EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

RUDALL

1:250 000 SHEET

WESTERN AUSTRALIA

SECOND EDITION

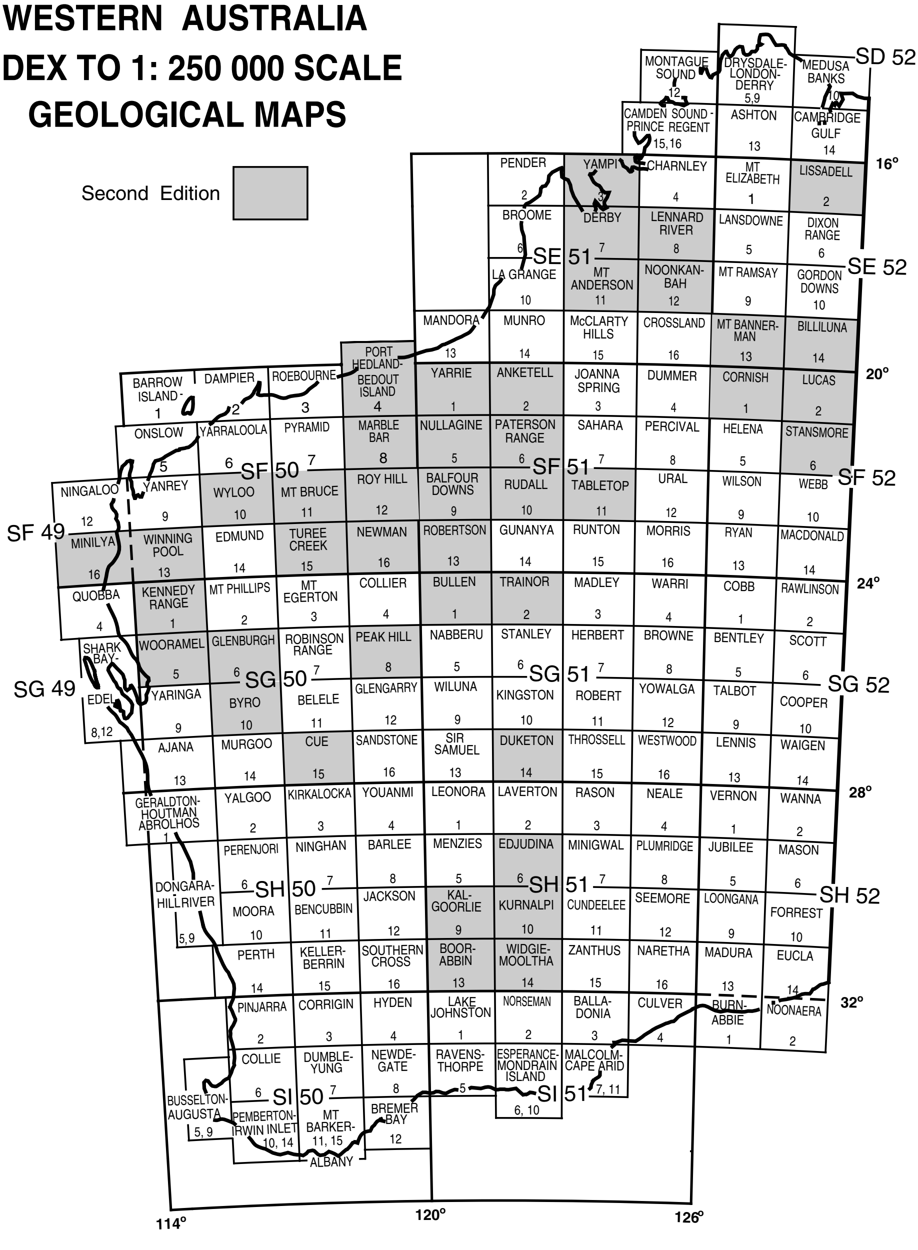
SHEET SF 51-10 INTERNATIONAL INDEX

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

WESTERN AUSTRALIA
INDEX TO 1: 250 000 SCALE
GEOLOGICAL MAPS

Second Edition



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

RUDALL

WESTERN AUSTRALIA

SECOND EDITION

SHEET SF 51-10 INTERNATIONAL INDEX

by

L. BAGAS, I. R. WILLIAMS, and A. H. HICKMAN

Perth, Western Australia 2000

MINISTER FOR MINES

The Hon. Norman Moore, MLC

DIRECTOR GENERAL

L. C. Ranford

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

David Blight

Copy editor: C. D'Ercole

REFERENCE
The recommended reference for this publication is:
BAGAS, L., WILLIAMS, I. R., and HICKMAN, A. H., 2000, Rudall, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 50p.

ISSN 0729-3720
National Library of Australia Card Number and
ISBN 0 7309 6672 0

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

Printed by Lamb Printers Pty Ltd, Perth, Western Australia

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

CONTENTS

FIGURES

TABLES

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

by L. Bagas, I. R. Williams, and A. H. Hickman

INTRODUCTION

The RUDALL* 1:250 000 geological sheet (SF 51-10), bounded by latitudes 22°00'S and 23°00'S and longitudes 121°30'E and 123°00'E (Fig. 1), is named after the Rudall River, which flows from west to east across the central part of the sheet area. Occupying the northern margin of the Little Sandy Desert and southwestern margin of the Great Sandy Desert, the area forms part of the Marble Bar District of the Pilbara Mineral Field. The Rudall River National Park covers about 60% of the sheet area, and is centred on the drainage of the Rudall River. Off-road access within the park requires prior approval from the Western Australian Department of Conservation and Land Management. Guidelines for mineral exploration and mining within the park are outlined in the Department of Minerals and Energy's General Information Series Pamphlet 11.

The Parnngurr (Cotton Creek) Aboriginal community is the only permanent settlement on RUDALL (1:250 000). The nearest town is Telfer, about 50 km north of the sheet area. A good quality, four-wheel drive track connects the southern part of the sheet area to Newman, via Balfour Downs Homestead and the Ethel Creek – Jigalong road. Otherwise, few other tracks exist and access is typically difficult.

PREVIOUS AND CURRENT INVESTIGATIONS

The isolation of the area and the lack of a permanent water supply impeded exploration until 1971, when gold was discovered at the Telfer Dome, approximately 50 km to the north. Chin et al. (1980), Bagas and Smithies (1998a), Hickman and Bagas (1998), and Williams and Bagas (1999) summarized the early exploration of the region. Reports of mineral exploration in the area from the mid-1970s onwards are available from the Western Australian minerals exploration database (WAMEX) open-file system held in the Geological Survey of Western Australia (GSWA) library.

In 1974 and 1975, the RUDALL 1:250 000 sheet area was mapped, at reconnaissance scale, by R. J. Chin, I. R. Williams, S. J. Williams, and R. W. A. Crowe (Chin et al., 1980) as part of the systematic 1:250 000-scale geological mapping of Western Australia by the GSWA. The conclusions reached from that work were first reported by Williams et al. (1976) and later expanded by Williams and Myers (1990).

The Australian Geological Survey Organisation (AGSO, then known as the Bureau of Mineral Resources — BMR) published preliminary Bouguer anomalies in 1970, total magnetic intensity maps in 1984, and radiometric contour maps in 1987.

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

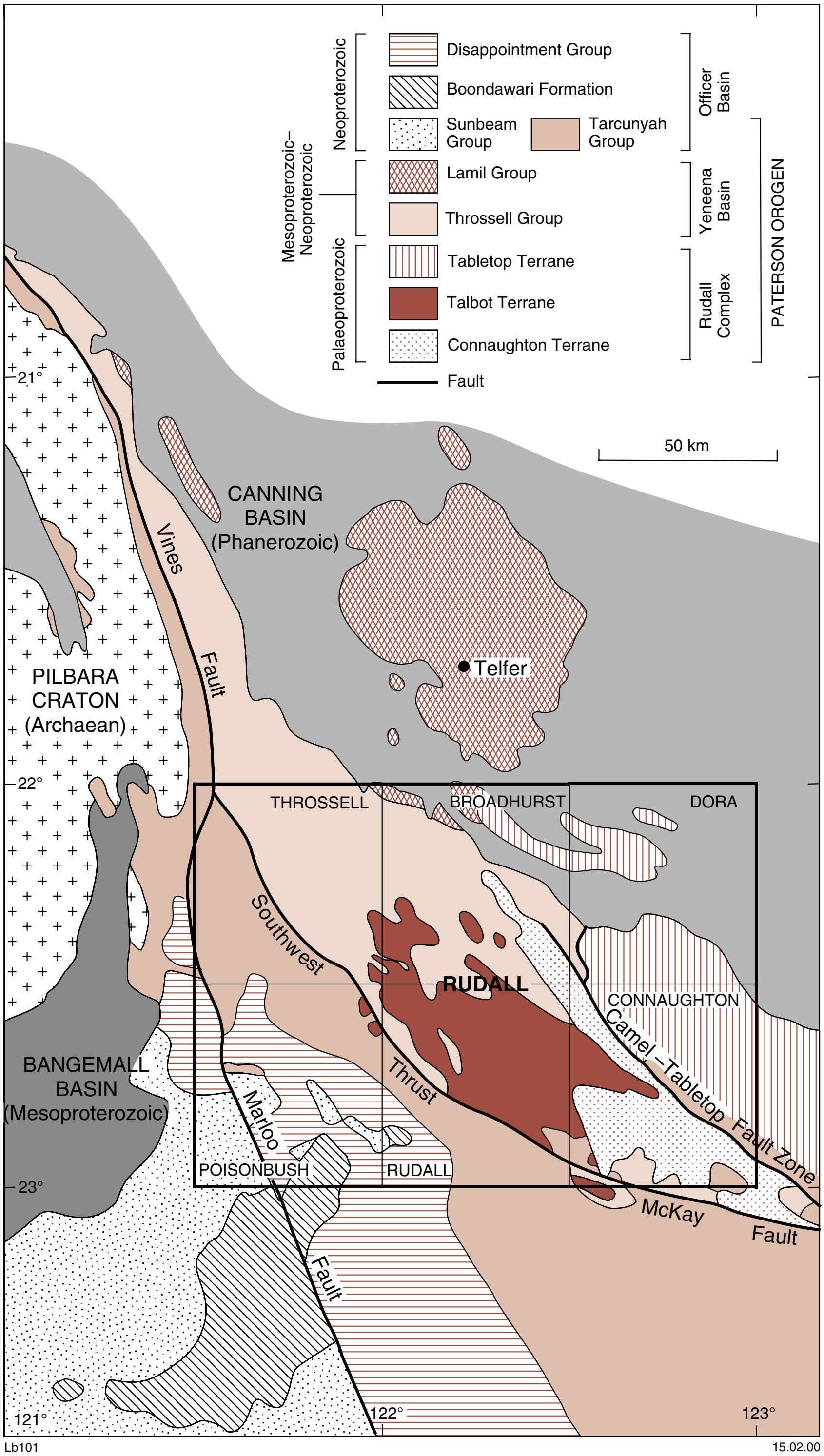


Figure 1. Regional geological setting of RUDALL (1:250 000)

In 1985, uranium was discovered at Kintyre on BROADHURST, adding new impetus to mineral exploration.

In 1989, GSWA commenced a program of detailed 1:100 000-scale geological mapping of the Rudall Complex, compiling onto 1:25 000-scale colour and 1:50 000-scale black and white aerial photography available from the Department of Land Administration (DOLA). By early 1998, maps for BROADHURST (Hickman and Clarke, 1993, 1994), CONNAUGHTON (Bagas and Smithies, 1996), RUDALL (Hickman and Bagas, 1996, 1998, 1999), THROSSELL (Williams et al., 1996; Williams and Bagas, 1999), GUNANYA (Bagas, 1997, 1998), BLANCHE–CRONIN (Bagas and Smithies, 1998b; Bagas, 1999a), and POISONBUSH (Williams and Bagas, 1998, 2000) had been published. The data from BROADHURST, CONNAUGHTON, POISONBUSH, RUDALL, and THROSSELL make up the second edition RUDALL 1:250 000 sheet (Bagas, 1999b).

CLIMATE AND VEGETATION

The climate is arid, with potential evaporation exceeding precipitation. Average rainfall is 200 mm per year, mainly derived from storm and cyclone activity between November and March. Average summer temperatures range from daily minima of about 25°C to maxima of 40°C, whereas daily winter temperatures typically vary between minima of 5°C and maxima of 25°C. Average annual evaporation is about 4400 mm, and prevailing winds blow from the east and southeast.

RUDALL (1:250 000) forms parts of the Great Sandy Desert and Little Sandy Desert natural regions of Beard (1970). Spinifex (*Triodia*) is present across the entire area, whereas other forms of vegetation are associated with different types of terrain; for example, sandplains also contain *Grevillea*, *Acacia*, soft shrubs (*Crotalaria*), *Eucalypts*, titree, and desert oak. Major drainage, such as the Rudall River, contains large *Eucalypts* and various grasses, and areas of rock outcrop include small scrub, grasses, mulga, and sparse *Eucalypts*.

PHYSIOGRAPHY

The physiography of RUDALL (1:250 000; Fig. 2) is a product of several periods of erosion and deposition. The most important events appear to have been Permian glaciation, Tertiary peneplanation, and Cainozoic erosion and deposition.

Permian land surface

Remnants of the Permian land surface (Fig. 2) are present in areas covered by Permian fluvial–glacial sediments deposited in glacial valleys during glacial retreat.

Tertiary and Recent land surfaces

Recent and Tertiary land surfaces have been divided into erosional and depositional land surfaces.

Erosional land surface

Units within the recent erosional surface represent various stages in the erosion of Tertiary or pre-Tertiary surfaces.

Divisions include dissected plateau, ridges, low hills, rock pavement, and low outcrop. Cliff lines, narrow gorges, and ravines commonly mark the edges of plateaus against the more

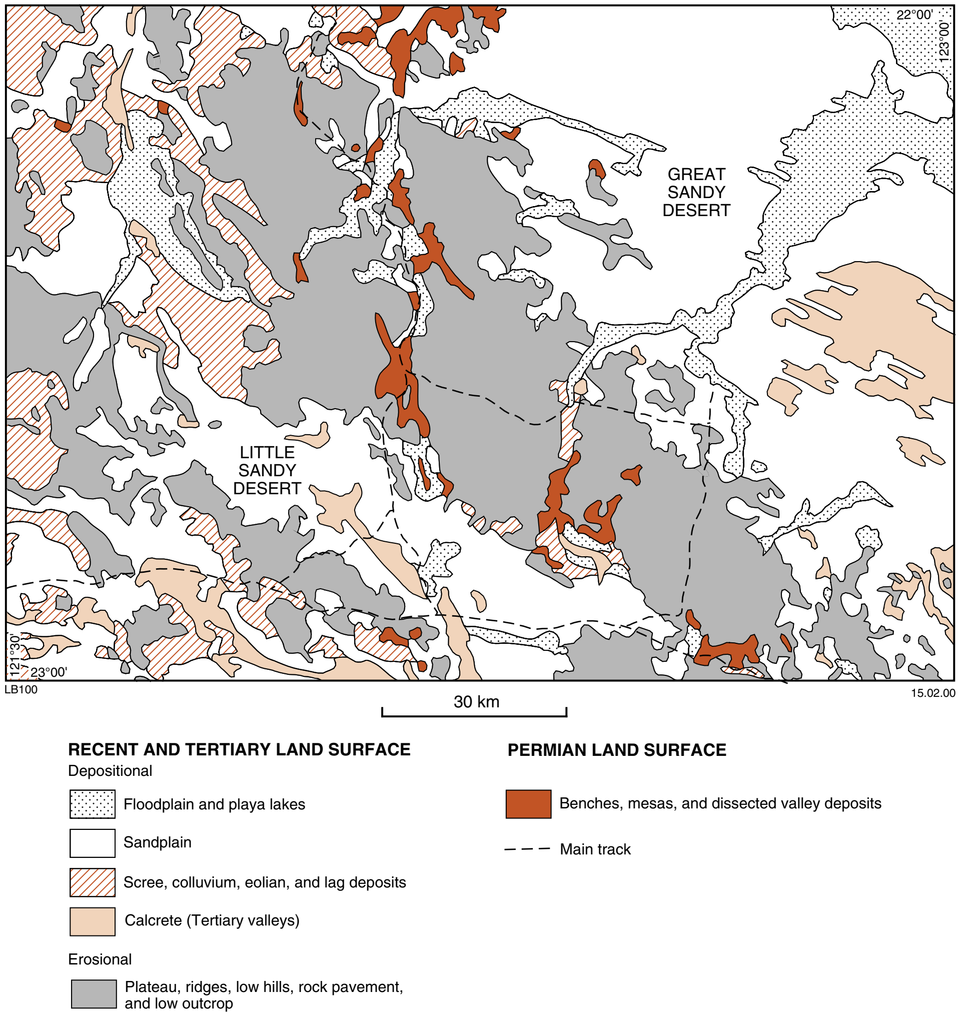


Figure 2. Physiography and main access

subdued landscape. Ridges are dissected and, in part, sinuous, rising to about 450 m above sea level, and are separated by valleys developed over less-resistant rock types. The valleys are filled locally by a thin Permian cover establishing a pre-Permian origin. The rock types present influence the form of the hills; orthogneiss and paragneiss characteristically produce rounded hills and quartzite produces country that is more rugged.

Rock pavement and low outcrop are mainly found in sandplain country. Erosion is restricted to wind action and water movement in small streams, and represents the last stage in the formation of a new peneplain.

Depositional land surface

Calcrete deposits throughout RUDALL (1:250 000) pre-date the sandplains, and are probably related to channels and lakes active during Cainozoic times. These deposits form low mounds in low-lying areas and are composed of massive, nodular, and vuggy limestone locally replaced by chalcedony.

Scree, colluvium, eolian, and lag deposits commonly flank sandplains, and represent locally derived clastic detritus from streams and channels draining hilly divisions. Some of these deposits are dissected by the present drainage.

Sandplains include seif (longitudinal) dune and dune-free sandplains. The northeastern part of RUDALL (1:250 000) includes the southwestern edge of the Great Sandy Desert. The southwestern part of the area includes the eastern edge of the Little Sandy Desert. The seif dune sandplain features easterly to southeasterly trending dunes that range in height up to 30 m, are many kilometres long, and spaced up to 3 km apart. The longitudinal profiles and their steep southern slopes are consistent with prevailing winds from the east-southeast. Crowe (1975) provided a further description of seif dunes. The dune-free sandplain is in areas subjected to periodic flooding, and in areas on the leeward side of hills.

Floodplains are present along and adjacent to creeks and rivers. Consolidated river gravel covered by recent alluvium outline a Tertiary drainage course incised by the present Rudall River.

REGIONAL GEOLOGICAL SETTING

RUDALL (1:250 000) occupies the central part of the northwestern exposure of the Paterson Orogen (Fig. 1). It includes the Palaeoproterozoic Rudall Complex (Williams, 1990a), Meso- to Neoproterozoic Yeneena Supergroup (Throssell and Lamil Groups; Williams and Bagas, 1999), and the Neoproterozoic Officer Basin (Sunbeam Group, Tarcunyah Group, Boondawari Formation, and Disappointment Group; Bagas et al., 1995, 1999). Figure 3 is a simplified map of the Proterozoic geology, and Table 1 summarizes the history of deformation and metamorphism in the area.

The Paterson Orogen is a northwesterly trending belt of folded and metamorphosed Proterozoic sedimentary and igneous rocks that extends about 1200 km across the central part of Western Australia. The orogen is exposed in the northwest along the eastern margin of the Pilbara Craton and in the Musgrave Complex of central Australia (Williams and Myers, 1990).

The northwestern exposure of the Paterson Orogen was originally referred to as the Paterson Province (Daniels and Horwitz, 1969; Blockley and de la Hunty, 1975). It is flanked to the west and southwest by Archaean rocks of the West Australian Craton (Myers, 1990a), and to the east by the Precambrian North Australian Craton (Bagas and Smithies, 1997). To the east, the orogen is unconformably overlain by late Neoproterozoic to Phanerozoic rocks of the Officer Basin (Bagas et al., 1999) and to the north by Phanerozoic rocks of the Canning Basin (Williams and Myers, 1990). RUDALL (1:250 000) is situated in the centre of this part of the orogen.

The Rudall Complex outcrops in the centre of the northwestern Paterson Orogen, and its relationship to the West Australian and North Australian Cratons is obscured by sedimentary rocks of the Earaheedy Group, Bangemall Group, Yeneena Supergroup, Officer Basin, and Canning Basin (Fig. 1).

The Rudall Complex consists of multiply deformed and metamorphosed sedimentary and igneous rocks, and these rocks extend for about 50 km to the southeast of the sheet area

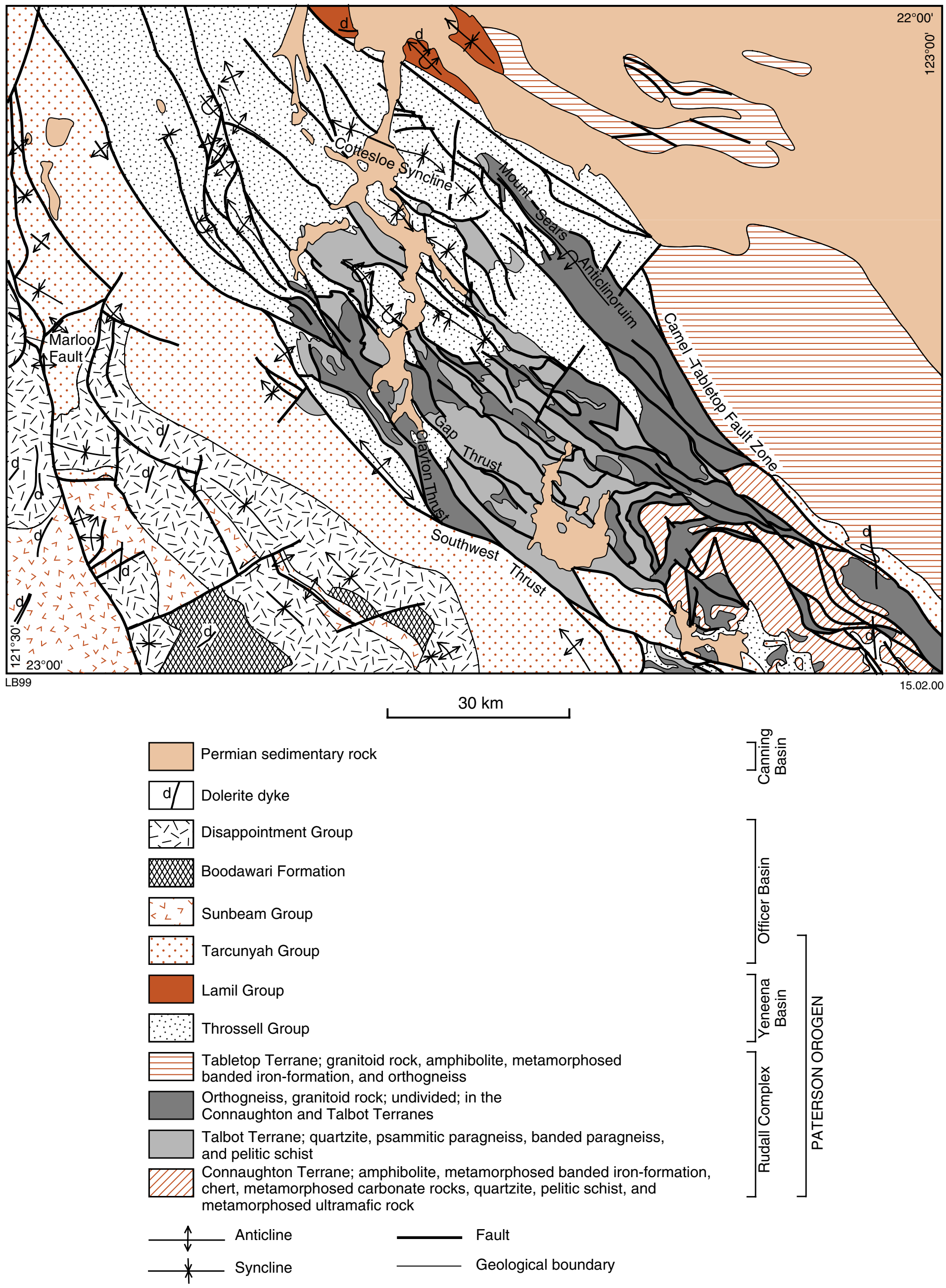


Figure 3. Simplified geological map showing major structures

(Chin et al, 1980; Crowe and Chin, 1979; Yeates and Chin, 1979; Williams and Williams, 1980). The present mapping placed emphasis on identification of protoliths of metamorphic rocks of the Rudall Complex. Mapping was initially lithological, but following map compilation it was evident that local stratigraphic successions could be recognized.

Table 1. Summary of geological events on RUDALL (1:250 000)

Age range (Ma)	*Geological event, structures, and metamorphism*
pre-2015	Deposition of the Connaughton Terrane succession and older turbiditic succession in the Talbot Terrane
~2015–1760	**Yapungku Orogeny (D_{1-2})**
~2015–1802	D_1: regional layer-parallel shear (direction unknown); identified on BROADHURST and RUDALL; S_1: penetrative layer-parallel schistosity; alignment of mica, quartz, and feldspar; M_1: amphibolite facies metamorphism; local melting; granitoid intrusion (*ꞒRgx*)
1801–1795	Crystallization of *ꞒRge* protolith (post-dates D_1); deposition of the Fingoon Quartzite and Larry, Yandagooge, Butler Creek, and Poynton Formations
1790–1765	Crystallization of *ꞒRga*, *ꞒRgd*, *ꞒRgm*, *ꞒRgo* protoliths
1790–1760	D_2 partly synchronous with M_2: northerly to northeasterly trending isoclinal folds, and associated thrusting with movement to the west; F_2: tight to isoclinal F_2 folds (axes were subhorizontal and trended north to north-northeast pre-D_4); S_2: schistosity due to alignment of mica and quartz; L_2: stretching lineation within S_2 (Clarke, 1991); M_2: high-pressure amphibolite to granulite facies metamorphism with local partial melting
1476–1286	Crystallization of post-D_2 and pre-D_4 intrusive rocks
1132 ± 21	Crystallization or metamorphism of pegmatite dykes in the Rudall Complex on RUDALL; maximum age for the Throssell and Lamil Groups
c. 1132–820	**Miles Orogeny (D_{3-4})** D_3: local recumbent folding affecting the Throssell Group on BROADHURST; deformation in response to southwesterly directed compression. Local faulting and quartz veining in the Rudall Complex – Throssell Group unconformity; D_4: regional deformation in response to southwesterly directed compression; F_4: upright, tight folding about northerly trending axes; fold plunges low, mainly to the northwest or southeast; limbs commonly sheared out; S_4: axial surface cleavage inclined steeply northeast; L_4: stretching lineations plunge down-dip on S_4; M_4: greenschist facies metamorphism
940–820	Epigenetic galena mineralization in the Throssell Group; minimum age for the Throssell Group
~820	Deposition of the Tarcunyah and Sunbeam Groups of the northwestern Officer Basin (post-dating the Throssell Group)
~ c. 800–610 Ma	**Blake Movement (D_5)** Local deformation; west-northwesterly directed compression. Structures include northeasterly trending open folds, domal structures in the Throssell Group, southwesterly plunging crenulations
630–620	Emplacement of post-D_4 and pre-D_6 granitoids before the Paterson Orogeny
pre- to syn-D_6	Deposition of the Boondawari Formation and Disappointment Group
c. 550	**Paterson Orogeny (D_6)** Brittle deformation in response to north-northeasterly directed compression; correlated with the Petermann Ranges Orogeny (600–540 Ma) of central Australia, King Leopold Orogeny (c. 560 Ma) in the Kimberley region, and the breakup of Rodinia (Myers et al., 1996); D_6: west-northwesterly and northwesterly striking, near-vertical strike-slip faults; S_6: spaced cleavage, axial to conjugate kink bands, deforming S_4
post-D_6	Deposition of sedimentary rocks in the Canning Basin and Cainozoic sediments

The stratigraphic subdivision of the metasedimentary rocks in the Rudall Complex follows that of Hickman et al. (1994). Certain areas contain insufficient evidence for lithostratigraphic correlation, and the stratigraphic positions of some paragneiss units are therefore left unassigned.

PROTEROZOIC GEOLOGY

RUDALL COMPLEX

The Rudall Complex has been subdivided into the Talbot, Connaughton, and Tabletop tectono-stratigraphic terranes (Fig. 1; Bagas and Smithies, 1998a). The Talbot Terrane has recognizable and mappable stratigraphic successions, which are formally named, and unassigned metasedimentary rocks (Hickman and Bagas, 1998). Rocks in the Connaughton and the poorly exposed Tabletop Terranes are lithologically mapped, and tectonic contacts have hindered the establishment of stratigraphic successions. Thus, some rocks types shown on the map are confined to individual terranes, whereas others are found in more than one terrane. The major lithological features of the three terranes are described first, followed by rock type descriptions in an order consistent with the map legend. Table 2 summarizes the distribution and estimated proportions of the rock types between the three terranes.

The discontinuous nature of the rocks in the Connaughton Terrane together with structural complexity, pervasive recrystallization, and a general lack of primary sedimentary and igneous features, make an interpretation of their original tectonic setting difficult. Amphibolite or mafic granulite, interpreted as metamorphosed volcanic rocks, are predominantly high-Fe tholeiitic in composition (Bagas and Smithies, 1998a).

In the lower part of the succession, the metavolcanic rocks are interlayered with metamorphosed banded iron-formation, carbonate rocks, chert, and shale. In the upper part, they are tectonically interleaved with mixed clastic metasedimentary rocks. Although the succession is tectonically disrupted, the metasedimentary rocks associated with the metavolcanics appear to coarsen upwards.

There is no maximum age constraint for the metamorphosed basalt and sedimentary rocks in the Connaughton Terrane. However, they are older than c. 1780 Ma, the age of the protolith of intrusive augen orthogneiss (*ᴇʀga*) in the Connaughton and Talbot Terranes (Nelson, 1996).

The Talbot Terrane consists principally of deformed and metamorphosed siliciclastic sedimentary and granitoid rocks. In general, the rocks have been metamorphosed to amphibolite facies during the Yapungku Orogeny under high pressures of at least 600 MPa between 1790 and 1760 Ma, producing a mixed gneiss and schist terrain (Smithies and Bagas, 1997a).

The stratigraphic subdivision of the metasedimentary rocks in the Talbot Terrane follows that of Hickman et al. (1994) and Hickman and Bagas (1998). Certain areas within RUDALL (1:250 000) contain insufficient evidence for lithostratigraphic correlation, and the stratigraphic position of some units are therefore left unassigned (see **Unassigned metasedimentary rocks**). No unconformities are recognized within the succession, and contacts with orthogneiss are tectonic or intrusive. The stratigraphic succession has been extensively fragmented by reverse faults of various ages (D_2 and D_4).

A maximum depositional age of c. 1790 Ma was obtained for the Fingoon Quartzite, based on the age of the youngest detrital zircon extracted from the unit (Nelson, 1995). Field observations suggest that the stratigraphically or structurally overlying Yandagooge and Butler Creek Formations were intruded by granitoids ranging in age between 1790 and

Table 2. Lithological composition of the tectono-stratigraphic terranes in the Rudall Complex

Rock type	*Talbot Terrane*	*Connaughton Terrane*	*Tabletop Terrane*
Granitoid rocks and pegmatite		5% of terrane *Ꝑge, Ꝑgl, Ꝑgm, Ꝑgp*	70% of terrane *Ꝑgl, Ꝑgf*
Orthogneiss	40% of terrane *ꝐRga, ꝐRgx, ꝐRgd, ꝐRge, ꝐRgg, ꝐRgb, ꝐRgm, ꝐRgp*	15% of terrane *ꝐRga, ꝐRgo, ꝐRgh, ꝐRgm*	
Metamorphosed mafic and ultramafic rocks	1% of terrane *ꝐRa, ꝐRu*	50% of terrane *ꝐRag, ꝐRam, ꝐRb, ꝐRac, ꝐRan, ꝐRae, ꝐRao, ꝐRu*	15% of terrane not exposed
Metasedimentary rocks	59% of terrane *ꝐRw, ꝐRf, ꝐRy, ꝐRyi, ꝐRc, ꝐRo, ꝐRq, ꝐRqa, ꝐRs, ꝐRp, ꝐRk, ꝐRi, ꝐRi, ꝐRm, ꝐRb*	10% of terrane *ꝐRi, ꝐRic, ꝐRir, ꝐRk, ꝐRm, ꝐRq*	14% of terrane *ꝐRm, ꝐRq*
Gneiss and schist of uncertain protolith		20% of terrane *ꝐRnb, ꝐRnm, ꝐRnc, ꝐRng, ꝐRns*	1% of terrane *ꝐRnm*

1765 Ma (Nelson, 1995). These data appear to establish that the augen orthogneiss (*ꝐRga*) and the sedimentary formations are closely similar in age, implying that both are related to the same orogeny (Hickman and Bagas, 1999). The succession indicates shoreline–shelf–slope environments in a subsiding foreland basin on the eastern margin of the Pilbara Craton (Hickman and Bagas, 1998, 1999).

The layered orthogneiss consists of complexly interlayered paragneiss, gneissic pegmatite, amphibolite, and several types of orthogneiss including the augen orthogneiss (*ꝐRga*; Hickman and Bagas, 1998). The oldest orthogneiss components of the layered gneiss (*ꝐRgx*) are older than the stratigraphic succession forming the Larry – Poynton Formations, and contain an early (S_1) foliation not present in the 1787–1765 Ma augen orthogneiss (Hickman and Bagas, 1998, 1999). One of the layered orthogneiss components is 2015 ± 26 Ma (Nelson, 1995).

The layered orthogneiss (*ꝐRgx*) is restricted to the central part of RUDALL (1:250 000) where contacts with unassigned metasedimentary units of the Talbot Terrane are intrusive. These metasedimentary rocks are probably older than the assigned stratigraphic succession (from the Larry Formation to the Poynton Formation).

The Tabletop Terrane comprises lithologies (amphibolite and metasedimentary rocks) that are similar to those in the Connaughton Terrane, but in different proportions (Table 2). The Camel–Tabletop Fault Zone separates the two terranes (Fig. 1). The original relationship between the two terranes is uncertain, but the Tabletop Terrane is intruded by voluminous post-D_2 granitic rocks and dolerite dykes that are not found in the Connaughton Terrane (Bagas, 1999a). These igneous rocks are about 1300 Ma (Nelson, 1995; Smithies and Bagas, 1997b).

Unassigned amphibolite and mafic granulite (ꝐRan, ꝐRab, ꝐRae, ꝐRam, ꝐRao, ꝐRac, ꝐRag)

The term amphibolite is used here to describe recrystallized medium- to coarse-grained amphibole- and plagioclase-rich rocks in which no igneous textures are preserved. Mafic granulite is characterized by the presence of brown hornblende and orthopyroxene.

Leucocratic, coarse to very coarse grained amphibolite (*ⱣRan*) outcrops south of the Harbutt Range (around CONNAUGHTON AMG 840597*), about 6 km south of Camel Rock (at CONNAUGHTON AMG 622979), and 5 km west of Camel Rock (CONNAUGHTON AMG 575040). Coarse leucocratic amphibolite is commonly massive, and derived from protoliths ranging from leucogabbro to anorthosite. South of the Harbutt Range (at CONNAUGHTON AMG 829604), a small outcrop of well-foliated, medium-grained amphibolite appears to be crosscut and enclosed by non-foliated, coarse leucocratic amphibolite. Coarse leucocratic amphibolite consists of interstitial clinopyroxene (now altered to actinolite and rarely to hornblende) in a framework of plagioclase (anorthite to bytownite) euhedra. Plagioclase forms between 60% (leucogabbro) and 90% (anorthosite) of the rock. Accessories include titanite, apatite, and magnetite (leucoxene).

Fine-grained amphibolite (*ⱣRab*), possibly derived from basalt, outcrops north of the South Rudall Dome on CONNAUGHTON. The amphibolite is interlayered with minor chert (*ⱣRic*), quartz mica schist (*ⱣRm*), and quartzite (*ⱣRq*), or forms thin layers within K-feldspar augen orthogneiss (*ⱣRga*) where it is locally epidotized (*ⱣRae*). The rock is highly foliated and consists of fine-grained hornblende (altered to actinolite) in a very fine grained matrix of quartz and plagioclase (altered to epidote and carbonate), with accessory magnetite, epidote, carbonate, and rare relict garnet. Fine-grained amphibolite is tectonically attenuated and bound by layer-parallel faults that have been folded and faulted. Xenoliths of the fine-grained amphibolite (*ⱣRab*) are preserved locally in K-feldspar augen orthogneiss (e.g. at CONNAUGHTON AMG 592841), indicating that the granite precursor to the orthogneiss intruded the protolith to the amphibolite.

Fine- to medium-grained quartz–epidote(–hornblende–actinolite–biotite–sericite) gneiss and schist (*ⱣRae*) outcrop approximately 5 km southwest of the Harbutt Range (CONNAUGHTON AMG 785612), and southeast of the South Rudall Dome (CONNAUGHTON AMG 591689). The unit is always in contact with orthogneiss (*ⱣRga*, *ⱣRgo*), and forms prominent outcrops parallel to the structural trend of the area. Mineral proportions vary widely from up to 75% quartz to 70% epidote by volume. In thin section, relict domains comprising plagioclase–hornblende indicate that the rock may be a silicified and epidotized garnet amphibolite (*ⱣRag*) or a medium-grained amphibolite (*ⱣRam*). In places, the rock shows millimetre- to centimetre-scale mineralogical banding defined by alternating layers rich in quartz (biotite), epidote and, in rare places, hornblende. The fine-grained gneiss and schist is commonly well foliated, but can be massive and banded with well-developed polygonal textures in places.

Medium-grained clinopyroxene- and quartz-bearing amphibolite (*ⱣRam*) is a common rock type in the Harbutt Range on CONNAUGHTON, where it is interlayered with thin units of garnetiferous amphibolite, orthogneiss, quartz–biotite(–muscovite) schist and quartzite. Medium-grained amphibolite also outcrops in the Connaughton Synform, where it is associated with major shear zones and faults, and is interlayered with quartzite and orthogneiss. The amphibolite is well foliated and locally shows distinct centimetre-scale layering due to metamorphic segregation. Plagioclase (andesine) and hornblende are the main constituents of the rock, with quartz forming 5–20%. Accessory minerals include titanite, apatite, magnetite (or leucoxene), rutile, biotite, zircon, and extensive secondary epidote. Some samples of the amphibolite may represent sheared and retrogressed garnet amphibolite. However, the high abundance of quartz in other samples indicates that the protolith may have locally included immature sediments (Bagas and Smithies, 1998a).

---

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

This variety of amphibolite (*Ꝑ*R*am*) also forms rafts in late granitoid rocks (*Ꝑgf*, *Ꝑgl*) in the Tabletop Terrane on the eastern part of RUDALL (1:250 000). The amphibolite is well foliated and consists of plagioclase, hornblende, and minor quartz. Accessory minerals include titanite, apatite, magnetite (or leucoxene), rutile, biotite, and zircon.

Garnet amphibolite with minor interlayers of compositionally banded orthogneiss (*Ꝑ*R*ao*) is present in the southeastern part of the sheet (CONNAUGHTON AMG 600670). The unit is lithologically similar to the compositionally layered orthogneiss (*Ꝑ*R*go*) except that it has a greater proportion of garnet amphibolite. Both units represent mixtures of different proportions of the orthogneiss and garnet amphibolite.

Medium- to coarse-grained mafic amphibolite (*Ꝑ*R*ac*) outcrops northeast of the Harbutt Range (CONNAUGHTON AMG 840705), east of Mount Eva (CONNAUGHTON AMG 680890), and west of Camel Rock (CONNAUGHTON AMG 510065) as thin, elongate pods or lenses in gneiss (typically *Ꝑ*R*ng*), or interlayered with ironstone and chert. The rock is commonly equigranular, well foliated to massive, and has a well-developed granoblastic texture. The unit includes granulite facies rocks in which brown hornblende and lesser andesine comprise 90 to 95% of the rock, and are accompanied by minor diopside, rare hypersthene, and accessory quartz, magnetite, titanite, and rutile. Amphibolite (*Ꝑ*R*ac*), which contains green hornblende and lacks orthopyroxene, outcrops as dyke-like bodies within the brown-hornblende-bearing variety and as inclusions in metamorphosed leucogabbro–anorthosite (*Ꝑ*R*an*).

Medium- to coarse-grained garnet amphibolite (*Ꝑ*R*ag*) is a common rock type around the South Rudall Dome on CONNAUGHTON (CONNAUGHTON AMG 565715), where it is associated with metamorphosed banded iron-formation, graphitic and sulfidic schist, and lesser quartzite and carbonate. Small outcrops of garnet amphibolite form discontinuous layers or lenses within non-garnetiferous amphibolite in the Harbutt Range (*Ꝑ*R*am*; e.g. CONNAUGHTON AMG 840670).

Garnet amphibolite contains abundant hornblende and andesine, with up to 20% quartz, rare diopside, and characteristically subrounded to prismatic garnet porphyroblasts up to 5 mm in diameter. Accessory minerals include titanite, leucoxene, rutile, apatite, and secondary epidote, calcite, and sericite. In more foliated samples, hornblende wraps around garnet and diopside porphyroblasts, defining an early foliation. No reaction textures have been observed between garnet, clinopyroxene, and hornblende. The amphibolite locally shows distinct centimetre-scale banding due to metamorphic segregation of amphibole-rich and plagioclase-rich layers (e.g. at CONNAUGHTON AMG 588743). In rare cases, garnet cores preserve sigmoidal trains of fine-grained epidote, hornblende, and titanite representing an early foliation (S_1; Bagas and Smithies, 1998a). The main foliation in the rock is therefore S_2.

*Unassigned metasedimentary rocks (Ꝑ*R*s, Ꝑ*R*q, Ꝑ*R*qa, Ꝑ*R*b, Ꝑ*R*m, Ꝑ*R*l, Ꝑ*R*i, Ꝑ*R*ic, Ꝑ*R*ir, Ꝑ*R*k, Ꝑ*R*p)*

Psammitic paragneiss *(Ꝑ*R*s)* includes fine-grained quartz–feldspar–mica gneiss, quartz–mica schist, pelitic schist, and quartzite layers. These probably represent metamorphosed sandstone–shale successions.

Quartzite (*Ꝑ*R*q*) in the northwestern part of RUDALL and in northern CONNAUGHTON is either massive or layered, with a pervasive S_2 foliation along recrystallized quartz grains or muscovite-rich planes with variable amounts of opaque minerals and rare tremolite and carbonate. The protolith was either chert or silica sandstone, but no sedimentary structures are preserved.

Medium-grained quartz–aluminosilicate schist (*ᵽRqa*) is a general term used for rare aluminosilicate-rich metasedimentary rocks that outcrop along the boundary between the Connaughton and Talbot Terranes in northern CONNAUGHTON. These include quartz–garnet–sillimanite–feldspar schist and quartz–kyanite–ilmenite(–sillimanite) schist (Bagas and Smithies, 1998a).

Banded paragneiss *(ᵽRb)* includes various proportions of closely intercalated quartzite, quartz–feldspar–mica (biotite or muscovite) gneiss, quartz–mica (biotite or muscovite) schist, and rare, thin (2–5 cm) layers of metamorphosed banded iron-formation. Banded paragneiss represents a metamorphosed succession of turbiditic sandstone, argillaceous siltstone, and shale.

Fine- to medium-grained quartz–biotite–muscovite(–Fe-oxide–tourmaline–garnet–K-feldspar) schist (*ᵽRm*) outcrops south of the Harbutt Range and about 10 km northeast of the South Rudall Dome on CONNAUGHTON in the Connaughton Terrane. The unit is interleaved with medium-grained amphibolite (*ᵽRam*), quartzite (*ᵽRq*), fine-grained amphibolite (*ᵽRab*), or infolded with orthogneiss. The protolith was an argillaceous sedimentary rock.

In the Talbot Terrane (e.g. BROADHURST AMG 990173), quartz–mica schist intercalated with thin (less than 30 cm thick), quartz-rich laminae *(ᵽRm)* contains varying amounts of quartz and biotite, with minor feldspar, opaque minerals, and garnet. The protoliths of this unit were probably shale and mudstone.

Small outcrops of fine- to medium-grained quartz–mica schist (*ᵽRm*) also outcrop in the Tabletop Terrane. The unit is interleaved with quartzite (*ᵽRq*) in an isolated outcrop about 15 km north of the Harbutt Range (at CONNAUGHTON AMG 858778).

Quartz–chlorite schist (*ᵽRl*) outcrops around the headwaters of Yandagooge Creek (BROADHURST AMG 993178). The rock is pervasively retrogressed and consists of fine-grained, light-green amphibole of uncertain composition, epidote, quartz, and chlorite (Hickman and Clarke, 1994). These minerals define an S_2 foliation enveloping coarser hornblende, plagioclase, opaque minerals, and epidote. The rock probably represents a metamorphosed argillaceous sedimentary rock, and is closely associated with calc-silicate gneiss and schist *(ᵽRk*; Hickman and Clarke, 1994*)*.

Metamorphosed banded iron-formation and chert (*ᵽRi*) are the most abundant rock types in the Connaughton Syncline and South Rudall Dome areas in the Connaughton Terrane. In the Talbot Terrane, they are very minor components commonly forming units less than 10 m thick, and consist of alternating 1–5 mm-thick layers of quartz and grunerite, magnetite or hematite (Hickman and Clarke, 1994).

The banded iron-formation is fine to medium grained and laminated. It consists of recrystallized quartz, aligned magnetite, rare garnet, and light-green amphibole, and accessory amounts of muscovite, apatite, and epidote. Some iron oxides may pseudomorph amphibole (?grunerite). The rock also contains sericite-rich patches, possibly after feldspar. The laminations commonly define a pervasive early foliation. Primary surfaces have not survived recrystallization.

Metamorphosed chert and lesser amounts of banded iron-formation (*ᵽRic*) outcrop throughout CONNAUGHTON. The unit commonly forms prominent outcrops interlayered and folded with mafic schist and gneiss, and micaceous quartzite, except in the far northwestern part of CONNAUGHTON where chert forms enclaves within gneiss (*ᵽRnm*). The unit is mineralogically diverse, ranging from pure chert to quartz–magnetite rock, although the dominant rock type is a ferruginous chert comprising a quartz–magnetite–garnet–diopside–grunerite–apatite assemblage.

Graphitic and sulfidic schists, thinly interlayered with quartz–mica–garnet schist, amphibolitic schist, and minor chert and quartz-carbonate rock (*ⱣRir*), outcrop at Mount Cotton on CONNAUGHTON. These rocks are extensively recrystallized and commonly chloritized, silicified, and carbonated, and are probably metamorphosed and metasomatized successions of sulfidic black shale, chemical sediments (banded iron-formation), and sediments derived from mafic volcanic rocks. The graphitic schist is very fine grained and consists of quartz, mica (sericite and biotite), chlorite, graphite, and disseminated sulfides (pyrrhotite, pyrite, chalcopyrite, sphalerite, and galena). The quartz–mica–garnet schist is very fine grained and includes chloritized biotite, opaque minerals, sericite, remnant porphyroblasts of sericitized and chloritized garnet, and rare dolomite. Amphibolitic schist is fine grained and includes: hornblende (?after pyroxene)–actinolite–sulfide(–epidote–quartz–biotite) schist; anthophyllite–cummingtonite–graphite–biotite–sulfide(–quartz–sericite) schist; quartz–hornblende–epidote–sulfide schist; and clinopyroxene (–orthopyroxene)–quartz–garnet–biotite–sulfide(–dolomite) schist. The quartz–carbonate rock is very fine grained and consists of carbonate, quartz, sulfides (pyrrhotite, pyrite, chalcopyrite, galena, and sphalerite), and variable amounts of sericite and graphite.

The mineral assemblages in the schist reflect metamorphism at the amphibolite–granulite facies transition. The presence of dolomite, ankerite, sericite, sulfides, chlorite, or epidote possibly indicates a later metasomatic alteration under greenschist facies conditions. The sulfides also fill fractures as veins parallel to the early foliation in the rocks.

Metamorphosed carbonate rock (*ⱣRk*) in the Connaughton Terrane outcrops as a thin horizon immediately above banded iron-formation in the South Rudall Dome on CONNAUGHTON. The unit is less than 20 m thick, poorly exposed, and heavily silicified.

In the Talbot Terrane, metamorphosed carbonate rocks outcrop as calc-silicate gneiss and schist (*ⱣRk*) around the headwaters of the Yandagooge Creek (BROADHURST AMG 995180). The rock includes well-layered quartz–plagioclase–epidote schist, hornblende(–plagioclase–biotite) gneiss and schist, epidote–biotite–plagioclase gneiss, and equigranular, schistose to gneissic para-amphibolite. The amphibolite consists of hornblende, plagioclase commonly replaced by sericite and epidote, quartz, ilmenite, and minor calcite. The hornblende (–sericitized plagioclase –biotite) gneiss and schist also contain quartz, sericite, clinozoisite, and chlorite.

Quartz–biotite–plagioclase gneiss and schist, containing layers of quartzite and pelitic schist (*ⱣRp*), outcrop 4 km north-northeast of Watrara Rockhole on BROADHURST (Hickman and Clarke, 1994). The gneiss consists of granoblastic quartz, plagioclase, biotite, and opaque minerals. The preferred alignment of biotite, and the elongation of quartz and plagioclase (partly pseudomorphed by sericite) grains define a pervasive foliation in the rock. In more retrogressed samples, primary grains are enveloped and, in places, transected by an anastomosing mylonitic S_2 foliation consisting of epidote, fine-grained biotite, sericite, and quartz.

Layered orthogneiss (ⱣRgx)

Layered gneiss (*ⱣRgx*) is a complex unit found in the central part of RUDALL (1:250 000). It consists of layers of quartz–feldspar–muscovite gneiss, biotite-rich gneiss, quartz–feldspar gneiss, orthogneiss, gneissic pegmatite, and various types of paragneiss, amphibolite, serpentinite, and banded iron-formation (which range in size from centimetre-wide xenoliths at outcrop scale to large enclaves several hundred metres in length). The orthogneiss was probably derived from several granitoid protoliths ranging in composition from granite and syenogranite to granodiorite.

Protoliths of the orthogneiss intruded the unassigned metasedimentary units of the Talbot Terrane (Hickman and Bagas, 1998). This indicates that at least some of the unassigned metasedimentary units are older than the orthogneiss component of the layered gneiss (*ꟼRgx*).

The complex orthogneiss is pervasively intruded by sheets and veins of augen orthogneiss (*ꟼRga*), suggesting that the granitoid protoliths of these rocks crystallized during separate intrusive events, which is consistent with currently available geochronological data. Furthermore, the layer-parallel foliation (S_1) of the layered gneiss (*ꟼRgx*) is tightly folded (F_2), but no S_1 foliation has been recognized in the augen orthogneiss (*ꟼRga*).

Zircons extracted from orthogneiss within the layered gneiss (*ꟼRgx*; GSWA 104932; BROADHURST AMG 035158) include a zircon population with an age of 2015 ± 26 Ma, whereas zircons extracted from several augen orthogneiss (*ꟼRga*) samples have single zircon populations with ages between 1765 and 1790 Ma (Nelson, 1995).

Stratigraphic units of the Talbot Terrane

Larry Formation (ꟼRw)

The Larry Formation (*ꟼRw*; Hickman and Bagas, 1998) is the lowest stratigraphic unit recognized in the Talbot Terrane. The base of the Larry Formation is not exposed, and the formation is transitionally overlain by the Fingoon Quartzite. There is an increase in the proportion of quartzite units towards the top of the formation (e.g. RUDALL AMG 250870), but this may be due to tectonic interleaving.

The formation forms low, poorly exposed, undulating terrain and consists of a highly weathered, tectonized, and monotonous succession of quartz–feldspar–mica paragneiss, quartz–mica schist, and minor amounts of variably micaceous quartzite. The paragneiss contains abundant quartz, feldspar (both microcline and oligoclase), and biotite, with accessory sericite and epidote.

The succession is interpreted to represent a metamorphosed assemblage of argillaceous rocks (siltstone and mudstone) and arenites (greywacke and variably clay-rich sandstone).

Fingoon Quartzite (ꟼRf)

The Fingoon Quartzite (*ꟼRf*; Hickman and Bagas, 1998) transitionally overlies the Larry Formation and includes quartzite, micaceous quartzite, and quartz–mica schist.

No primary sedimentary structures were recognized in the rocks of the Fingoon Quartzite, but flaggy, compositional layering probably includes attenuated bedding. Massive and layered quartzite, with a pervasive foliation outlined by recrystallized quartz grains, contains various proportions of opaque minerals, muscovite, sericite, and rutile. Minor amounts of pebbly quartzite with quartz pebbles in a medium-grained quartzite matrix are present towards the base of the unit in the northwestern end of the Fingoon Range.

About 200 m from the top of the formation is a flaggy succession of muscovite-rich quartzite intercalated with muscovite schist. Psammitic quartz–feldspar–muscovite schist and gneiss are also present.

The contact between the Fingoon Quartzite and Yandagooge Formation is commonly tectonic and forms a highly strained zone of variable lithology. However, just south of the Cassandra prospect (RUDALL AMG 310844), quartzite and mica schist are intercalated, apparently representing a transitional zone and indicating that the two formations are conformble.

The thickness of the Fingoon Quartzite ranges from at least 1500 m in Fingoon Range (around RUDALL AMG 250950), where it is complexly folded and faulted, to less than 500 m near the Minder prospect (RUDALL AMG 320800), where the formation is less complexly folded. North of Rudall River, the formation is tectonically attenuated and includes refolded D_2 isoclines and thrusts.

Yandagooge Formation (ⱣRy, ⱣRyi)

The Yandagooge Formation (*ⱣRy*; Hickman and Bagas, 1998) is commonly recessive in outcrop, forming sparsely vegetated, low-lying rubbly rises covered with a veneer of quartz colluvium. With the exception of lithological layering, primary sedimentary features are absent. The formation is less than 1500 m thick, has a conformable transition from the overlying Fingoon Quartzite, and is interlayered with K-feldspar augen orthogneiss (*ⱣRga*; Hickman and Bagas, 1998).

The Yandagooge Formation is a widespread and lithologically distinctive unit of the Rudall Complex, and includes metamorphosed pelitic and semipelitic rocks with lenticular layers of banded iron-formation and chert (*ⱣRyi*), and thin units of quartzite. A relatively psammitic facies of the formation is present north of the Rudall River where muscovite–feldspar–quartz gneiss represents metamorphosed feldspathic sandstone. The dominant rock type of the formation is quartz–mica schist containing thin layers of muscovitic quartzite.

The quartz–mica schist is interlayered with thin units of banded iron-formation, quartzite, micaceous quartzite, and chert. The quartz–mica schist contains varying amounts of quartz, muscovite, and biotite, with minor amounts of feldspar (predominantly plagioclase), finely disseminated opaque minerals, and garnet. The chert is composed of deformed and recrystallized quartz, with minor amounts of mica (predominantly muscovite) and opaque minerals, and rare sericitized plagioclase. The banded iron-formation is finely laminated, consisting of quartz, Fe-oxide material (possibly after amphibole), aligned magnetite, clay, accessory muscovite, and rare, relict garnet.

The dominant fabric is a penetrative S_1 foliation, which is defined by the preferred alignment of muscovite, biotite, tourmaline, quartz, opaque minerals, and sericite. S_1 is typically parallel to the S_2 schistosity, except at F_2 fold hinges where S_2 (which is parallel to F_2 axial surfaces) cuts across S_1 (which is parallel to compositional banding). Post-S_2 chlorite commonly pseudomorphs rare biotite.

Butler Creek Formation (ⱣRc)

The Butler Creek Formation (*ⱣRc*; Hickman and Bagas, 1998) is a monotonous succession of banded paragneiss, schist, banded iron-formation, and quartzite that is present in many areas of eastern RUDALL and western CONNAUGHTON. The unit formed an incompetent layer during deformation and therefore, is complexly folded and faulted. Its contacts with other units are commonly tectonic and the nature of stratigraphic relations with other formations is commonly difficult to determine.

The Butler Creek Formation consists of grey or brown schist (pelite derived from a shale or muddy sandstone) intercalated with fine to coarse paragneiss (metamorphosed feldspathic greywacke), local banded iron-formation, and rare units of light-grey to white quartzite or argillaceous quartzite. These rock types are commonly intercalated in 0.1 – 2 m-thick bands. Pelitic units contain quartz, biotite, muscovite or sericite, secondary chlorite, and small amounts of plagioclase (commonly albite or oligoclase). The metagreywacke is fine grained and contains quartz, muscovite, microcline aggregates, subordinate albite, minor biotite, and secondary sericite. Quartzite is commonly thinly banded, fine to medium grained, and contains quartz, minor amounts of biotite and sericite, and accessory tourmaline. Pebble bands are rare, with clasts being entirely composed of vein quartz. The unit contains belts of tectonically interleaved paragneiss and orthogneiss, and ultramafic and mafic rocks near major D_2 faults.

The lack of continuous suitable marker horizons and structural complexity makes the primary stratigraphic thickness of the Butler Creek Formation difficult to determine. A section at least 1000 m thick is present just south of the Rudall River, but the area probably contains unrecognized isoclinal folds.

The Butler Creek Formation is interpreted to represent a turbidite succession with a source area dominated by granitoid and perhaps felsic volcanic rocks. This is indicated by the local presence of scattered clasts of microcline and minor amounts of quartz and biotite set in a semipelitic matrix.

Poynton Formation (₽Ro)

The Poynton Formation (*₽Ro*; Hickman and Bagas, 1998) is a succession of quartzite, metagreywacke, quartz–muscovite schist, and minor amounts of pelitic schist and banded iron-formation structurally overlying rocks correlated with the Butler Creek Formation.

The lower part of the Poynton Formation, north of Poynton Creek on RUDALL, is a 100 m-thick unit of quartzite containing minor intercalations of quartz–feldspar–muscovite paragneiss and 1–2 m thick layers interpreted to be metamorphosed conglomerate. The clast-like structures of the metamorphosed conglomerate are well rounded, 20–50 mm across, and are composed of coarse quartz or quartz and muscovite. The matrix material is finer grained and includes minor amounts of biotite and plagioclase.

Above the basal quartzite is a 100–200 m-thick unit of interlayered quartzite and quartz–feldspar–muscovite paragneiss and schist. This is interpreted as either metamorphosed arkosic sandstone or a felsic volcanogenic sedimentary rock. A 100–200 m-thick sheet of orthogneiss separates the arkosic unit from the upper part of the formation.

The upper part of the Poynton Formation is at least 400 m thick and consists of compositionally layered quartz–feldspar–biotite paragneiss with numerous thin units of quartzite and quartz–biotite schist. Some exposures of the formation contain 0.5 – 1.0 m-thick compositionally layered rhythmic units, which consist of feldspathic quartzite layers grading upward into plagioclase–quartz–muscovite–biotite gneiss overlain by 50–100 mm-thick layers of biotite–epidote–quartz microgneiss. These rhythmic units are interpreted to be metamorphosed sandstone–greywacke–shale graded beds of a turbidite succession. Biotite–plagioclase–quartz schist, probably representing metamorphosed silty shale, is locally present within the upper part of the formation westward from Rooney Creek on RUDALL.

Mafic and ultramafic intrusive rocks (₽Ra, ₽Ru)

In the Connaughton Terrane, medium-grained serpentine–tremolite–magnetite rock (*₽Ru*) is locally foliated, but commonly preserves olivine cumulate textures that identify its protolith as either dunite or peridotite. Ultramafic rock is most abundant about 4 km east of Mount Eva (CONNAUGHTON AMG 665890) and throughout the Harbutt Range on CONNAUGHTON, where it outcrops as discontinuous layers, up to 5 km long, within amphibolite and metasedimentary rocks.

The Talbot Terrane contains minor amounts of mafic and ultramafic metamorphosed intrusive rocks, most of which contain S_2 structures and therefore, clearly pre-date the Throssell Group (see **Structure**).

Layers and pods of ultramafic rocks *(ṔRu)* are found in the orthogneiss and metasedimentary rocks of the Talbot Terrane and are locally foliated, but commonly preserve olivine cumulate textures that identify their protoliths as either dunite or peridotite. The ultramafic rocks are less than 200 m thick and composed of serpentine, tremolite, chlorite, opaque minerals, and serpentinite pseudomorphs after olivine or pyroxene. The unit is close to major D_2 and D_4 faults (e.g. around the Rudall River), where it is tectonically interleaved with paragneiss or orthogneiss, and locally boudinaged.

Ortho-amphibolite (*ṔRa*), probably representing metamorphosed gabbro and dolerite, is present as numerous small enclaves within orthogneiss included in the layered orthogneiss (*ṔRgx*) and in sheets and large boudins in paragneiss, and are intruded by veins of microgranite. The largest bodies of the ortho-amphibolite are sheets that intruded the Fingoon Quartzite (Hickman and Bagas, 1998). Much of the amphibolite in this area is sheared and metasomatized. Alteration minerals include epidote, clinozoisite, scapolite, carbonate, and phlogopite, and metasomatism has locally produced calc-silicate gneiss (e.g. RUDALL AMG 105020).

Orthogneiss

About 50% of the outcrop area of the Rudall Complex on RUDALL (1:250 000) is composed of orthogneiss, approximately half of which is a microcline–quartz–plagioclase–biotite(–muscovite) gneiss (*ṔRga*) containing numerous augen (deformed megacrysts) of K-feldspar. The augen orthogneiss is the only gneiss that outcrops in both the Connaughton and Talbot Terranes, except for minor outcrops of mica orthogneiss (*ṔRgm*).

Orthogneiss common to both the Connaughton and Talbot Terranes (ṔRga)

The K-feldspar augen orthogneiss (*ṔRga*) is a microcline–quartz–plagioclase–biotite gneiss containing numerous microcline augen. The microcline augen are deformed megacrysts that are commonly stretched out within the foliation plane (S_2), and locally recognizable only as spindles of granular microcline.

The augen orthogneiss ranges from a poorly foliated porphyritic granite or monzogranite to quartz–feldspar–muscovite schist. The orthogneiss consists of a strongly foliated and granoblastic mosaic of microcline, plagioclase, and quartz with variable amounts of biotite and muscovite. Minor sphene, allanite, and epidote, and accessory amounts of opaque minerals, apatite, and zircon are present. Plagioclase is sericitized or saussuritized, and microcline forms elongate to lenticular coarse-grained mosaics. Megacrystic microcline augen commonly enclose small crystals of plagioclase and biotite. Where the feldspar augen are chiefly composed of oligoclase, the rock composition is granodiorite.

In highly foliated samples, quartz, biotite, muscovite, and sericite enveloping feldspar and quartz phenocrysts define S_2. The foliation is commonly folded by F_4 folds or crenulated by S_4. No earlier deformation (D_1) is evident.

Sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon dates of 1790 ± 17, 1787 ± 5, 1769 ± 7, and 1765 ± 15 Ma have been obtained from samples of the augen orthogneiss collected at four localities up to 40 km apart on RUDALL and CONNAUGHTON (Nelson, 1995, 1996). The two older dates are from highly foliated orthogneiss, and the others are from moderately foliated orthogneiss. The correlation between decreasing intensity of foliation and decreasing age of the augen orthogneiss possibly indicates that the augen orthogneiss was pre- to syn-D_2 and that D_2 has a maximum age of c. 1790 Ma. The 1790 ± 17 Ma result, however, was from a sample containing six populations of zircons. The youngest population is 1790 ± 17 Ma and interpreted as the crystallization age of the orthogneiss protolith. The older zircon populations gave ages that range up to 2425 ± 7 Ma, and are interpreted to be xenocrystic.

Protoliths for the augen orthogneiss (*ⱣRga*) intruded all levels of the paragneiss succession (Hickman and Bagas, 1995).

Orthogneiss in the Connaughton Terrane (ⱣRgh, ⱣRgm ⱣRgo)

In Harbutt Range and northwest of Camel Rock on CONNAUGHTON, amphibole-bearing orthogneiss (*ⱣRgh*) is found as sheets within amphibolite or as larger bodies enclosing blocks of amphibolite (*ⱣRac*), ultramafic rock (*ⱣRu*), and chert (*ⱣRic*). The orthogneiss (*ⱣRgh*) differs from the banded orthogneiss (*ⱣRgo*) in that hornblende forms a primary constituent.

The orthogneiss (*ⱣRgh*) is medium grained, equigranular, and commonly well foliated. Plagioclase is the dominant feldspar mineral and biotite the dominant mafic mineral. Hornblende is commonly rimmed by biotite, and appears to decrease in abundance with increasing abundance of K-feldspar. Accessory minerals include zircon, allanite, titanite, and apatite. Although the gneiss shows obvious signs of recrystallization (particularly of quartz), granoblastic textures typical of many samples of K-feldspar augen orthogneiss are not observed, and it is probable that the amphibole-bearing orthogneiss has not been metamorphosed higher than upper greenschist facies. The protolith to amphibole-bearing orthogneiss ranged from granodiorite to monzogranite.

Biotite–muscovite orthogneiss (*ⱣRgm*) with a monzogranitic composition outcrops north of the Connaughton Synform (around CONNAUGHTON AMG 624815). The rock is a fine- to medium-grained, equigranular to slightly porphyritic, homogeneous gneiss interlayered with the K-feldspar augen orthogneiss.

Banded orthogneiss (*ⱣRgo*) outcrops in southwestern CONNAUGHTON and forms sheets within garnet amphibolite (*ⱣRag*) and medium-grained amphibolite (*ⱣRam*). It also forms large bodies that enclose and are interleaved with lenses of amphibolite (*ⱣRao*) and quartzite (*ⱣRq*). The orthogneiss is commonly conspicuously banded, both in outcrop and on aerial photographs. Thin layers of quartz–feldspar–muscovite gneiss alternate with biotite-rich gneiss, quartz–feldspar gneiss, and gneissic pegmatite. The composition of the gneiss ranges from granite to granodiorite. Numerous inclusions of amphibolite and quartzite range in size from centimetre-scale to large lenses several hundred metres in length.

A sample of the compositionally banded orthogneiss has a SHRIMP age of 1777 ± 7 Ma (GSWA 113035; CONNAUGHTON AMG 603680). This age is interpreted as the crystallization age for the orthogneiss protolith (Nelson, 1996).

Orthogneiss in the Talbot Terrane (ⱣRgp, ⱣRgm, ⱣRgg, ⱣRgb, ⱣRge, ⱣRgd)

Pegmatite (*ⱣRgp*) is a common constituent of the Rudall Complex, but outcrops are commonly too small to distinguish on RUDALL (1:250 000). Much of the pegmatite is strongly deformed and may be related to pre-D_1 granitoid protoliths of the orthogneiss. Elsewhere, close interlayering of pegmatite with both orthogneiss and paragneiss indicates derivation from relatively proximal partial melting. The main mineral constituents are quartz, plagioclase, and muscovite, with quartz-rich varieties commonly containing tourmaline.

Biotite–muscovite monzogranitic orthogneiss (*ⱣRgm*) outcrops south of Larry Creek (RUDALL AMG 230810) as a fine- to medium-grained, equigranular, homogeneous gneiss. Microscopic examination indicates that the plagioclase component is sodic oligoclase. The secondary epidote is mainly intergranular, which indicates prolonged annealing.

Fine- to medium-grained, compositionally layered orthogneiss with a syenogranite or monzogranite composition (*ⱣRgg*) outcrops north of the Rudall River (RUDALL AMG 260045). The unit contains nebulitic biotite-rich layers defining complex fold structures, and outwardly resembles parts of the layered gneiss (*ⱣRgx*). Sheared and boudinaged amphibolite-facies metadolerite layers are interpreted to be early dykes. One sample of the orthogneiss (RUDALL AMG 260047; GSWA 112310) contains two zircon populations dated at 1972 ± 4 and 1802 ± 14 Ma (Nelson, 1995). Field evidence suggests lit-par-lit injection of an older orthogneiss by leucocratic layers and veins.

Banded garnetiferous granodioritic orthogneiss (*ⱣRgb*) outcrops in the core of the Mount Sears Anticlinorium on RUDALL, and is isolated from the main outcrop of the Rudall Complex. The granodiorite to diorite orthogneiss contains complexly folded nebulitic and wispy biotite-rich zones. It contains minor, small (0.1 – 0.2 mm in diameter) garnets in a medium- to coarse-grained, well-layered gneiss. Aggregates of sericite in more mafic zones may have replaced sillimanite, and it is possible that some parts of the gneiss had aluminous metasedimentary protoliths. Layering in the more leucocratic portions of the gneiss results from the segregation of biotite–plagioclase and quartz–microcline zones. The unit was subjected to high-grade metamorphism, followed by retrogression.

Even-grained syenogranite to monzogranite orthogneiss (*ⱣRge*) is a minor, but widespread constituent of the Rudall Complex. The larger outcrops are found in the central part of RUDALL (1:250 000), adjacent to outcrops of banded garnetiferous orthogneiss (*ⱣRgb*; around RUDALL AMG 461085), and south of Larry Creek (RUDALL AMG 260830). The rock is a non-foliated to foliated, medium- to coarse-grained monzogranite containing quartz, microcline, oligoclase, and muscovite.

Biotite granodioritic orthogneiss (*ⱣRgd*) outcrops in the Rudall River valley (RUDALL AMG 270003) as a dark-grey gneiss spotted with blebs of quartz, and forms a large dyke or stock within quartzite, metagreywacke, and pelitic schist of the Larry Formation. In thin section, elongate blebs of quartz are set in an andesine–biotite matrix, with minor muscovite, opaque minerals, microcline, and secondary epidote and carbonate. Most of the quartz probably represents xenoliths from the quartzite host. Biotite granodioritic orthogneiss (*ⱣRgd*; GSWA 111854; RUDALL AMG 270003) intruding the Larry Formation in the core of the Dunn Antiform has been dated at 1778 ± 17 Ma (Nelson, 1995), indicating that it is probably a variant of the augen orthogneiss (*ⱣRga*) suite.

A broad zone of aplite and microgranite veins and stockworks in augen orthogneiss (*ⱣRga*) is present within a radius of 10 km from Rudall Crossing. These units are sufficiently large enough to show on RUDALL (Hickman and Bagas, 1998). The microgranite does not contain an S_2 foliation, and other felsic units of this late intrusive suite either cut S_2 or intrude D_2 shear zones. A stock of weakly foliated biotite–muscovite monzogranite (*ⱣRge* on RUDALL AMG 280860; see 1:100 000 map, Hickman and Bagas, 1996; too small to represent at 1:250 000 scale) could be related to these late-stage granitic intrusions.

Other quartzofeldspathic metamorphic rocks

Quartzofeldspathic gneiss and schist of uncertain protolith (ⱣRnb, ⱣRnc, ⱣRnm, ⱣRng, ⱣRns)

The mineralogy of some quartzofeldspathic gneiss and schist is not consistent with derivation from an igneous protolith. Other samples are sheared or recrystallized to the extent that their protolith can not be recognized. In many outcrops, however, the quartzofeldspathic gneiss and schist are associated with various types of orthogneiss.

Medium-grained quartz–feldspar–biotite(–muscovite) gneiss (*ⱣRnb*) outcrops on CONNAUGHTON where it is wedged between quartzite (*ⱣRq*) and augen orthogneiss or garnet amphibolite (*ⱣRga*), or is closely associated with garnetiferous gneiss (*ⱣRng*). The proportion of quartz roughly correlates with the degree of shearing and decreases from 60% to around 30% in proximity to the augen orthogneiss. Furthermore, the more highly sheared rocks are muscovite rich, but biotite becomes the dominant mica in less sheared rocks.

Charnockite (*ⱣRnc*) outcrops approximately 6 km northeast of the Harbutt Range on CONNAUGHTON. It is a fine- to medium-grained quartz–microcline–plagioclase–garnet (altered to biotite)–hypersthene (altered to actinolite)–spinel–biotite gneiss. The rock shows discontinuous grain size bands from 10 to 20 mm thick. Discontinuous trains of garnet and hypersthene show a preference for the medium-grained bands and accentuate the gneissic fabric of the rock. Both charnockite and garnet gneiss have peraluminous compositions, and it is possible that these rocks are metamorphosed immature sedimentary rocks from a granitic provenance (Bagas and Smithies, 1998a).

A quartz–microcline–plagioclase–biotite gneiss (*ⱣRnm*) outcrops 5 km northeast of the Harbutt Range (CONNAUGHTON AMG 880700), 5 km east of Mount Eva (CONNAUGHTON AMG 693867) in the Connaughton Terrane, and near the eastern edge of RUDALL (1:250 000) in the Tabletop Terrane (CONNAUGHTON AMG 935663). The rock is medium grained, equigranular, and commonly shows a well-developed polygonal (granoblastic) texture. Biotite is the only mafic mineral. The amount of quartz varies up to around 40% and the feldspar is dominantly microcline, with plagioclase comprising less than 10%.

Medium-grained quartz–K-feldspar–plagioclase–mica–garnet gneiss (*ⱣRng*) is equigranular. It is typically rich in biotite and feldspar, and discontinuous biotite-rich layers, or schlieren, are common and complexly folded. Small subhedral grains of garnet are distributed throughout the rock, typically as an accessory or minor phase, although some samples are garnet-rich. Accessory phases include muscovite, zircon, titanite, allanite, apatite, and opaque minerals. The felsic mineralogy may be consistent with derivation from igneous protoliths ranging in composition from granodioritic to granitic; however, the abundance of garnet in many samples may also reflect a sedimentary origin, or peraluminous granite.

Mylonitic quartz–sericite(–K-feldspar–muscovite–biotite) schist (*ⱣRns*) outcrops to the west of the Camel–Tabletop Fault Zone on southeastern CONNAUGHTON. Early fabrics of the rock are destroyed by intense cataclasis, which has granulated the quartz and sericitized feldspar.

LATE GRANITOID ROCKS

Late granitoid rocks are restricted to the Connaughton and Tabletop Terranes.

Granitoid rocks (Ᵽge, Ᵽgf, Ᵽgl, Ᵽgm, Ᵽgp)

Even-grained to slightly porphyritic, medium-grained syenogranite to monzogranite (*Ᵽge*) outcrops east of the South Rudall Dome (around CONNAUGHTON AMG 617688). The monzogranite is massive to weakly foliated, contains angular amphibolite xenoliths of various sizes, and consists of quartz, microcline, oligoclase, muscovite, biotite, and rare garnet. It forms a semicircular outcrop with a diameter of less than 2 km, and intrudes banded orthogneiss (*ƁRgo*), K-feldspar augen orthogneiss (*ƁRga*), and amphibolite (*ƁRao*). The monzogranite is affected by D_4, and its intrusive age may be post D_2.

Massive to weakly foliated leucocratic granitoid rocks are porphyritic (*Ɓgf*), equigranular (*Ɓgl*), megacrystic (*Ɓgm*), or pegmatitic (*Ɓgp*). Although these rocks show some signs of recrystallization, particularly of quartz, igneous textures are commonly preserved. It is probable that the rocks have not been metamorphosed higher than upper greenschist facies (M_4, see **Metamorphism**). Intrusions of the equigranular granite and pegmatite crosscut D_2 fabrics. Porphyritic granitoid (*Ɓgf*) is confined to the Tabletop Terrane near the eastern boundary of RUDALL (1:250 000), while the other granitoids are confined to the Harbutt Range area.

Equigranular granite (*Ɓgl*) crosscuts early (D_2) tectonic fabrics in the Connaughton and Tabletop Terranes. The rock has been partly recrystallized (M_4), and is massive to weakly foliated (S_4). A sample of the granite collected east of the Camel–Tabletop Fault Zone (from CONNAUGHTON AMG 851803) in the Tabletop Terrane has a SHRIMP U–Pb zircon crystallization age of 1310 ± 4 Ma (Nelson, 1996). The relationship between this granitoid and the Throssell Group cannot be determined.

Pegmatite (*Ɓgp*), locally tectonized by a late deformation event (D_6, see **Structure**), collected in the Connaughton Terrane, near the Camel–Tabletop Fault Zone (at CONNAUGHTON AMG 520062), crosscuts early (D_2) tectonic fabrics and has a SHRIMP U–Pb zircon crystallization age of 1291 ± 10 Ma (Nelson, 1995).

AMYGDALOIDAL BASALT (*Ɓb*)

A fine-grained amygdaloidal basalt (*Ɓb*) outcrops south of the Connaughton Synform (around CONNAUGHTON AMG 687680) in the Connaughton Terrane. It unconformably overlies the Rudall Complex and is overlain by the Taliwanya Formation of the Throssell Group. Although the latter contact is not exposed, the presence of rare mafic clasts of the basalt in the Taliwanya Formation (CONNAUGHTON AMG 700655) indicates that the formation is younger than the basalt. The basalt has not been included in the Throssell Group because of the unclear nature of the contact between the two units.

Amygdaloidal basalt is a dark-green, non-foliated rock that consists of clinopyroxene, saussuritized plagioclase, accessory magnetite, and minor amounts of orthopyroxene, olivine, and secondary amphibole. The rock is heavily epidotized in places, and the amygdales contain quartz and calcite.

YENEENA SUPERGROUP

As defined by Williams (1990b), the 'Yeneena Group' included three geographically separate packages of fluvial-marine sedimentary rocks. These packages have now been given 'group' status, and from west to east are named the Tarcunyah, Throssell, and Lamil Groups (Bagas et al., 1995; Williams and Bagas, 1999). The 'Yeneena Group' has accordingly been redefined as the Yeneena Supergroup, but includes only the Throssell and Lamil Groups (Bagas et al., 1995; Williams and Bagas, 1999). This redefinition must be considered as being tentative until more chronological data become available and the relationship between the Throssell and Lamil Groups is established.

The Throssell Group unconformably overlies the Rudall Complex, and has a concealed and discordant contact with the Lamil Group (Hickman and Clarke, 1994; Bagas, in prep.).

This contact is most probably a northwestern extension of the Camel–Tabletop Fault Zone (Fig. 1).

The Tarcunyah Group unconformably or disconformably overlies the Throssell Group on CONNAUGHTON, and for this reason, it has been excluded from the supergroup (Bagas and Smithies, 1998a). The boundary between the Throssell and Tarcunyah Groups on the RUDALL and THROSSELL is the major Southwest Thrust (Fig. 1).

Throssell Group

Although recent work supports a Neoproterozoic age for the Tarcunyah Group (c. 800 Ma; Bagas et al., 1995, 1999), the age of the Throssell and Lamil Groups has not been determined directly. However, isotopic evidence indicates that the age of the Throssell Group is almost certainly younger than 1250 Ma, and probably older than 900 Ma (Hickman and Bagas, 1998).

The Throssell Group consists of the siliciclastic Coolbro Sandstone and Taliwanya Formation, and the carbonaceous Broadhurst and Pungkuli Formations.

The lithology and sedimentary structures of the Coolbro Sandstone and Taliwanya Formation are consistent with a fluvial-deltaic depositional environment (Williams and Bagas, 1999; Bagas and Smithies, 1998a). The Broadhurst and Pungkuli Formations are interpreted to be deposited in a starved basin under euxinic conditions (Hickman et al., 1994; Bagas and Smithies, 1998a). In the southwest, the basin was periodically supplied with coarser siliciclastic material deposited under higher energy conditions, most likely representing shallow-marine extensions of nearby deltaic deposition at or near a continental margin (Williams and Bagas, 1999). The group was probably deposited in a strike-slip basin (Hickman and Bagas, 1995, 1999).

Coolbro Sandstone (ⱣTc, ⱣTcp, ⱣTcs)

The Coolbro Sandstone (*ⱣTc*; Williams et al., 1976) is a fine- to coarse-grained sandstone. The unit forms prominent outcrops and is massive to well bedded, with individual beds ranging between 0.5 and 3 m thick. The bedding surfaces are commonly difficult to distinguish from strong S_3 or S_4 foliation surfaces. The sandstone becomes finer grained in the upper part of the formation where it is more commonly interbedded with siltstone lenses. It is conformably overlain by the Broadhurst Formation.

Regionally, the Coolbro Sandstone thins rapidly to the southwest (Chin et al., 1980). The formation is reduced in thickness from up to 4000 m on BROADHURST to less than 30 m on THROSSELL and POISONBUSH, where it outcrops as coarse-grained sandstone, pebbly sandstone, and pebble to cobble polymictic conglomerate (*ⱣTcp*).

Trough and planar cross-beds are commonly found throughout the sandstone. Northerly directed palaeocurrents in the southern part of the Broadhurst Range and on Miles Ridge on RUDALL suggest that this is due to onlap against a basement topographic high (Hickman and Bagas, 1998).

Polymictic conglomerate (*ⱣTcp*) contains rounded boulders and pebbles of gneiss, granitoid rocks, quartzite, chert, schist, and vein quartz. These conglomerate units are lenticular, particularly where boulder-sized clasts are present, and are interpreted as channel-fill or braided stream deposits. Well-sorted, matrix-supported, vein quartz conglomerate beds locally display crude vertical grading and are commonly ferruginous, indicating a pyrite component in the fresh rock. The rock commonly grades into a fine- to medium-grained quartz sandstone, which forms the bulk of the formation. The sandstone is metamorphosed and consists of flattened or recrystallized quartz grains, and a variable sericitic matrix. Tourmaline is a common accessory. The rocks have been dynamically metamorphosed (S_4 foliation) under low-grade, greenschist facies conditions during early deformation assigned to the Miles Orogeny (which is described in the section on **Structure**). Trough and planar cross-beds are common throughout the sandstone units.

Shale or pelitic schist (*ⱣTcs*) forms units up to 50 m thick in the centre of RUDALL (1:250 000), and forms parts of faulted isoclinal outliers in the Rudall Complex. Shale units have commonly reacted incompetently to stress during early deformation (associated with the Miles Orogeny), and are partly converted into carbonaceous schist veined by quartz. Some of the quartz veins contain highly anomalous gold and silver contents (Hickman and Bagas, 1998).

Taliwanya Formation (ⱣTt)

The Taliwanya Formation (*ⱣTt*; Bagas and Smithies, 1998a) is the basal formation of the Throssell Group in the southeastern part of RUDALL (1:250 000). Stratigraphic relationships between the Taliwanya and overlying Pungkuli Formations of the McKay Range and the Coolbro Sandstone and Broadhurst Formation of the Throssell and Broadhurst Ranges are problematical because of the lack of outcrop in intervening areas, but the four units are tentatively grouped together lithostratigraphically. The Taliwanya Formation is interpreted as a correlative of the Coolbro Sandstone on lithological grounds, although it is much thinner than the Coolbro Sandstone on BROADHURST (Hickman and Clarke, 1994) and RUDALL (Hickman and Bagas, 1998).

The Taliwanya Formation is up to 170 m thick and principally composed of arkose and arkosic sandstone with rare, heavy mineral bands. The formation also contains local thick beds of polymictic conglomerate, and rare, thin interbeds of fine-grained lithic wacke, siltstone, and shale. The shale becomes more abundant towards the conformable contact with the overlying Pungkuli Formation. The conglomerate contains pebbles, cobbles, and boulders of quartzite, vein quartz, orthogneiss, and rare angular clasts of ironstone. The clasts are commonly rounded or subrounded, supported by an arkosic matrix, and locally display an upward decrease in clast-size into the overlying arkosic sandstone. The conglomerate is interpreted as a channel-fill deposit. Cross-bedding and asymmetrical ripple marks are locally preserved in the sandstone (Bagas and Smithies, 1998a).

Broadhurst Formation (ⱣTb, ⱣTba, ⱣTbq, ⱣTbc, ⱣTbb)

The Broadhurst Formation (Williams et al., 1976) conformably overlies the Coolbro Sandstone, and is separated from the overlying Choorun Formation of the Tarcunyah Group by the dextral, transpressional Southwest Thrust.

The Broadhurst Formation is characterized by poorly outcropping, metamorphosed, grey, carbonaceous (graphitic) shale and siltstone, sandstone, lithic wacke, and dolomite (*ⱣTb*). A strong magnetic signature due to magnetite in the shale units also commonly characterizes the formation.

In northwestern RUDALL, the Broadhurst Formation includes thick lenses of well-exposed, metamorphosed, fine- to coarse-grained sandstone, siltstone, shale, and minor carbonate (*ⱣTba*). This unit is interbedded with brown to red-brown, fine- to medium-grained sandstone, shale, and siltstone (*ⱣTbq*). Much of the sandstone is cross-bedded with a palaeocurrent direction predominantly from the southwest (Hickman and Bagas, 1998; Williams and Bagas, 1999). Locally graded bedded and upward-fining sequences are evident in repetitive sandstone, siltstone, and shale successions.

Sandstone interbedded with siltstone and shale (*ƁTbq*) also outcrops in the lower part of the Broadhurst Formation between Coolbro Creek and the Cottesloe prospect (on BROADHURST AMG 250320). The sandstone is separated from the Coolbro Sandstone by 50–100 m of shale and carbonate rock. The carbonate rock (*ƁTbc*) is composed of dolomite and limestone, and is grey, thinly bedded to laminated, carbonaceous, and sulfidic.

Metamorphosed carbonaceous and sulfidic shale and siltstone (*ƁTb*) have been intersected in mineral exploration bore holes in a sandplain west of Moses Chair (THROSSELL AMG 957607) and in valley floors west of the Coolbro Sandstone plateau, which contain the headwaters of the Coolbro Creek (e.g. THROSSELL AMG 813443).

Basalt (*ƁTbb*) outcrops at one locality 12 km west of Mount Isdell (BROADHURST AMG 010612; Hickman and Clarke, 1994).

The Broadhurst Formation is tightly folded and faulted. Although estimates of the thickness are hampered by the complex structure, it does appear that the formation, as with the underlying Coolbro Sandstone, thins southwards. The maximum estimates for the thickness of the Broadhurst Formation is around 2000 m or greater (Hickman and Clarke, 1994; Williams and Bagas, 1999).

Pungkuli Formation (ƁTp, ƁTpk)

The Pungkuli Formation (*ƁTp*; Bagas and Smithies, 1998a) is exposed in and north of McKay Range, where it is disconformably overlain by the Gunanya Sandstone of the Tarcunyah Group (Bagas and Smithies, 1998a). The formation is about 900 m thick and resembles the Broadhurst Formation to which it may be a correlative. The Pungkuli Formation consists of interbedded, laminated, slightly micaceous, grey to dark brown-black shale, locally carbonaceous shale and siltstone, thin units of sulfidic shale and sandstone, and minor carbonate and chert. Lenticular bedding and rare, wave-ripple marks suggest deposition in a quiet shallow-water environment.

Thinly bedded, light-pink, grey to cream coloured recrystallized dolomite interbedded with light-grey chert, calcareous shale, siltstone, and minor black sulfidic and carbonaceous shale and sandstone (*ƁTpk*) is well exposed at the base of the Pungkuli Formation in McKay Range (e.g. CONNAUGHTON AMG 645630). Fine-scale cross-bedding, flute marks in thin sandstone interbeds, and stromatolites in carbonate (e.g. CONNAUGHTON AMG 640633) are indicative of sedimentation in shallow-water conditions. The interbedded sequence of carbonate and clastic sedimentary rocks (*ƁTpk*) is at least 300 m thick (Bagas and Smithies, 1998a).

Lamil Group

Carbonate and pelitic rocks of the Isdell Formation underlie northeastern BROADHURST and probably the northeastern corner of THROSSELL (Williams and Bagas, 1999; Hickman and Clarke, 1994). Stratigraphic contacts between the Isdell and Broadhurst Formations to the south have not been recognized in this area (Hickman and Clarke, 1994), and there is some doubt on whether to include this formation in the Lamil Group or Throssell Group. The relationships between the Isdell Formation and the Lamil and Throssell Groups remain unclear, although the contact between the Throssell Group and Isdell Formation is known to be geophysically discordant on BROADHURST (Hickman and Clarke, 1994).

The Lamil Group on PATERSON was deposited in an intracratonic setting that may have been a pull-apart basin in a strike-slip system (Bagas, in prep.).

Isdell Formation (ꝒLi, ꝒLic, ꝒLik)

The Isdell Formation(*ꝒLi*; Williams et al., 1976) is exposed around Mount Isdell near the northern boundary of RUDALL (1:250 000), and is composed of carbonate rocks intercalated with relatively thin units of calcareous siltstone and shale. The total thickness of the formation exceeds 1000 m (Hickman and Clarke, 1994).

Dark-grey carbonate containing minor shale (*ꝒLic*) is well exposed to the south and west of Mount Isdell. The rock is chiefly dolomitic limestone and dolomite, and is carbonaceous and locally sulfidic. Both graded bedding and fine-scale cross-bedding are locally preserved.

A sequence of pale-grey and cream carbonate intercalated with calcareous siltstone and shale (*ꝒLik*) is well exposed near to and east of Mount Isdell. The rock is similar to the dark-grey carbonate (*ꝒLic*), although its carbon content is lower and calcarenite beds are more common. The unit includes a non-mineralized, stratiform gossanous zone that extends over a strike length of 8 km about 7 km east of Mount Isdell (Hickman and Clarke, 1994).

OFFICER BASIN

Bagas et al. (1995) proposed that the Tarcunyah Group is a correlative of the lower part of the Savory Group (Williams, 1992, 1994). They further proposed that the Tarcunyah and lower Savory Groups are also equivalent to Supersequence 1 of the Centralian Superbasin (Walter et al., 1994, 1995), and are part of the Officer Basin, rather than components of a separate basin. Detailed seismic interpretation by Perincek (1996) improved this correlation, which has been further strengthened using stromatolites and palynology (Grey and Cotter, 1996; Grey and Stevens, 1997; Stevens and Grey, 1997). Since then, the term Savory Basin (Williams, 1992, 1994) has been abandoned, although its subdivisions (Wells and Blake Sub-basins, Trainor Platform) have been retained as tectonic subdivisions of the Officer Basin (Bagas et al., 1999). The overlying cover rocks, now dated as Lower Ordovician (Table Hill Volcanics) and younger, are assigned to the Gunbarrel Basin (Stevens and Apak, 1999).

Separate names have also been proposed for the lower succession (Sunbeam Group, after Sunbeam Creek on the TRAINOR 1:250 000 sheet) and upper succession (Disappointment Group, after Lake Disappointment on the GUNANYA 1:250 000 sheet) of the former Savory Group. The Boondawari Formation, lying between the Sunbeam and Disappointment Groups, remains ungrouped (Bagas et al., 1999). Generalized stratigraphic correlations of formations of the Officer Basin on RUDALL (1:250 000) are presented in Figure 4.

Tarcunyah Group

The Tarcunyah Group (*ꝒU*; Williams and Bagas, 1999) unconformably overlies the Rudall Complex. The group is separated from the older Throssell Group by the Vines Fault (Williams and Trendall, 1998) on the northwestern margin of RUDALL (1:250 000), and by the northwesterly trending Southwest Thrust and McKay Fault. The group is unconformably overlain by, or is in faulted contact with, outliers of the Neoproterozoic Tchukardine Formation of the Disappointment Group on western RUDALL (Williams and Bagas, 1999).

In approximate stratigraphic order from oldest to youngest, the Tarcunyah Group consists of the Gunanya Sandstone, Karara Formation, Googhenama Formation, Waters Formation, Choorun Formation, Waroongunyah Formation, Brownrigg Sandstone, Yandanunyah Formation, Wongarlong Formation, and Nooloo Formation. This order takes into account the uncertainty of the stratigraphic relationship of the Choorun Formation in the succession.

Gunanya Sandstone (ⱣUu)

The Gunanya Sandstone (*ⱣUu*; Hickman and Bagas, 1998; Bagas and Smithies, 1998a) is about 500 m thick. The unit consists of conglomerate and arkosic sandstone with thin interbeds of pebbly sandstone and feldspathic grit. The conglomerate at the base is less than 10 m thick, lensoidal in form, and upward fining, containing well-sorted and rounded matrix-supported pebbles of vein quartz. The sandstone is medium to coarse grained, characteristically light pink to purple in colour, and closely resembles the Karara Formation (*ⱣUk*). Abundant trough cross-beds and asymmetrical ripple marks indicate that the sandstone was deposited from southeasterly flowing currents, presumably in a fluvial to deltaic environment.

Karara Formation (ⱣUk)

The Karara Formation (*ⱣUk*; Williams et al., 1976; Crowe and Chin, 1979) is restricted to a small area in the southeast, where it unconformably overlies the Rudall Complex in the Camel–Tabletop Fault Zone. The formation consists of conglomerate, crossed-bedded and ripple-marked sandstone, and minor amounts of quartz–feldspar wacke and shale. The

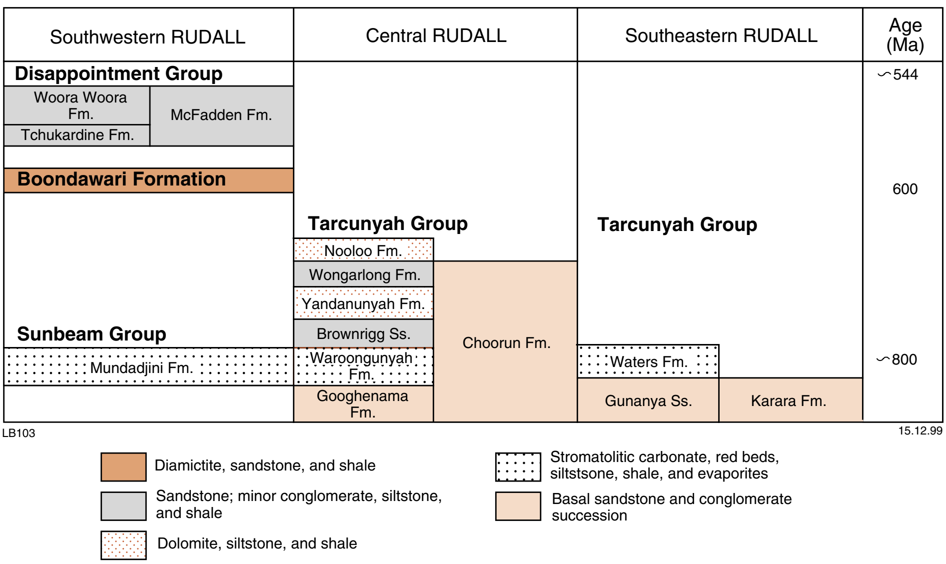


Figure 4. Generalized stratigraphic correlations of the formations included in the northwestern Officer Basin. Column headings refer to separate areas on RUDALL (1:250 000)

conglomerate is thin and lensoidal at the base of the formation, and contains subrounded clasts, up to 1 m in diameter, which are derived from the Rudall Complex. The conglomerate fines upwards into a well-bedded, fine-grained, and distinctively pink coloured sandstone. The basal conglomerate is common within the Camel–Tabletop Fault Zone, indicating that the zone may have been an active growth fault during the deposition of the Karara Formation under shallow-water conditions. The formation closely resembles the Gunanya Sandstone, with which it is correlated (Bagas and Smithies, 1998a).

Googhenama Formation (ꝒUg)

The Googhenama Formation (*ꝒUg*; Williams, 1990b) is around 300–400 m thick and on lithological grounds is probably a correlative of the Gunanya Sandstone. In the northwestern part of RUDALL (1:250 000), the Googhenama Formation commonly outcrops in the cores of anticlines in an en echelon set of northwesterly plunging folds. The formation consists of brown to dark-red-brown, fine- to coarse-grained and cross-bedded sandstone, pebbly sandstone, and pebble to large cobble conglomerate. The formation also includes minor purple siltstone, and thinly bedded, blue-purple, pink, and grey micritic carbonate rocks. The conglomerate is commonly polymictic and matrix supported with clasts composed of white vein quartz, quartzite, and chert, and shows graded bedding in places. The palaeocurrent directions, derived from the cross-bedding in sandstone, indicate currents from the northwest around to the northeast, away from the Pilbara Craton, which lies to the west (Williams and Bagas, 1999).

Waters Formation (ꝒUt)

The Waters Formation (*ꝒUt*; Hickman and Bagas, 1998) is up to 100 m thick and conformably overlies the Gunanya Sandstone. The formation consists of reddish-brown to grey, carbonaceous shale containing gossanous (oxidized sulfidic shale) and nodular limonite horizons. The shale contains thin interbeds of planar and trough cross-bedded, fine- to coarse-grained, upward-fining sandstone and minor carbonate. The cross-beds indicate northerly to northeasterly flowing palaeocurrents. The carbonate units are commonly concealed by calcrete or silcrete, but where exposed are dark grey and include thin gossanous layers. Boulders of stromatolitic carbonate have been found (RUDALL AMG 465620), although no stromatolites were found in the bedrock (Hickman and Bagas, 1998).

Choorun Formation (ꝒUh, ꝒUhh)

The Choorun Formation (*ꝒUh*; Williams and Bagas, 1999) is at least 1800 m thick and well exposed as dissected ridges and plateaus in the western part of RUDALL (1:250 000). The formation is restricted to the west of the Southwest Thrust, which separates the Choorun Formation from the Throssell Group to the east. The formation unconformably overlies the Rudall Complex about 5 km to the northeast (POISONBUSH AMG 930048) and 5 km east of the Choorun Water Hole (POISONBUSH AMG 935007), and is conformably overlain by the Nooloo Formation (*ꝒUn*). The relationship between these two formations and the other formations included in the Tarcunyah Group is not clear; however, the Choorun Formation is a possible correlative of the Waroongunyah and Googhenama Formations. An axial planar cleavage is evident in fold closures in the Choorun Formation, but, unlike the Coolbro Sandstone of the Throssell Group to the east of the Southwest Thrust, the formation lacks the multiple deformation, penetrative foliation, and low-grade greenschist facies regional metamorphism.

The Choorun Formation is an upward-fining succession consisting of a basal matrix-supported, cobble to pebble conglomerate, pebbly sandstone with a high detrital muscovite content (*ꝒUh*), and minor siltstone, silty shale, and shale (*ꝒUhh*). The clasts are composed of vein quartz, quartzite, and sandstone. The conglomerate is transitionally overlain by pink-red to red-brown, coarse- to medium-grained sandstone. Siliceous nodules are also characteristic of many sandstone units in the formation. Cross-beds and ripple marks in the sandstone indicate that the palaeocurrent directions are towards the north and northeast. The sandstone is probably fluvial in origin (Williams and Bagas, 2000).

A tourmaline-rich, dark-green to grey-green rock, which was tentatively identified as lapilli tuff, was sampled from an isolated outcrop from the siltstone–shale unit (*ᵽUhh*) about 100 m northeast of the Curran Curran Rockhole (at POISONBUSH AMG 910085). The rock is pervasively metasomatized by silicification and tourmalinization (Nelson, 1999). The sample contained at least six zircon populations (Nelson, 1999). The youngest population, with an age of 544 ± 10 Ma, was interpreted to indicate the maximum depositional age for the rock (Nelson, 1999). This younger than expected age for the Choorun Formation possibly indicates that the rock collected for dating is not part of the Tarcunyah Group, to which an age of c. 800 Ma has been assigned. This older age is based on studies of stromatolite and acritarch data that placed the Tarcunyah Group in Supersequence 1 of the Centralian Superbasin (Stevens and Grey, 1997).

Waroongunyah Formation (ᵽUw)

The Waroongunyah Formation (*ᵽUw*; Williams, 1989) conformably overlies the Googhenama Formation on the joining BALFOUR DOWNS 1:250 000 sheet to the west (Williams and Bagas, 1999). The formation is about 600 m thick and contains dolomite interbedded with pink to grey-white siltstone and shale, and thin beds of brown, fine-grained sandstone containing scattered halite pseudomorphs. The dolomite outcrops as brown, grey, blue, and pink, massive to laminated dolomite, stromatolitic dolomite, commonly silicified oolitic dolomite, and sandy dolomite. The stromatolitic dolomite has been identified at several localities along the western margin of RUDALL (1:250 000) (THROSSELL AMG 455399, THROSSELL AMG 459384, and THROSSELL AMG 465333). On lithostratigraphic grounds, the formation is probably a correlative of the Waters Formation (*ᵽUt*).

The Waroongunyah Formation is a transgressive shallow-marine sequence probably deposited shorewards of carbonate build-ups. These may have been barrier islands or carbonate platforms marginal to the Pilbara Craton (Williams and Bagas, 1999).

Brownrigg Sandstone (ᵽUr)

The Brownrigg Sandstone (*ᵽUr*; Williams, 1989) is at least 600 m thick (Williams and Bagas, 2000) and exposed on the eastern side of the Marloo Fault along the northern boundary of POISONBUSH. The formation is faulted against the younger Wongarlong Formation to the east, and the Tchukardine and Woora Woora Formations of the Disappointment Group to the west.

The Brownrigg Sandstone consists of white, cream to light-brown, fine- to coarse-grained quartz sandstone with scattered, small pebbles of vein quartz. The formation is well bedded with flaggy and massive units. Cross-beds, ripple marks, and current striae are common. Cross-bedding in the thicker units can be up to 3 m thick. The palaeocurrent direction is commonly towards the northeast and east. Ripple marks are symmetrical wave-based forms. The formation is probably a shallow-marine shelf deposit (Williams and Bagas, 2000).

Yandanunyah Formation (ᵽUy)

The Yandanunyah Formation (*ᵽUy*; Williams, 1989) outcrops in the west of RUDALL (1:250 000) (around THROSSELL AMG 458293; see 1:100 000 map, Williams et al., 1996; too small to represent at 1:250 000 scale), where it conformably overlies the Brownrigg

Sandstone and underlies the Wongarlong Formation. The formation is about 300 m thick and consists of interbedded purple, red, yellow, and white siltstone and shale, calcareous shale that is commonly capped by a siliceous breccia (*Czx*), and minor silicified, blue-white oolitic and laminated carbonate that is stromatolitic in places. The oolitic rocks are similar to those found in the Waroongunyah Formation, suggesting similar environmental depositional conditions.

Wongarlong Formation (ⱣUo, ⱣUov)

The Wongarlong Formation (*ⱣUo*; Williams and Bagas, 1999) is at least 1200 m thick and conformably overlies the Yandanunyah Formation (*ⱣUy*) in the west. Much of the Wongarlong Formation was previously mapped as the Choorun Formation (Chin et al. 1980; Williams, 1989).

A faulted slice of Wongarlong Formation is thrust onto the Tchukardine Formation of the Disappointment Group near the headwaters of Yeneena Creek (THROSSELL AMG 470145). Around Tchukardine Pool (POISONBUSH AMG 565065), the Wongarlong Formation is bound to the west by the dextral, strike-slip Marloo Fault, which has juxtaposed the formation against the older Brownrigg Formation in the north and the younger Woora Woora Formation to the west and southwest. To the east and south, the Wongarlong Formation is unconformably overlain by the Tchukardine Formation of the Disappointment Group (Williams and Bagas, 2000). A narrow, easterly trending inlier of Wongarlong Formation is also faulted against the Mundadjini Formation of the Sunbeam Group about 4 km north of Poisonbush Range (around POISONBUSH AMG 600890). This inlier is also faulted to the west by the Marloo Fault and is unconformably overlain, along the northern margin, by the Tchukardine Formation. A narrow, steeply dipping, partly sand covered ridge of Wongarlong Formation extends 15 km south and southeast from the northern margin in the central-north part of POISONBUSH. The structure in this region appears to be a faulted anticline.

The Wongarlong Formation (*ⱣUo*) consists of medium- to fine-grained sandstone interbedded with laminated and micaceous siltstone, shale, and silty shale. Brown oxidation spots, brown, bladed or needle-like pseudomorphs after gypsum, and intraformational clasts of siltstone and shale are found in places in the sandstone. Some alternating sandstone and siltstone–shale units form upward-coarsening successions. Cross-bedding is common in the lower parts of the sandstone beds and ripple marks are common in the upper parts, which suggests waning currents after the earlier higher energy conditions for the cross-bedded units.

Deeply weathered basalt or fine-grained dolerite (*ⱣUov*) outcrops in the western part of RUDALL (1:250 000) (POISONBUSH AMG 529109). The rock is now a mottled brown-grey to white clay, with patches of dark-blue–green chlorite. Structures within the clay material strongly resemble pillow margins suggesting that the rock is subaqueous basalt. The interstices between these pillows are filled with the dark-blue–green chlorite. Fragments of the underlying sandstone are caught up and recrystallized within the base of the mafic material (Williams and Bagas, 2000).

The Wongarlong Formation has been interpreted to be a shallow-marine shelf deposit characterized by repetitive thickening and coarsening upward cycles that are up to 30 m thick (Williams and Bagas, 1999).

Nooloo Formation (ⱣUn)

The Nooloo Formation (*ⱣUn*; Williams and Bagas, 1999) is a poorly exposed unit in the western part of the area (on THROSSELL and POISONBUSH). The formation is bound by faults on THROSSELL (Williams and Bagas, 1999), and appears to conformably overlie the Wongarlong and Choorun Formations on POISONBUSH (Williams and Bagas, 2000).

The Nooloo Formation consists of thinly bedded carbonate (dolomite and limestone) with rare, blue chert nodules, calcareous shale and siltstone, thinly bedded, fine- to coarse-grained sandstone, siltstone, shale, and rare carbonate-cemented sandstone with a cellular-weathering pattern. Where the dolomite is absent, interbedded sandstone, siltstone, shale, pebbly conglomerate, and wacke prevail. Shale and siltstone are strongly silicified in places and resemble chert in the field. Cross-beds and symmetrical ripple marks are prominent in some of the sandstone interbeds, and indicate a palaeocurrent direction from the southwest.

The Nooloo Formation is interpreted to be a deep-water shelf deposit (Williams and Bagas, 1999).

Sunbeam Group

The Sunbeam Group of the northwestern Officer Basin (Bagas et al., 1999) comprises the oldest formations of the now superseded Savory Group (Williams, 1992). The formations within the group have been assigned to the c. 800 Ma Supersequence 1 of the Centralian Superbasin (Bagas et al., 1995, 1999; Walter et al., 1995). Only the Mundadjini Formation of the group is exposed on RUDALL (1:250 000).

Mundadjini Formation (Ꝑsm)

The Mundadjini Formation (*Ꝑsm*; Williams and Tyler, 1991) outcrops in the southwestern areas covered by RUDALL and POISONBUSH (Hickman and Bagas, 1998; Williams and Bagas, 2000). The formation consists of medium- to coarse-grained, cross-bedded sandstone interbedded with pebble conglomerate and rare siltstone. The sandstone is thinly to thickly bedded, commonly flaggy, and in places contains intraclasts of sandstone and siltstone. Tabular and trough cross-bedding, symmetrical and asymmetrical ripple bedding, and current striae have been observed in the sandstone beds. The palaeocurrent directions, recorded from cross-bedding, are predominantly towards the northeast (Williams, 1992). The conglomerate contains pebbles of vein quartz, quartzite, banded chert, and jasper. Some of the conglomerate beds appear to be channel fills (Williams and Bagas, 2000).

The Mundadjini Formation is interpreted to be a fluvial deposit or a deltaic to shallow-marine sandstone (Williams, 1992; Hickman and Bagas, 1998).

Boondawari Formation (*Ꝑi*)

The Boondawari Formation (*Ꝑi*; Williams and Tyler, 1991) unconformably overlies the c. 800 Ma Sunbeam Group and is unconformably overlain by the sandstone succession of the Disappointment Group (Bagas et al., 1999). The Boondawari Formation is retained as a separate formation, but could be subdivided and raised to group status in the future. The formation is a glacial deposit and is correlated with the Marinoan glaciation of the c. 600 Ma Supersequence 3 of the Centralian Superbasin (Walter et al., 1994; Bagas et al., 1995; Grey, 1995).

Small exposures of the Boondawari Formation (*Ꝑi*; Williams and Tyler, 1991) are found in the southwest of the area (Hickman and Bagas, 1998; Williams and Bagas, 2000). The formation consists of diamictite, sandstone, siltstone, shale, and mudstone. The diamictite contains well-rounded, striated or faceted pebbles to small boulders of chert, shale, and quartzite in a ferruginous mudstone matrix. Occasional dropstones are also found in the shale and siltstone. The shale has varve-like laminations and fine-scale cross-bedding in silty beds. Well-preserved ripple marks found in sandstone interbeds indicate westerly to west-northwesterly flowing currents. The Boondawari Formation has been interpreted to be a shallow-marine deposit strongly influenced by glacial conditions (Williams, 1987, 1992).

Disappointment Group

The Boondawari Formation is unconformably overlain by the sandstone succession of the Disappointment Group, which comprises the McFadden, Tchukardine, and Woora Woora Formations. The group was deposited in the Wells Sub-basin (formally the Wells Foreland Basin of Williams, 1992) during the onset of tectonism (Williams, 1992, 1994) associated with the c. 550 Ma Paterson Orogeny (Bagas and Smithies, 1998a), which is described in **Structure**. This sandstone succession is a probable correlative of the c. 580–544 Ma latest Supersequence 3 or early Supersequence 4 of the Centralian Superbasin (Walter and Veevers, 1997).

Tchukardine Formation (ᵽDt)

The Tchukardine Formation (*ᵽDt*; Williams, 1992), exposed in the southwest, is estimated to be over 700 m thick (Williams, 1992). The formation is lithologically similar to the lower part of the McFadden Formation and may be equivalent to it.

The Tchukardine Formation unconformably overlies the Wongarlong (*ᵽUo*) and Mundadjini (*ᵽsm*) Formations, and consists of sandstone with rare silty shale, conglomerate, and siltstone (Hickman and Bagas, 1998; Williams and Bagas, 1999, 2000). The sandstone is medium grained, cross-bedded, and contains glauconite in places (Williams, 1992). Large cross-bed sets, commonly up to 10 m thick, are characteristic of the formation and locally so large as to be visible on 1:50 000-scale aerial photographs. Some cross-beds have asymptotic profiles indicative of a high flow regime (Hickman and Bagas, 1998). The dominant palaeocurrent direction is westerly or southwesterly (Williams, 1992).

The Tchukardine Formation is interpreted to be a sandy marine-shelf deposit. The presence of glauconite in the formation and the very large cross-beds suggests that the Tchukardine Formation may be the product of migrating sand-waves and tidal current ridges on a sandy marine shelf (Williams, 1992).

Woora Woora Formation (ᵽDo)

The Woora Woora Formation (*ᵽDo*; Williams, 1992) is exposed along the western margin of RUDALL (1:250 000), west of the Marloo Fault. Although the formation is faulted against the Tchukardine Formation (*ᵽDt*) in this area, it disconformably overlies it elsewhere (Williams, 1992).

The Woora Woora Formation is a distinctive white-flecked, purple to purple-brown, fine- to coarse-grained sandstone with minor lithic wacke and siltstone. Bedding is commonly flaggy. Large tabular cross-beds up to 5–6 m thick are common, but trough cross-beds appear to be absent. Some of the larger cross-beds are heterogeneous in grain size and show graded bedding within the individual flaggy foresets, a feature that it shares with the McFadden Formation (Williams, 1992). The Woora Woora Formation is lithologically similar to the upper part of the McFadden Formation to the southeast and may be equivalent to it.

Palaeocurrent directions, derived from cross-bedding, are directed towards the southwest. The Woora Woora Formation is interpreted to be a deltaic deposit that prograded towards the southwest (Williams, 1992).

McFadden Formation (ᵽDf)

The McFadden Formation (Williams, 1992) is estimated to be at least 1500 m thick. In the Emu Range (RUDALL), it is in faulted contact with the Tchukardine Formation (*ᵽDt*), whereas in the Horsetrack Range (POISONBUSH), it disconformably overlies the Mundadjini Formation (*ᵽsm*). The formation consists of fine- to coarse-grained and poorly sorted lithic, feldspathic, and quartz sandstone with minor pebbly sandstone, pebble conglomerate, and siltstone. They commonly form flaggy to thick-bedded, very large tabular and trough cross-beds up to 10 m thick. Many of the large cross-beds are asymptotic, which is indicative of high-energy conditions. Palaeocurrent directions are commonly towards the southwest (Williams, 1992).

The McFadden Formation is interpreted to be the product of migrating, sandy, giant ripple marks in channels probably related to a prograding, high-energy, transverse, sandy delta encroaching onto a sandy, shallow-marine shelf (Williams, 1992).

MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS, GOSSAN, QUARTZ, AND BRECCIA (*ᵽo*, *ᵽuz*, *go*, *fb*, *qh*, *q*, *d*)

Thin sills and stockworks of gabbro and dolerite (*ᵽo*) and silicified ultramafic rocks (*ᵽuz*) intrude the Isdell and Broadhurst Formations in northern BROADHURST (Hickman and Clarke, 1994). These rocks are poorly exposed, highly altered, and their ages are uncertain.

Gossan, or gossanous rock (*go*) units are limonite–goethite concentrations formed by surface oxidation of sulfide mineralization. Such sulfide mineralization is either epigenetic (commonly accompanying quartz veining) or syngenetic (developed from sulfide rich layers in the Throssell Group). The gossans also carry quartz veinlets.

Silicified fault breccia (*fb*) is mainly associated with late (D_6) brittle faults. Examples are found on the northern slopes of the McKay Range (RUDALL AMG 487630). Angular fragments of country rock are enveloped by a silicified and ferruginized matrix of rock flour; some microcrystalline pseudotachylyte veinlets are locally present.

Several parallel quartz–hematite veins (*qh*), striking around 080°, cut pyrite-bearing, medium-grained sandstone belonging to the Coolbro Sandstone in an area 13 km south-southeast of Throssell Range (THROSSELL AMG 774418; see 1:100 000 map, Williams et al., 1996; too small to represent at 1:250 000 scale). Such quartz veins, when broken, yield scattered fresh grains of specular hematite.

Quartz (*q*) veins are widespread and commonly located in faults, tension gashes oblique to the large faults, and shear zones. Some of the veins are limonitic, particularly along their margins, indicating wallrock sulfidation. Other veins contain limonite and goethite in late fractures. Some veins contain tourmaline or rutile. The vein quartz consists mainly of the massive cryptocrystalline variety, although some fault zones contain brecciated quartz that has been annealed by later siliceous material. Such quartz breccia indicates reactivation with multiple movement along pre-existing fault lines.

Northerly trending dolerite dykes (*d*) intrude the Rudall Complex in the southeastern part of CONNAUGHTON, and small pods of dolerite intrude the Rudall Complex in the McKay Antiform. The dolerite clearly post-dates D_2 and D_4 structures that affect the Throssell

Group. No intrusive contact has been observed in the field, although magnetic data indicate that the dykes intrude the Throssell and Tarcunyah Groups in southeastern CONNAUGHTON and BLANCHE.

The dolerite dykes occupy late, extensional northerly trending fractures. Williams (1992) described similar dykes in the northwestern Officer Basin (former Savory Basin), and implied a post-600 Ma age, although no direct geochronology has been undertaken. In the southeastern corner of the map (at CONNAUGHTON AMG 978567; see 1:100 000 map, Bagas and Smithies, 1996; too small to represent at 1:250 000 scale), a dolerite dyke intrudes amphibolite and mylonite (*ERns*). The dyke is lenticular, has a chilled margin, and is about 10 m wide. It consists of microphenocrysts of plagioclase in a granular matrix of augite, plagioclase, and opaque minerals.

PERMIAN ROCKS

Most of the Permian sedimentary rocks are confined to glacial valleys incised in the underlying basement (Fig. 5). Glacial striae, grooves, and chattermarks are best preserved on Proterozoic sandstone surfaces. These indicate that ice movement was northwards towards the Canning Basin. The Permian succession belongs to the fluvioglacial Paterson Formation, which is found in both the Officer and Canning Basins.

Paterson Formation (Pa)

Remnants of the Paterson Formation (*Pa*; Traves et al., 1956; Towner and Gibson, 1983) are found throughout RUDALL (1:250 000) in northerly trending palaeovalleys or lapping onto Proterozoic rocks (Williams and Bagas, 2000). The formation consists of fluvioglacial sediments, and outcrops as isolated mesas or partially dissected benches flanking larger hills.

The basal tillite deposits of the Paterson Formation consist of well-rounded pebbles to boulders. These are set in the clay matrix, locally exceed 5 m in diameter, and include quartzite, orthogneiss, and paragneiss from an extensive source region. Many boulders and cobbles are polished, faceted, and striated. The tillite is overlain by interbedded, cross-bedded, medium- to coarse-grained sandstone, siltstone, and mudstone. The upper surface of the Paterson Formation is commonly silicified.

CAINOZOIC GEOLOGY

Cainozoic deposits occur in almost all parts of RUDALL (1:250 000), and include consolidated residual and colluvial deposits, together with Quaternary eolian, colluvial, and alluvial deposits, and minor lacustrine and eluvial deposits.

Areas of recent and active sedimentation are mapped as Quaternary. Older and significantly dissected sediments are mapped as Cainozoic, although some laterite and silcrete may be latest Mesozoic in age (Idnurm and Senior, 1978).

Small areas of consolidated and dissected colluvium, sheetwash, fan deposits, and talus (Czc) are found overlying the Rudall Complex. The consolidated colluvium consists of red-brown, ferruginous gravel, sand, and silt, and is locally derived from a variety of sources. Colluvium derived from Permian fluvioglacial sediments and tillite (*Czcg*) exhibits a distinctive light-tone pattern on aerial photographs east of May Creek and around the

Rudall airstrip on RUDALL. Consolidated alluvial conglomerate (*Czag*) along the Rudall River and Poynton Creek on RUDALL is dissected by the present drainage, and forms banks up to 10 m above colluvium (*Czc*) in the beds of the watercourses. The unit is variably indurated by siliceous or ferruginous cement. Gravel and boulder beds (*Czg*) dissected by the present drainage system represent locally derived coarse talus. This unit is found on BROADHURST in sloping aprons marginal to hills, and is variably indurated by siliceous or ferruginous cement.

Most Precambrian outcrops show some evidence of ferruginization, leaching, or silicification typical of lateritic profiles. Gently undulating duricrust caps, including ferricrete or ironstone deposits (*Czl*) and silcrete deposits (*Czz*), are recently dissected to expose underlying

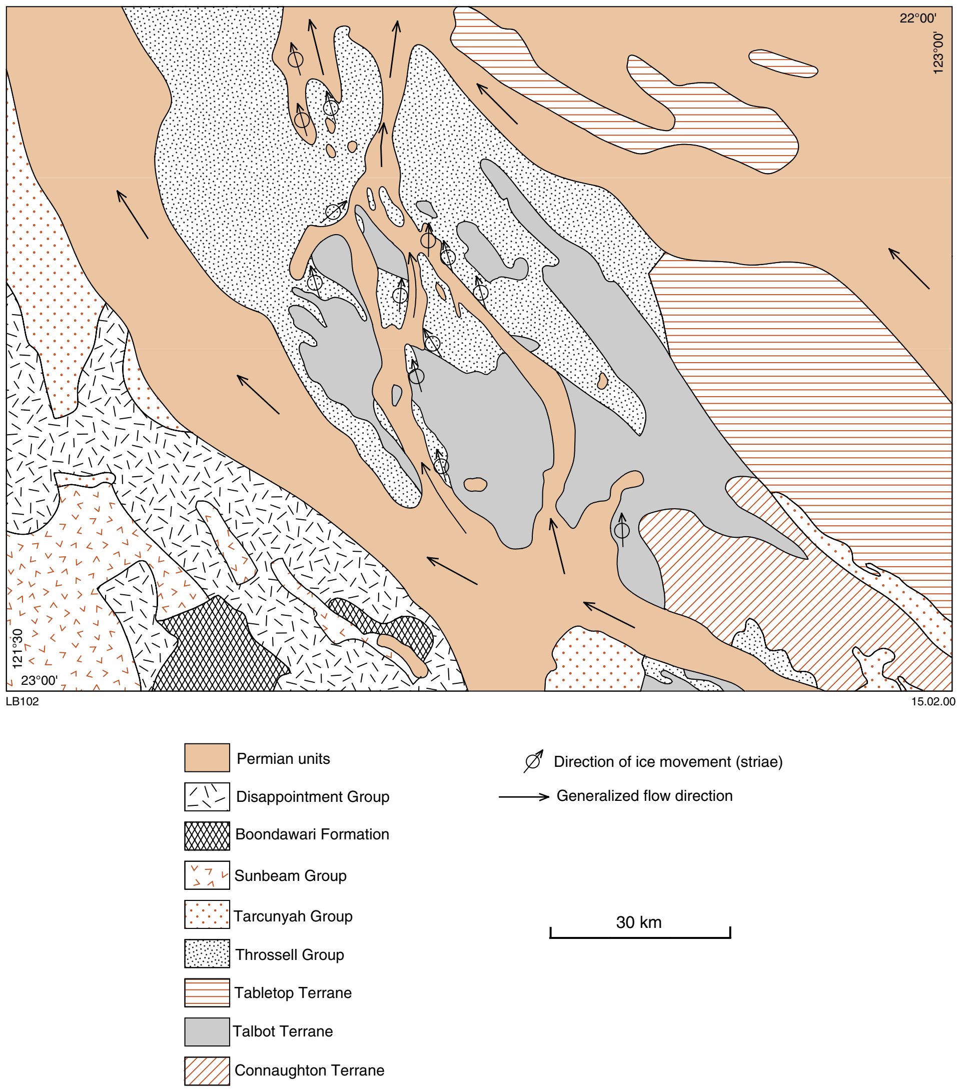


Figure 5. Permian palaeovalleys

bedrock. A distinctive siliceous chert breccia (*Czx*) overlies weathered dolomite of the Yandanunyah Formation on the western margin of THROSSELL. The duricrust represents remnants of Cainozoic weathering profiles in which the original rock structures or textures are poorly preserved. The ferricrete grades downwards into leached and kaolinized deeply weathered rock. These sediments are probably Tertiary in age and may represent a Tertiary continent-wide weathering event (Idnurm and Senior, 1978).

Calcrete (*Czk*) consisting of massive, vuggy or nodular, sandy limestone is only a few metres thick and found in drainage channels, such as Cotton Creek and Tarcunyah Creek, and along old major drainage courses that are transgressed and overlain by seif dunes (such as in northern CONNAUGHTON). Secondary silicification locally results in incomplete replacement by a vuggy and opaline silica cap-rock.

QUATERNARY DEPOSITS

The present drainage courses and associated floodplains contain alluvium (*Qa*), consisting of unconsolidated clay, silt, sand, and gravel. Gravels tend to be confined to active channels within the dissected plateau and rocky hill areas. Elsewhere, the alluvium tends to be sandy, and probably includes a considerable input of windblown sand. The continuation of channels into the sandplains suggests periods of rapid run-off. The floodplain deposits contain eroded sand and clay mixed with eolian sands.

Locally derived talus, colluvial sands, soil, and gravel (*Qc*) form gently sloping scree and outwash fans. Watercourses weakly incise the colluvium. Extensive colluvial fans locally grade downstream into alluvium.

Playa lake deposits (*Ql*, *Qle*, *Qlg*) are confined to major drainage areas or lie in low interdunal areas with internal drainage. These units consist of clay, silt and evaporite minerals, and scattered pebbles. They occupy low-lying areas marginal to drainage channels or at the termination of creeks against sand dunes. Underlying the dry lake surface is a mixture of black to brown mud, evaporites, and sand. The gypsum deposits (*Qle*) are concentrated in kopi dunes along the eastern side of dry lakes, whereas reworked eolian deposits (*Qlg*) tend to develop on the western side of dry lakes. The dry lake surfaces are not vegetated except for seasonal grasses and scattered *Eucalypts*.

Mixed lacustrine (*Ql*) and eolian (*Qs*) deposits that can not be subdivided are labelled as such on the map sheet (*Qd*). The unit consists of numerous small claypans separated by small, sand–silt dunes. These are commonly lunette dunes derived from the pan surface. Although the unit is found in defined drainage lines, it can also be found with the sheetwash deposits (*Qw*). A small area of swelling-clay (‘crab hole’) or gilgai eluvium (*Qb*) lies in the northwestern corner of POISONBUSH, where it is surrounded by sheetwash (*Qw*). This deposit appears to be a type of claypan.

Poorly developed red-earth sediments (*Qw*) cover the central and western part of CONNAUGHTON. This unit is covered with dense mulga, which has grown in a distinctive swirled pattern commonly referred to as ‘tiger bush’ pattern (Wakelin-King, 1999). The sediments have formed over mature, deeply weathered plains or after mature alluvium, and contain varying amounts of ferricrete granules and, in places, are calcareous.

Sand containing laterite granules and pebbles (*Qp*) produces characteristic dark photo-patterns. This unit is a mixture of residual and partly transported ferricrete granules, pebbles, and eolian sand, and commonly overlies shale, pelitic schist, or nodular laterite. The residual component indicates ferruginous bedrock.

Longitudinal (seif) dunes, chain dunes, and flat to undulating sandplain (*Qs*) consist of dark-red eolian sand and clayey sand. The sand is composed of iron-stained quartz grains up to 0.5 mm in diameter. The dunes are up to 30 m high, many kilometres long, and have a pronounced west to northwest orientation in the direction of the prevailing winds. Sand movement is confined to the dune crests, and a cover of spinifex and small bushy *Eucalypts* stabilizes their sides. Some dunes terminate on the eastern sides of outcrop or where cut by drainage channels. The depth of the sand between dunes is commonly less than 2–3 m, as revealed by exposed pediments.

STRUCTURE

The RUDALL 1:250 000 sheet lies within the northwestern part of the Paterson Orogen (Williams and Myers, 1990). The orogen is a northwesterly trending belt of deformed metasedimentary and meta-igneous rocks that extends from the eastern margin of the Pilbara Craton to central Australia where it includes the Musgrave Complex.

The Paterson Orogen includes the Palaeoproterozoic Rudall Complex (which is subdivided from west to east into the Talbot, Connaughton, and Tabletop Terranes), the unconformably overlying Mesoproterozoic to Neoproterozoic Throssell and Lamil Groups of the Yeneena Supergroup, and the Neoproterozoic Tarcunyah Group (Fig. 1).

Interpretations of the structural history of the Paterson Orogen have been presented by Chin et al. (1980), Myers (1990a,b), Clarke (1991), Hickman and Clarke (1994), Hickman et al. (1994), Myers et al. (1996), Bagas and Smithies (1998a), and Hickman and Bagas (1998). Here, the structural evolution of the orogen is discussed within the general framework suggested by Bagas and Smithies (1998a), who defined the Yapungku Orogeny (D_{1-2}), Miles Orogeny (D_{3-4}), and redefined the Paterson Orogeny (D_6).

A summary of deformation and metamorphism is presented in Table 1. The major structures of RUDALL (1:250 000) are illustrated on Figure 3.

YAPUNGKU OROGENY (D_{1-2})

The Rudall Complex was intensely deformed and metamorphosed between about 2000 and 1760 Ma during two deformation events (D_1 and D_2), collectively referred to as the Yapungku Orogeny (Bagas et al. 1995; Bagas and Smithies, 1998a). The orogeny appears to be related to plate collision, which involved progressive stacking of thrust sheets and emplacement of granitoid rocks, now represented by K-feldspar augen orthogneiss (*ⱣRga*).

Metasedimentary rocks were deformed by the first episode of deformation, D_1, before 1790 Ma and before the emplacement of granitoid rocks (*ⱣRga*). Rocks within the complex (including *ⱣRga*) were then deformed during D_2 and metamorphosed during M_2, producing a pervasive micaceous schistosity (S_2) parallel to the axial planes of tight to isoclinal F_2 folds (Bagas and Smithies, 1998a).

A SHRIMP zircon age of 1778 ± 16 Ma (Nelson, 1995) was obtained from a post-D_2 vein of aplite crosscutting a ?syn-D_2 ultramafic body (*ⱣRu*) that occupies a major D_2-fault zone on RUDALL (Hickman et al., 1994). This relationship and the minimum age for the augen orthogneiss (*ⱣRga*), which has D_2 fabrics, indicate a minimum age of c. 1760 Ma for D_2.

D_1 structures

In the Talbot Terrane, the existence of a layer-parallel penetrative schistosity (S_1), folded by isoclinal F_2 folds, and in places crenulated by S_2 that is parallel to F_2 axial surfaces, suggests the presence of at least one phase of regional deformation prior to D_2 (Clarke, 1991; Hickman and Bagas, 1998). The observation that S_1 was parallel to compositional layering in paragneiss units suggests that it may have formed during subhorizontal tectonic interleaving (thrusting) or is axial planar to large-scale, isoclinal recumbent folds.

In the Connaughton Terrane, where the granulite facies of metamorphism was reached, pre-D_2 textures are preserved in the cores of garnets (Bagas and Smithies, 1998a). These cores contain S-shaped trails of fine-grained epidote, titanite, and hornblende truncated against rims of inclusion-free garnet, and are interpreted to reflect garnet growth (D_1) before metamorphism at granulite facies. The inclusion-free overgrowths are interpreted as the product of the M_2 event.

D_2 structures

The second deformation event was not a single, short-term event affecting all parts of the Rudall Complex at precisely the same time. This is established by D_2 thrust stacking, with structures in the northeast and east apparently over-riding earlier structures to the southwest (Hickman and Bagas, 1998). The event is characterized by tight to isoclinal folds (F_2), and a foliation (S_2) that tends to be parallel to layering (except at the hinge zones of the folds), and includes the magmatic emplacement of ultramafic rocks parallel to S_2. The emplacement of the ultramafic rocks was apparently partly controlled by D_2 shear zones (Bagas and Smithies, 1998a; Hickman and Bagas, 1998).

Complex tight to isoclinal F_4 folding has obscured the original orientation of D_2 structures (Fig. 6), although F_2 folds plunging shallowly towards the north have also been observed in F_4 axial regions (RUDALL AMG 256906). Away from the F_4 axial regions and in areas of shearing (e.g. RUDALL AMG 265903), F_2 folds are parallel to F_4 folds. In this area, early (S_2) foliation is now commonly steeply inclined, principally towards the northeast or southwest. Stretching lineations (L_2) observed in the northwestern part of the RUDALL plunge between 15° and 40° towards the north to northeast (Hickman and Bagas, 1998). This orientation is at an acute angle to the trend of the F_2 fold axes and indicates that the F_2 folds have been rotated towards parallelism with the F_4 folds during progressive shearing associated with D_4. This is supported by the intensity of D_4 faulting that has disrupted both the Rudall Complex and Throssell Group in the area. Furthermore, D_2 shear zones would have been incompetent units subjected to reactivation during the D_4 event. Consequently, the recognition of D_2 shear zones within D_4 normal (lag) and thrust faults depends on the extreme attenuation inconsistent with adjacent F_4 folds, associated minor F_2 folds and faults, or sheared pre-D_4 intrusions of microgranite, aplite, or pegmatite. Therefore, the local D_4 effects on D_2 structures are difficult or impossible to determine in the field.

The South Rudall Dome on CONNAUGHTON provides the least deformed exposure of the Rudall Complex. The dome is a doubly plunging antiform and the result of interference between a northerly plunging, isoclinal F_2 anticline and a southeasterly trending F_4 anticline. The northern end of the dome plunges at about 35° to the north, while the southern end plunges at about 20° to the south-southwest. The units on the eastern and western sides dip steeply away from the core of the dome. The F_2 anticline had a subhorizontal axis trending north to north-northeast before D_4 (Bagas and Smithies, 1998a), consistent with the proposed pre-D_4 orientation for F_2 folds on RUDALL (Hickman and Bagas, 1998).

Large-scale isoclinal F_2 folds in the Connaughton Hills in the western part of CONNAUGHTON are also interpreted to have had subhorizontal axes trending in a north-northeasterly direction prior to refolding and rotation during D_4 (Bagas and Smithies, 1998a).

The succession of amphibolite (*ⱣRab*), chert (*ⱣRic*), quartz–mica schist (*ⱣRm*), and quartzite (*ⱣRq*) 8 km north of the South Rudall Dome on CONNAUGHTON is tectonically attenuated along shears, which juxtaposed it against K-feldspar augen orthogneiss (*ꝒRga*). This succession is included in the Connaughton Terrane, and its contacts with the augen orthogneiss are interpreted as major D_2 thrusts dipping to the southeast. C-S fabrics and porphyroblast tails in the augen orthogneiss indicate that the sense of movement along these thrusts was towards the northwest. Originally, the D_2 thrusts trended in a northerly direction, with the movement towards the west. The southeasterly dipping thrust along the northern boundary of this succession marks the boundary between the Talbot and Connaughton Terranes. Northeasterly dipping D_4 faults disrupt this D_2 thrust contact to the east. The southern extension of the thrust is disrupted by faults associated with the McKay Fault. A pervasive and closely spaced, layer-parallel schistosity (S_2) is present in the amphibolite and schist parallel to the D_2 thrusts and the axial planes of small-scale F_2 folds.

Augen orthogneiss, north of the Connaughton Terrane, was thrust over banded paragneiss (*ꝒRb*) and quartzite (*ꝒRq*) of the Talbot Terrane during D_2. This thrust dips towards the southeast and has the same sense of movement as the thrusts marking the contact between the Connaughton and Talbot Terranes further south. The D_2 fabrics in the area have been folded and crenulated by a major F_4 synform plunging about 65° towards 120° (Bagas and Smithies, 1998a).

Gneiss and charnockite occupy the core of a poorly exposed dome to east of the Harbutt Range and west of the Camel–Tabletop Fault Zone on CONNAUGHTON. The surrounding rocks include banded iron-formation, amphibolite, schist, and peridotite. The lithological contacts are tectonized, and the units are overprinted by the northwest–southeasterly trending S_4 fabric and by D_6 faults (related to the Camel–Tabletop Fault Zone). The dome may be the product of F_2–F_4 fold interference similar to the Connaughton Synform and South Rudall Dome (Bagas and Smithies, 1998a).

LB108 15.3.00

Figure 6. Isoclinally folded F_2 fold that has been refolded by an upright F_4 fold. The outcrop is located 10 km east-northeast of the Cassandra prospect (RUDALL AMG 426882)

MILES OROGENY (D_{3-4})

The Miles Orogeny (D_{3-4}; Bagas and Smithies, 1998a) is the dominant event responsible for the major northwesterly trending folds and faults in both the Rudall Complex and Yeneena Supergroup. It does not affect the Tarcunyah Group.

Chin and de Laeter (1981) reported a Rb–Sr isochron age of 1132 ± 21 Ma for pegmatite veins cutting D_2 fabrics in orthogneiss of the area. They proposed that the pegmatite was emplaced after the waning stages of D_2. Subsequent recrystallization during D_4–M_4 may have been responsible for resetting of the Rb–Sr isotopic system giving the younger age. Alternatively, the pegmatite could have been generated during the earlier part of D_4 and not emplaced in the Throssell Group. In either case, the approximate age of D_4 was said to be 1132 ± 21 Ma (Chin and de Laeter, 1981). However, mineralization within the Broadhurst Formation of the Throssell Group is hosted by D_4 structures, syn- to post-D_4 in age, and has provided Pb model ages between 940 and 520 Ma (Blockley and Myers, 1990; Hickman and Clarke, 1994). The t76 ($^{207}Pb/^{206}Pb$) model ages alone, however, indicate that the timing of galena mineralization is about 940–820 Ma, the minimum age of the Broadhurst Formation is c. 900 Ma, and that D_4 is older than c. 800 Ma.

Several massive to weakly foliated granitoids intrude the Lamil Group near Telfer and post-date structures assigned to D_4 (Hickman et al., 1994). One of the weakly foliated granitoids, the Mount Crofton Granite 'Complex', gave a Rb–Sr age of 598 ± 24 Ma (Trendall, 1974), a Pb–Pb age of 690 ± 48 Ma (McNaughton and Goellnicht, 1990; Goellnicht et al., 1991), and a SHRIMP U–Pb zircon age of 621 ± 13 Ma (Nelson, 1995). The nearby Minyari monzogranite has a SHRIMP U–Pb zircon age of 633 ± 13 Ma (Nelson, 1995). This demonstrates that D_4 and the Lamil Group are older than c. 630 Ma.

D_3 structures

On BROADHURST (Hickman and Clarke, 1994), D_3 structures include mesoscopic isoclines and a major isocline south of Kintyre. Mesoscopic isoclines transected by the slaty cleavage (S_4) are locally preserved in more pelitic rocks of the Broadhurst Formation (BROADHURST AMG 200390). The axial planes of these F_3 folds are approximately orthogonal to S_4 of the upright F_4 folds, and must have been recumbant prior to D_4.

A major F_3 syncline is inferred to explain outcrop and magnetic patterns in the southern section of the Yandagooge Inlier on BROADHURST (Hickman and Clarke, 1994). This syncline is refolded by the F_4 ancline in the Coolbro Sandstone east of the Wellington prospect (BROADHURST AMG 048185). The closure of the syncline, as defined by the base of the Broadhurst Formation, strikes to the east and its northern, overturned limb is largely replaced by a major thrust (Hickman and Clarke, 1994).

Other D_4 structures on BROADHURST include local S_3 cleavage subparallel to bedding and faulting along the Rudall Complex – Throssell Group unconformity, and within the Throssell Group (Hickman et al., 1994). In the eastern part of BROADHURST, the reclined F_3 fold axial planes and associated S_3 cleavage strike around 120°. Anastomosing D_3 thrusting has led to stratigraphic repetition, and D_3 structures are crenulated by F_4 folds and cleaved by S_4. The general orientation of the F_3 folds in eastern BROADHURST indicates a northeast- to southwest-oriented compressional regime similar to that of D_4, and thus both have been grouped into the Miles Orogeny (Bagas and Smithies, 1998a).

Small recumbent folds with shallow easterly dips in banded, silicified metasiltstone and phyllite of the Broadhurst Formation 15 km northwest (THROSSELL AMG 837267) of the Three Sisters Hills may be D_3 structures (Williams and Bagas, 1999).

On RUDALL (Hickman and Bagas, 1998), the southwestern limb of the Poynton Synform is faulted and quartz veined along the Rudall Complex – Throssell Group unconformity. This tectonic contact is transgressed and offset by northwesterly striking D_4 faults, implying significant horizontal or subhorizontal movement before the D_4 event. This localized faulting may correlate with the D_3 phase of westerly or northwesterly directed isoclinal folding and thrusting described on BROADHURST (Hickman and Clarke, 1994).

D_4 structures

The D_4 event produced large F_4 folds, steep normal and reverse faults with a component of either dextral or sinistral strike-slip displacement, a well-developed S_4 foliation, and an associated retrogressive greenschist metamorphism (M_4) in the Rudall Complex and prograde metamorphism (M_4) in the Throssell and Lamil Groups.

The F_4 folds represent major D_4 structures with fold axes that swing from 345° in the north of THROSSELL to about 300° on CONNAUGHTON. Fold profiles are tight to isoclinal and are characteristically inclined or overturned to the southwest. However, the McKay Antiform, which is located south of the McKay Fault on CONNAUGHTON, is overturned towards the east-northeast (Bagas and Smithies, 1998a). The difference in fold style may relate to back-thrusting or local drag along the D_6 McKay Fault. Alternatively, the McKay Antiform is a D_6 structure analogous to those associated with the Vines Fault on THROSSELL (Williams and Bagas, 1999).

Regionally, F_4 folds are accompanied by a strong axial planar cleavage (S_4), which dips steeply northeast. The fold axes plunge moderately to the northwest on THROSSELL and to southeast on CONNAUGHTON. This regional reversal of the plunge of F_4 folds has been observed across a northeasterly trending zone in the central part of northern RUDALL and may be the result of interference with an open F_5 anticline that trends northeast (Hickman and Bagas, 1998).

The conspicuous feature of the F_4 folds is that most of the fold axes in the Coolbro Sandstone are anticlines on BROADHURST and broad synclines on RUDALL and western CONNAUGHTON. A common feature of these anticlines is reverse faulting along the southwestern limbs and normal faulting along the northeastern limbs. This has produced a series of stacked anticlinal structures on BROADHURST, where the intervening synclines are either partly truncated or missing. Such fold axes are spaced with wavelengths of between 1 and 6 km. However, the intensity of folding and faulting increases rapidly to the southwest towards the Southwest Thrust (Williams and Bagas, 1999). For example, 28 km northwest of the Three Sisters Hills (near THROSSELL AMG 770370) the Broadhurst Formation is intensely and isoclinally folded with an amplitude of around 50 m.

Most of the D_4 faults have a lineation plunging steeply to the northwest or southeast. Individual faults extend laterally for tens of kilometres and exhibit both dip-slip and strike-slip movement. Thrust or reverse faults with northwesterly plunging lineations have a dextral component of strike-slip movement, whereas southeasterly plunging lineations are typically associated with sinistral strike-slip. The vertical displacement of the faults range from a few hundred metres to at least 3 km (Hickman and Bagas, 1999). On a regional scale, the faults intersect at acute angles and, overall, represent an anastomosing system.

The Southwest Thrust, which marks the boundary between the older Throssell Group and younger Tarcunyah Group, is postulated to be a sole thrust with a displacement of many kilometres (Hickman and Bagas, 1998). The tightly folded and faulted zone on the northeast side of the Southwest Thrust is interpreted to be the imbricate zone associated with this major southwest-directed sole thrust (Williams and Bagas, 1999).

Late reactivation and interference with pre-existing structures complicate F_4 fold geometry in the Rudall Complex. The most obvious consequence of this superimposition is that F_4 folds in the Rudall Complex commonly plunge at an angle up to 65°, which is significantly steeper than the angle of plunge of F_4 folds in the Throssell Group, although plunge directions remain the same. Examples of this are the major synform in the Rudall Complex on eastern CONNAUGHTON.

Field and magnetic data indicate that major corridors of intense and anastomosing faulting or shearing are separated by zones of folding and minor faulting on CONNAUGHTON. Examples are the Connaughton Synform and structures in the Harbutt Range area. The Camel–Tabletop Fault Zone, a cataclastic D_6 structure, truncates these structures.

The Connaughton Synform is a tectonically complex area of isoclinal F_2 folds and D_2 thrusts that have been refolded, faulted, and rotated during D_4. The major structure in the area is a tight D_4 synform that plunges to the southeast. An interesting feature of the Connaughton Synform is the presence of a southeasterly plunging F_2 anticline on its western side. If simple F_4 folding was superimposed on a subhorizontal F_2 fold, which trended in a northerly direction, the resulting plunge of this refolded F_2 anticline would have been towards the north on the southwestern limb of the F_4 fold. This discrepancy can be explained by a relative anticlockwise block-rotation of the anticlinal hinge zone against the near vertical D_4 faults bounding it to the east and west.

BLAKE MOVEMENT (D_5)

Several northeasterly trending, open to tight fold axes with southeasterly dipping axial planes have been mapped in the Tarcunyah Group (Bagas and Smithies, 1998a; Williams and Bagas, 1999), and the Rudall Complex (Hickman and Bagas, 1998). These structures indicate compression to the northwest, have been assigned to D_5, and are tentatively correlated with the Blake Movement in the northeasterly trending Blake Sub-basin (former Blake Fault and Fold Belt of Williams, 1992) of the Officer Basin (Bagas et al., 1999), which lies 60 km to the southwest along strike. The age of this folding event is poorly constrained between about 800 and 610 Ma (Williams, 1992).

The Blake Movement, which is recorded in the Sunbeam Group (Bagas et al., 1999) along the northwest margin of the Officer Basin (previously included in the former Savory Basin; Williams, 1992), is connected with basin inversion and northwest–southeast-directed compression (Williams, 1992, 1994). Open northeasterly trending folds cutting the Throssell Group rocks have also been recorded in the southeast (around CONNAUGHTON AMG 640633; Bagas and Smithies, 1998a). These F_5 folds refold F_4 fold axes and S_4 cleavage.

PATERSON OROGENY (D_6)

The Paterson Orogeny (D_6; as redefined by Bagas and Smithies, 1998a) post-dates the glacial deposits in the Boondawari Formation of the northwestern Officer Basin, is a correlative of the Petermann Ranges Orogeny, and is about 550 Ma (Bagas et al., 1995; Bagas et al., 1999). Myers et al. (1996) proposed that the Paterson Orogeny was the product of intracratonic deformation during the breakup of Rodinia.

The Disappointment Group (Bagas et al., 1999) was deposited in the incipient Wells Sub-basin (formally the Wells Foreland Basin; Williams, 1992, 1994) of the northwestern Officer Basin. This happened during the final stages of the Paterson Orogeny, as shown by stepped faults with steep reverse movement towards the southwest and vertical displacements measured in centimetres. Anastomosing kink bands, which have vertical displacements of up to 10 mm along the axial plane in places, commonly intersect these small faults. These are oblique to the faults and may form congruent sets (Williams, 1992).

The D_6 structures consist of northerly to northwesterly striking dextral faults and east-northeasterly striking sinistral faults (with associated spaced cleavage, S_6), and tight to open northwesterly to west-northwesterly trending F_6 folds. Several D_4 faults were reactivated during the D_6 event, as confirmed by the observation that northerly striking D_6 faults commonly branch off the D_4 faults.

Many of the large-scale northwesterly and west-northwesterly striking faults with transpressional movement include D_4 faults reactivated during D_6. Examples of such faults are the Vines Fault, Southwest Thrust, McKay Fault, and Camel–Tabletop Fault Zone, which appear to be long-lived structures that have been reactivated several times. All these faults have major lateral and vertical movement components.

Tight to open and locally en echelon folds in the Tarcunyah Group, which trend 290° in the south and swing to 345° in the north, are assigned to D_6. These folds lack the strong penetrative foliation (S_4), which is found in the Throssell Group and Rudall Complex. Many of the folds have flexural-slip associated with them and a weak axial-planar cleavage is evident in a few tight folds. The intersection of the northwesterly trending F_6 folds with the northeasterly trending F_5 folds has produced several elongate domes and basins in the western part of the area (Williams and Bagas, 1999).

Tight F_6 folds, which plunge about 20° towards the northwest and are overturned to the southwest, are found in the Tarcunyah Group located 5 km west of the Three Sisters Hills (THROSSELL AMG 860125). West-southwesterly trending, en echelon F_6 folds lie on the northeastern side of the Southwest Thrust and in units of the Broadhurst Formation, which commonly exhibit a crenulation cleavage (S_6) superimposed on S_4 (Williams and Bagas, 1999).

Major D_6 structures on CONNAUGHTON consist of a conjugate set of northwesterly and east-northeasterly striking faults and shear zones, and an associated spaced cleavage (S_6). These faults clearly post-date D_4 folding and associated faulting, although they may follow pre-existing structures. In addition to significant vertical movement, the northwesterly trending faults, such as the Camel–Tabletop Fault Zone, display dextral movements, and the west-northwesterly trending faults, such as the McKay Fault and minor faults in the Harbutt Range, a sinistral component.

The Camel–Tabletop Fault Zone is a kilometre-scale zone recognized in the Mount Eva area on CONNAUGHTON, which separates two very different terranes. Magnetic and field observations on eastern CONNAUGHTON and BLANCHE (Yeates and Chin, 1979; Bagas, 1999a) indicate that basement rocks to the east are predominantly Mesoproterozoic granitoid rocks, whereas Palaeoproterozoic orthogneiss predominates to the west. The fault zone can be traced with airborne geophysics from BROADHURST to RUNTON, where it joins with the southeastern extension of the McKay Fault, and then continues southeast, coinciding with the southern side of the Warri Gravity Ridge (Iasky, 1990). This ridge separates the West Australian Craton from continental crust to the northeast (Myers, 1993; Myers et al., 1996), and is a major structure that formed during the 600–540 Ma Petermann Ranges Orogeny of central Australia (Grey, 1990; Camacho and Fanning, 1995; Walter et al., 1995). The northern extent can not be accurately traced due to the lack of detailed geophysical data for the area.

The Camel–Tabletop Fault Zone consists of a number of closely spaced, anastomosing faults. The fault zone acted as a growth fault during the deposition of basal conglomerate in the Karara Formation before the compressional D_6 event, and was reactivated during D_6 (Bagas and Smithies, 1998a).

The McKay Fault is a major steeply, south-southwesterly dipping D_6 fault along the northeastern edge of the McKay Range and is associated with southwesterly trending, sinistral splay faults. It has truncated both the northern limb of the McKay Antiform and, to the north, the contact between the Connaughton and Talbot Terranes of the Rudall Complex. The antiform is east-southeasterly plunging and contains a core of quartzite, schist, and orthogneiss of the Talbot Terrane, unconformably overlain by the Throssell Group. North of the hinge zone to the McKay Antiform, the Gunanya Sandstone is juxtaposed against the Throssell Group and Connaughton Terrane along the McKay Fault. This suggests that the fault has sinistral and vertical components of movement.

METAMORPHISM

Evidence for M_1, associated with D_1 in the Rudall Complex, is extremely scarce since subsequent tectonism and metamorphic recrystallization were intense. Clarke (1991) found that M_1 in the Yandagooge Inlier on BROADHURST was a low-pressure event characterized by an andalusite–staurolite assemblage in pelitic rocks. Constraints on the timing of M_1 are that it happened before emplacement of the c. 1800 Ma monzogranite gneiss (*ⱣRge*) and 1790–1765 Ma K-feldspar augen orthogneiss (*ⱣRga*), and after emplacement of the layered gneiss (*ⱣRgx*) at 2015–1960 Ma.

Metamorphism (M_2) associated with D_2 reached up to the granulite facies (Smithies and Bagas, 1997a), and was partly synchronous with the intrusion of the protolith to the augen orthogneiss (*ⱣRga*), which is between 1790 and 1765 Ma (Nelson, 1995). Clarke (1991) recognized a middle amphibolite-facies assemblage (M_2) in the Talbot Terrane, and established that prevailing metamorphic conditions peaked at greater than 600 ± 100 MPa and 620 ± 50°C (Clarke, G. L., 1990, pers. comm.). Similar metamorphic mineral assemblages were recognized on RUDALL (Hickman and Bagas, 1998).

Amphibolite and mafic granulite in the Connaughton Terrane contain various combinations of the minerals hornblende, plagioclase, quartz, garnet, orthopyroxene, and clinopyroxene. Thermobarometry on these assemblages indicates that temperatures peaked in the amphibolite–granulite transition of metamorphism at around 800°C, while pressures reached 1200 MPa (Smithies and Bagas, 1997a). These peak metamorphic pressures indicate that the crust was locally thickened by at least 40 km, and probably records the collision between the Pilbara Craton and a continent to the northeast during the Palaeoproterozoic.

Greenschist metamorphism (M_4), associated with D_4, affected both the Rudall Complex and Throssell Group at greenschist facies, but some greenschist assemblages in the Rudall Complex may represent late-M_2 retrogression. The effects of M_4 are not uniformly distributed. Recrystallization of mineral assemblages is most pronounced in zones of deformation, but is apparent somewhat in all rocks of the Rudall Complex and Throssell Group. Characteristic of M_4 is the overprinting assemblage epidote, actinolite, albite (quartz, chlorite, calcite), or sericite and quartz. Peak M_4 is between c. 1132 and 800 Ma.

The sedimentary formations in the Officer Basin show no evidence of recrystallization after diagenesis (Williams and Bagas, 1999).

ECONOMIC GEOLOGY

Mineral exploration in the area has concentrated on nickel, base metals (copper, lead, zinc), gold, uranium, and diamonds. Despite rock-chip, auger, soil, and lag geochemical sampling, and gravity, magnetic, and radiometric surveys by several exploration companies, few anomalies have been identified, except for uranium at Kintyre (BROADHURST) and base metal mineralization at Maroochydore (BROADHURST). A number of kimberlitic indicators and microdiamonds have been detected within the region, although no kimberlite pipes have yet been found. Low grade gypsum forms dunes adjacent to the playa lake in this area.

Exploration company data covering RUDALL (1:250 000) are held in the WAMEX open-file system at the GSWA library. Anomalous samples collected by the GSWA during routine sampling of gossans, gossanous or sulfidic vein quartz, and visibly mineralized rock observed during fieldwork are described by Hickman and Clarke (1994), Bagas and Smithies (1998a), Hickman and Bagas (1998, 1999), and Williams and Bagas (1999).

GOLD

Subeconomic gold mineralization is associated with a few of the uranium prospects around the headwaters of Larry Creek (RUDALL), where veins occupying D_4 faults have up to 3 ppm gold (Hickman and Bagas, 1998).

About 3 km east of Talbot Soak (RUDALL), a sulfidic semipelitic member of the Coolbro Sandstone contains between 0.53 and 1.10 ppm gold (Hickman and Bagas, 1998).

URANIUM (AND ASSOCIATED COPPER, LEAD, AND ZINC)

Exploration for uranium and other mineral commodities was intensified after the discovery of the Kintyre uranium deposit on BROADHURST in 1985. This exploration targeted unconformity vein-style uranium, base metals, gold, and platinum-group element (PGE) mineralization using airborne geophysics and stream-sediment geochemistry. Hickman and Bagas (1999) summarized the geology of the uranium prospects on RUDALL.

The Kintyre deposit is an unconformity-associated, vein-type uranium deposit. It was discovered by Rio Tinto Exploration (then called CRA Exploration) in 1985 through surface follow-up of a number of radiometric anomalies detected during an airborne survey near the unconformity between the Yandagooge Formation of the Rudall Complex and Coolbro Sandstone (Jackson and Andrew, 1990). The published resource (from the combined Kintyre, Whale, and Pioneer ore deposits) is 36 000 t of contained U_3O_8 with grades averaging between 1.5 and 4.0 kg/t U_3O_8 (Jackson and Andrew, 1990). Drilling has identified an indicated resource of 24 000 t of U_3O_8 and more than 11 000 t of inferred resources at a 0.5kg/t U_3O_8 cutoff grade.

The mineralization is confined to axial-planar cleavage in the axial region of a F_2 antiform. The ore body forms a shallowly dipping lens to a depth of about 150 m and is hosted by sheared chloritic schist in contact with dolomitic limestone and graphitic schist. The main ore mineral is veined pitchblende with accessory copper, lead, and zinc mineralization, native bismuth, gold, platinum, and palladium. The gold locally grades up to 15 g/t near, or in, the pitchblende veins. Other uranium deposits in the Kintyre area are described in Hickman and Clarke (1994).

Anomalous, but subeconomic, copper, lead, zinc, gold, silver, molybdenum, chromium, nickel, and PGE have also been noted in association with uranium on RUDALL. The mineralization is probably due to secondary or recent mobilization and subsequent precipitation in regolith (Hickman and Bagas, 1998).

COPPER, LEAD, AND ZINC

The Broadhurst Formation of the Throssell Group hosts stratabound and stratiform copper, lead, and zinc mineralization, such as the widely separated Maroochydore (BROADHURST), Cottesloe (BROADHURST), and Nifty (LAMIL) prospects, indicating that the Broadhurst Formation is prospective over a large area (Hickman and Clarke, 1994). The primary mineralization at the Maroochydore prospect is stratabound in shale and siltstone, with an inferred resource of about 14 Mt averaging 1.6% Cu and 0.07% Co (Hickman and Clarke, 1994). The Cottesloe prospect is stratabound and hosted by shale and carbonate (Hickman and Clarke, 1994).

Copper, lead, zinc, and uranium mineralization is known in the Yandagooge Formation of the Rudall Complex around Kintyre and west of Sunday Creek on BROADHURST (Hickman and Clarke, 1994).

Visible copper mineralization is found at Camel Rock (CONNAUGHTON AMG 623040). The host rocks are metamorphosed banded iron-formation (*ƁRi*) with traces of chalcopyrite and malachite, quartz–carbonate, sericite–chlorite schist, and thin bands of medium-grained amphibolite (*ƁRam*). The richest copper mineralization with an average of 0.43% Cu is found in a 2 m-thick stockwork of magnetite, chalcopyrite, and pyrite veinlets in banded iron-formation. Up to 2% barium mineralization has also been found at depth in the area (Bagas and Smithies, 1998a).

Mount Cotton (CONNAUGHTON AMG 594759) is a significant Cu–Pb–Zn–U prospect in a northeasterly trending, gossanous quartz vein, hosted by garnetiferous and ferruginous schist (*ƁRir*) and banded iron-formation (*ƁRi*). The mineralization has grades of up to 2% Cu, 1.5% U, and 0.6% Zn, and contains traces of Ag and Au (Chin et al., 1980).

Ironstone in garnetiferous amphibolite (CONNAUGHTON AMG 626792) assayed 2660 ppm Pb, and a malachite-stained vein quartz just east of this locality assayed 4.3% Cu, 11 ppm Ag, and 1.1 ppm Au (Bagas and Smithies, 1998a).

A malachite-rich quartz vein exposed in alluvial rubble, collected from the southern part of the Connaughton Synform (CONNAUGHTON AMG 662742), assayed 19.4% Cu, 70 ppm Mo, and 1 g/t Au. Another sample of a malachite-rich quartz vein exposed through colluvium, from the northern part of the Connaughton Synform (CONNAUGHTON AMG 667773), assayed 4% Cu, 2260 ppm Pb, 445 ppm Zn, and 263 ppm As (Bagas and Smithies, 1998a).

A poorly exposed, weakly mineralized, lenticular gossan in the northern part of the South Rudall Dome (CONNAUGHTON AMG 567731) has a boxwork texture after pyrite, pyrrhotite, and chalcopyrite, and contains traces of galena and sphalerite. Silicified carbonate veins in the southern part of the South Rudall Dome (CONNAUGHTON AMG 569698) host chrysocolla, galena, and minor malachite. Samples from the area assayed up to 16.8% Cu, 300 ppm Ag, 2.60% Pb, and 1.1% Zn (Bagas and Smithies, 1998a).

PLATINUM-GROUP ELEMENTS (PGE)

In 1971, North West Oil and Minerals NL undertook PGE exploration by drilling ultramafic rocks (*ƁRu*) in the Rudall River area (around RUDALL AMG 207073). Although values of between 1.99 and 6.65 ppm Pt were claimed from depths of up to 240 m, Blockley (1972) was unable to duplicate the results.

RARE EARTH ELEMENTS (REE)

Anomalous concentrations of REE are found in gossan hosted by fine-grained amphibolite (*ƁRab*; CONNAUGHTON AMG 560828 and 534751), schist (*ƁRm*; CONNAUGHTON AMG 519836), orthogneiss (*ƁRga*; CONNAUGHTON AMG 564784), and banded iron-formation (*ƁRi*; CONNAUGHTON AMG 548788) about 10 km north of the South Rudall Dome (Bagas and Smithies, 1998a).

BARITE

Barite veins up to 0.3 m wide are present to the southwest of Watrara Pool (e.g. RUDALL AMG 006071), and there is additional mineralization between this locality and about 6.5 km to the southwest (RUDALL AMG 020048). Hickman and Bagas (1998) gave a description of the veins.

The barium sulfate content of the veins reaches up to about 80% (47% Ba), the chief impurities being iron (hematite) and silica. Although the largest vein is over 100 m long and up to 4 m thick, the level of impurities and the remote location make the deposits subeconomic (Hickman and Bagas, 1999).

GYPSUM

Gypsum deposits were located about 2 and 3 km north of Rudall Crossing (RUDALL AMG 110088 and 108097 respectively; Hickman and Bagas, 1998).

SEMIPRECIOUS GEMSTONES

Coloured opaline rocks suitable for polishing are found along the Rudall River near Rooney Creek, and in siliceous caprock developed on the ultramafic rocks near the Rudall River (Chin et al, 1980).

WATER RESOURCES

Permanent and semipermanent pools are present along the major courses where alluvium is sufficiently thick and extensive to hold groundwater resources. Areas of calcrete may contain large, although saline, groundwater supplies. Significant groundwater supplies are likely to be found in fractured and sheared rocks of the Rudall Complex, and the Throssell and Tarcunyah Groups. Permian sandstone units in the buried glacial valleys may also be potential aquifers, although salinity levels are untested.

REFERENCES

BAGAS, L., 1997, Gunanya, W.A. Sheet 3451: Western Australia Geological Survey, 1:100 000 Geological Series.

BAGAS, L., 1998, Geology of the Gunanya 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 10p.

BAGAS, L., 1999a, Geology of the Blanche–Cronin 1:100 000 sheet (part sheets 3551 and 3552): Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 16p.

BAGAS, L., 1999b, Rudall, W.A. Sheet SF51-10 (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series.

BAGAS, L., in prep., Geology of the Paterson 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.

BAGAS, L., GREY, K., and WILLIAMS, I. R., 1995, Reappraisal of the Paterson Orogen and Savory Basin: Western Australia Geological Survey, Annual Review 1994–95, p. 55–63.

BAGAS, L., GREY, K., HOCKING, R. M., and WILLIAMS, I. R., 1999, Neoproterozoic successions of the northwestern Officer Basin: a reappraisal: Western Australia Geological Survey, Annual Review 1998–99, p. 39–44.

BAGAS, L., and SMITHIES, R. H., 1996, Connaughton, W.A. Sheet 3452: Western Australia Geological Survey, 1:100 000 Geological Series.

BAGAS, L., and SMITHIES, R. H., 1997, Palaeoproterozoic tectonic evolution of the Rudall Complex, and comparison with the Arunta Inlier and Capricorn Orogen: Western Australia Geological Survey, Annual Review 1996–97, p. 110–115.

BAGAS, L., and SMITHIES, R. H., 1998a, Geology of the Connaughton 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 38p.

BAGAS, L., and SMITHIES, R. H., 1998b, Blanche–Cronin, W.A. Part Sheets 3551 and 3552: Western Australia Geological Survey, 1:100 000 Geological Series.

BEARD, J. S., 1970, The natural regions of the deserts of Western Australia: Journal of Geology, v. 57, p. 677–711.

BLOCKLEY, J. G., 1972, A reported platinum find in the Rudall River area: Western Australia Geological Survey, Annual Report 1971, p. 103–104.

BLOCKLEY, J. G., and de la HUNTY, L. E., 1975, Paterson Province, *in* The Geology of Western Australia: Western Australia Geological Survey, Memoir 2, p. 114–118.

BLOCKLEY, J. G., and MYERS, J. S., 1990, Proterozoic rocks of the Western Australian Shield — geology and mineralization, *in* Geology of the mineral deposits of Australia and Papua New Guinea *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 607–615.

CAMACHO, A., and FANNING, C. M., 1995, Some isotopic constraints on the evolution of the granulite and upper amphibolite facies terranes in the eastern Musgrave Block, central Australia: Precambrian Research, v. 71, p. 155–181.

CHIN, R. J., and de LAETER, J. R., 1981, The relationship of new Rb–Sr isotopic dates from the Rudall Metamorphic Complex to the geology of the Paterson Province: Western Australia Geological Survey, Annual Report 1980, p. 132–139.

CHIN, R. J., WILLIAMS, I. R., WILLIAMS, S. J., and CROWE, R. W. A., 1980, Rudall, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 22p.

CLARKE, G. L., 1991, Proterozoic tectonic reworking in the Rudall Complex, Western Australia: Australian Journal of Earth Sciences, v. 38, p. 31–44.

CROWE, R. W. A., 1975, The classification, genesis and evaluation of sand dunes in the Great Sandy Desert: Western Australia Geological Survey, Annual Report 1974, p. 46–49.

CROWE, R. W. A., and CHIN, R. J., 1979, Runton, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 16p.

DANIELS, J. L., and HORWITZ, R. C., 1969, Precambrian tectonic units of Western Australia: Western Australia Geological Survey, Annual Report 1968, p. 37–38.

GOELLNICHT, N. M., GROVES, D. I., and McNAUGHTON, N. J., 1991, Late Proterozoic fractionated granitoids of the mineralized Telfer area, Paterson Province, Western Australia: Precambrian Research, v. 51, p. 375–391.

GREY, K., 1990, Amadeus Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 335–349.

GREY, K., 1995, Late Proterozoic stromatolites from Skates Hills Formation, Savory Basin, Western Australia, and a review of the distribution of *Acaciella australica*: Australian Journal of Earth Sciences, v. 42, p. 123–132.

GREY, K., and COTTER, K. L., 1996, Palynology in the search for Proterozoic hydrocarbons: Western Australia Geological Survey, Annual Review 1995–96, p. 70–80.

GREY, K., and STEVENS, M. K., 1997, Neoproterozoic palynomorphs of the Savory Sub-basin, Western Australia, and their relevance to petroleum exploration: Western Australia Geological Survey, Annual Review 1996–97, p. 49–54.

HICKMAN, A. H., and BAGAS, L., 1995, Tectonic evolution and economic geology of the Paterson Orogen — a major reinterpretation based on detailed geological mapping: Western Australia Geological Survey, Annual Review 1993–94, p. 67–76.

HICKMAN, A. H., and BAGAS, L., 1996, Rudall, W.A. Sheet 3352: Western Australia Geological Survey, 1:100 000 Geological Series.

HICKMAN, A. H., and BAGAS, L., 1998, Geology of the Rudall 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 30p.

HICKMAN, A. H., and BAGAS, L., 1999, Geological evolution of the Palaeoproterozoic Talbot Terrane and adjacent Meso- and Neoproterozoic successions, Paterson Orogen, Western Australia: Western Australia Geological Survey, Report 71, 91p.

HICKMAN, A. H., and CLARKE, G. L., 1993, Broadhurst, W.A. Sheet 3353: Western Australia Geological Survey, 1:100 000 Geological Series.

HICKMAN, A. H., and CLARKE, G. L., 1994, Geology of the Broadhurst 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 40p.

HICKMAN, A. H., WILLIAMS, I. R., and BAGAS, L., 1994, Proterozoic geology and mineralization of the Telfer–Rudall region, Paterson Orogen: Geological Society of Australia (W.A. Division); Excursion Guidebook 5, 56p.

IASKY, R. P., 1990, Officer Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 362–380.

IDNURM, M., and SENIOR, B. R., 1978, Palaeomagnetic ages of late Cretaceous and Tertiary weathering profiles in the Eromanga Basin, Queensland: Palaeography, Palaeoclimatology, Palaeoecology, v. 24, p. 263–277.

JACKSON, D. G., and ANDREW, R. L., 1990, Kintyre uranium deposit, *in* Geology of the mineral deposits of Australia and Papua New Guinea *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 653–658.

McNAUGHTON, N. J., and GOELLNICHT, N. M., 1990, The age and radiothermal properties of the Mount Crofton Granite: Australian Journal of Earth Sciences, v. 37, p. 103–106.

MYERS, J. S., 1990a, Precambrian tectonic evolution of part of Gondwana, southwestern Australia: Geology, v. 18, p. 537–540.

MYERS, J. S., 1990b, Geological Evolution, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 735–755.

MYERS, J. S., 1993, Precambrian history of the West Australian craton and adjacent orogens: Earth and Planetary Science, Annual Review, v. 21, p. 453–485.

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

NELSON, D. R., 1995, Compilation of SHRIMP U–Pb zircon geochronology data, 1994: Western Australia Geological Survey, Record 1995/3, 244p.

NELSON, D. R., 1996, Compilation of SHRIMP U–Pb zircon geochronology data, 1995: Western Australia Geological Survey, Record 1996/5, 168p.

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

PERINCEK, D., 1996, The age of Neoproterozoic–Palaeozoic sediments within the Officer Basin of the Centralian Superbasin can be constrained by major sequence-bounding unconformities: APPEA Journal, v. 36, pt 1, p. 350–368.

SMITHIES, R. H., and BAGAS, L., 1997a, High pressure amphibolite–granulite facies metamorphism in the Paleoproterozoic Rudall Complex, central Western Australia: Precambrian Research, v. 83, p. 243–265.

SMITHIES, R. H., and BAGAS, L., 1997b, The Tabletop Terrane of the Proterozoic Rudall Complex: preliminary notes on the geology, granitoid geochemistry and tectonic implications: Western Australia Geological Survey, Annual Review 1996–97, p. 89–94.

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

STEVENS, M. K., and GREY, K., 1997, Skates Hills Formation and Tarcunyah Group, Officer Basin — carbonate cycles, stratigraphic position, and hydrocarbon prospectivity: Western Australia Geological Survey, Annual Review 1996–97, p. 55–60.

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

TRAVES, D. M., CASEY, J. N., and WELLS, A. T., 1956, The geology of the southwestern Canning Basin, Western Australia: Australia Bureau of Mineral Resources, Report 29, 76p.

TRENDALL, A. F., 1974, The age of a granite near Mount Crofton, Paterson Range sheet: Western Australia Geological Survey, Annual Report 1974, p. 92–96.

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

WALTER, M. R., and VEEVERS, J. J., 1997, Australian Neoproterozoic palaeogeography, tectonics, and supercontinental connections: Australian Geological Survey Organisation, Journal of Geology and Geophysics, v. 17, p. 73–92.

WALTER, M. R., GREY, K., WILLIAMS, I. R., and CALVER, C. R., 1994, Stratigraphy of the Neoproterozoic to Early Palaeozoic Savory basin, Western Australia, and correlation with the Amadeus and Officer Basins: Australian Journal of Earth Sciences, v. 41, p. 533–546.

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

WILLIAMS, I. R., 1987, Late Proterozoic glaciogene deposits in the Little Sandy Desert, Western Australia: Australian Journal of Earth Sciences, v. 34, p. 153–154.

WILLIAMS, I. R., 1989, Balfour Downs, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 38p.

WILLIAMS, I. R., 1990a, Rudall Complex, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 276–279.

WILLIAMS, I. R., 1990b, Yeneena Basin, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 277–282.

WILLIAMS, I. R., 1992, Geology of the Savory Basin, Western Australia: Western Australia Geological Survey, Bulletin 141, 115p.

WILLIAMS, I. R., 1994, The Neoproterozoic Savory Basin, Western Australia, *in* The Sedimentary Basins of Western Australia *edited by* P. G. PURCELL and R. R. PURCELL: Petroleum Exploration Society of Australia; Sedimentary Basins of Western Australia Symposium, Perth, W.A., 1994, Proceedings, p. 841–850.

WILLIAMS, I. R., and BAGAS, L., 1998, Poisonbush, W.A. Sheet 3252: Western Australia Geological Survey, 1:100 000 Geological Series.

WILLIAMS, I. R., and BAGAS, L., 1999, Geology of the Throssell 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 24p.

WILLIAMS, I. R., and BAGAS, L., 2000, Geology of the Poisonbush 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 21p.

WILLIAMS, I. R., BAGAS, L., and SMITHIES, R. H., 1996, Throssell, W.A. Sheet 3253: Western Australia Geological Survey, 1:100 000 Geological Series.

WILLIAMS, I. R., BRAKEL, A. T., CHIN, R. J., and WILLIAMS, S. J., 1976, The stratigraphy of the Eastern Bangemall Basin and Paterson Province: Western Australia Geological Survey, Annual Report 1975, p. 79–83.

WILLIAMS, I. R., and MYERS, J. S., 1990, Paterson Orogen, *in* Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3, p. 282–283.

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

WILLIAMS, I. R., and TYLER, I. M., 1991, Robertson, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 36p.

WILLIAMS, I. R., and WILLIAMS, S. J., 1980, Gunanya, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 13p.

YEATES, A. N., and CHIN, R. J., 1979, Tabletop, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 19p.

BAGAS et al.

Rudall, Western Australia, Second Edition

GSWA

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

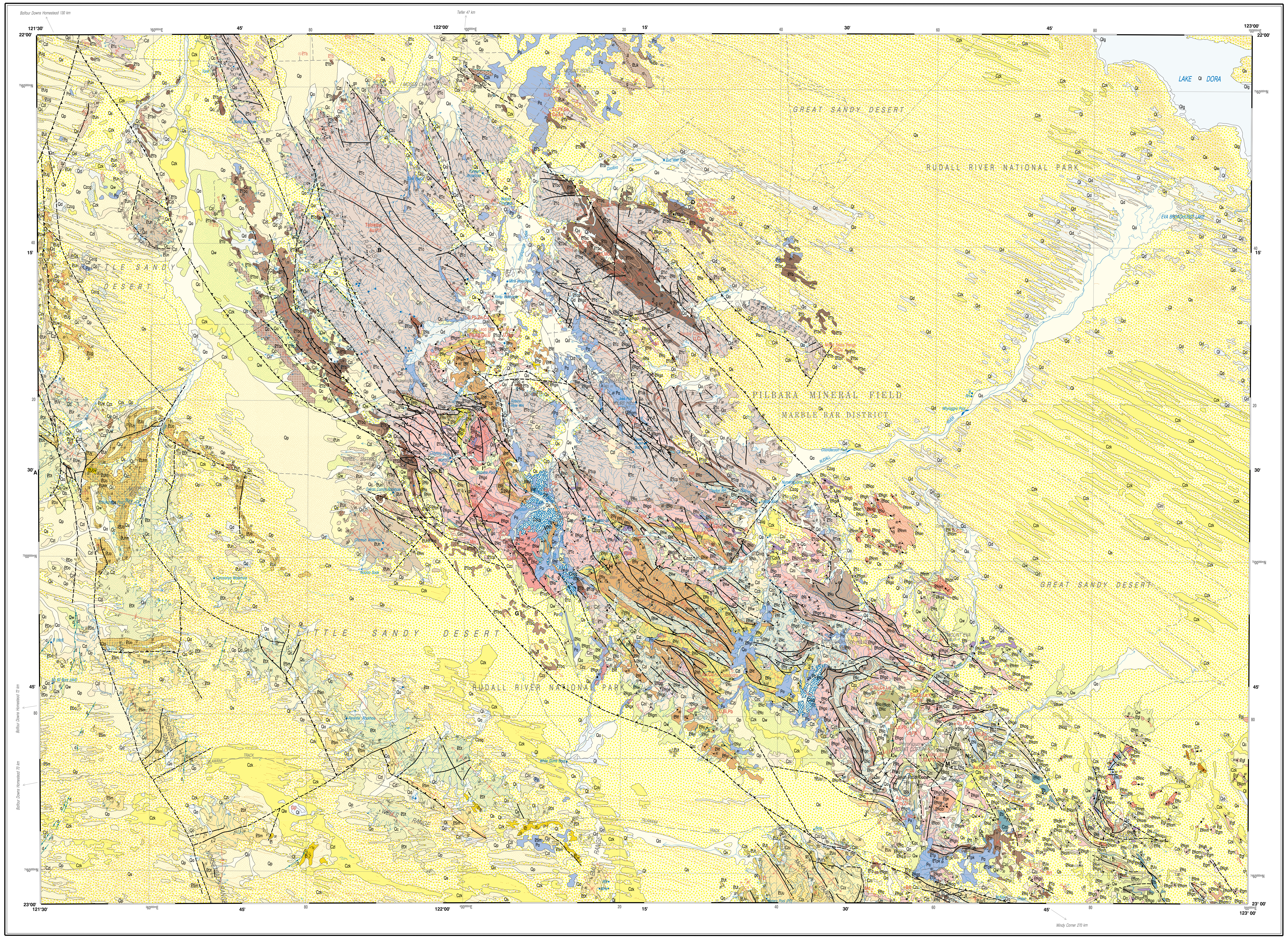
Information Centre
Department of Minerals and Energy
100 Plain Street
East Perth WA 6004
Phone: (08) 9222 3459   Fax: (08) 9222 3444
www.dme.wa.gov.au

AUSTRALIA 1:250 000 GEOLOGICAL SERIES

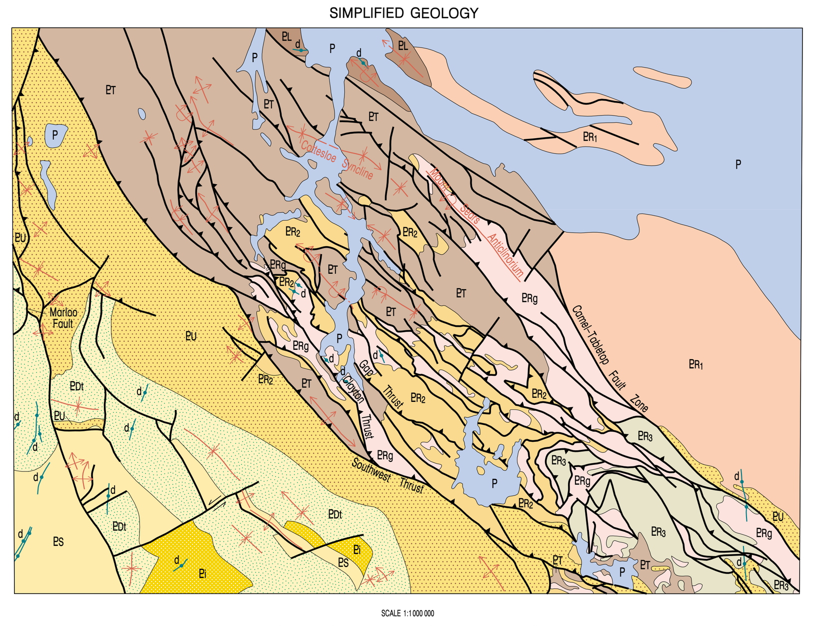
RUDALL

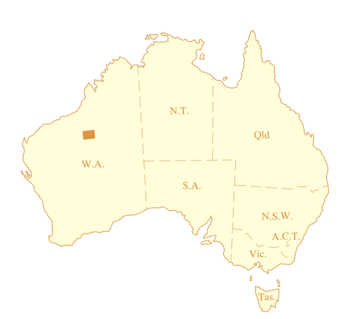
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SF 51-10

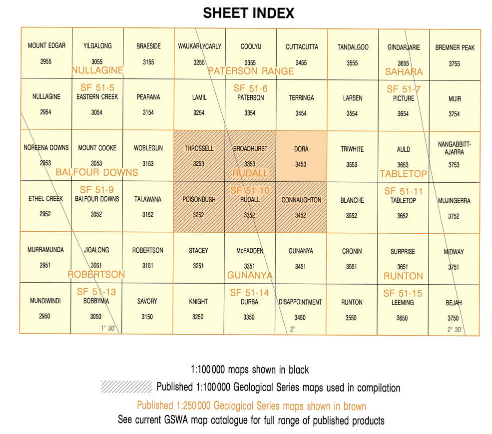


SIMPLIFIED GEOLOGY





SHEET INDEX



Compiled by L. Bagas 1998

Geology by L. Bagas 1991–97 and after GSWA maps (see sheet index)

Edited by N. Tetlaw

Cartography by D. Ladbrook and B. Williams

Topography from the Department of Land Administration Sheet SF 51-10, with modifications from geological field survey

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

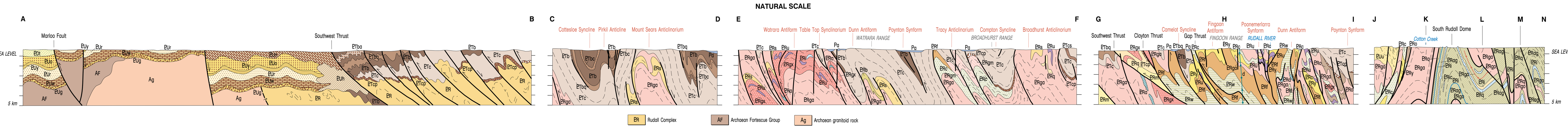
This map is also available in digital form

Printed by the Land Information Centre, Bathurst, New South Wales

The recommended reference for this map is:
BAGAS, L., 1999, Rudall, W.A. Sheet SF 51-10: Western Australia Geological Survey, 1:250 000 Geological Series

DIAGRAMMATIC SECTIONS

NATURAL SCALE



REFERENCE

PATERSON FORMATION: sandstone, claystone, conglomerate, and boulder beds; tillite and fluvioglacial deposits

ⱣUw WAROONGUNYAH FORMATION: laminated to massive dolomite, stromatolitic dolomite, sandy dolomite, siliceous oolite, siltstone, and shale
ⱣUg GOOGHENAMA FORMATION: medium- to coarse-grained sandstone, and polymictic pebble to cobble conglomerate
ⱣUt WATERS FORMATION: shale, finely laminated and locally stromatolitic dolomite, upward-fining sandstone–siltstone–shale rhythmic units, and sulfidic beds
ⱣUu GUNANYA SANDSTONE: medium- to coarse-grained arkosic sandstone; local beds of siltstone, grit, and conglomerate; abundant cross-bedding
ⱣUk KARARA FORMATION: medium- to coarse-grained arkosic sandstone; minor beds of quartz–feldspar wacke, shale, and conglomerate

Ᵽo Gabbro and dolerite
Ᵽuz Ultramafic rock, variably silicified

Lamil Group

ⱣLi ISDELL FORMATION: thinly bedded carbonate rocks, calcareous siltstone, and minor shale
ⱣLic Dark grey carbonate rock; locally sulfidic
ⱣLik Pale grey to cream carbonate rock interbedded with shaly calcarenite; locally sulfidic

Yeneena Supergroup — Throssell Group — Yeneena Basin

ⱣTb BROADHURST FORMATION: shale, lithic wacke, sandstone, and dolomite
ⱣTba Interbedded fine-to coarse-grained sandstone, siltstone, silty shale, dolomite, and stromatolitic dolomite
ⱣTbq Interbedded fine- to medium-bedded sandstone and siltstone; minor shale
ⱣTbc Carbonate rock and minor shale; commonly sulfidic
ⱣTbb Basalt

ⱣTc COOLBRO SANDSTONE: massive and thickly bedded sandstone; minor siltstone, shale, and carbonate rocks; basal conglomerate in some areas
ⱣTcs Shale or pelitic schist
ⱣTcp Conglomerate; polymictic clasts generally well rounded and matrix-supported

ⱣTp PUNGKULI FORMATION: shale, reddish brown to grey; minor sandstone, dolomite, and sulfidic rocks, stromatolitic
ⱣTpk Dolomite, grey to cream or pink and finely laminated; minor sandstone, shale, and pyritic shale; metamorphosed
ⱣTt TALIWANYA FORMATION: arkose to arkosic sandstone, medium- to coarse-grained

Ᵽb Amygdaloidal basalt; metamorphosed

Ᵽge Syenogranite and monzogranite; even-grained; massive to weakly foliated
Ᵽgf Granitoid rock with feldspar phenocrysts; massive to strongly foliated
Ᵽgl Leucogranite; medium- to coarse-grained; massive to weakly foliated
Ᵽgm Leucogranite; coarse-grained with K-feldspar megacrysts; massive to weakly foliated
Ᵽgp Pegmatite; quartz–K-feldspar–biotite–muscovite-bearing; massive to weakly foliated

ⱣRnb Quartz–feldspar–biotite(–muscovite) gneiss
ⱣRnc Charnockite; quartz–K-feldspar–plagioclase–garnet–orthopyroxene gneiss
ⱣRnm Quartz–microcline–plagioclase–biotite(–muscovite) gneiss
ⱣRng Quartz–K-feldspar–plagioclase–garnet(–muscovite) gneiss
ⱣRns Mylonite; quartz–sericite(–K-feldspar–plagioclase–muscovite–biotite) rock

ⱣRgp Pegmatite; variably foliated and locally gneissic
ⱣRgh Orthogneiss to strongly foliated granodiorite to monzogranite; hornblende-bearing; medium- to coarse-grained; generally interleaved with, and contains inclusions of, amphibolite
ⱣRgm Leucocratic, muscovite-rich orthogneiss derived from fine- to medium-grained granite
ⱣRga Orthogneiss derived from porphyritic biotite granite to monzogranite; generally contains augen of K-feldspar
ⱣRgg Compositionally layered orthogneiss derived from fine- to medium-grained granite or monzogranite; contains alternating biotite- and feldspar-rich layers; local lenticular inclusions of metamorphosed mafic, ultramafic, and sedimentary rocks
ⱣRgb Banded garnetiferous granodioritic orthogneiss
ⱣRge Even-grained granitic to monzogranitic orthogneiss
ⱣRgd Biotite granodioritic orthogneiss
ⱣRgo Compositionally layered orthogneiss derived from fine- to medium-grained granite or monzogranite; includes alternating biotite- and feldspar-rich layers; local lenticular inclusions of mafic rocks

ⱣRu Metamorphosed ultramafic rock; chiefly serpentinite
ⱣRa Ortho-amphibolite; metamorphosed gabbro and dolerite

Rudall Complex (stratigraphic succession incompletely determined)

ⱣRo POYNTON FORMATION: quartzite, commonly micaceous, with thin intercalations of quartz–muscovite schist; minor psammitic gneiss and biotite–plagioclase–quartz schist
ⱣRc BUTLER CREEK FORMATION: banded paragneiss containing layers of quartz–feldspar(–biotite) gneiss, quartz–biotite schist, micaceous quartzite, quartz–muscovite schist, and amphibole–chlorite schist; local metamorphosed banded iron-formation
ⱣRy YANDAGOOGE FORMATION: dominantly pelitic to semi-pelitic assemblage of quartz–mica schist, hematitic biotite schist, and minor intercalations of muscovitic quartzite and quartzite; local quartz–feldspar–muscovite psammitic gneiss, pyritic graphitic schist, chert, and metamorphosed banded iron-formation
ⱣRyi Metamorphosed banded iron-formation and chert
ⱣRf FINGOON QUARTZITE: dominantly massive or layered micaceous quartzite; includes local quartz–muscovite schist and psammitic gneiss
ⱣRw LARRY FORMATION: intercalated banded quartz–feldspar–mica gneiss, quartz–mica schist, and quartzite; psammitic gneiss locally developed near top of formation
ⱣRgx Lithologically layered orthogneiss derived from fine- to medium-grained granite or monzogranite, mafic, ultramafic, and metasedimentary rocks

Unassigned units of various ages

ⱣRb Banded paragneiss containing quartz–feldspar(–biotite) gneiss, quartz–biotite schist, micaceous quartzite, quartz–muscovite schist, and amphibole–chlorite schist; local metamorphosed banded iron-formation
ⱣRm Quartz–chlorite schist and muscovite schist; metamorphosed shale
ⱣRl Quartz–mica schist; metamorphosed argillaceous sedimentary rock
ⱣRi Metamorphosed banded iron-formation and chert; includes silicified graphitic schist
ⱣRic Metachert and locally metamorphosed banded iron-formation
ⱣRir Graphite–quartz–garnet–biotite–sulfide schist and metamorphosed banded iron-formation; minor metachert
ⱣRk Carbonate schist; metamorphosed carbonate rock and calcareous sandstone
ⱣRp Quartz–biotite–plagioclase gneiss and schist, containing layers of quartzite and pelitic schist

ⱣRs Psammitic gneiss; includes fine-grained quartz–feldspar–muscovite gneiss, muscovite-rich gneiss, quartz–mica schist, and quartzite layers
ⱣRq Quartzite; commonly micaceous; thin intercalations of quartz–muscovite schist
ⱣRqa Quartz–aluminosilicate schist; quartz–kyanite–ilmenite schist, quartz–sillimanite–K-feldspar schist, and quartz–sillimanite–K-feldspar–garnet schist

ⱣRan Amphibolite: leucocratic, coarse- to very coarse-grained, plagioclase–amphibole rock; massive to foliated; meta-leucogabbro and meta-anorthosite
ⱣRab Epidote and quartz-bearing amphibolite; fine-grained
ⱣRae Amphibolite; mesocratic to leucocratic, silicified and epidotized; foliated
ⱣRam Clinopyroxene and quartz-bearing amphibolite; foliated and locally gneissic
ⱣRao Garnet, clinopyroxene, and quartz-bearing amphibolite interleaved with granitic gneiss (ⱣRgo); foliated
ⱣRac Orthopyroxene and clinopyroxene-bearing amphibolite; massive to foliated and locally gneissic
ⱣRag Garnet, clinopyroxene, and quartz-bearing amphibolite; foliated and locally gneissic

SYMBOLS

Geological boundary
- exposed
Fault
- exposed
- concealed
- concealed, position uncertain
- normal, tick on downthrown side
- thrust or reverse, triangle on upthrown side
- strike slip, showing relative horizontal displacement
Fold, showing axial trace and generalized plunge direction
- anticline; exposed, concealed
- syncline; exposed, concealed
- overturned anticline; exposed, concealed
- overturned syncline; exposed, concealed
Small-scale fold axis, showing trend and plunge direction
- anticline
- syncline
- S-vergence
Bedding, showing strike and dip
- inclined
- overturned
- trend, from aerial photography
Palaeocurrent, showing trend and sense of direction
- from asymmetrical ripple marks, direction known
- from cross-bedding, direction known
Glacial striae, showing trend and sense of ice movement
Way-up indicator
- graded bedding
- cross-bedding
- stromatolite growth direction
Metamorphic foliation, showing strike and dip
- inclined
- vertical
- trend (section only)
Cleavage, showing strike and dip
- inclined
- vertical
Lineation, showing trend and plunge
- inclined
Mineral lineation, showing trend and plunge
Crenulation, showing trend and plunge of axis
Fracture, joint, or vein, showing strike and dip
- inclined
Airphoto lineament
Aeromagnetic trend
Trace fossil locality
Stromatolite fossil locality

Major track, maintained
Track
Landing ground
Aboriginal community — Parnngurr
Building
National park boundary
Horizontal control, minor
Sand dune

Watercourse with ephemeral pools, rockholes or waterholes
Rockhole, waterhole — RH, WH
Soak — Sk
Bore — B
Windpump
Tank — Tank
Abandoned — (abd)
Position doubtful — (PD)

Prospect — Cassandra
Mineral exploration drillhole, showing subsurface data — ⱣTb
Mineral occurrence
Geochemical anomaly from gossan assay (anomaly criteria: >1000 ppm, except for Ba >1%; Mn >10%; Au >0.5 ppm; PGE >1 ppm)

Antimony	Sb
Arsenic	As
Asbestos, chrysotile	Asbc
Barite	Ba
Bismuth	Bi
Cerium	Ce
Chromium	Cr
Cobalt	Co
Copper	Cu
Garnet	Ga
Gold	Au
Gypsum	Gp
Kyanite	Ky
Lanthanum	La
Lead	Pb
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Niobium	Nb
Platinum Group Elements	PGE
Rutile	R
Silver	Ag
Strontium	Sr
Tungsten	W
Tourmaline	Tour
Uranium	U
Yttrium	Y
Zinc	Zn
Zirconium	Zr

DEPARTMENT OF MINERALS AND ENERGY
L. C. RANFORD, DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:250 000

5000 Metres 0 5 10 15 20 25 30 Kilometres

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 20 000 metre interval of the Australian Map Grid Zone 51

RUDALL

SHEET SF 51-10

SECOND EDITION 1999

© Western Australia 1999