kimberley area of Western Australia: Australian National University, PhD thesis (unpublished).

BULTITUDE, R. J., 1971, The Antrim Plateau Volcanics, Victoria River District, Northern Territory: Australia BMR Geology and Geophysics, Record 1971/69.

COATES, R. P., and PREISS, W. V., 1980, Stratigraphic and geochronological reinterpretation of late Proterozoic glaciogenic sequences in the Kimberley Region, Western Australia: Precambrian Research, v. 13, p. 181–208.

CORKERAN, M., GREY, K., LI, Z. X., PLUMB, K. A., POWELL, C. McA., and VON DER BORCH, C. C., 1996, Neoproterozoic glacial episodes in the Kimberley region, northwestern Australia: Geological Society of Australia, Abstracts 41, p. 97.

DOW, D. B., and GEMUTS, I., 1967, Dixon Range, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 15p.

DOW, D. B., and GEMUTS, I., 1969, Geology of the Kimberley Region, Western Australia — the East Kimberley: Western Australia Geological Survey, Bulletin 120, 135p.

ETHERIDGE, M. A., RUTLAND, R. W. R., and WYBORN, L. A. I., 1987, Orogenesis and tectonic process in the early to middle Proterozoic of Northern Australia, *in* Proterozoic Lithospheric Evolution *edited by* A. KRONER: Geodynamic Series 17, American Geophysical Union, Washington D.C., p. 131–147.

ESSLEMONT, G., 1990, The geology and geochemistry of the Brockman alkaline volcanics and rare metal deposit: University of Western Australia, BSc Honours thesis (unpublished).

GEMUTS, I., 1971, Metamorphic and igneous rocks of the Lamboo Complex, East Kimberley Region, Western Australia: Australia BMR, Bulletin 107, 71p.

GEMUTS, I., and SMITH, J. W., 1968, Gordon Downs, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 23p.

GRIFFIN, T. J., and GREY, K., 1990, King Leopold and Halls Creek Orogens, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 232–253.

GRIFFIN, T. J., and MYERS, J. S., 1988, Geological Note: a Proterozoic terrane boundary in the King Leopold Orogen, Western Australia: Australian Journal of Earth Sciences, v. 35, p. 131–132.

GRIFFIN, T. J., SHEPPARD, S., and TYLER, I. M., 1994, Geochemical constraints on the tectonic evolution of the Early Proterozoic orogens in the Kimberley region of Western Australia: Geological Society of Australia Abstracts, v. 37, p. 151–152.

GRIFFIN, T. J., and TYLER, I. M., 1992, Geology of the southern Halls Creek Orogen — a summary of field work in 1992: Western Australia Geological Survey, Record 1992/17, 28p.

GRIFFIN, T. J., and TYLER, I. M., in prep., The Geology of the King Leopold Orogen: Western Australia Geological Survey, Bulletin 143.

GRIFFIN, T. J., TYLER, I. M., and PLAYFORD, P. E., 1993, Lennard River, W.A. (third edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 56p.

GRIFFIN, T. J., TYLER, I. M., and SHEPPARD, S., in prep., Geology of the Angelo 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

HANCOCK., S. L., 1991, Tectonic development of the Lower Proterozoic basement in the Kimberley district of northwestern Western Australia: University of Adelaide, PhD thesis (unpublished).

HANCOCK, S. L., and RUTLAND, R. W. R., 1984, Tectonics of an Early Proterzoic geosuture — The Halls Creek orogenic subprovince, northern Australia: Journal of Geodynamics, v. 1, p. 387–432.

HARTE, B., and HUDSON, N. F. C., 1979, Pelite facies series and the temperatures and pressures of Dalradian metamorphism in E. Scotland, *in* The Caledonides of the British Isles — Reviewed *edited by* A. L. HARRIS, C. H. HOLLAND, and B. E. LEAKE: Special publication of the Geological Society of London, no. 8, p. 323–337.

HOATSON, D., 1993, Correlation of structurally disrupted layered ultramafic–mafic intrusions in the East Kimberley: Is Big Ben part of the Panton intrusion?: AGSO Research Newsletter, no. 19, p. 9–10.

HOATSON, D., and TYLER, I. M., 1993, Prospective layered mafic–ultramafic intrusions in the East Kimberley: AGSO Research Newsletter, no. 18, p. 8–9.

HOCKING, R. M., and COCKBAIN, A. E., 1990, Regolith *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 591–602.

MEHNERT, K. R., 1968, Migmatites and the origin of granitic rocks: Amsterdam, Elsevier, 405p.

MORY, A. J., 1990, Ord Basin *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 415–425.

MORY, A. J., and BEERE, G. M., 1988, Geology of the onshore Bonaparte and Ord Basins: Western Australia Geological Survey, Bulletin 134, 184p.

MYERS, J. S., SHAW, R. D., and TYLER, I. M., 1996, Tectonic evolution of Proterozoic Australia: Tectonics, v. 15, p. 1431–1446.

OGASAWARA, M., 1988, Geochemistry of the Early Proterzoic granitoids in the Halls Creek orogenic subprovince, northern Australia: Precambrian Research, v. 40/41, p. 469–486.

ORTH, K., 1997, Notes on the Geology of the Koongie Park Formation southwest of Halls Creek, Western Australia: Australian Geological Survey Organisation, Record 1997/25, 18p.

PAGE, R. D., BLAKE, D. H., TYLER, I. M., GRIFFIN, T. J., and THORNE, A. M., 1994, New geological and geochronological constraints on VMS prospectivity near Halls Creek, W.A.: AGSO Research Newsletter, no. 20, v. 1, p. 5–7.

PAGE, R. W., and HANCOCK, S. L., 1988, Geochronology of a rapid 1.85–1.86 Ga tectonic transition — Halls Creek Orogen, northern Australia: Precambrian Research, v. 40/41, p. 447–467.

PAGE, R. W., HOATSON, D. M., and FOUDOULIS, C., 1995, High-precision geochronology of Palaeoproterozoic layered mafic–ultramafic intrusions in the East Kimberley: AGSO Research Newsletter, no. 22, p. 7–8.

PAGE, R. W., SHEPPARD, S., GRIFFIN, T. J., and TYLER, I. M., in prep. b, Geology and SHRIMP geochronology of Palaeoproterozoic granites in the Lamboo Complex of the Halls Creek Orogen, Western Australia: Journal of the Geological Society of London.

PAGE, R. W., and SUN, S-s., 1994, Evolution of the Kimberley Region, W.A. and adjacent Proterozoic inliers — new geochronological constraints: Geological Society of Australia Abstracts, v. 37, p. 332–333.

PLUMB, K. A., 1981, Late Proterozoic (Adelaidian) tillites of the Kimberley–Victoria River region, Western Australia and Northern Territory, *in* Earth's pre-Pleistocene Glacial Record *edited by* M. J. HAMBREY and W. B. HARLAND: Cambridge University Press, Cambridge, p. 528–530.

PLUMB, K. A., 1996, Revised correlation of Neoproterozoic glacial successions from the Kimberley region, northwestern Australia: Geological Society of Australia, Abstracts 41, p. 344.

PLUMB, K.A., and GEMUTS, I., 1976, Precambrian geology of the Kimberley region, Western Australia: 25th International Geological Congress Excursion Guide no. 44C, 69p.

RAMSAY, J. G., and HUBER, M. I., 1987, The techniques of modern structural geology, Volume 2: Folds and Fractures: London, Academic Press, 392p.

ROBERTS, H. G., GEMUTS, I., and HALLIGAN, R., 1972, Adelaidean and Cambrian stratigraphy of the Mount Ramsay 1:250 000 Sheet area, Kimberley region, Western Australia: Australia BMR, Report 150, 72p.

ROBERTS, H. G., HALLIGAN, R., and GEMUTS, I., 1965, Geology of the Mount Ramsay 1:250 000 sheet area, E/52-9, Western Australia: Australian Geological Survey Organisation, Record 1965/156, 209p.

ROBERTS, H. G., HALLIGAN, R., and PLAYFORD, P. E., 1968, Mount Ramsay, W.A.: Australia BMR, 1:250 000 Geological Series Explanatory Notes, 24p.

ROCK, N. M. S., 1991, Lamprophyres: Blackie, Glasgow, 285p.

RUTLAND, R. W. R., 1981, Structural framework of the Australian Precambrian, *in* Precambrian of the Southern Hemisphere *edited by* D. R. HUNTER: Developments in Precambrian Geology 2, Amsterdam, Elsevier, p. 1–32.

SANDERS, T., in prep., Mineral occurrences of the Halls Creek Orogen, East Kimberley District, Western Australia: Western Australia Geological Survey, Report 66.

SHAW, R. D., ETHERIDGE, M. A., and LAMBECK, K., 1991, Development of the late Proterozoic to mid-Palaeozoic, intracratonic Amadeus Basin in Central Australia: a key to understanding tectonic forces in plate interiors: Tectonics, v. 10, p. 688–721.

SHAW, R. D., TYLER, I. M., GRIFFIN, T. J., and WEBB, A., 1992, New K–Ar constraints on the onset of subsidence in the Canning Basin, Western Australia: Australia BMR, Journal of Australian Geology and Geophysics, v. 13, p. 31–35.

SHEPPARD, S., 1996, Mafic–felsic magma mingling in the Bow River batholith of the Halls Creek Orogen: Western Australia Geological Survey, Annual Review 1995–96, p. 56–60.

SHEPPARD, S., GRIFFIN, T. J., and TYLER, I. M., 1995, Geochemistry of felsic igneous rocks from the southern Halls Creek Orogen: Western Australia Geological Survey, Record 1995/4, 81p.

SHEPPARD, S., GRIFFIN, T. J., and TYLER, I. M., 1997a, The tectonic setting of granites in the Halls Creek and King Leopold Orogens, Northwest Australia: Australian Geological Survey Organisation, Record 1997/44, p. 107–109.

SHEPPARD, S., GRIFFIN, T. J., TYLER, I. M., and PAGE, R. W., in prep., Geochemical and Nd isotopic evidence for the petrogenesis of Palaeoproterozoic granites in the Lamboo Complex, Northwest Australia: Journal of the Geological Society of London.

SHEPPARD, S., TYLER, I. M., and HOATSON, D. M., 1997b, Geology of the Mount Remarkable 1:100 000 sheet, Western Australia: Western Australia Geological Survey, 1:100 000 Geological Series, Explanatory Notes, 27p.

TAYLOR, W. R., ESSLEMONT, G., and SUN, S-s., 1995b, Geology of the volcanic-hosted Brockman rare-metals deposit, Halls Creek Mobile Zone, northwest Australia, Part II — Geochemistry and petrogenesis of the Brockman volcanics: Mineralogy and Petrology, v. 52, p. 231–255.

TAYLOR, W. R., PAGE, R. W., ESSLEMONT, G., ROCK, N. M. S., and CHALMERS, D. I., 1995a, Geology of the volcanic-hosted Brockman rare-metals deposit, Halls Creek Mobile Zone, northwest Australia, Part I — Volcanic environment, geochronology and petrography of the Brockman volcanics: Mineralogy and Petrology, v. 52, p. 209–230.

THOMPSON, A. B., 1982, Dehydration melting of pelitic rocks and the generation of H_2O-undersaturated granitic liquids: American Journal of Science, v. 282, p. 1567–1595.

THORNE, A. M, and TYLER, I. M., 1996, Mesoproterozoic and Phanerozoic sedimentary basins in the northern Halls Creek Orogen: constraints on the timing of strike-slip movement on the Halls Creek Fault system: Western Australia Geological Survey, Annual Review 1995–96, p. 156–168.

THORNETT, J. R., 1987, Evolution of a high-grade metamorphic terrain in the Proterozoic Halls Creek mobile zone, Western Australia: University of Western Australia, PhD thesis (unpublished).

TYLER, I. M., and GRIFFIN, T. J., 1990, Structural development of the King Leopold Orogen, Kimberley Region, Western Australia: Journal of Structural Geology, v. 12, p. 703–714.

TYLER, I. M., and GRIFFIN, T. J., 1993, Yampi, W.A. (second edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 32p.

TYLER, I. M., and GRIFFIN, T. J., 1994, Dockrell, W.A. Sheet 4360: Western Australia Geological Survey, 1:100 000 Geological Series.

TYLER, I. M., GRIFFIN, T. J, HOCKING, R. M., and PLAYFORD, P. E., in prep. b, Explanatory notes on the Mount Ramsay 1:250 000 Sheet SE/52-9, Western Australia (second edition): Western Australia Geological Survey.

TYLER, I. M., GRIFFIN, T. J., PAGE, R. W., and SHAW, R. D., 1995, Are there terranes in the Lamboo Complex of the Halls Creek Orogen: Western Australia Geological Survey, Annual Review 1993–94, p. 37–46.

TYLER, I. M., GRIFFIN, T. J., and SHAW, R. D., 1991, Early Palaeozoic tectonism and reactivation of pre-existing basement structures at the margins of the Kimberley Craton, Western Australia: Geological Society of Australia, Abstracts v. 31, p. 70–71.

TYLER, I. M., HOATSON, D. M., SHEPPARD, S., BLAKE, D. H., and.WARREN, R. G., in prep. a, The geology of the McIntosh 1:100 000 geological sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

TYLER, I. M., and PAGE, R. W., 1996, Palaeoproterozoic deformation, metamorphism and igneous intrusion in the central zone of the Lamboo Complex, Halls Creek Orogen: Geological Society of Australia, Abstracts, v. 41, p. 450.

VERNON, R.H., 1991, Interpretation of microstructures of microgranitoid enclaves, *in* Enclaves and granite petrology *edited by* J. DIDIER and B. BARBARIN: Amsterdam, Elsevier, Developments in Petrology, v. 13, p. 277–291.

WALTER, M. R., VEEVERS, J. J., CALVER, C. R., and GREY, K., 1995, Neoproterozoic stratigraphy of the Centralian Superbasin, Australia: Precambrian Research, v. 73, 173–195.

WARREN, R. G., 1994a, Role of early extensional faults in the Grants Patch district, east Kimberley, Western Australia: Geological Society of Australia, Abstracts, v. 37, p. 453–454.

WARREN, R. G., 1994b, Gold mineralisation in the northern East Kimberley gold district, Western Australia: AusIMM Annual Conference, 1994, p. 117–121.

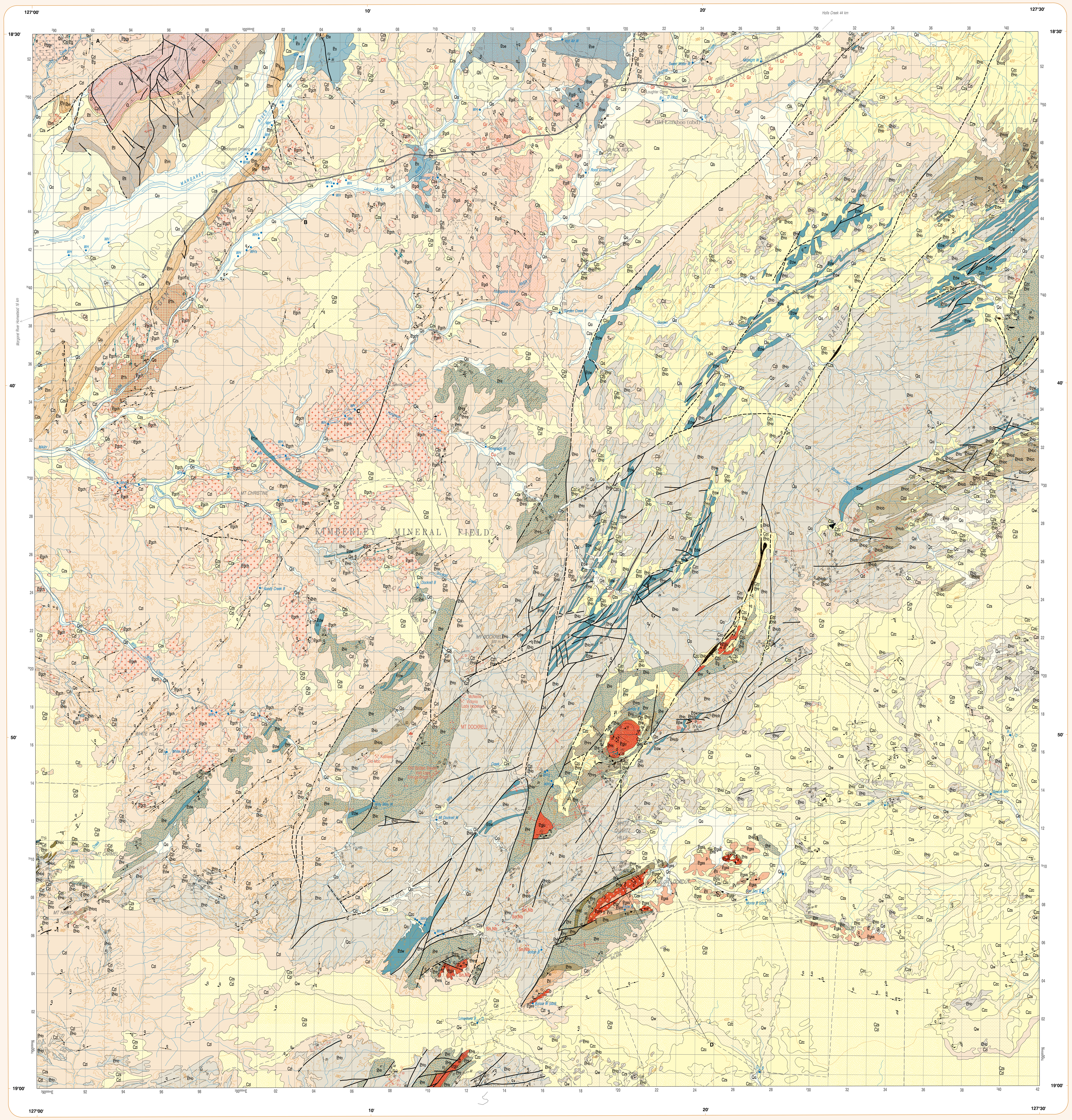
WILCOX, R. E., HARDING, T. P., and SEELY, D. R., 1973, Basic wrench tectonics: American Association of Petroleum Geologists, Bulletin, v. 57, p. 74–96.

WYBORN, L.A.I., 1988, Petrology, geochemistry and origin of a major Australian 1880–1840 Ma felsic volcano-plutonic suite: a model for intracontinental felsic magma generation: Precambrian Research, v. 40/41, p. 37–60.

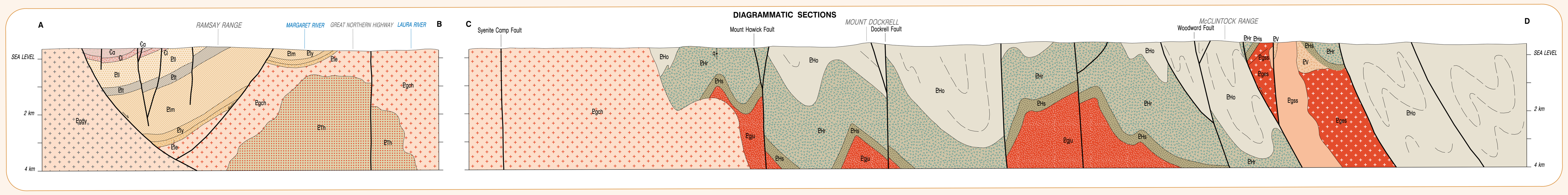
WYBORN, L.A.I., and PAGE, R.W., 1983, The Proterozoic Kalkadoon and Ewen batholiths, Mount Isa Inlier, Queensland: source, chemistry, age, and metamorphism: BMR Journal of Australian Geology and Geophysics, v. 8, p. 53–69.

DOCKRELL

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTIONS



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa | Qb | Qw

Qa Alluvium — unconsolidated silt, sand, and gravel
Qb Black soil — clay and silt
Qw Alluvium and colluvium — sheet wash deposits, red-brown sandy and clayey soil

Czs | Czc | Czl

Czs Colluvium and alluvium — partly consolidated silt, sand, and gravel; adjacent to drainage; sand plain on laterite surface
Czc Colluvium — partly consolidated scree and valley-fill deposits
Czl Laterite — massive and pisolitic ferruginous duricrust; forms plateaus overlying weathered rock (Ᵽg—granitoid); steep breakaways commonly form at the margins

q Quartz veins, of various ages; youngest generation postdates Cambrian units

PALAEOZOIC — CAMBRIAN

Ꞓa **ANTRIM PLATEAU VOLCANICS:** dark grey vesicular and amygdaloidal basalt; generally deeply weathered

Ꞓl **LALLY CONGLOMERATE:** medium- to coarse-grained quartz sandstone and cobble conglomerate

PROTEROZOIC

c. 670 Ma — Louisa Downs Group

Ᵽll **LUBBOCK FORMATION:** grey, green, or purple siltstone and shale; interbedded with fine- to medium-grained quartz wacke

Ᵽlt **TEAN FORMATION:** feldspathic sandstone, quartz wacke, quartz sandstone, pebble conglomerate, siltstone, and shale; minor dolomite

Ᵽlm **McALLY SHALE:** black, grey, and green shale; minor siltstone and fine- to very fine-grained sandstone

Ᵽly **YURABI FORMATION:** flaggy to blocky quartz sandstone and feldspathic sandstone; grey and purple siltstone, shale, dolomitic siltstone, and sandy dolomite

Ᵽle **EGAN FORMATION:** tillite, arkose, dolomite, limestone, sandstone, siltstone, and shale

d Dolerite dyke

c. 1740 Ma — p po Veins and dykes: p—pegmatite; po—rhyolite porphyry

LAMBOO COMPLEX

c. 1780 Ma — Ᵽgss **SAN SOU MONZOGRANITE:** medium- to fine-grained biotite monzogranite; scattered fine-grained mafic inclusions

c. 1820 Ma — Ᵽgch | Ᵽgdi | Ᵽggy | Ᵽgst

Ᵽgch **MOUNT CHRISTINE GRANITOID:** coarsely porphyritic to medium-grained biotite monzogranite; hornblende-biotite granodiorite and tonalite; locally foliated
Ᵽgdi **DILLINGER MONZOGRANITE:** medium- to fine-grained, leucocratic biotite monzogranite; abundant mafic inclusions adjacent to contacts with gabbro
Ᵽggy **GRIMPY MONZOGRANITE:** weakly porphyritic, fine-grained biotite monzogranite
Ᵽgst **LOADSTONE MONZOGRANITE:** weakly porphyritic biotite monzogranite and syenogranite; minor microgranodiorite

Ᵽo | Ᵽoe

Ᵽo Undivided porphyritic to even-grained, medium- to fine-grained gabbro, tonalite, pyroxenite, and hornblendite; extensively veined by granitoid rocks locally
Ᵽoe **EMULL GABBRO:** medium- to fine-grained gabbro and tonalite extensively veined by DILLINGER MONZOGRANITE, aplite, quartz-feldspar porphyry, and pegmatite

c. 1840 Ma — Ᵽe **KOONGIE PARK FORMATION:** metamorphosed laminated fine sandstone; felsic volcaniclastic rocks, and minor carbonate

Tickalara Metamorphics

ᵽTh | ᵽTm

ᵽTh Quartz-muscovite-biotite-cordierite hornfels
ᵽTm Migmatitic quartz-plagioclase-muscovite-biotite-(sillimanite-)andalusite-cordierite(-chlorite) pelite and amphibolite

Ᵽdw **WOODWARD DOLERITE:** fine- to medium-grained metadolerite

c. 1855 Ma — Halls Creek Group

ᵽHh Quartz-K-feldspar-biotite-cordierite-sillimanite pelitic hornfels; locally retrogressed to quartz-muscovite-biotite-chlorite-(sillimanite) pelitic schist

ᵽHo **OLYMPIO FORMATION:** low- to medium-grade metamorphosed, thin- to medium-bedded quartz-muscovite (-biotite-chlorite-andalusite-garnet) pelitic rocks and turbiditic quartz wacke, greywacke, and arkosic psammitic rocks

ᵽHoq Metamorphosed thick-bedded, turbiditic quartzitic sandstone, and minor pelite

ᵽHob **Butchers Gully Member:** metamorphosed and altered alkaline volcanic and volcaniclastic rock, chloritic with carbonate-rich matrix, ferruginous chert

ᵽHoc Metamorphosed chert, locally ferruginous

ᵽHr **BISCAY FORMATION:** metamorphosed basaltic volcanic and volcaniclastic rock; minor dolerite sills, and interbedded pelite; carbonate and chert lenses

ᵽHrs Metamorphosed interbedded sandstone and argillite

ᵽHrt Metamorphosed basaltic volcanic and volcaniclastic rock with carbonate-rich matrix

ᵽHs **SAUNDERS CREEK FORMATION:** metamorphosed quartz sandstone, feldspathic sandstone, and quartz pebble conglomerate

c. 1910 Ma — Ᵽgju | Ᵽges

Ᵽgju **JUNDA MICROGRANITE:** partly recrystallized, fine-grained leucocratic monzogranite
Ᵽges **ESAW MONZOGRANITE:** partly recrystallized, garnet-muscovite granite

Ᵽv **DING DONG DOWNS VOLCANICS:** amygdaloidal metabasalt and amphibolite; minor pelite and metagabbro

Ᵽvs Pelite and cordierite-bearing quartzo-feldspathic rock

Ᵽvm Metagabbro; minor meta-anorthosite

Geological boundary
- accurate
- inferred

Fault
- accurate
- concealed

Shear zone

Fold, showing direction of plunge
- anticline
- syncline
- overturned anticline
- overturned syncline
- synformal anticline
- antiformal syncline
- overturned synformal syncline
- minor anticline — 23
- minor syncline — 27

Small-scale folds showing strike and dip of axial surface, direction of plunge, and nature of vergence (Z, S, or M profile)
- D_2 — 2 86 Z 19
- D_5 — 5 81 S 53

Bedding, showing strike and dip
- inclined — 30
- vertical
- horizontal
- overturned — 55

Strike and dip estimated from aerial photography
- 0–15°
- 15–45°
- 45–90°
- vertical
- overturned 15–45°
- overturned 45–90°
- trend of bedding (also visible through surficial deposits)

Igneous layering
- inclined — 77

Way-up indicator
- top of bed

Cleavage, slaty or spaced, showing strike and dip
- D_2
  - inclined — 2 86
  - vertical — 2
- D_5
  - inclined — 5 78
  - vertical — 5

Cleavage, crenulation, showing strike and dip
- D_2
  - inclined — 2 78
- D_5
  - inclined — 5 80
  - vertical — 5
- D_6
  - inclined — 6 46
  - vertical — 6

Foliation, showing strike and dip
- D_1
  - inclined — 1 46
- D_2
  - inclined — 2 72
  - vertical — 2
- D_4
  - inclined — 4 80
- D_5
  - inclined — 5 75
  - vertical — 5

Lineation, showing direction of plunge
- stretching lineation — 48
- axis of crenulation — 30
- bedding—cleavage intersection — 58

Joints, showing strike and dip
- inclined — 17

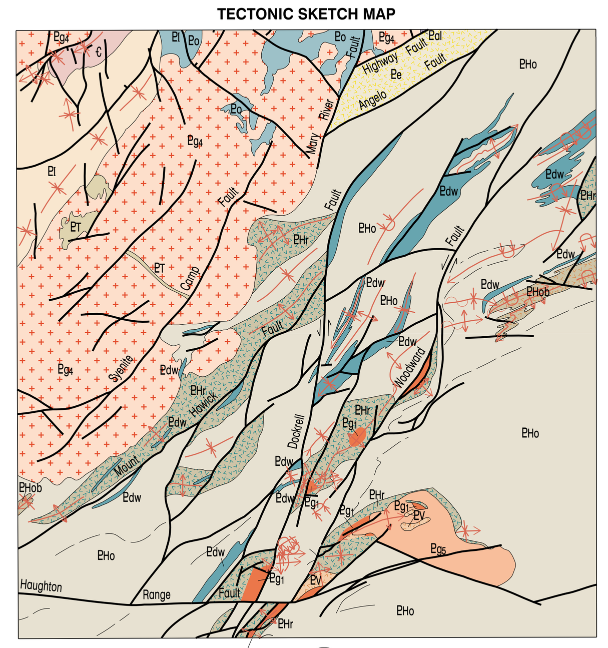
Air photo lineament

Highway with national route marker — 1
Formed road
Track
Fence, generally with track
Homestead — Old Lamboo
Building
Yard — Yd
Locality — Syenite Camp
Microwave repeater station
Horizontal control; major, minor
Contour line, 20 metre interval — 380
Watercourse, ephemeral
Bore — B
Well — W
Windpump
Dam — D D
Waterhole — WH
Soak — Sk
Abandoned — (abd)

Mining centre — MT DOCKRELL
Mine (gold unless otherwise indicated) — Victoria
Alluvial working
Quarry
Battery
Mineral occurrence
- Chalcedony — Ch
- Copper — Cu
- Niobium (columbite) — Nb
- Tin — Sn

Industrial minerals
- Rock, crushed aggregate — Rc
- Gravel — Gr

TECTONIC SKETCH MAP

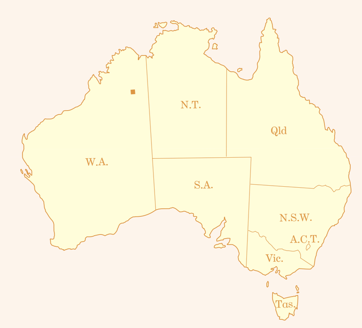


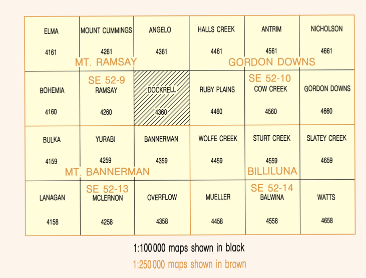
Ꞓ Antrim Plateau Volcanics
Ᵽl Louisa Downs Group
Ᵽg5 Granitoid rocks c. 1780 Ma
Ᵽg4 Granitoid rocks c. 1820 Ma
Ᵽo Gabbroic rocks
Ᵽe Koongie Park Formation
Ᵽal Lamboo Ultramafics
ᵽT Tickalara Metamorphics
Ᵽdw Woodward Dolerite
Halls Creek Group: ᵽHo Olympio Formation; ᵽHob Butchers Gully Member; ᵽHr Biscay Formation and Saunders Creek Formation
Ᵽg1 Granitoid rocks c. 1910 Ma
Ᵽv Ding Dong Downs Volcanics

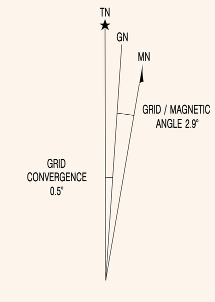
LAMBOO COMPLEX

Fault
Thrust fault
Strike-slip fault
Normal fault
Shear zone

SCALE 1:500 000
0 5 10 15 20
Kilometres







True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1994 and moves easterly by about 0.1° in 5 years.

DEPARTMENT OF MINERALS AND ENERGY
HON. GEORGE CASH, J.P., M.L.C.
MINISTER FOR MINES
L. C. RANFORD, ACTING DIRECTOR GENERAL

PIETRO GUJ
DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

SCALE 1:100 000

1000 0 1 2 3 4 5 6 7 8 9 10
Metres — Kilometres

TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 52

Geology by: I.M. Tyler and T.J. Griffin 1991–92
Edited by: C. Strong, and G. Loan
Cartography by: D. Ladbrook, M. Prause, and G. Loan of the Cartographic Services Branch, Surveys and Mapping Division, Department of Minerals and Energy, Western Australia
Compiled and produced using computer-assisted graphic applications, and available in digital form
Topographic base (1986) supplied by the Department of Land Administration and modified from geological field survey
Published by and available from the Geological Survey of Western Australia, Department of Minerals and Energy, 100 Plain Street, East Perth, W. A. 6004
Printed by the State Print, Department of State Services, Western Australia

DOCKRELL

SHEET 4360 FIRST EDITION 1994