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GEOLOGY OF THE THROSSELL 1:100 000 SHEET

by I. R. Williams and L. Bagas

1:100 000 GEOLOGICAL SERIES

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DEPARTMENT OF MINERALS AND ENERGY

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Cover photograph:
Tight folding of Broadhurst Formation rocks about 10 km south of Throssell Range (AMG 720455), looking south.

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Geology of the Throssell 1:100 000 sheet

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Abstract

The THROSSELL 1:100 000 sheet is situated on the southwestern margin of the northwesterly component of the Paterson Orogen. The orogen comprises components of the Palaeoproterozoic Rudall Complex, the Mesoproterozoic to Neoproterozoic metasedimentary Yeneena Supergroup, and the Neoproterozoic sedimentary Tarcunyah Group. The latter is unconformably overlain by the Neoproterozoic Tchukardine Formation of the Officer Basin. Scattered outliers of Lower Permian fluvioglacial Paterson Formation of the Canning Basin unconformably overlie rocks affected by the orogen.

The Rudall Complex is composed of metamorphosed siliciclastic rocks, including the Yandagooge Formation, interlayered with orthogneiss. These components belong to the tectono-stratigraphic Talbot Terrane. The Rudall Complex was deformed and metamorphosed during the Yapungku Orogeny, a complex event involving at least two pre-Yeneena Supergroup deformation episodes that are related to northeast–southwest compression between c. 2000 and c. 1760 Ma. The Yeneena Supergroup was deposited in the Yeneena Basin, a strike-slip basin produced by continuing northeast–southwest convergence. In the mapped area, the Yeneena Supergroup mainly contains the older Throssell Group; the younger Lamil Group is not exposed.

The Throssell Group consists of the fluvial siliciclastic Coolbro Sandstone, which unconformably overlies the Rudall Complex and conformably underlies the carbonaceous-rich Broadhurst Formation. The Yeneena Supergroup was deformed and metamorphosed during the Miles Orogeny. The poorly constrained age of the event is between >1300 and c. 800 Ma, and is in response to renewed southwest-directed compression. The Throssell Group is faulted against the younger Tarcunyah Group by the Southwest Thrust.

The Tarcunyah Group is a northwestern extension of the Officer Basin. The group contains rock units that can be correlated with Supersequence 1 of the Centralian Superbasin. The Tarcunyah Group comprises seven formations: the basal Googhenama and Choorun Formations, and the Waroongunyah Formation, Brownrigg Sandstone, Yandanunyah Formation, and the newly defined Wongarlong and Nooloo Formations. The Tarcunyah Group was deformed by the southwest-directed transpressional Paterson Orogeny around 550 Ma.

The unconformably overlying Tchukardine Formation of the Disappointment Group was deposited in an incipient foreland basin marginal to, and contemporaneously with, the Paterson Orogeny.

THROSSELL has been extensively prospected for gold, copper, lead, zinc, uranium, PGEs, and diamonds; some anomalous areas have been outlined.

KEYWORDS: Paterson Orogen, Rudall Complex, Yeneena Supergroup, Throssell Group, Tarcunyah Group, Disappointment Group, Officer Basin, Talbot Terrane, metamorphism, deformation

Introduction

The THROSSELL* 1:100 000 map sheet (SF 51-10, 3253) is bounded by latitudes 22°00'S and 22°30'S and longitudes 121°30'E and 122°00'E, and is situated on the northern margin of the Little Sandy Desert at the point where it is separated from the Great Sandy Desert by the north-northwesterly trending Throssell Range. The sheet derives its name from this range, which was named after the Hon. George Throssell, the then Commissioner of Crown Lands, by W. F. Rudall in 1897. THROSSELL is situated in the northwestern corner of the RUDALL 1:250 000 sheet.

* Capitalized names refer to standard map sheets

Unlike the adjacent Pilbara region to the west, THROSSELL has not been subjected to pastoral activities, and apart from temporary mineral exploration camps, transient aboriginal groups, and tourists, it is uninhabited. The northwest corner of the Rudall River National Park, declared in 1977, extends into the southeast quadrant of THROSSELL where it covers the headwaters of Yandagooge Creek and Rudall River in the east and part of the Tarcunyah Creek drainage in the west.

The region is accessible from a graded road that crosses the northeast margin of the sheet. This road links the Telfer gold mine, 54 km to the northeast, to the Kintyre – Rudall River area, which is east and southeast of THROSSELL. Access can also be gained from Balfour Downs Homestead, 130 km to the southwest, via a poorly maintained graded track that crosses the northern half of THROSSELL to join the Telfer – Rudall River track 5 km southwest of Moses Chair (AMG 934559)*. Four kilometres northwest of THROSSELL, the Balfour Downs track is linked, by a rough, sandy track, to the Nifty copper mine access road and Woodie Woodie, 55 km to the northwest. The Christie Crossing (Oakover River) – Rudall River track, used by exploration companies in the 1970s, intersects the southern margin of THROSSELL in the Tarcunyah Creek area (AMG 620112). Disused exploration tracks in the eastern third of the sheet area link the Christie Crossing – Rudall River track in the Three Sisters Hills area (AMG 920137) northwards to the Balfour Downs track. These tracks skirt the western edge of a rugged, dissected sandstone plateau that contains the headwaters of the Coolbro and Yandagooge Creeks. This area is inaccessible to four-wheel drive vehicles. The rest of THROSSELL, with the exception of the Throssell Range on the northern boundary, is accessible to four-wheel drive vehicles either from disused exploration tracks in the central and northern parts or by difficult cross-country traversing in the western and southern areas.

Previous and current investigations

Brief descriptions of the area can be found in early exploration journals. W. F. Rudall reconnoitred the area in 1897 during his unsuccessful search for missing members of the Calvert scientific and exploring expedition (Rudall, 1898). Independently and concurrently, F. H. Hann also traversed the region in 1897 searching for gold and suitable pastoral country (Donaldson and Elliot, 1998). A brief, early account of the geology in the THROSSELL area can be found in Talbot (1920, 1928). The first systematic regional mapping in the area was carried out by officers of the Geological Survey of Western Australia (GSWA) in 1975 as part of the RUDALL 1:250 000 sheet mapping project (Chin et al., 1980).

* 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 this sheet, to within 100 m.

The Bureau of Mineral Resources (BMR), now the Australian Geological Survey Organisation (AGSO), published preliminary Bouguer anomaly maps in 1970, radiometric-contour and total-count images in 1987, and total magnetic intensity maps in 1988. The data were acquired for the RUDALL 1:250 000 sheet that includes the THROSSELL area. Reports of mineral exploration in the area from the mid-1970s and onwards are available from the WAMEX open-file system held in the GSWA library (Appendix 1).

The present survey, part of the 1:100 000-scale mapping program of the Paterson Orogen commenced in 1987, was undertaken during the 1992–94 field seasons using black and white 1:50 000-scale airphotos flown in 1988. The THROSSELL 1:100 000 sheet was published in 1996 (Williams et al., 1996). This data has been incorporated in the 2nd edition RUDALL 1:250 000 sheet (Bagas, 1999a).

Climate, vegetation, and physiography

The climate on THROSSELL is arid (desert), with summer rainfall peaking in February. Most rain comes from summer thunderstorms associated with monsoonal troughs or from decaying southerly to southeasterly moving tropical cyclones. Lighter winter rains fall between May and July. The mean annual rainfall is around 200 mm. Apart from the cyclone season (December to April), the humidity is low, with high evaporation rates of up to 4000 mm per annum. Summers are very hot, with mean daily maximum temperatures over 40°C in December and January, and winters are mild, with mean daily minimum temperatures around 10–11°C in July (Pink, 1992).

Most of THROSSELL (about 94%) falls within the Keartland Botanical District (Fig. 1), while the remaining area, which lies along the northeast margin, is covered by the Canning Botanical District (Beard and Webb, 1974). Both districts are part of the Eremaean Botanical Province (Beard, 1975).

Within the Canning Botanical District, the sand-ridge country carries a mixed-shrub steppe of *Acacia*, *Hakea*, and *Grevillea* species, feather-top spinifex (*Plectrachne schinzii*), and scattered desert bloodwoods (*Corymbia dichromophloia*; Hill and Johnson, 1995; previously described as *Eucalyptus dichromophloia;* Beard and Webb, 1974). The sandplain country contains a shrub steppe of Waterwood (*Acacia coriacea*) and *Hakea* sp., and buck spinifex (*Triodia basedowii*).

The wide variety of vegetation found in the Keartland Botanical District reflects the varied landforms. The mixed-shrub steppe and spinifex of the sand ridge, and shrub steppe and spinifex of the sandplain, are similar to vegetation types of the adjacent Canning Botanical District. In the central parts of THROSSELL, the broad palaeodrainage valley of the Tarcunyah Creek supports patches of Coolabah (*Eucalyptus microtheca*) and desert bloodwood tree savannah. Strips of tea-tree scrub

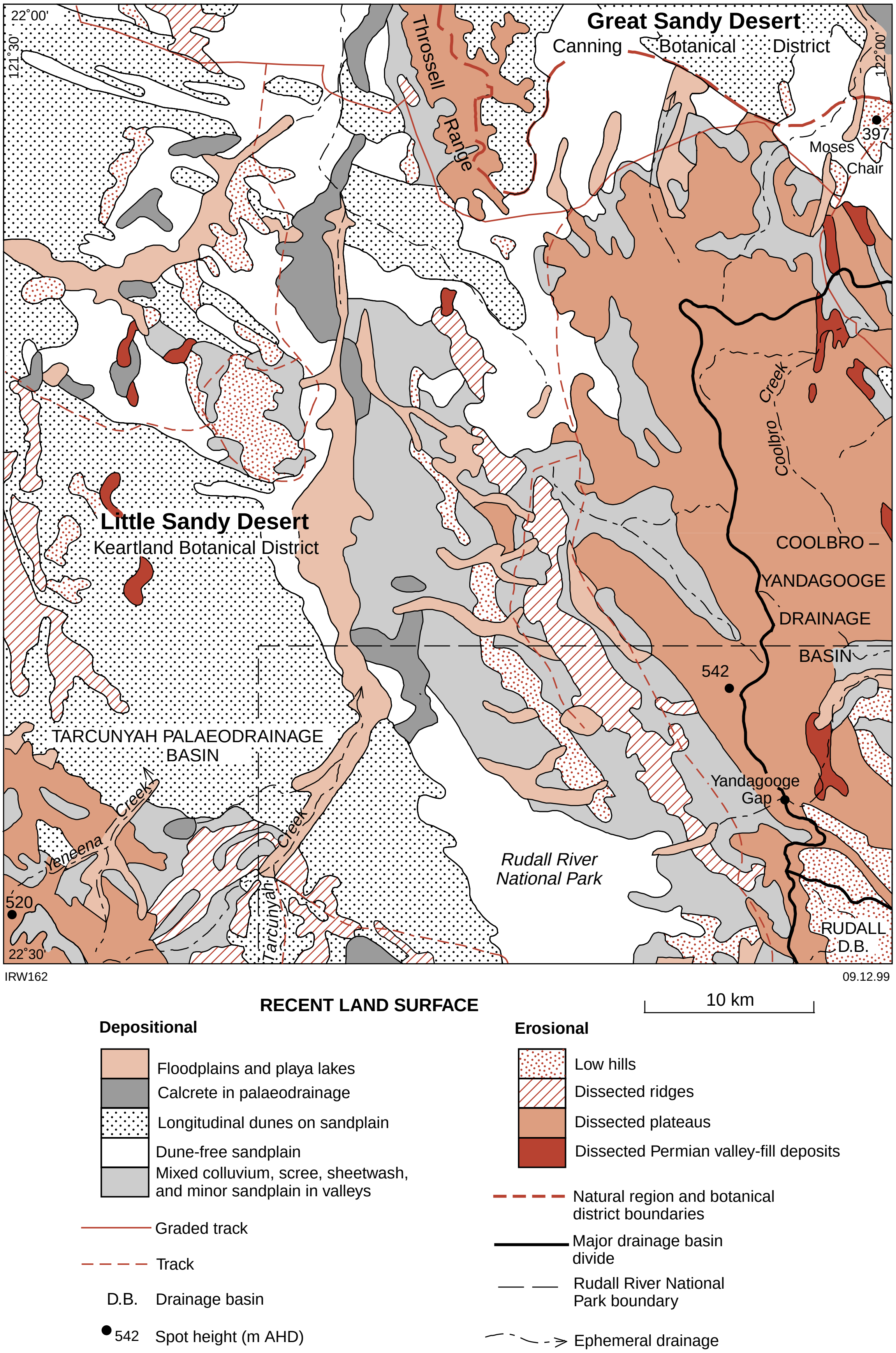

Figure 1. Natural regions, botanical districts, physiographic, and drainage map of THROSSELL

(*Melaleuca* sp.) are found along channels in this area, particularly where the channels cut through valley calcrete. Large creeks in the Rudall and Coolbro–Yandagooge drainage basins carry sparse Coolabah, River Gum (*Eucalyptus Camaldulensis*), and *Acacia* species. Away from the main channels, the Rudall River drainage basin carries a shrub steppe of Kanji (*Acacia pyrifolia*), with mixed soft (*Triodia pungens*) and hard (*Triodia basedowii*) spinifex. The Throssell Range and rocky hills, dissected ridges, and plateaus in the eastern and western parts of THROSSELL are covered with a grass steppe of soft spinifex (*Triodia pungens*) and sparsely scattered Snappy Gum (*Eucalyptus brevifolia*).

Physiographic divisions (Fig. 1) on THROSSELL have been adapted from CONNAUGHTON, where depositional regimes are distinguished from erosional regimes (Bagas and Smithies, 1998). The Canning Botanical District corresponds to the Great Sandy Desert Natural Region (Beard, 1970). On THROSSELL, this region consists of longitudinal (seif) dune fields in which individual dunes consistently trend 300° and are up to 10 m high. The sand-ridge areas are separated by dune-free sandplain. Such dunes are particularly common on the east-sloping, windward side of the Throssell Range. The Great Sandy Desert region is separated from the Little Sandy Desert region to the west by the Throssell Range and to the south by the broad, dissected sandstone plateau that contains the headwaters of the Coolbro Creek.

The physiographically diverse Little Sandy Desert region occupies most of THROSSELL. Large areas of longitudinal (seif) and chain dunes, together with minor net-dune complexes, lie to the west of the north-trending Tarcunyah Creek palaeodrainage that transects THROSSELL. These dunes are up to 15 m high and trend between 290 and 300°. They encroach, and partly bury, dissected ridges and plateaus along the western edge of THROSSELL. Other small, sand dune covered areas lie west of the gap between the Throssell Range and the dissected plateau containing the headwaters of the Coolbro Creek, and east of Tarcunyah Creek along the southern boundary (Fig. 1). Most of the region east of Tarcunyah Creek is occupied by a large dissected plateau that is fringed to the west by dissected ridges and low hills (Fig. 1). The dissected plateau is marked by cliffs or steep escarpments. North of Yandagooge Gap, relief is up to 150 m where unnamed hills attain a maximum height of 540 m AHD (Australian Height Datum). Box canyons and deep rocky gorges contain semi-permanent rockholes and pools in this area. The dissected plateaus, ridges, and low hills are bordered to the west by mixed colluvium, scree, and sheetwash areas (Fig. 1). This area is dune-free and corresponds to the lee side of the hills for the prevailing wind direction.

The dissected plateau area also marks the divide between the ephemeral, east-flowing Coolbro and Yandagooge creeks and the Rudall River drainage from the north-flowing Tarcunyah Palaeodrainage Basin, which was a tributary of the Percival Palaeoriver to the north (van de Graaff et al., 1977; Williams and Trendall, 1998a; Fig. 1). The Tarcunyah Palaeodrainage Basin contains dissected trunk-valley calcrete (Fig. 1). Although the headwaters and some sections of the main drainage still flow after heavy rains, the palaeodrainage system probably ceased to flow in its entirety by the Middle Miocene. This corresponds with the onset of arid conditions (van de Graaff et al., 1977).

Dissected remnants of Permian valley-fill deposits are preserved near the eastern and western margins of THROSSELL (Fig. 1).

Regional geological setting

THROSSELL lies in the northwest part of the Paterson Orogen (Williams and Myers, 1990). This region had previously been referred to as the Paterson Province (Daniels and Horwitz, 1969; Blockley and de la Hunty, 1975).

The term Paterson Orogen now applies to an arcuate, northwest-trending belt, about 1200 km long, of folded and metamorphosed sedimentary and igneous rocks that range in age from Palaeoproterozoic to Neoproterozoic and have a common tectonic history (Williams and Myers, 1990). The Orogen is exposed along the eastern margin of the Pilbara Craton, in the Telfer region and along Rudall River drainage in the northwest, and in the Musgrave Complex area 450 km to the southeast (Myers and Hocking, 1998). These two exposed areas are structurally linked by the subsurface Paterson–Musgrave structural trend (Austin and Williams, 1978), which is outlined by a strong gravity high known as the Anketell Gravity Ridge (Fraser, 1976) or Warri Ridge (Iasky, 1990).

Myers (1993), Myers et al. (1996), and Bagas and Smithies (1998) suggest that the Paterson Orogen is the result of collision and amalgamation of the Western Australian Craton with continental crust from the east and northeast (North Australian Craton).

THROSSELL is flanked to the west by Archaean rocks of the Pilbara Craton and the Mesoproterozoic sedimentary Manganese Subgroup of the Bangemall Basin (Fig. 2; Williams and Trendall, 1998c). On THROSSELL, the Paterson Orogen, which underlies the entire sheet area, can be subdivided between the Palaeoproterozoic Rudall Complex (Chin et al., 1980; Williams, 1990a), Mesoproterozoic to Neoproterozoic Yeneena Supergroup (Appendix 2), and the Neoproterozoic Tarcunyah Group (Appendix 2). The Rudall Complex exposure is restricted to the southeast corner of THROSSELL (Fig. 3) in the headwaters of the Rudall River and Yandagooge Creek. The outcrops lie at the western end of the exposed complex, which extends 150 km to the east-southeast (Chin et al., 1980; Hickman and Clarke, 1994; Hickman and Bagas, 1998; Bagas and Smithies, 1998; Bagas, 1999b). The complex forms the core and oldest component of the Paterson Orogen. On THROSSELL, the complex comprises felsic, mafic, and ultramafic intrusive rocks, and sedimentary rock. These rocks were deformed and metamorphosed at least twice before deposition of the Yeneena Supergroup. Geochronology data indicate that deformation, metamorphism, and granitoid intrusion took place between c. 2000 and 1760 Ma (Hickman et al., 1994; Bagas and Smithies, 1998). This event is called the

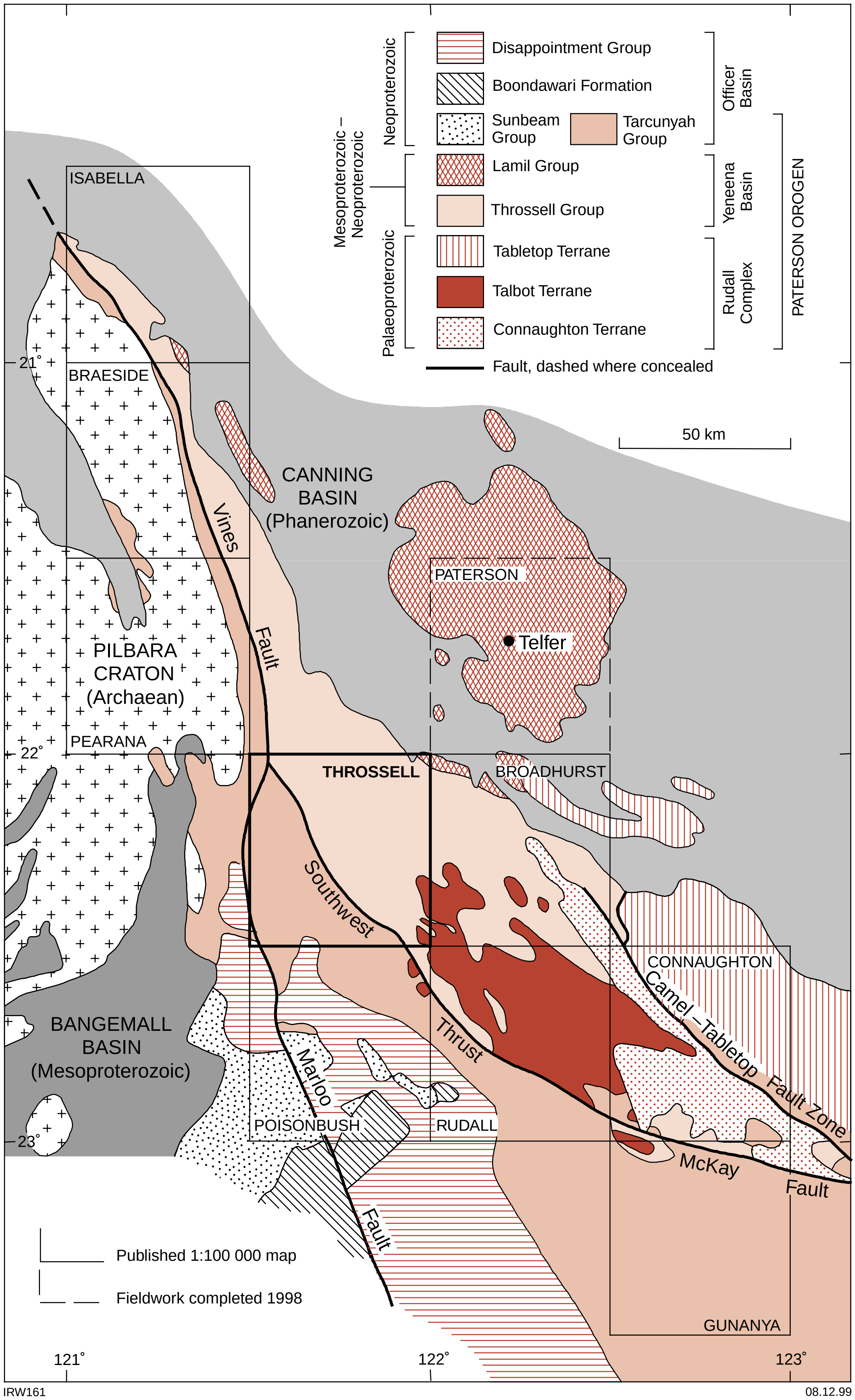

Figure 2. Regional geological setting of THROSSELL

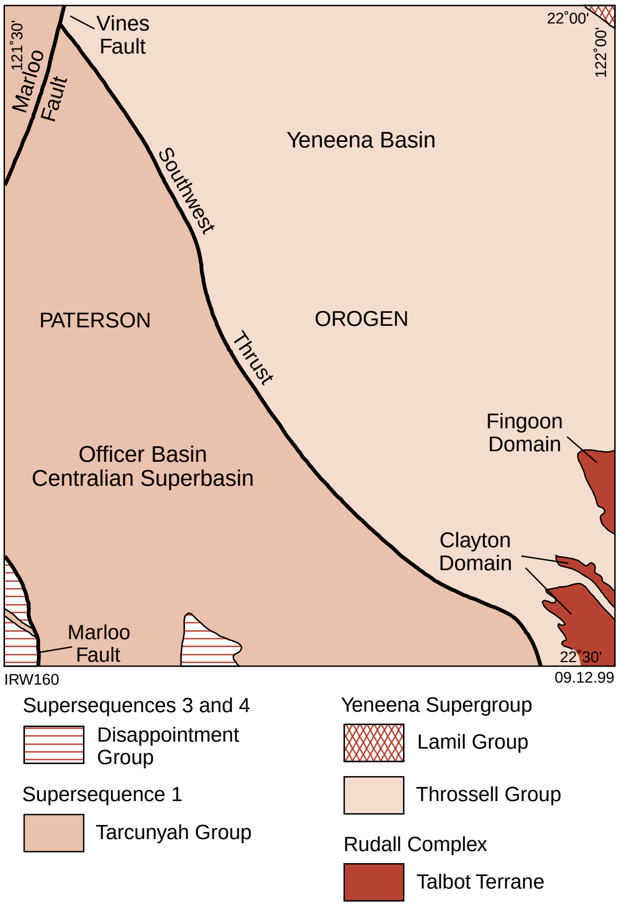

Figure 3. Major structural units on Throssell

Yapungku Orogeny and covers the D_{1-2} events (Bagas and Smithies, 1998). The Yapungku Orogeny may be contemporaneous with the Capricorn Orogeny of the West Australian Craton (Bagas and Smithies, 1997), and partly contemporaneous with the Strangeways Orogeny in the Arunta Inlier of central Australia (Bagas and Smithies, 1997).

The metasedimentary successions that unconformably overlie the Rudall Complex were, in earlier publications, assigned to the Yeneena Group (Williams et al., 1976; Chin et al., 1980; Williams 1990b). In this publication, the Yeneena Group has been redefined and renamed Yeneena Supergroup (Appendix 2). The Mesoproterozoic to Neoproterozoic Yeneena Supergroup, which contains the newly defined Throssell and Lamil Groups (Appendix 2), is restricted to metasedimentary successions that lie east of the Vines Fault (Williams and Trendall, 1998b) and northeast of the Southwest Thrust, an area that covers over half of Throssell. Together, these faults roughly transect Throssell from the northwest to the southeast corners (Fig. 3). The area occupied by the Throssell Group and overlying Lamil Group approximately corresponds to the central and northeastern zones, respectively, of the Yeneena Basin (Williams, 1990b).

On Throssell, the Throssell Group unconformably overlies the Rudall Complex, and while its relationship with the overlying Lamil Group is not exposed, observations in the adjoining Broadhurst map-sheet area suggest a discordant contact (Hickman and Clarke, 1994). This relationship is inferred to extend across the northeast corner of Throssell.

Both the Throssell and Lamil Groups have undergone low-grade greenschist-facies metamorphism. The Throssell Group, in particular, is subjected to tight, isoclinal folding, with overturning directed mainly towards the southwest. The folds are associated with brittle–ductile reverse, thrust, and lag faults, and shear zones. This deformation is assigned to the Miles Orogeny (D_{3-4}; Bagas et al., 1995; Bagas and Smithies, 1998). Uncertainty remains as to the age of this orogeny. Constraints using available data are poor and range between a maximum age of c. 1300 Ma (igneous intrusion) and a minimum age of c. 800 Ma (Bagas and Smithies, 1998).

The minimum age of the Miles Orogeny is based on the observation that the younger Tarcunyah Group (c. 800 Ma) lying west of the Southwest Thrust is not subjected to greenschist-facies metamorphism. In the Telfer region, northeast of Throssell, the Lamil Group is intruded by post-tectonic granitoids dated at c. 630 Ma (Nelson, 1995). Hence, the Miles Orogeny must be older than 630 Ma. This event, which is characterized by strong southwesterly directed transpressional movement, has been directly linked to the collision of the North Australian Craton with the northeastern margin of the West Australian Craton. This process is connected with the assemblage of the supercontinent Rodinia (Myers et al., 1996).

The Neoproterozoic Tarcunyah Group (Appendix 2) lies southwest of the Southwest Thrust, where it occupies slightly less than half the sheet area. The Tarcunyah Group roughly corresponds to the western zone of the Yeneena Basin in earlier publications (Williams, 1990b). Although the Tarcunyah Group on Throssell is faulted against the Throssell Group, elsewhere it is unconformable; for example, southeast of the McKay Range (Bagas and Smithies, 1998). The Tarcunyah Group is unconformable on the Rudall Complex in the adjoining Poisonbush sheet area (Williams and Bagas, in prep.). To the west, on Balfour Downs (1:250 000), the Tarcunyah Group unconformably overlies the late Archaean Gregory Granitic Complex and Fortescue Group, and the Mesoproterozoic Manganese Subgroup of the Bangemall Basin (Williams and Trendall, 1998a,b,c).

Significantly, the absence of metamorphism, and the different structural style, helps to distinguish the Tarcunyah Group rocks from the adjoining Throssell Group. Preliminary work on stromatolites and acritarchs also suggests that the Tarcunyah and Throssell Groups have different geological histories (Bagas et al., 1995). The palaeontological data (Grey and Cotter, 1996; Grey and Stevens, 1997; Stevens and Grey, 1997) also support the contention that the Tarcunyah Group is a correlative of Supersequence 1 of the Centralian Superbasin (Walter et al., 1995; Bagas et al., 1995, 1999). From this it can be concluded that the

Tarcunyah Group is a northwesterly extension of the Officer Basin*.

In the southwest corner of THROSSELL, some northeast-trending fold axes and faults may be related to the Blake Movement (D_5; Williams, 1992, 1994). These open to locally steep folds are the result of a basin inversion event that marks the northwestern margin of the Officer Basin to the southwest (called Savory Basin; Williams, 1992). Recent work has confirmed that the Savory Basin is an integral part of the Officer Basin (Bagas et al., 1995; Perincek, 1996). Consequently, the term Savory Basin has been abandoned as a separate entity (Bagas et al., 1999).

The intracratonic Centralian Superbasin (850–544 Ma; Walter et al., 1994), to which the Tarcunyah Group now belongs, was disrupted by the Paterson Orogeny (c. 550 Ma). The Paterson Orogeny, redefined by Bagas and Smithies (1998) as a D_6 event, is correlated, and is a continuum of, the Petermann Orogeny (560–525 Ma) of central Australia (Grey, 1990; Camacho and Fanning, 1995; Walter et al., 1995). On THROSSELL, this event is marked by strong transpressional reactivation of earlier faults, particularly the Southwest Thrust. The Tarcunyah Group forms folds with northwest-trending fold axes that become tighter eastwards towards the Southwest Thrust. The fold axes are obliquely truncated by steep reverse and lag faults. The folding and thrusting events of the Paterson Orogeny are thought to be related to the breakup of the supercontinent of Rodinia (Myers et al., 1996).

Two small, faulted areas of flat-lying Tchukardine Formation lie in the southwest corner of THROSSELL. Previously included in the Savory Group of the Savory Basin, the Tchukardine Formation has been reassigned to the newly named Disappointment Group (Bagas et al., 1999). The Disappointment Group, which belongs to the Officer Basin, contains rocks correlated with Supersequences 3 and 4 of the Centralian Superbasin (Bagas et al., 1999).

The Paterson Orogen is unconformably overlain by Early Permian fluvioglacial sedimentary rocks, including tillite, that are outliers of the Canning Basin (Middleton, 1990).

Proterozoic rocks

Proterozoic rocks of the Paterson Orogen on THROSSELL comprise the moderately exposed Palaeoproterozoic Rudall Complex (>1760 Ma), the well-exposed Meso-proterozoic to Neoproterozoic Throssell Group and unexposed Lamil Group (c. 1300 – c. 850 Ma), and the moderately to well-exposed Neoproterozoic Tarcunyah Group (c. 830 – 700 Ma). This latter group, together with the well-exposed Neoproterozoic Tchukardine Formation of the Disappointment Group (<600 Ma; Bagas et al., 1999), are part of the Officer Basin.

* This new conclusion is not recorded on the accompanying THROSSELL 1:100 000 sheet

Rudall Complex

Exposure of the Rudall Complex (Williams, 1990a) is limited to two small areas in the southeast corner of THROSSELL. The complex is restricted to the valley floors and low hills within the headwaters of the Yandagooge and Watrara creeks; the latter is a tributary of the Rudall River. The complex is unconformably overlain by the Throssell Group, which forms steep escarpments. In both areas, the complex is part of the Talbot Terrane (Bagas and Smithies, 1998), with the Yandagooge Creek area falling within the tectono-stratigraphic Fingoon Domain, whilst the Watrara Creek area lies within the Clayton Domain (Hickman and Bagas, 1998; Fig. 3).

Talbot Terrane

The Talbot Terrane consists principally of deformed and metamorphosed siliciclastic sedimentary rocks and granitoids. Similar components have been described from the Rudall Complex on BROADHURST (Hickman and Clarke, 1994), RUDALL (1:100 000; Hickman and Bagas, 1998), and western CONNAUGHTON (Bagas and Smithies, 1998). In general, the rocks have been metamorphosed to amphibolite facies under high pressures, producing a mixed gneiss and schist terrain (Smithies and Bagas, 1997). This metamorphic event is assigned to the Yapungku Orogeny (Bagas and Smithies, 1998).

On THROSSELL, the paragneiss and schist of the Rudall Complex preserve insufficient stratigraphic evidence to permit a complete stratigraphic interpretation. The absence of way-up evidence, combined with fragment-ation by granitoid intrusion and deformation, prevents the recognition of the original succession. However, the Yandagooge Formation in the Fingoon Domain can be followed westward from BROADHURST onto THROSSELL. The Yandagooge Formation is intimately interlayered with augen orthogneiss *(#Rga)*, the dominant rock type found in the Talbot Terrane (Hickman and Bagas, 1998). Beyond recognition of the Yandagooge Formation, stratigraphic subdivisions have not been attempted on THROSSELL.

Unassigned metasedimentary rocks (#Rs, #Rss, #Rm, #Rmb, #Rb, #Rk)

Psammitic paragneiss *(#Rs)* includes fine-grained quartz–feldspar–mica gneiss, quartz–mica schist, and quartzite layers. These probably represent metamor-phosed sandstone–shale successions. The unit lies in the northwestern part of the Fingoon Domain. In the Clayton Domain to the south (Fig. 3), on the eastern margin, fine-grained quartz–feldspar–mica gneiss intercalated with pelitic schist represents metamorphosed interbedded feldspathic sandstone and shale (*#Rss*).

Small exposures of quartz–mica schist intercalated with thin (less than 30 cm thick) quartz-rich laminae *(#Rm)* are present in the Clayton Domain. A component of this unit contains varying amounts of quartz–biotite schist *(#Rmb)* with minor feldspar, opaque minerals, and garnet. The protoliths of this unit were probably shale and mudstone.

Banded paragneiss *(#Rb)* can be found in the northwestern part of the Clayton Domain. This unit 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 *(#Rb)* represents a metamorphosed succession of turbiditic sandstone, argillaceous siltstone, and shale, and may be a correlative of the Butler Creek Formation on RUDALL (1:100 000; Hickman and Bagas, 1998).

Calc-silicate gneiss and schist in the Clayton Domain *(#Rk)* 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, sericitized plagioclase, epidote, quartz, ilmenite, and minor calcite. The hornblende(–plagioclase–biotite) gneiss and schist are composed of hornblende, sericitized plagioclase, quartz, biotite, sericite, clinozoisite, and chlorite.

Yandagooge Formation (#Rym)

The Yandagooge Formation *(#Rym*; Hickman and Bagas, 1998) is a widespread and lithologically distinctive unit of the northwestern part of the Fingoon Domain (Fig. 3), previously called the Yandagooge Inlier (Hickman and Clarke, 1994). The dominant rock type of the formation on THROSSELL is a metamorphosed pelitic schist comprising alternating muscovite–biotite–quartz and quartz–muscovite(–sericitized plagioclase) laminae, and minor chert *(#Rym)*. The quartz–mica schist contains varying amounts of quartz, muscovite, biotite, and minor feldspar (predominantly plagioclase), garnet, and finely disseminated opaque minerals. The chert consists of recrystallized quartz, minor mica (predominantly muscovite) and opaque minerals, and rare sericitized plagioclase.

The dominant fabric in the schist is a penetrative S_1 foliation that is defined by the preferred alignment of muscovite, biotite, tourmaline, quartz, opaque minerals, and sericite. S_1 is generally parallel to the S_2 schistosity, except at F_2 fold hinges, where S_2 (parallel to F_2 axial surfaces) cuts across S_1 (parallel to compositional banding). Where biotite is present it is commonly pseudomorphed by post-S_2 chlorite.

The formation is generally recessive in outcrop, forming sparsely vegetated, low-lying rubbly rises covered with a veneer of vein-quartz colluvium. With the exception of lithological layering, primary sedimentary features are lacking. The formation is interlayered with orthogneiss (*#Rga)*.

Metamorphosed ultramafic rock (#Ru)

Layers and pods of metamorphosed ultramafic rock *(#Ru)* are found in the orthogneiss and metasedimentary rock of the Rudall Complex in the Clayton Domain. The ultramafic rock is less than 200 m thick and is composed of serpentine, tremolite, chlorite, opaque minerals, and serpentinite pseudomorphs after olivine or pyroxene. The unit is in proximity to major D_4 faults, where it is tectonically interleaved with paragneiss or orthogneiss, and locally forms large boudins.

Orthogneiss (#Rga)

At least 80% of the outcrop area in the Rudall Complex on THROSSELL is composed of a microcline–quartz–plagioclase–biotite orthogneiss *(#Rga)* containing numerous augen (deformed megacrysts) of K-feldspar. sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon dates of between 1790 and 1765 Ma (Nelson, 1995) have been obtained from four widely spaced samples of augen orthogneiss collected on RUDALL (1:100 000) and CONNAUGHTON.

Augen orthogneiss *(#Rga)* is generally well exposed, and forms sparsely vegetated, low, rocky hills. The intensity of the S_2 foliation is variable, with rocks ranging from a poorly foliated porphyritic granite, or monzogranite, to a quartz–feldspar–muscovite schist. S_1 has not been recognized in the augen orthogneiss (*#Rga*) anywhere within the Rudall Complex (Hickman and Bagas, 1998: Bagas and Smithies, 1998). The S_2 foliation is defined by quartz and K-feldspar elongation, and mica alignment. In intensely foliated samples, S_2 is defined by quartz, biotite, muscovite, and sericite enveloping feldspar and quartz phenocrysts. The foliation is generally folded by F_4 folds or crenulated by S_4. Some outcrops of augen orthogneiss have been intruded by aplite veins that appear to lack D_2 schistosity.

Augen orthogneiss *(#Rga)* consists of a strongly foliated granoblastic mosaic of microcline, plagioclase, and quartz, with variable amounts of biotite and muscovite. Minor sphene, allanite, and epidote, and accessory opaque minerals, apatite, and zircon are also 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 rock composition is granodiorite, the feldspar augen are chiefly composed of oligoclase.

Yeneena Supergroup

In early publications, the term Yeneena Group was applied to all sedimentary and metasedimentary rocks in the Paterson Province (later renamed Paterson Orogen; Williams and Myers, 1990) that unconformably overlie the Rudall Complex (Williams et al., 1976; Chin et al., 1980). The Yeneena Group was cited to be the sole lithostratigraphic unit of the Yeneena Basin (Williams, 1990b). However, at the same time, it was also pointed out that the Yeneena Group could be subdivided into three zones. Each zone had a distinct igneous, tectonic, metamorphic, and palaeogeographic history, and were informally named the Western, Central, and Northeastern zones.

The present survey has confirmed that, on THROSSELL, the lithostratigraphic, structural, and metamorphic characteristics of the rocks in the southwestern half (the Western zone), are distinctly different from those in the northeastern half of the sheet (the Central zone). The boundary between the two zones coincides with the major Southwest Thrust (Fig. 3). This thrust extends northwestwards to link with the Vines Fault, a steep reverse fault that plays a similar role to the Southwest Thrust in that it separates less-deformed, unmetamorphosed sedimentary rocks to the west from multiply deformed metasedimentary rocks to the east (Williams and Trendall, 1998a,b,c).

The three zones, recognized in the earlier defined Yeneena Group (Williams, 1990b), roughly correspond to three newly named groups. These are, from west to east, the Tarcunyah, Throssell, and Lamil Groups (Appendix 2). In this new scheme, the Yeneena Group has been upgraded to Yeneena Supergroup, which now comprises the older, multiply deformed, metasedimentary Throssell and Lamil Groups. These groups occupy the Yeneena Basin (Williams, 1990b), a probable strike-slip basin (Hickman et al., 1994). The younger Tarcunyah Group to the west is now part of the northwest extension of the Officer Basin (Bagas et al., 1995).

Throssell Group (*#T*)

The Throssell Group (Appendix 2) occupies most of the northeastern half of THROSSELL. It unconformably overlies the Rudall Complex in the southeast corner and has a non-exposed, discordant contact (Hickman and Clarke, 1994) with the overlying Lamil Group (Bagas, in prep.) in the northeast corner of THROSSELL. The northwest-trending Southwest Thrust marks the contact with the younger Tarcunyah Group to the west.

The Throssell Group consists of the basal siliciclastic Coolbro Sandstone and conformably overlying carbonaceous Broadhurst Formation.

Coolbro Sandstone (#Tc, #Tcp, #Tcc)

The Coolbro Sandstone (*#Tc;* Williams et al., 1976) is a fine- to coarse-grained sandstone. It forms prominent outcrops and weathers to a grey-brown to orange-brown colour. The formation is well exposed in the Throssell Range and headwaters of the Coolbro Creek (Fig. 1). The formation is massive to well bedded, with individual beds ranging between 0.5 and 2.5 m thick. The bedding surfaces are sometimes difficult to distinguish from strong S_4 foliation surfaces in areas of tight to overturned folds. In the upper parts of the formation, the sandstone becomes finer grained and is interbedded with some siltstone lenses. These units, which appear to be a transition into the conformably overlying Broadhurst Formation, are marked by convolute and slump bedding.

It is difficult to estimate the thickness of the Coolbro Sandstone on THROSSELL due to the complex folding, but Hickman and Clarke (1994) suggest a maximum thickness of between 3000–4000 m for the sandstone on BROADHURST, adjacent to the eastern boundary of THROSSELL. The thickness decreases rapidly to the south, where, in the Three Sisters Hills area (AMG 935125), it is less than 30 m thick.

Trough and planar cross-beds are common throughout the sandstone. Palaeocurrent directions are consistently towards the north and northeast, away from exposed Rudall Complex, which seems to have been the basement high and the source of the Coolbro Sandstone epiclastic material.

Petrographically, the sandstones are meta-arenites with flattened or recrystallized quartz grains and the initial intergranular clay material has been replaced by sericite. Tourmaline is a common accessory mineral. This dynamic metamorphism is indicative of greenschist-facies conditions.

The base of the Coolbro Sandstone, which is only exposed in the southeast corner of THROSSELL, is marked by discontinuous, lenticular, polymictic, matrix- and clast-supported conglomerate units (*#Tcp*). The clasts are generally well rounded, with size ranging from pebbles to boulders over 0.5 m in size. Clasts include gneiss, various granitoids, chert, quartzite, vein quartz, and schist; all are lithologies found in the underlying Rudall Complex. Such conglomerates are probably channel fills.

Oligomictic, matrix-supported quartz-pebble conglomerate (*#Tcc*) is found in the cores of two large anticlinal structures; one trending north-northwesterly from Yandagooge Gap (AMG 902228), the other a north-trending structure 10 km southwest of Moses Chair (AMG 870550). The quartz-pebble conglomerate is interbedded with coarse-grained and pebbly sandstones. These conglomerates are interpreted as braided-stream deposits. The lithology and sedimentary structures of the Coolbro Sandstone are consistent with a fluvial–deltaic depositional environment.

Broadhurst Formation (#Tb, #Tbs, #Tbq, #Tba)

The Broadhurst Formation (*#Tb*; Williams et al., 1976) consists of two topographically distinct components: firstly, a non-exposed to very poorly exposed metamorphosed carbonaceous and sulfidic shale and siltstone unit (*#Tbs*) and, secondly, well-exposed, metamorphosed interbedded sandstone, siltstone, shale, and minor carbonate units (*#Tbq* and *#Tba*). The former underlies sand-covered plains and broad valleys, whilst the latter is exposed in dissected plateaus and strike ridges. Metamorphosed carbonaceous and sulfidic shale and siltstone (*#Tbs*) have been intersected in mineral exploration boreholes in sandplain west of Moses Chair (AMG 957607) and in valley floors west of the Coolbro Sandstone plateau, which contains the headwaters of the Coolbro Creek (e.g. AMG 813443). The metamorphosed interbedded sandstone, siltstone, shale, and carbonate unit (*#Tba*) is found in the central and southeastern parts of THROSSELL. These northward-thinning units form parallel ridges (containing complex folds) stretching 45 km north-northwesterly from Three Sisters Hills (AMG 920139). These siliciclastic, carbonaceous-poor units appear to intertongue with the carbonaceous-rich shale and siltstone unit (*#Tbs*). It should be noted that both sandstone units

(#Tbq and *#Tba)* were mapped together as the Choorun Formation on the 1st edition RUDALL 1:250 000 sheet (Chin et al., 1980).

The complex folds, evident in the Broadhurst Formation on THROSSELL, make it difficult to estimate the formation thickness. Although estimates of around 2000 m have been obtained from adjacent BROADHURST (Hickman and Clarke, 1994), the thick siliciclastic units *(#Tbq* and *#Tba)* found in the formation in the central parts of THROSSELL suggest a total thickness greater than 2000 m.

The poorly outcropping carbonaceous-rich unit *(#Tbs)* consists mainly of red-brown weathering or grey, black, and blue-black, metamorphosed carbonaceous shale and siltstone. These are interbedded with minor micaceous siltstone and thin-bedded, grey-white, fine-grained sandstone. Limonite–goethite after euhedral pyrite, and gossanous zones *(go)* after disseminated sulfide, have been found in outcrop. Fresh pyrite crystals and fine-grained disseminated sulfide (pyrite–pyrrhotite) have been intersected in exploration drillholes. Trace-element analyses of iron-rich and gossanous samples collected from the Broadhurst Formation are given in Appendix 3. On BROADHURST, the Broadhurst Formation is characterized by a strong magnetic signature. This feature is less obvious on THROSSELL, where magnetic anomalies are smaller, more specific, and confined to the northeastern quadrant. Strong dynamic metamorphism in the Three Sisters Hills area (AMG 920130) altered the metamorphosed shale and siltstone to quartz–sericite–chlorite schist and graphitic schist.

The metamorphosed sandstone, siltstone, and shale unit *(#Tbq)* is conformably enclosed within the metamorphosed shale and siltstone unit *(#Tbs)* described above. The unit is dominantly white, grey, tan, brown, and reddish-brown, fine- to medium-grained sandstone and siltstone. These are interbedded with minor micaceous siltstone, coarse-grained sandstone, red, cream, and grey-weathering shale, and rare pebble conglomerate. Cross-bedding is common in the sandstone, with the palaeocurrent direction being predominantly from the southwest. Graded bedding is rare. Scattered pyrite crystals up to 1 cm size, some filling joints and fractures, are common in a faulted, domal structure (AMG 742365) 16.5 km west-southwest of Tabletop gold prospect (AMG 894423). The metamorphosed sandstone, siltstone, and shale unit *(#Tbq)* can be found in well-defined strike ridges and, in places, underlies small plateaus. The configuration of the strike ridges outlines numerous complex fold structures in the area that stretches north-northwest of the Three Sisters Hills (AMG 920139).

The metamorphosed sandstone, siltstone, shale, and carbonate unit *(#Tba)* consists of equal proportions of fine- to coarse-grained, red-brown, brown, and white-grey sandstone; red, purple, grey, and greenish siltstone; and red, purple, and grey-blue shale. This unit forms parallel ridges west of the siliciclastic (*#Tbq*) exposures. The two units are separated by metamorphosed carbonaceous shale and siltstone *(#Tbs)*. Minor pebble conglomerate and grey-blue micritic and oolitic carbonate are also present. Possible biogenic lamination has been observed in some carbonate beds. Cross-bedding and some graded bedding are present in the sandstones, and upward-fining sequences are evident in repetitive sandstone, siltstone, and shale successions.

The Broadhurst Formation appears to have been deposited in a fault-controlled basin (Hickman et al., 1994) regarded as a starved basin with euxinic conditions. In the southwest, the basin was periodically penetrated by coarser siliciclastic material deposited under higher energy conditions, most likely representing shallow-marine extensions of nearby deltaic deposition.

Lamil Group *(#L)*

It is postulated, from the adjoining BROADHURST sheet (Hickman and Clarke, 1994), that rocks belonging to the Lamil Group (Bagas, in prep.) underlie the northeast corner of THROSSELL. Although not exposed in this area, the Lamil Group is probably represented by carbonate and pelitic rocks of the Isdell Formation (Williams et al., 1976; Hickman and Clarke, 1994), the basal formation of the Lamil Group. On THROSSELL, the relationship between the Lamil Group and underlying Throssell Group remains unclear; it is discordant on BROADHURST (Hickman and Clarke, 1994).

Officer Basin*

Recent reappraisals (Bagas et al., 1995; Perincek, 1996; Bagas et al., 1999) have supported earlier tentative proposals that the Savory Basin (Williams, 1992, 1994) was a continuation of the Officer Basin (Iasky, 1990). The extension of the Officer Basin northwestwards to include the area previously mapped as Savory Basin was made possible by the redefining and separation of the Officer Basin into two stacked basins (Hocking et al., 1994). The term Officer Basin was retained for the Neoproterozoic and Cambrian rocks that are part of the Centralian Superbasin (Walter et al., 1995), whilst the overlying cover rocks, now dated as Lower Ordovician (Table Hill Volcanics; Stevens and Apak, 1999) and younger, are assigned to the Gunbarrell Basin.

The newly enlarged Officer Basin also includes the Tarcunyah Group, which is tectonically still part of the Paterson Orogen.

Tarcunyah Group *(#U)*

The Tarcunyah Group (Appendix 2) occupies most of the southwest half of THROSSELL. The group unconformably overlies the Rudall Complex on the adjoining POISONBUSH sheet (Williams and Bagas, in prep.). The Tarcunyah Group is separated from the older Throssell Group by the Vines Fault (Williams and Trendall, 1998b) on the northern margin of the sheet, and by the northwesterly trending Southwest Thrust for the remainder of THROSSELL. In the southwest corner and on the southern margin, it is

* This replaces the Savory Basin on the accompanying THROSSELL 1:100 000 map sheet

unconformably overlain by, or is in faulted contact with, outliers of the Neoproterozoic Tchukardine Formation of the Disappointment Group* (Bagas et al., 1999).

The Tarcunyah Group comprises seven formations: the basal Choorun and Googhenama Formations, and the overlying Waroongunyah Formation, Brownrigg Sandstone, and Yandanunyah, Wongarlong, and Nooloo Formations.

Choorun Formation (#Uh)

The Choorun Formation (Williams et al., 1976) has been redefined and restricted to coarse- and medium-grained siliciclastic rocks. These rocks lie along the eastern margin of the Tarcunyah Group outcrop and unconformably overlie the Rudall Complex (Williams and Bagas, in prep.). The formation is conformably overlain by the Nooloo Formation. The relationship of the Choorun Formation to the other formations of the Tarcunyah Group beneath the Nooloo Formation on the western side of THROSSELL and in the northeast corner of BALFOUR DOWNS (1:250 000; Williams, 1989) is unclear.

On THROSSELL, most of the Choorun Formation is found in a area of jumbled hills, informally known as the ‘Tarcunyah dome’, centred around AMG 600430 and lying about 18 km southwest of the Throssell Range. In this area, the formation is fault bounded, with the eastern margin corresponding to the Southwest Thrust, a dextral transpressional fault that has thrusted Broadhurst Formation of the Throssell Group against the Choorun Formation. A small outcrop of coarse-grained sandstone assigned to the Choorun Formation is exposed on the southern margin of THROSSELL, 2.5 km south-southwest of Three Sisters Hills (at AMG 904115).

The Choorun Formation comprises distinctively pinkish-red to red-brown, medium- to coarse-grained sandstone interbedded with minor pebbly sandstone and conglomerate. Siliceous nodules are characteristic of the sandstones. The formation is at least 1800 m thick (Williams and Bagas, in prep.). The Choorun Formation, unlike the nearby siliciclastic Coolbro Sandstone of the Throssell Group, lacks a penetrative foliation.

Cross-beds are common and some are over 1 m thick. Palaeocurrent directions are generally from the south and southwest, and the sandstone appears to be fluvial.

Googhenama Formation (#Ug, #Ugc)

Scattered outcrops of the Googhenama Formation (Williams, 1990b) extend northwards from 2 km north of the Yeneena Creek termination (AMG 523253) to the northwest corner of THROSSELL. The outcrops are commonly fold closures. They form an en echelon set of northwest-plunging folds that are bounded to the east by a large normal fault (or lag fault) and to the west by a steep reverse fault.

* This is shown as Savory Group on the accompanying THROSSELL 1:100 000 sheet

The formation consists of brown to dark red-brown, fine- to coarse-grained sandstone, pebbly sandstone, pebble to large-cobble conglomerate, and minor purple siltstone *(#Ug)*. The coarse-grained sandstone is more common than the fine-grained varieties. The conglomerate is generally polymictic and matrix supported, with clasts composed of white vein quartz, quartzite, and banded and multicoloured cherts. The formation is around 300–400 m thick on THROSSELL.

Thin-bedded, blue, purple, violet, pink, and grey micritic carbonate rocks *(#Ugc)* with scattered blue chert pods and interbedded red siltstone and fine-grained sandstone are found low in the succession.

Some conglomerates show graded bedding and many sandstone units are cross-bedded. The palaeocurrent directions, derived from the cross-bedding, indicate currents from the northwest around to the southwest, away from the Pilbara Craton, which lies to the west of THROSSELL.

Waroongunyah Formation (#Uw)

On the adjoining BALFOUR DOWNS 1:250 000 sheet, the Waroongunyah Formation (Williams, 1989) conformably overlies the Googhenama Formation. However, on THROSSELL, it is separated from the Googhenama Formation by a steep reverse splay fault off the Marloo Fault, which lies to the west (Fig. 4). Scattered outcrops of the Waroongunyah Formation lie along the western margin of THROSSELL, between AMG 470266 and AMG 455444. Scattered silicified outcrops are also found in broad, sandy valleys occupied by tributaries of the Yeneena Creek in the southwest corner of THROSSELL. The formation is about 600 m thick along the western margin.

The Waroongunyah Formation contains a distinctive assemblage of brown, grey, blue, and pink, massive to laminated dolomite, stromatolitic dolomite, oolitic dolomite, and sandy dolomite, interbedded with pink to grey-white siltstone and shale, and minor brown, fine-grained sandstone. Scattered halite casts have been identified in the fine-grained sandstone. The oolitic dolomite, which is common in the Yeneena Creek area (AMG 535162), is generally strongly silicified.

The stromatolitic dolomite has been identified at several localities along the western margin of THROSSELL (for example, at AMG 455398, AMG 459375, AMG 458379, AMG 495114, and AMG 465333). The Waroongunyah Formation in this area occupies the eastern limb of a tight, elongate, north-trending basin, the western side of which lies in the adjoining BALFOUR DOWNS 1:250 000 sheet area. The formation contains stromatolites on both sides of the basin (Williams, 1989; Grey, 1984); they are associated with the brown dolomite, in which they are present in more than one horizon. Small columnar forms, some inclined and some branched, appear to grow from a common base. These bioherms are similar to stromatolites found on BALFOUR DOWNS (1:250 000; Grey, 1984) and on RUNTON (1:250 000; Grey, 1978). The stromatolitic dolomites on BALFOUR DOWNS (1:250 000) were previously assigned to the Isdell Formation (Williams, 1989). Domed stromatolitic

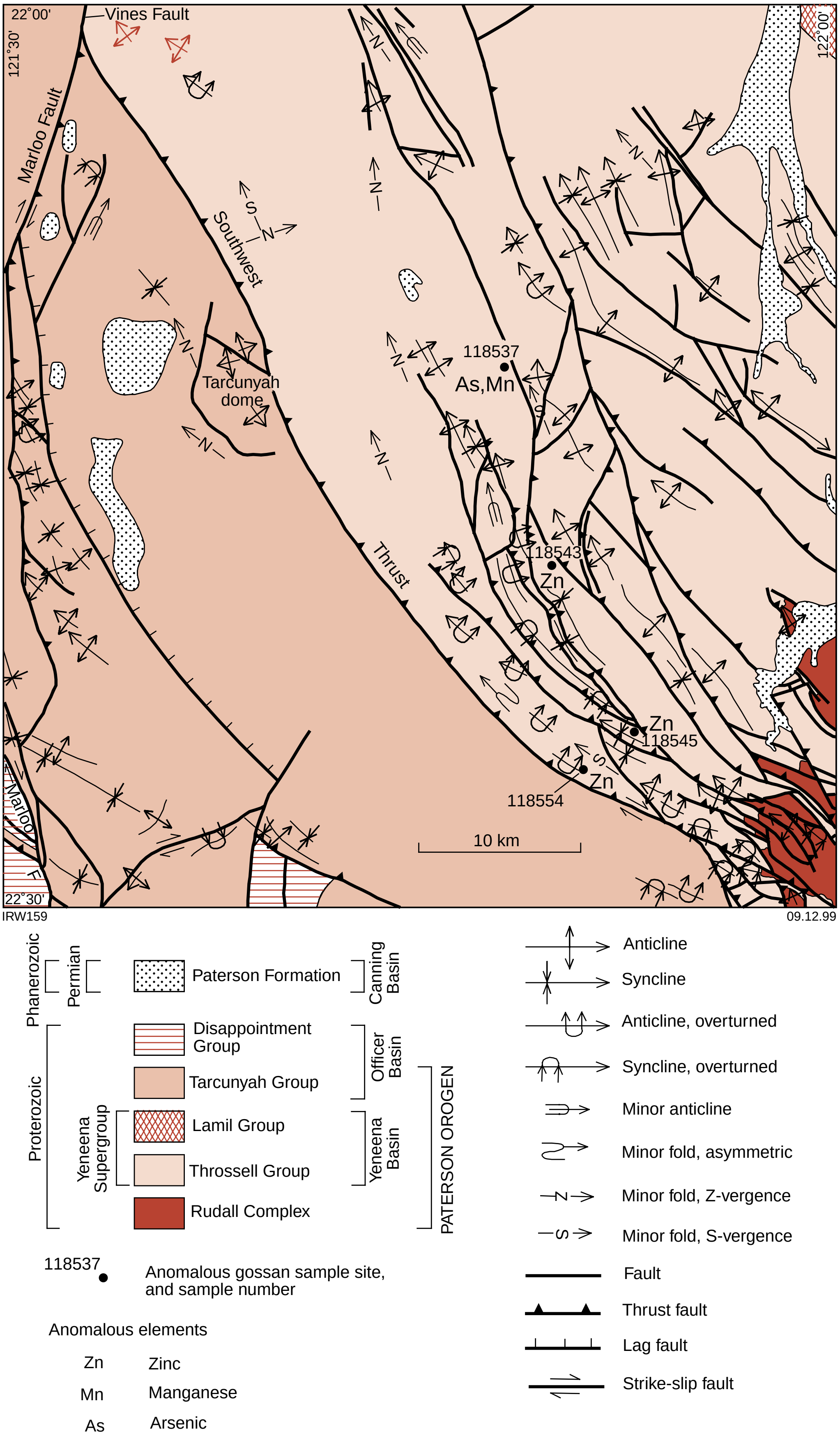

Figure 4. Structural sketch map of THROSSELL. See Appendix 3 for gossan sample-analyses data

bioherms have also been found in the formation in the southwest corner of THROSSELL around AMG 495113.

The Waroongunyah Formation is a transgressive shallow-marine sequence that was probably deposited shorewards of carbonate build-ups, which may have been barrier islands or carbonate platforms marginal to the Pilbara Craton.

Brownrigg Sandstone (#Ur)

The Brownrigg Sandstone (Williams, 1989) is exposed in a north-plunging structural basin, 7.5 km northwest of the termination of Yeneena Creek (AMG 463257) and in a series of domes and basins in the Yeneena Creek drainage in the southwest corner of THROSSELL.

The formation, which is at least 600 m thick, is characterized by a uniform succession of white-, cream-, and brown-weathering, medium- to fine-grained quartz sandstone. The formation is well bedded with flaggy and massive units. Cross-beds up to 2–3 m thick, symmetrical ripple marks, and current striae are common. Palaeocurrent direction, derived from cross-beds, is generally from the southwest and west. The formation is probably a shallow-marine shelf deposit.

Yandanunyah Formation (#Uy)

The Yandanunyah Formation (Williams, 1989) occupies a small area on the western margin of THROSSELL, around AMG 458293. Here, silicified shale, dolomite — some showing poor stromatolite forms — and calcareous shale occupy the core of a north-trending basin. The carbonate unit is generally capped by a siliceous breccia (*Czx*).

A continuous band of Yandanunyah Formation parallels the northeasterly trending divide between the Yeneena and Tarcunyah creeks (AMG 516130 to AMG 590188) in the southwest corner of THROSSELL. The formation lies conformably between the Brownrigg Sandstone and the overlying Wongarlong Formation. In this area, the formation comprises about 300 m of interbedded purple, red, yellow, and white siltstone and shale with minor silicified blue-white oolitic and laminated carbonates. The oolitic rocks are similar to those found in the Waroongunyah Formation, suggesting a similar environment of deposition.

Wongarlong Formation (#Uo, #Uoh, #Uov)

The main exposure of the newly defined Wongarlong Formation (Appendix 2) conformably overlies the Yandanunyah Formation in the Tarcunyah Creek area along the southern margin of THROSSELL, centred around AMG 570140. Farther west, a faulted slice of Wongarlong Formation has been upthrusted against the Tchukardine Formation in the headwaters of Yeneena Creek (AMG 470145). In previous work, much of the Wongarlong Formation had been mapped as Choorun Formation (Chin et al. 1980; Williams, 1989).

On THROSSELL, the Wongarlong Formation (*#Uo*) is well exposed in a series of strike ridges in which the ridges consist of light-brown to dark red-brown, medium- to fine-grained sandstone and distinctive white to grey orthoquartzite. The orthoquartzite contains scattered brown oxidation spots and brown, bladed or needle-like gypsum casts. The valleys between the ridges are underlain by purple-, red-, and grey-green-laminated and micaceous siltstone and purple-, red-, and white-weathering shale and silty shale. The siltstone–shale unit (*#Uoh*) is thicker in the higher parts of the formation. The formation is at least 1200 m thick.

Some alternating sandstone and siltstone–shale units form upward-coarsening successions. Other sandstones, immediately overlying the siltstone–shale units, contain siltstone and shale intraclasts. Cross-bedding is common in the lower parts of the sandstone units. This is replaced in the upper parts by ripple marks. This suggests waning currents after the earlier high-energy conditions for the cross-bedded units.

In a small structural basin on the southern margin of THROSSELL (AMG 529121), the Wongarlong Formation includes a small area of deeply weathered, fine-grained mafic rock, that could be either basalt or fine-grained dolerite (*#Uov*). The rock is now mottled brown-grey to white clay, broken up by pillow-like structures that strongly resemble subaqueous, pillowed basalt. The interstices between the pillow-like structures are filled with dark blue-green chlorite. Fragments of the underlying sandstone are caught up and recrystallized within the base of the mafic material. Since the overlying material has been removed by later erosion, it is not clear whether the mafic material is intrusive, as suggested by the basal features, or extrusive, as indicated by the pillow-like forms of the weathered material.

The Wongarlong Formation appears to be a shallow-marine shelf deposit characterized by the repetitive, upward-coarsening cycles that are up to 30 m thick.

Nooloo Formation (#Un, #Unh, #Uns)

The poorly outcropping, newly defined Nooloo Formation (Appendix 2) underlies a broad zone that stretches from low hills lying 5 km west-southwestwards from the Three Sisters Hills, on the southern margin (AMG 865125), to low ridges lying 18 km west of the Throssell Range, in the northwest quadrant of THROSSELL (AMG 520570). The formation is bordered by faults to the southwest, northwest, and northeast. On the adjoining POISONBUSH sheet (Williams and Bagas, in prep.), the Nooloo Formation appears to conformably overlie the Wongarlong and Choorun Formations.

Red- to purple-weathering siltstone and shale (*#Unh*) conformably overlie the Choorun Formation on the northern margin of POISONBUSH (Williams and Bagas, in prep.). In the central part of THROSSELL, similar pelitic units are faulted against the Choorun Formation. The bulk of the formation (*#Un*) consists of blue, grey, pink, violet, and brown, thin-bedded dolomite and limestone, and calcareous shale and siltstone. Carbonate-cemented sandstone with a cellular-weathering pattern overlies the dolomite west of the Three Sisters Hills. Calcite veining and calcite-filled or lined cavities have been observed in the dolomites west of the Throssell Range. Stromatolites and biogenic activity in general appear to be absent from these dolomites. The dolomites are interbedded with a range of thin-bedded, red-brown to brown, fine- to coarse-grained sandstone, siltstone, and shale. Where the dolomite is absent, interbedded sandstone, siltstone, shale, pebbly conglomerate, and wacke (*#Uns*) prevail. Shale and siltstone are sometimes strongly silicified and resemble chert in the field, and blue chert pods lie in the bedding planes of some dolomites. Cross-beds and symmetrical (wave) ripple marks are prominent in some of the interbedded sandstones, and the cross-beds suggest that the palaeocurrent direction is generally to the northeast. The Nooloo Formation is a deep-water shelf deposit.

Disappointment Group

The newly named Disappointment Group (Bagas et al., 1999) covers the McFadden, Woora Woora, and Tchukardine Formations, the youngest formations of the now-superseded Savory Group. The Disappointment Group was deposited in the Wells Foreland Basin (Williams, 1992), which was recently renamed the Wells Sub-basin (Bagas et al., 1999). These rocks unconformably overlie the glacigenic Boondawari Formation (Williams, 1992, 1994). The Tchukardine Formation is the northernmost formation of the Disappointment Group and the only formation of the group that is exposed on THROSSELL.

Tchukardine Formation (#St)

The Tchukardine Formation (Williams, 1992) is well exposed in the southwest corner of THROSSELL, and in small scattered outcrops surrounded by sand along the southern margin, east of Tarcunyah Creek.

Most of the Tchukardine Formation consists of red-brown to brown-weathering, medium-grained sandstone with lesser fine- and coarse-grained varieties. The formation is estimated to be over 700 m thick (Williams, 1992). Large cross-beds, up to 10 m thick, are characteristic of the formation, and some cross-beds have asymptotic profiles indicative of a high-energy flow regime.

The base of the Tchukardine Formation is exposed in the headwaters of the Yeneena Creek around AMG 468151. It consists of a basal matrix-supported conglomerate, 0.5 to 1 m thick, resting unconformably on the Wongarlong Formation of the Tarcunyah Group. The clasts seem to be locally derived from the underlying sandstone. The conglomerate is overlain by medium-grained silicified sandstone, which, in turn, is overlain by distinctive chocolate-coloured shale and siltstone. The shale hosts widely spaced pebbles and cobbles and superficially resembles the glacigenic diamictite of the Boondawari Formation (Williams, 1992). 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).

Unassigned quartz veins, quartz–hematite veins, and gossan (*q, qh, go*)

White quartz veins (*q*), up to 4 km long, occupy many major fault zones cutting the Coolbro Sandstone and Broadhurst Formation of the Throssell Group. They also fill tension gashes oblique to the large faults, the configuration of which indicate both sinistral and dextral strike-slip movements along such faults. In contrast, apart from the Choorun Formation adjacent to the Southwest Thrust, quartz veins are absent from the younger Tarcunyah Group rocks and overlying Tchukardine Formation. The white 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 several movement episodes along pre-existing fault lines. In an area 13 km south-southeasterly of the Throssell Range (AMG 774418), several parallel quartz–hematite veins (*qh*), striking around 080°, cut pyrite-bearing, medium-grained sandstone belonging to the Coolbro Sandstone. Such quartz veins, when broken, yield scattered, fresh grains of specular hematite. Nearby, a gossanous zone (*go*) of goethite, probably after iron sulfide, parallels the quartz–hematite veins. The gossanous zone also carries drusy-quartz veinlets.

Other goethite–quartz gossanous zones were located in a shear zone in Coolbro Sandstone just west (AMG 680619) of the Throssell Range; in several parallel shear zones in fine-grained sandstone of the Broadhurst Formation, 2 km west (AMG 685581) of the Throssell Range; and from a laterite-capped hill overlying Broadhurst formation, 10 km east (AMG 855600). Trace-element analyses of some of these gossans is given in Appendix 3.

Structure

THROSSELL lies within the Paterson Orogen (Williams and Myers, 1990), a northwest-trending belt of deformed sedimentary and metasedimentary and meta-igneous rocks that include the Palaeoproterozoic Rudall Complex, the unconformably overlying Mesoproterozoic to Neoproterozoic Throssell and Lamil Groups of the Yeneena Supergroup, and the Neoproterozoic Tarcunyah Group. 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 (1998), and Hickman and Bagas (1998). The structural evolution of the orogen on THROSSELL is discussed within the general framework outlined by Hickman and Clarke (1994), who recognized six phases of deformation on the adjacent BROADHURST sheet. The main structural elements are presented in Figure 4.

The Rudall Complex is the product of a number of depositional, intrusive, tectonic, and metamorphic events. The complex was intensely deformed and metamorphosed during the Yapungku Orogeny, an event which comprises D_1 and D_2, and, on present geochronological evidence, took place between c. 2000 and 1760 Ma (Bagas et al., 1995; Hickman and Bagas, 1998). All major rock units of the Rudall Complex were affected by D_2 deformation between 1790 and 1760 Ma (Bagas and Smithies, 1998).

The Yapungku Orogeny appears to be related to plate collision, which involved progressive stacking of thrust sheets, and emplacement of granitoids now represented by augen orthogneiss (*#Rga*). The effects of this orogeny are difficult to analyse due to later intensive D_4 and D_6 refolding, faulting, and block rotation. The effects of D_1 can only be recognized in the hinge zones of D_2 folds where S_1 is cross-cut by the S_2 foliation, which is parallel to F_2 axial surfaces.

The Miles Orogeny (D_{3-4}; Bagas et al., 1995; Bagas and Smithies, 1998) is a deformation event observed in both the Rudall Complex and Yeneena Supergroup. D_3 thrusts, recumbent fold axes, and associated axial-planar cleavage are not well developed on THROSSELL. The D_3 fabrics are crenulated, cleaved, and faulted by D_4. The D_4 deformation produced large folds that trend between 300 and 345°, thrusts and steep reverse faults with a component of either dextral or sinistral strike-slip transport, 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 Group. The effects of M_4 are lacking in the Tarcunyah Group in the southwestern half of THROSSELL. D_3 and D_4 represent southwesterly directed compression and are interpreted as sequential events during the Miles Orogeny. Many structures formed during the Miles Orogeny were reactivated by later D_6 deformation events.

In the southwest corner of THROSSELL, northeast-trending folds with southeast-dipping axial planes affect the Tarcunyah Group. These folds are interpreted to belong to the Blake Movement (D_5), a fault and fold event connected with basin inversion along the northwestern margin of the Officer Basin. This area was previously referred to as the Savory Basin (Williams, 1992, 1994).

The Paterson Orogeny, as redefined by Bagas and Smithies (1998), is the D_6 event that post-dates the glacigenic Boondawari Formation of the former Savory Basin (Williams, 1992), now Officer Basin, and is a correlative of the Petermann Orogeny (Myers, 1990b; Bagas et al., 1995). This deformation event produced shears and faults that have marked lateral and vertical movement, as well as tight to open, north-westerly to west-northwesterly trending folds. These structures can be seen in exposures both east and west of the Southwest Thrust. Many of the large faults observed in northeastern THROSSELL appear to be earlier structures that have been reactivated several times during the geological history of the area. They are classified as D_6 structures because they now truncate or off-set earlier structures.

Both D_{3-4} and D_6 structures indicate major compression from the northeast. Myers et al. (1996) proposed that the Miles Orogeny coincided with the assembly of Australian cratons as part of Rodinia, whilst the Paterson Orogeny was the product of intracratonic deformation during the breakup of Rodinia.

Yapungku Orogeny (D_{1-2})

The Rudall Complex was deformed and metamorphosed during the Yapungku Orogeny (D_{1-2}) before deposition of the Throssell, Lamil, and Tarcunyah Groups. Metasedimentary rocks were deformed by the first episode of deformation, D_1, before 1790 Ma and before the emplacement of the K-feldspar augen orthogneiss (*#Rga)* protolith (Bagas and Smithies, 1998). Rocks within the complex were then deformed during D_2 and metamorphosed during M_2, producing a pervasive micaceous schistosity (S_2) parallel to the axial planes of F_2 isoclines (Bagas and Smithies, 1998).

No large-scale D_1 structures have been identified within THROSSELL. Penetrative S_1 foliation is parallel to compositional banding in the paragneiss units (*#Rb)* in the northern end of the Clayton Domain (Hickman and Bagas, 1998). Here, the S_1 foliation is deformed by isoclinal F_2 folds, and, away from the F_2 hinge zones, cannot be distinguished from S_2.

On THROSSELL, BROADHURST (Clarke, 1991), and RUDALL (1:100 000; Hickman and Bagas, 1998), the existence of a layer-parallel penetrative schistosity (S_1), folded by D_2 folds and, in places, crenulated by a cross-cutting S_2, suggests the presence of at least one phase of regional deformation prior to D_2. The observation that S_1 is parallel to compositional layering in the paragneiss units suggests that it may have formed axial-planar to large-scale isoclinal recumbent folds (Hickman and Bagas, 1998).

Hickman and Clarke (1994) established that D_2 produced tight to isoclinal folds, and a regional schistosity (S_2) in all major rock units of the Rudall Complex. S_2 has been rotated by later F_4 folds and is now generally steeply inclined, principally towards the northeast or southwest. Large-scale and tectonically disrupted isoclinal F_2 folds can be found in the paragneiss (*#Rb*) and orthogneiss (*#Rga*) of the Rudall Complex. These structures are parallel to the large F_4 folds in the Throssell Group immediately to the west. A stretching lineation (L_2) observed in the Clayton Domain plunges between 15 and 40° towards the north to northeast. 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 to become parallel with the F_4 folds during progressive shearing during D_4. This is supported by the intensity of F_4 faulting that has disrupted both the Rudall Complex and Throssell Group in the area. The complex D_2 structures of the Rudall Complex are discussed in detail by Hickman and Clarke (1994), Hickman and Bagas (1998), and Bagas and Smithies (1998). Mapping on RUDALL (1:100 000; Hickman and Bagas, 1998) has indicated that the D_2 event included magmatic emplacement of peridotite sheets parallel to S_2, apparently partly controlled by D_2 shear zones. The distribution of ultramafic rocks on THROSSELL is largely restricted to D_2 faults that have been folded and reactivated during D_4.

Miles Orogeny (D_{3-4})

Although D_3 structures have been described in detail on the adjacent BROADHURST sheet (Hickman and Clarke, 1994), the identification of such structures in the Throssell Group is not as clear-cut on THROSSELL. Small recumbent folds, with shallow easterly dipping axial planes, in banded silicified metasiltstone and phyllite of the Broadhurst Formation 15 km northwest (AMG 837267) of the Three Sisters Hills are possible candidates for D_3 structures. The recumbent folds are intersected by an upright crenulation cleavage trending about 290°.

Major D_4 structures are represented by regional-scale F_4 folds. The trends of the fold axes swing from 300° in the south to 345° in the north of THROSSELL. Fold profiles are generally tight to isoclinal, and are inclined or overturned to the southwest. The folds are accompanied by a strong axial-planar foliation (cleavage) that generally dips steeply northeast. The fold axes plunge moderately (about 30°) to the northwest, away from the folded unconformity with the Rudall Complex, which lies in the southeast corner of THROSSELL. In the Coolbro Sandstone, most large-scale folds are anticlines. These are commonly parallel to large faults with both down-dip and strike-slip movements. Steep reverse faults commonly lie to the southwest of the major anticlinal fold axes. This has produced a series of stacked anticlinal structures, where the intervening synclines are either truncated or missing. Such fold axes are well-spaced within the competent Coolbro Sandstone, with distances between anticlinal axes ranging from 1 to 6 km. However, the intensity of folding and faulting increases rapidly to the southwest towards the Southwest Thrust (Fig. 4), in the region corresponding to the overlying, less-competent Broadhurst Formation. For example, the siliciclastic unit (*#Tbq*) of the Broadhurst Formation is intensely isoclinally folded in the area 28 km northwest of the Three Sister Hills (AMG 770370). In this area, as many as 20 fold axes per kilometre are present. Both anticlinal and synclinal axes are preserved. The Southwest Thrust, which marks the boundary between the older Throssell Group and younger Tarcunyah Group, is postulated to be a sole thrust (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. These structures are described in more detail in the section **Paterson Orogeny**.

The D_4 deformation is accompanied by prograde greenschist-facies regional metamorphism (M_4) in the Throssell and Lamil Groups.

Blake Movement (D_5)

Several northeasterly trending, open to tight fold axes have been mapped in unmetamorphosed Tarcunyah Group west of the Southwest Thrust. These are also found in the Choorun Formation in the central parts of THROSSELL (AMG 595450) and in the Brownrigg Sandstone and Yandanunyah and Wongarlong Formations in the area marking the drainage divide between the Yeneena and Tarcunyah creeks (AMG 590159) in the southwest corner of THROSSELL. At this latter locality a tight overturned syncline indicates compression to the northwest. This fold episode is assigned to D_5.

Since the Tarcunyah Group is now correlated with rocks of Supersequence 1 of the Centralian Superbasin, and is also postulated to be the northwest extension of the Officer Basin (Bagas et al., 1995; Bagas and Smithies, 1998; Bagas et al., 1999), it seems appropriate to correlate these northeasterly trending structures with the northeasterly trending Blake Fault and Fold Belt, which lies 60 km to the southwest along strike. (Williams, 1992, 1994). This post-800 Ma deformation event, which is recorded along the northwest margin of the Officer Basin (previously called the Savory Basin; Williams, 1992) in the newly named Sunbeam Group (Bagas et al., 1999; previously called Savory Group; Bagas et al., 1995), is connected with basin inversion and northwesterly–southeasterly directed compression (Williams, 1992, 1994). Bagas and Smithies (1998) also recorded open, northeasterly trending folds cutting the Throssell Group rocks in the southern parts of CONNAUGHTON. These folds, which refold S_4 cleavage and F_4 fold axes, were tentatively assigned to D_5.

Paterson Orogeny (D_6)

Tight to open, sometimes en echelon, folds in the unmetamorphosed Tarcunyah Group, which trend 290° in the south and swing to 345° in the north, are assigned to the Paterson Orogeny (D_6). These folds lack the strong penetrative foliation (S_4) that is found in the Throssell Group. Many of the folds are flexural-slip in origin, although a weak axial-planar cleavage is evident in some tight folds. The intersection of the northwest-trending D_6 folds with the northeast-trending D_5 folds has produced several elongate domes and basins in the southwest corner of THROSSELL. Tight, overturned (to the southwest) F_6 folds that plunge 20° towards 300° in unmetamorphosed sandstone, siltstone, and carbonate of the Nooloo Formation, 5 km west of the Three Sisters Hills (at AMG 860125), parallel west-southwesterly trending en echelon F_6 folds that lie on the northeastern side of the Southwest Thrust. These latter folds lie in the interbedded metasandstone, graphitic metasiltstone, and quartz–sericite–chlorite schist unit (*#Tba*) of the Broadhurst Formation. The rocks contain a strong foliation (S_4), which is refolded by the west-northwesterly en echelon F_6 folds that plunge 25° towards 300°. The quartz–sericite–chlorite schist contains quartz eyes that show a sinistral sense of movement with top over to the southwest, the main transport direction of the thrust system in this area. The tightly folded rocks in the Broadhurst Formation that plunge consistently to the northwest are probably F_6 folds (see **Miles Orogeny**).

The Southwest Thrust, in the southeast corner of THROSSELL, is probably a reactivated D_4 thrust with a dextral transpressional movement (D_6); it links with the dextral transpressional Vines Fault (Williams and Trendall, 1998b), just south of the northern boundary of THROSSELL (AMG 504653). Many of the northwesterly and west-northwesterly striking faults may be D_4 faults reactivated during the Paterson Orogeny (D_6). The overall arcuate form of the major faults on THROSSELL reflect the impingement of the North Australian Craton with the Pilbara Craton. These faults mark the area where the northwest-trending Paterson Orogen swings more north-northwesterly along the contact with the Pilbara Craton.

The Tchukardine Formation was deposited in the Wells Sub-basin (Bagas et al., 1999). This happened during the final stages of the Paterson Orogeny, as shown by stepped microfaults with steep reverse movement towards the southwest and vertical displacements measured in centimetres. These small faults are commonly intersected by anastomosing kink bands, which sometimes have vertical displacements of up to 1 cm along the axial plane. These are oblique to the microfaults and may form congruent sets (Williams, 1992).

In the headwaters of the Yeneena Creek, around AMG 478140, a steep reverse fault that has thrust Wongarlong Formation over Tchukardine Formation is, in turn, cut by the later dextral transpressional Marloo Fault.

Palaeozoic rocks

Permian rocks

The distribution of Lower Permian sedimentary rocks is shown in Figure 1. These deposits are confined to glacial valleys incised into the underlying Proterozoic basement. Glacial striae, grooves, and chattermarks are preserved on the eroded Proterozoic sandstone surface. These indicate that ice movement was northwards, toward the Canning Basin. The Permian succession belongs to the fluvio-glacial Paterson Formation.

Paterson Formation (Pa)

Remnants of the Paterson Formation (Traves et al., 1956; Towner and Gibson, 1983) are found along the eastern margin of THROSSELL in the headwaters of Yandagooge Creek (AMG 930240) and in several parallel, north trending palaeovalleys crossing the east-flowing Coolbro Creek in the vicinity of Duck Pool (AMG 943483). Several small exposures lie south of the Throssell Range, onlapping the Proterozoic rocks. Disconnected low, rubbly outcrop and boulder-strewn eluvium (*Qt*) trace out a palaeovalley in the western half of THROSSELL. This palaeovalley roughly parallels the present-day Tarcunyah Creek.

The basal unit of the Paterson Formation consists of pebble- to boulder-bearing diamictite. This is probably a tillite, as it rests directly on the polished Proterozoic sandstone basement. Boulders, set in the clay matrix, are up to 2 m in size and comprise mainly quartz sandstone and quartzite. Many boulders and cobbles are polished, faceted, and striated. The diamictite is overlain by interbedded, cross-bedded, medium- to coarse-grained sandstone, and siltstone and mudstone. The upper surface of the Paterson Formation is commonly silicified. The Paterson Formation belongs to depositional Sequence Pz5 (Middleton, 1990). Recent correlation with equivalent rocks in the Carnarvon Basin has placed the Paterson Formation in the Asselian – lower Sakmarian age (Mory and Backhouse, 1997).

Cainozoic deposits

Cainozoic deposits cover over 60% of THROSSELL and are widespread in the lower-central, central, northwestern, and northern margins of the sheet. Superficial material includes consolidated residual and colluvial deposits, together with Quaternary eolian, colluvial, and alluvial deposits, and minor lacustrine and eluvial deposits.

Dissected, and partly silicified, valley calcrete (*Czk*; Butt et al., 1977) is patchily exposed along the floor of the large Tarcunyah Palaeodrainage Basin, which contains the ephemeral Tarcunyah Creek (Fig. 1). A major tributary that joins this palaeodrainage from the west, 6 km west of the Throssell Range (AMG 640615), also contains scattered outcrops of calcrete. The calcrete is massive or nodular, sometimes vuggy, grey-white limestone. There is generally a minor surface silicification of chalcedonic and opaline silica.

Small areas of dissected consolidated colluvium (*Czc*) are found overlying the Rudall Complex, and in the floors of glacial palaeovalleys where the Permian Paterson Formation has been removed. The unit is dissected by present-day drainage, although the colluvium unit (*Czc*) is not directly related to this system. The consolidated colluvium consists of silica- and iron-cemented silt, sand, and gravel, and is sometimes crudely bedded.

Many of the Proterozoic sandstones have thin, silicified caprock on the upper surfaces. Silcrete deposits (*Czz*) consisting of brown to grey, silica-cemented, angular quartz grains are restricted to the Yandanungah Formation in tributaries of the Yeneena Creek (AMG 532155). A distinctive siliceous chert breccia (*Czx*) overlies weathered dolomite of the Yandanunyah Formation on the western margin of THROSSELL (AMG 455320).

Massive to pisolitic laterite and ferruginous duricrust (*Czl*) are widely scattered on THROSSELL, although individual exposures are generally small. Low ridges of massive to pisolitic laterite overlie the Nooloo Formation west of the informally named ‘Tarcunyah dome’ (AMG 550443). The plateau regions overlying the Coolbro Sandstone in the headwaters of the Coolbro and Yandagooge creeks are capped by laterite. Low mounds of laterite are also found overlying the Broadhurst Formation in the broad valley areas.

Quaternary deposits

The topography and prevailing southeasterly winds broadly subdivide the Quaternary units on THROSSELL into three groups. Dune-frequent eolian deposits favour the windward or easterly and southeasterly sides of the rocky hills, plateaus, and strike ridges. In contrast, the lee or westerly and northwesterly sides of the hills host a mixture of alluvial, colluvial, and sheetwash deposits that grade into dune-free and pebble-lag sandplain. Alluvial and lacustrine deposits occupy ephemeral and palaeodrainage lines.

The alluvial unit (*Qa*) consists of unconsolidated sand, silt, and gravel. The unit is confined to the main drainage lines and adjacent floodplains, which are all ephemeral on THROSSELL. Gravels tend to be confined to active channels within the dissected plateau and rocky hill areas. Elsewhere, the alluvium tends to be sandy, which probably includes a considerable input of wind-blown sand. The continuation of channels into the sandplains suggests periods of rapid run-off.

Lacustrine deposits (*Ql*) are not common on THROSSELL. Most lie along a tributary in the Tarcunyah Drainage Basin, 11 km northwest of Tarcunyah dome (AMG 530510). The claypans are brackish. Low interdunal areas with internal drainage also carry some claypans that are generally fresh. Large individual claypans consist of a clay, silt, or silty sand surface, sometimes with a scattered small-pebble veneer.

The mixed claypan and dune unit (*Qd*) is more widespread than the laustrine deposits (*Ql*). The unit consists of numerous small claypans separated by small, sand–silt dunes. These are commonly lunette dunes derived from the claypan surface. Although the unit lies in defined drainage lines, it can also be found with the sheetwash deposits (*Qw*). Large areas of the mixed claypan and dune unit lie 15 km south and 14 km southwest of Throssell Range (around AMG 720410 and AMG 580540 respectively). Such areas frequently lie adjacent to low outcrop and the claypans commonly have scattered pebbles on the clay surface.

Red-brown, fine- to medium-grained eolian sand (*Qs*) comprising iron-stained quartz grains is widespread on THROSSELL. The eolian sand occupies broad sandplains on the western (lee) sides of hills and plateaus from where it is blown westwards to form dune fields that partly bury the eastern sides of adjacent hills and plateaus. The dune fields consist primarily of longitudinal (seif) and chain dunes, with some net dunes appearing in depressions in the southwest corner of THROSSELL. In some areas, the sandplain is covered by a fine veneer of ironstone and quartz pebbles (*Qp*).

Recent colluvium (*Qc*) in the form of scree and talus is found in narrow valleys in the southwest corner, and adjacent to rocky outcrops in the east-central parts of THROSSELL. The colluvial unit (*Qc*) commonly lies adjacent to large sheetwash areas (*Qw*). This unit is particularly widespread northwest of Yandagooge Gap (AMG 902230) and west of low strike ridges of Broadhurst Formation. The sheetwash areas have a distinctive banded vegetation pattern sometimes referred to as ‘tiger bush’ pattern (Wakelin-King, 1999).

Patchy areas of scattered boulders, cobbles, and pebbles on, and embedded in, clay, silt, and sand (*Qt*) trace out a Permian glacial valley west of Tarcunyah dome. Similar eluvial deposits lie near Duck Pool (AMG 944483) on Coolbro Creek.

Economic geology

THROSSELL is located in the Marble Bar District of the Pilbara Mineral Field. There has been no mineral production from the area and, due to the remoteness, little interest was shown in the area before the early 1970s. This interest was stimulated by discoveries outside the THROSSELL sheet area, and started with the discovery of gold in 1971 on PATERSON to the northeast (Trywhitt, 1995) at what is now the Telfer mine.

In 1977, the southeast corner of THROSSELL (about 24% by area) was assigned to the Rudall River National Park (Fig. 1). Special attention to the exploration methods employed in this area is now required.

The discovery of stratabound copper, lead, and zinc mineralization in metamorphosed shale and siltstone of the Broadhurst formation at Nifty (LAMIL) and Maroochydore (BROADHURST) in 1984 saw an immediate flurry of exploration activity directed towards the Broadhurst Formation on THROSSELL. Similarly, the discovery of uranium at Kintyre (BROADHURST) in 1985 saw exploration activity focused on the Rudall Complex and basal Coolbro Sandstone in the southeast quadrant of THROSSELL. The search for sedimentary-hosted base metal deposits, mainly copper, was extended to the Tarcunyah Group in the early 1990s, particularly along the western margin of THROSSELL. Sparse visible gold was extracted from gravels in the headwaters of Coolbro Creek, at Tabletop prospect (AMG 894423). The gold is thought to come from northwesterly trending quartz veins that cut the Coolbro Sandstone in this region (Schiller, 1980).

Extensive rock-chip, soil, auger, stream sediment, and lag sampling by many exploration companies has identified a few prospective areas on THROSSELL. Follow-up RC, RAB, hammer, and diamond drilling have, to date, failed to locate extensive mineralization.

A total of 30 gossan and gossanous quartz samples were collected during field mapping. These have been analysed for 32 elements (Appendix 3).

Exploration-company data covering THROSSELL, submitted to the GSWA since 1975, are held in the WAMEX open-file system at the GSWA library. This information is summarized in Appendix 1. Anomalous gossan-sample sites are shown on Figure 4.

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Appendix 1

Company data on WAMEX open file for THROSSELL

WAMEX Item number [(a)]	*Duration*	*Title*	*Company*
458	1975–1975	Curran Curran gold exploration	Broken Hill Company
974	1977–1978	Three Sisters copper, lead, zinc exploration	CRA Exploration
1694	1978–1981	Paterson Province uranium, copper, lead, zinc exploration	Occidental Minerals Corporation
8551	1979–1996	Yandagooge diamond, uranium, base metal, gold, PGE exploration	CRA Exploration
1361	1980–1981	Tabletop Hill gold exploration	CRA Exploration
2046	1980–1981	Rudall River area uranium, nickel, copper exploration	Geopeko, Mobil Energy Minerals Australia
2610	1981–1983	Balfour Downs copper, uranium exploration	Oilmin, Petromin, Transoil
2779	1981–1983	Watrara – May Creek uranium exploration	Aquitaine Australia Minerals
3234	1983–1986	Rudall River copper, lead, zinc exploration	Esso Exploration Australia
3419	1983–1987	Rudall River base metal, uranium, diamond exploration	CRA Exploration
4239	1984–1990	Stuarts Call – First Day Range copper, lead, zinc exploration	City Resources, Esso Exploration Australia
6091	1984–1992	Three Sisters gold, base metal, uranium exploration	Duval Mining Australia, PNC Exploration Australia, Queensland Mines
3494	1985–1986	Tchukardine Pool copper, lead, zinc exploration	BHP Minerals
6270	1986–1992	Rudall uranium, base metal, gold exploration	CRA Exploration
7632	1987–1994	Paterson Province gold, uranium, base metal exploration	Idemitsu Minerals Australia, Uranerz Australia
7761	1987–1994	Paterson Joint Venture gold, uranium, copper, lead, zinc exploration	Idemitsu Minerals Australia, Normandy Exploration, Uranerz Australia
7676	1988–1994	Yandagooge gold, uranium, base metal exploration	Uranerz Australia, UAL
9110	1988–1996	Paterson base metal exploration	Normandy Exploration
6637	1989–1992	Tarcunyah gold, uranium, base metal exploration	Idemitsu Minerals Australia
7758	1991–1994	Throssell Range diamond, base metal, gold exploration	City Resources, Murchison United
8718	1991–1996	Throssell Range base metal exploration	Murchison United
7879	1992–1994	Throssell Plain base metal, gold exploration	CRA Exploration
8529	1992–1995	Gregory Range gold, base metal exploration	CRA Exploration, Newcrest Mining
9585	1992–1997	Vines copper, base metal exploration	MIM Exploration
8936	1993–1995	Euro base metal exploration	Pancontinental Gold Operations, RGC Exploration
9174	1995–1996	Throssell Range copper exploration	Murchison United
9650	1996–1997	Gregory Pool gold, base metal exploration	BHP Minerals

NOTE: (a) WAMEX Item numbers refer to the open-file statutory mineral exploration reports held in the WAMEX (Western Australian Mineral Exploration) database at the Department of Minerals and Energy library, Western Australia

Appendix 2

Definitions of new and revised stratigraphic names

Stratigraphic name	*Derivation of name*	*Type area*	*Distribution, thickness, and lithology*	*Relationships and age*	*Remarks*
Yeneena Supergroup	Yeneena Creek AMG 490162	–	Distributed across THROSSELL, BROADHURST, PATERSON, and LAMIL; scattered exposures on ISABELLA, BRAESIDE, PEARANA, POISONBUSH, RUDALL (1:100 000), CONNAUGHTON, GUNANYA, and BLANCHE–CRONIN. Maximum thickness about 1200 m. Sandstone, siltstone, shale, conglomerate, carbonaceous shale, and dolomite; metamorphosed	Comprises older Throssell and younger Lamil Groups; contact relationships unclear; unconformable on Rudall Complex. Tectonic contact (Vines Fault, Southwest Thrust) with younger Tarcunyah Group in the west; unconformable beneath Tarcunyah Group in the south. Poor age constraints: <1300 to >850 Ma	Originally Yeneena Group (Williams et al., 1976; Chin et al., 1980); later divided into Western, Central, and Northeastern zones (Williams, 1990b). Yeneena Supergroup now roughly covers the Central and Northeastern zones
Throssell Group	Throssell Range AMG 700640	–	Distributed across THROSSELL, BROADHURST, and LAMIL, scattered exposures on ISABELLA, BRAESIDE, PEARANA, POISONBUSH, RUDALL (1:100 000), CONNAUGHTON, GUNANYA, and BLANCHE–CRONIN. Maximum thickness around 5500 m. Sandstone, conglomerate, siltstone, shale, carbonaceous shale, and minor carbonate; metamorphosed	Comprises basal Coolbro Sandstone and conformably overlying Broadhurst Formation; unconformably overlies Rudall Complex; relationship to overlying Lamil Group unclear. Tectonic contact (Vines Fault, Southwest Thrust) with younger Tarcunyah Group in the west, unconformable beneath Tarcunyah Group in the south. Poor age constraints: <1300 to c. 1100 Ma	Roughly corresponds to Central zone of the Yeneena Basin (Williams, 1990b)
Tarcunyah Group	Tarcunyah Creek AMG 620179	–	Distributed across THROSSELL scattered exposures; on WARRAWAGINE, ISABELLA, BRAESIDE, PEARANA, WOBLEGUN, POISONBUSH, RUDALL, (1:100 000) CONNAUGHTON, GUNANYA, and BLANCHE–CRONIN. Maximum thickness around 4300 m. Sandstone, conglomerate, siltstone, shale, dolomite, and stromatolitic dolomite	Comprises basal Googhenama and Choorun Formations and conformably overlying Waroongunyah Formation, Brownrigg Sandstone, and Yandanunyah, Wongarlong, and Nooloo Formations. Unconformably overlies the Throssell Group; unconformably overlain by the Tchukardine Formation of the Disappointment Group (previously Savory Group). Poor age constraints: <830 to c. 600 Ma	Roughly corresponds to zone of the Yeneena Basin (Williams, 1990b). Correlated with Supersequence 1 of the Centralian Superbasin; is a northwest extension of Officer Basin (Bagas et al., 1995; Bagas et al., 1999)
Wongarlong Formation	Wongarlong Rockhole AMG 388370 (WOBLEGUN)	a. Wongarlong Rockhole area b. West of Tarcunyah Creek, section from AMG 548130 to AMG 594129	Exposed on WOBLEGUN, THROSSELL, and POISONBUSH. Maximum thickness around 1200 m. Sandstone, orthoquartzite, and minor siltstone and shale (*#uo*); silty shale, shale, and siltstone (*#uoh*); altered pillowed mafic lava (*#uov*)	Conformably overlies Yandanunyah Formation; relationship to overlying Nooloo Formation unclear due to non-exposure; unconformably overlain by Tchukardine Formation. Poor age constraints: <840 Ma	Previously mapped as Choorun Formation on BALFOUR DOWNS (1:250 000; Williams, 1989) and western side of RUDALL (1:250 000; Chin et al., 1980)
Nooloo Formation	Nooloo Soak AMG 869985 (POISONBUSH)	a. AMG 880120 for *#uns*, *#unh*, *#un* b. AMG 520570 for *#un*	Exposed on THROSSELL and POISONBUSH. Top of formation missing; at least 1000 m thick. Thin-bedded dolomite, limestone, and interbedded sandstone, and siltstone (*#un*); interbedded sandstone, siltstone, wacke, and pebbly sandstone (*#uns*); shale and siltstone (*#unh*)	Conformably overlies Choorun Formation; relationship to Wongarlong Formation not exposed. A correlative of Waters Formation (Hickman and Bagas, 1998). Poor age constraints: <830 Ma	Previously mapped as Isdell Formation on BALFOUR DOWNS (1:250 000; Williams, 1989) and western side of RUDALL (1:250 000; Chin et al., 1980)

Appendix 3

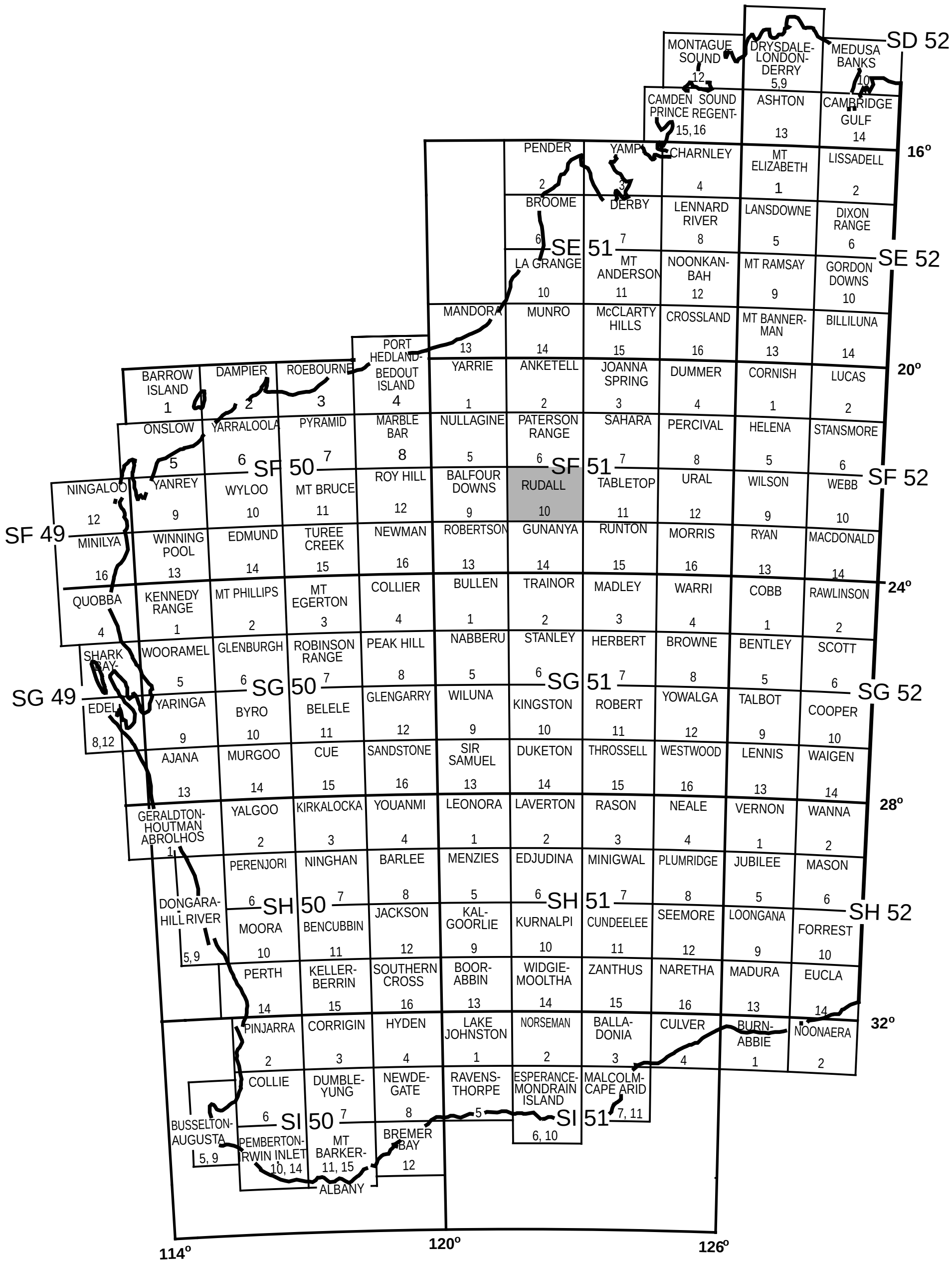
Analytical data for iron-rich and gossanous samples from THROSSELL

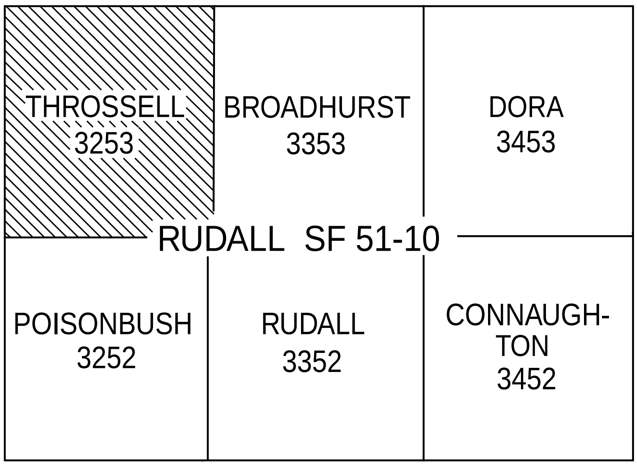
GSWA sample number *Location (AMG)*	*118532* *681620*	*118533* *686584*	*118534* *839567*	*118535* *834560*	*118536* *814433*	*118537* *778446*	*118538* *765426*	*118539* *775418*	*118540* *785410*	*119541* *770379*	*118542* *788392*	*118543* *799325*	*118544* *808316*	*118545* *848225*	*118546* *711483*
Fe_2O_3(%)	55.8	64.9	69.4	66.1	69.4	31.4	60.7	43.3	68.3	62.7	67.0	52.2	59.8	72.0	75.7
Ag	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Au (ppb)	7	4	2	2	2	4	3	5	4	<2	<2	2	<2	<2	5
As	66	48	16	96	31	[a]2 660	16	330	90	101	95	144	83	14	284
Ba	856	674	213	190	241	7 960	352	700	460	416	421	285	177	448	5 350
Bi	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Cd	<5	6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ce	26	749	38	47	12	47	24	443	23	<6	16	33	37	27	9
Cr	36	5	16	19	20	<4	23	95	15	29	22	37	21	8	<4
Co	10	24	19	39	22	282	4	<4	48	17	30	17	14	371	46
Cu	110	153	23	127	51	41	13	315	716	138	260	242	205	70	117
Ga	6	<3	3	4	4	<3	5	3	<3	5	3	9	6	<3	<3
Ge	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
La	22	148	25	30	12	28	12	762	27	5	15	23	28	19	4
Mn	69	324	49	534	25	[a]129 000	330	92	1 410	79	1 600	159	140	4 410	267
Mo	<2	<2	<2	<2	<2	<2	<2	2	<2	2	<2	2	2	<2	2
Nb	8	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7
Ni	46	99	24	195	57	196	31	2	181	36	29	134	90	383	21
Pb	23	154	11	674	6	6	<4	318	42	25	11	99	11	20	62
Rb	33	2	22	21	22	31	38	4	18	28	17	58	41	15	<2
Sb	<4	<4	<4	<4	<4	<4	<4	4	<4	10	<4	<4	<4	<4	11
Sn	4	<4	<4	5	<4	4	11	<4	7	10	5	8	4	<4	<4
Sr	34	64	3	12	1	581	3	127	8	17	13	3	9	13	92
Ta	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Te	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	9
Th	8	4	6	3	3	6	7	<2	4	14	6	7	7	4	4
U	8	11	<2	3	3	5	2	4	12	3	8	14	3	2	6
V	276	16	36	45	42	53	43	24	27	74	59	53	45	17	188
W	7	11	<4	14	4	17	<4	<4	12	<4	5	12	6	29	<4
Y	17	19	13	12	24	16	10	9	14	8	10	32	25	97	2
Zn	120	185	872	318	299	285	383	16	486	223	180	[a]1 140	804	[a]2 430	49
Zr	97	61	71	46	32	93	87	23	50	42	68	76	46	38	14

Appendix 3 (continued)

GSWA sample number *Location (AMG)*	*118547* *723448*	*118548* *725404*	*118549* *731374*	*118550* *744367*	*118551* *789329*	*118552* *775280*	*118553* *830207*	*118554* *820200*	*118555* *678441*	*119556* *683610*	*118557* *621597*	*118558* *572540*	*118559* *474386*	*116281* *856502*	*116282* *856601*
Fe_2O_3(%)	70.8	46.6	52.9	13.5	55.1	66.3	65.0	75.6	94.3	39.3	30.4	68.4	33.5	44.9	66.8
Ag	<2	<2	<2	<2	<2	<2	<2	2	<2	2	<2	2	2	<2	10
Au (ppb)	2	<2	2	13	<2	4	2	2	3	4	3	2	3	7	13
As	19	18	112	28	17	130	52	24	427	4	18	123	11	18	78
Ba	200	247	1 050	2 400	568	143	167	60	40	1 370	1 070	1 620	91	638	323
Bi	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	6	<4
Cd	<5	6	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ce	28	31	60	<6	26	90	27	43	7	22	31	35	12	263	45
Cr	15	31	19	25	31	20	21	13	5	18	73	8	23	44	32
Co	23	<4	12	<4	20	44	45	70	34	<4	<4	28	26	6	71
Cu	19	66	88	12	161	59	18	39	11	69	33	29	29	177	61
Ga	3	6	4	<3	6	4	5	<3	<3	<3	3	<3	<3	8	3
Ge	<3	<3	<3	<3	<3	<3	<3	<3	50	4	<3	3	<3	<3	<3
La	20	22	40	4	24	73	27	31	4	14	20	19	17	180	34
Mn	137	52	330	<4	50	239	556	2 240	49	61	94	10 900	2 160	280	610
Mo	<2	<2	<2	<2	<2	<2	<2	<2	14	2	3	4	<2	2	2
Nb	<7	8	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7
Ni	61	42	66	5	106	142	132	156	6	42	20	10	35	60	194
Pb	49	11	187	24	12	22	7	14	6	72	24	22	<4	7	<4
Rb	14	73	32	6	50	23	25	<2	<2	<2	2	3	19	77	20
Sb	9	<4	<4	15	<4	<4	<4	<4	6	<4	<4	<4	<4	<4	<4
Sn	<4	10	6	<4	5	6	11	<4	<4	<4	<4	9	16	10	10
Sr	49	18	27	23	19	160	25	28	17	207	111	33	14	85	8
Ta	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Te	<6	<6	<6	<6	<6	<6	<6	<6	6	7	<6	<6	<6	<6	<6
Th	2	8	5	6	9	5	5	<2	<2	<2	3	<2	4	16	9
U	3	4	4	<2	5	6	<2	3	7	<2	3	<2	2	16	7
V	99	65	40	20	48	139	41	19	22	34	369	40	79	76	37
W	10	6	8	<4	12	12	10	12	<4	6	5	<4	4	6	15
Y	20	19	24	5	65	25	12	20	10	36	6	28	10	35	22
Zn	187	417	440	3	879	924	626	(a)1 590	21	83	28	46	21	174	421
Zr	37	106	44	72	71	45	54	11	<5	17	14	38	57	71	63

NOTES: Trace elements in parts per million unless otherwise specified
Localities are specified by the Australian Map Grid (AMG) standard six-figure reference whereby the first group of three figures (eastings) and the second group (northings) together uniquely define position, on this sheet, to within 100 m
(a) Major anomaly





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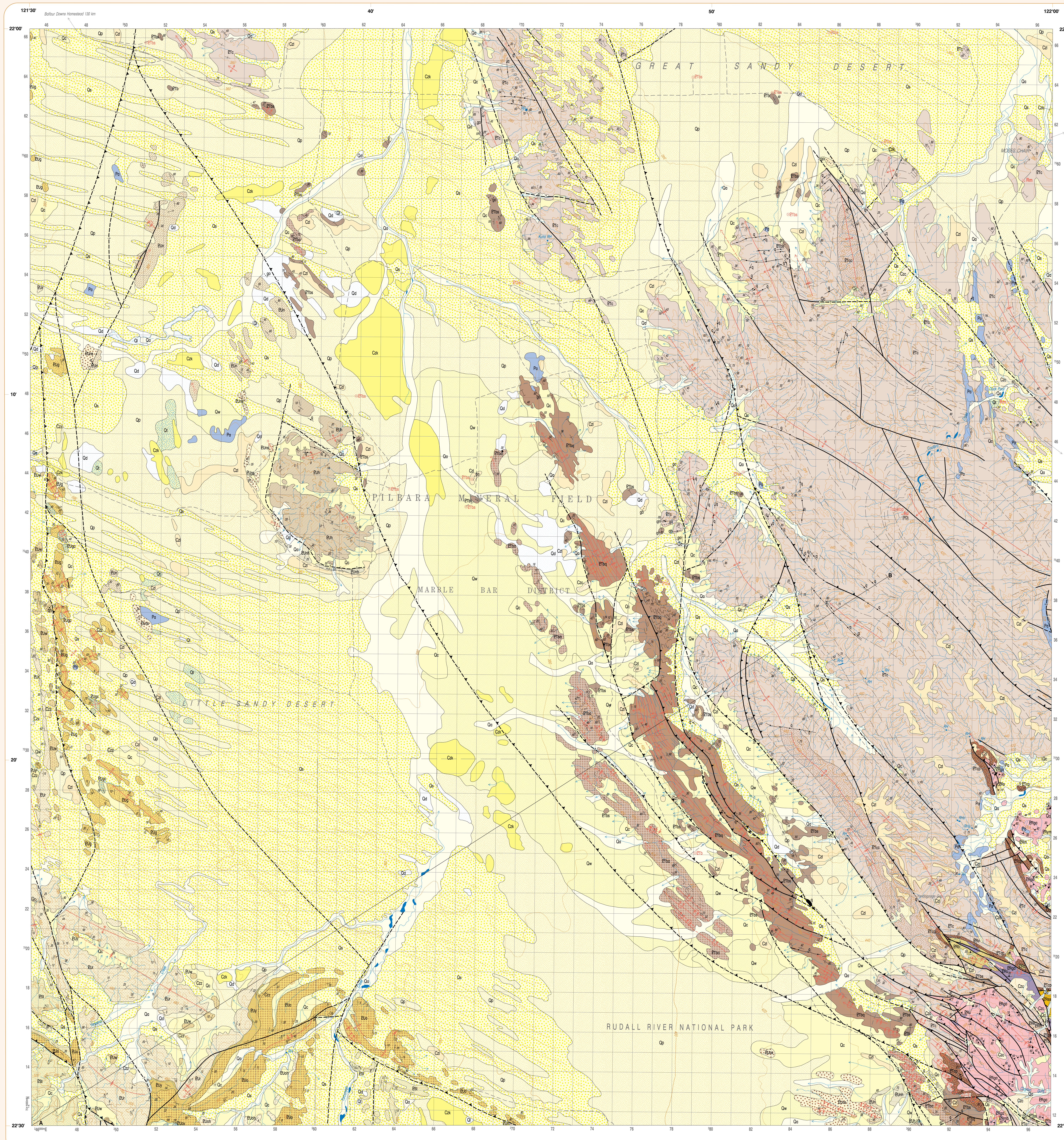
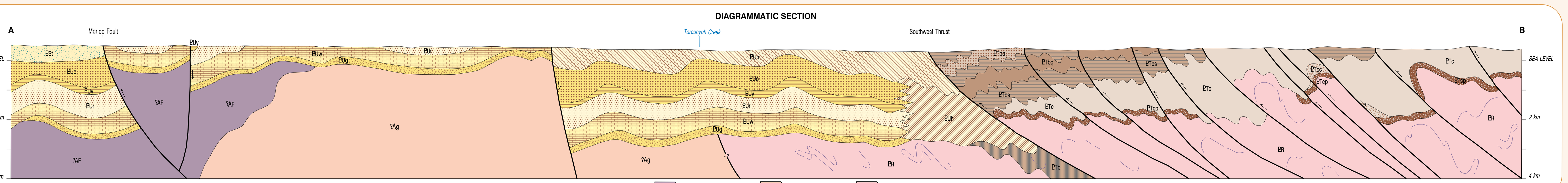
25.11.99

THROSSELL

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTION



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa Ql Qd Qs Qp Qc Qw Qt

- Qa Alluvium — unconsolidated silt, sand, and gravel; in drainage channels and on adjacent floodplains
- Ql Lacustrine deposits — clay, silt, and silty sand; playa (saline) and claypan (fresh) deposits
- Qd Mixed lacustrine and eolian deposits — clay, silt and sand; vegetated swamps, numerous small claypans with fringing lunette dunes
- Qs Eolian deposits — sand, in sheets and longitudinal (seif), chain and net dunes
- Qp Eolian sand with ironstone pebble, rock fragment, and quartz pebble veneer; in sheets and between dunes
- Qc Colluvium — quartz pebble and rock fragment veneer on sand, silty sand; adjacent to or over shallow bedrock; scree, talus
- Qw Colluvium and alluvium — silt, sand, and gravel on low slopes and sheetwash areas
- Qt Eluvium — scattered boulders, cobbles, and pebbles on clay, silt, and sand; lag deposit derived from weathered fluvioglacial PATERSON FORMATION

Czk Czc Czz Czx Czl

- Czk Calcrete — massive, nodular, and vuggy limestone, some surface silicification; in palaeodrainage lines
- Czc Colluvium — consolidated silt, sand, gravel; fluviatile, dissected by active channels
- Czz Silcrete and siliceous duricrust
- Czx Chert breccia developed over dolomite; overlies YANDANUNYAH FORMATION
- Czl Massive and pisolitic laterite, and ferruginous duricrust

PERMIAN

Pa **PATERSON FORMATION:** fine- to coarse-grained sandstone, siltstone and mudstone, some with dropstones; diamictite; fluvioglacial deposits — CANNING BASIN

PROTEROZOIC

- q Quartz veins and pods; various ages
- qh Quartz-hematite vein
- go Gossan, zone of gossanous rock

<610 Ma — Savory Group — SAVORY BASIN

ⱣSt **TCHUKARDINE FORMATION:** medium- to coarse-grained sandstone, quartz wacke, siltstone, shale; minor conglomerate

c. 800 Ma — Tarcunyah Group

- ⱣUn **NOOLOO FORMATION:** thin-bedded to massive dolomite and limestone; minor thin-bedded, fine- to coarse-grained sandstone and siltstone
- ⱣUns Interbedded fine- to coarse-grained sandstone, pebbly sandstone, wacke, and siltstone
- ⱣUnh Red to purple weathering shale and siltstone
- ⱣUov Altered pillowed mafic lava
- ⱣUo **WONGARLONG FORMATION:** fine- to coarse-grained sandstone and orthoquartzite; minor siltstone and shale
- ⱣUoh Siltstone, silty shale, and shale
- ⱣUy **YANDANUNYAH FORMATION:** laminated to thin-bedded dolomite; interbedded with minor stromatolitic dolomite, dolomitic siltstone, shale, and siltstone
- ⱣUr **BROWNRIGG SANDSTONE:** white to grey, fine- to medium-grained quartz sandstone and medium- to coarse-grained sandstone with scattered pebbles
- 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
- ⱣUgc Laminated to thin-bedded dolomite, dolomitic siltstone, and thin-bedded blue chert
- ⱣUh **CHOORUN FORMATION:** red-brown, medium- to coarse-grained sandstone, pebbly sandstone, quartz wacke, nodule-bearing sandstone, polymictic pebble to cobble conglomerate and quartz pebble conglomerate

>900 Ma — Yeneena Supergroup — Throssell Group — Yeneena Basin — PATERSON OROGEN

- ⱣTb **BROADHURST FORMATION:** grey shale, carbonaceous shale, siltstone, and fine-grained sandstone
- ⱣTbs Grey carbonaceous shale and siltstone, sulfidic in part; graphitic schist, quartz-sericite schist, and phyllite in the Three Sisters Hills area
- ⱣTba Interbedded fine- to coarse-grained sandstone, siltstone, silty shale, dolomite, and stromatolitic dolomite
- ⱣTbq Interbedded fine- to medium-grained sandstone, siltstone and minor shale; scattered pyrite in places
- ⱣTc **COOLBRO SANDSTONE:** massive to thick-bedded sandstone; minor siltstone and shale
- ⱣTcc Quartz pebble and cobble conglomerate interbedded with coarse-grained sandstone with scattered pebbles
- ⱣTcp Basal polymictic conglomerate; pebble to boulder clasts, matrix supported

Rudall Complex

1765-1790 Ma

- ⱣRga Orthogneiss derived from porphyritic biotite granitoid; generally contains augen of K-feldspar
- ⱣRu Metamorphosed ultramafic rock; mainly serpentinite
- ⱣRym **YANDAGOOGE FORMATION** Quartz-muscovite schist; minor chert

c. 2000 Ma

- ⱣRm Muscovite schist; metamorphosed argillaceous sedimentary rock
- ⱣRmb Quartz-muscovite-biotite schist; metamorphosed siltstone
- ⱣRb Banded paragneiss with interlayered quartzite, quartz-feldspar gneiss, quartz-muscovite schist, biotite schist, and para-amphibolite; metamorphosed sandstone, siltstones, and shale
- ⱣRk Calc-silicate gneiss and schist; metamorphosed carbonate rock and calcareous arenite
- ⱣRs Psammitic paragneiss; includes fine-grained quartz-feldspar-muscovite gneiss, quartz-muscovite schist, and quartzite layers
- ⱣRss Psammitic paragneiss; rare units of pelitic schist

Geological boundary
- exposed

Fault
- exposed
- concealed
- concealed, position uncertain
- reverse or thrust
- lag
- strike-slip fault showing relative horizontal displacement

Fold, showing trend and plunge direction
- anticline, concealed
- syncline, concealed
- overturned anticline, concealed
- overturned syncline, concealed

Minor fold, showing trend and plunge direction
- minor anticline
- minor syncline
- asymmetric
- minor fold, showing nature of vergence (Z, M, or S profile)

Bedding, showing strike and dip
- inclined
- vertical
- overturned
- trend from aerial photography

Glacial striae
- direction of movement

Direction of movement of sediment-bearing current
- from cross-bedding

Way-up indicator
- graded bedding
- cross-bedding
- stromatolite growth direction

Metamorphic foliation, showing strike and dip
- inclined

Strongly foliated rock

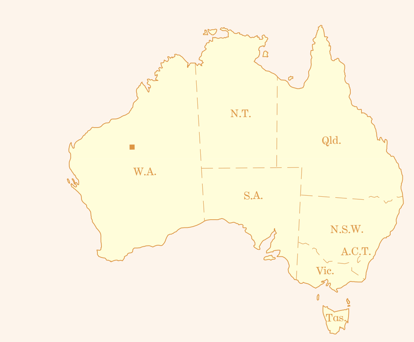
Cleavage, showing strike and dip
- inclined
- vertical
- axis of crenulation with plunge

Mineral lineation, showing trend and plunge direction
- inclined

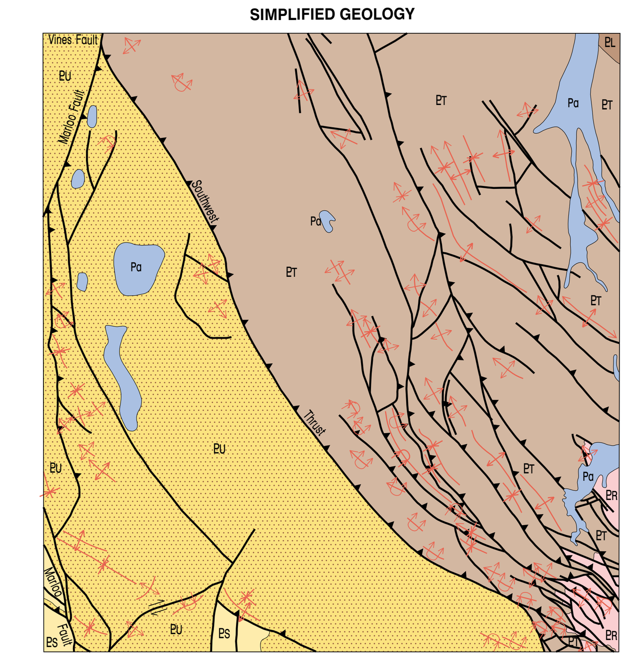
Stromatolite locality

Major track (maintained)
Track
Locality — Yandagooge Gap
National Park boundary
Breakaway
Sand dune
Contour line, 20 metre interval — 440
Watercourse, ephemeral
Pool — P
Earth tank — T
Rockhole, waterhole — RH WH
Position doubtful — (PD)

Quarry
Mineral exploration drillhole, showing subsurface data — ⱣTbs
Mineral occurrence
Gold — Au
Road materials — Rm



SIMPLIFIED GEOLOGY



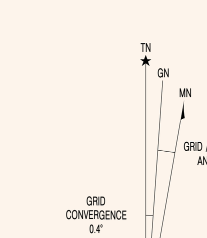
SCALE 1:500 000
0 5 10 15 20
Kilometres

Phanerozoic	Permian	Pa	Paterson Formation	CANNING BASIN
Proterozoic		ⱣS	Savory Group	SAVORY BASIN
		ⱣU	Tarcunyah Group	PATERSON OROGEN
	Yeneena Supergroup	ⱣL	Lamil Group	Yeneena Basin
	Yeneena Supergroup	ⱣT	Throssell Group	Yeneena Basin
		ⱣR	Rudall Complex	

MOUNT EDGAR 2955	YILGALONG 3055	BRAESIDE 3155	WAUKARLYCARLY 3255	COOLYU 3355	CUTTACUTTA 3455
NULLAGINE 2954	EASTERN CREEK 3054	PEARANA 3154	LAMIL 3254	PATERSON 3354	TERRINGA 3454
NOREENA DOWNS 2953	MOUNT COOKE 3053	WOBLEGUN 3153	THROSSELL 3253	BROADHURST 3353	DORA 3453
ETHEL CREEK 2952	BALFOUR DOWNS 3052	TALAWANA 3152	POISONBUSH 3252	RUDALL 3352	CONNAUGHTON 3452

NULLAGINE SF 51-5 — PATERSON RANGE SF 51-6 — BALFOUR DOWNS SF 51-9 — RUDALL SF 51-10

1:100 000 maps shown in black
1:250 000 maps shown in brown



True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1994 and moves easterly by about 0.1° in 8 years.

DEPARTMENT OF MINERALS AND ENERGY
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K.R. PERRY, DIRECTOR GENERAL

PIETRO GUJ
DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

SCALE 1:100 000
1000 0 1 2 3 4 5 6 7 8 9 10
Metres — Kilometres
TRANSVERSE MERCATOR PROJECTION
Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 51

Geology by I. R. Williams 1992-4, L. Bagas 1993, and R. H. Smithies 1993

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