EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

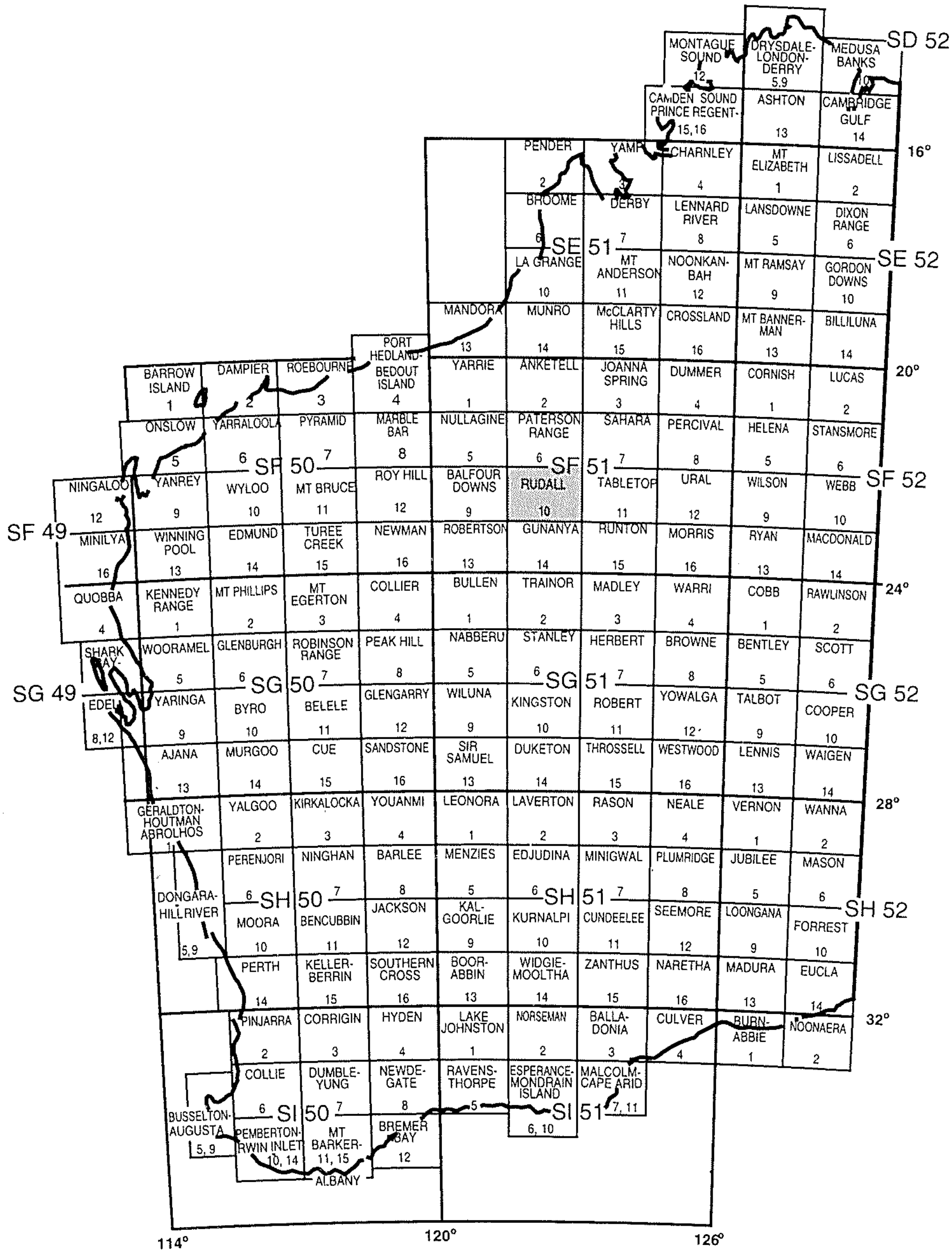
GEOLOGY OF THE RUDALL 1:100 000 SHEET

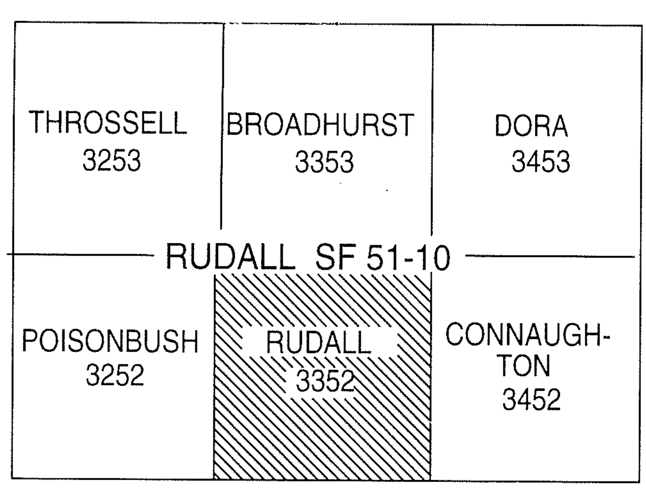
by A. H. Hickman and L. Bagas

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY





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Cover photograph:

Tight F_4 folds (Miles Orogeny) folding strongly developed S_2 foliation (late Yapungku Orogeny) in orthogneiss derived from porphyritic biotite granite (9 km east-southeast of Rudall Crossing, AMG 201030).

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Abstract

Mapping of the RUDALL 1:100 000 sheet has provided detailed geological information on the stratigraphy, structure, tectonic evolution, and mineralization of the central part of the Proterozoic Paterson Orogen. The orogen comprises three major lithostratigraphic units: the Rudall Complex, Yeneena Supergroup, and Tarcunyah Group.

The Rudall Complex is composed of gneiss, schist, and quartzite representing a range of igneous and sedimentary rocks that were deformed and metamorphosed during at least two pre-Yeneena Supergroup orogenic events involving northeast–southwest plate collision. The first of these, between 2015 and 1787 Ma, involved one or more episodes and the second occurred at about 1765 Ma.

The Yeneena Supergroup is composed of the Throssell and Lamil Groups, but the latter is absent on RUDALL. The Throssell Group is a sandstone–shale–carbonate succession unconformably overlying the Rudall Complex, which was deposited after 1250 Ma in a strike-slip basin system formed in response to continued northeast–southwest convergence. This succession was deformed by the Miles Orogeny at about 900–800 Ma, and resulting tectonic closure of the basins was followed by unconformable deposition of deltaic to shallow-shelf sediments of the Tarcunyah Group.

Subsequent deformation of the Tarcunyah Group involved upright folding, thrusting, and dextral strike-slip movements along a relatively narrow tectonic zone trending northwesterly across the central part of RUDALL. To the southwest of this zone, the upper part of the Savory Group was deposited in a foreland basin at about 600 Ma.

RUDALL contains no mines, but discoveries of minor gold, uranium, base-metal, and barite mineralization merit further investigation.

KEYWORDS: Paterson Orogen, Rudall Complex, Throssell Group, Tarcunyah Group, Savory Group, Proterozoic, plate tectonics, fold belt, thrust faults, metamorphism, mineralization, geochronology.

Introduction

Location and access

The RUDALL* 1:100 000 sheet covers the southern and central parts of the RUDALL 1:250 000 sheet between latitudes 22°30' and 23°00'E and longitudes 122°00' and 122°30'S. The area occupies the central part of the Paterson Orogen (Fig. 1) and is situated between the Great Sandy Desert and Little Sandy Desert. RUDALL is included in the Eastern Land Division and the Marble Bar District of the Pilbara Mineral Field. It is named after the Rudall River, which flows from west to east across the northern part of the sheet. The Rudall River National Park (1 569 459 ha) covers the northern two-thirds of RUDALL, and is centred on the drainage of the Rudall River.

There is no permanent habitation on RUDALL. The nearest town is Telfer, about 90 km to the north. A gravel road links the Rudall River National Park to Telfer in the north and the Canning Stock Route in the southeast. A good-quality, four-wheel drive track connects the southern part of RUDALL to Newman, via Balfour Downs Homestead and the Ethel Creek – Jigalong road. Few other tracks are present in the area and off-road access within the park requires prior approval from the Western Australian Department of Conservation and Land Management.

* Capitalized names refer to standard map sheets. Where 1:100 000 and 1:250 000 sheets have the same name, the 1:100 000 sheet is implied unless otherwise indicated.

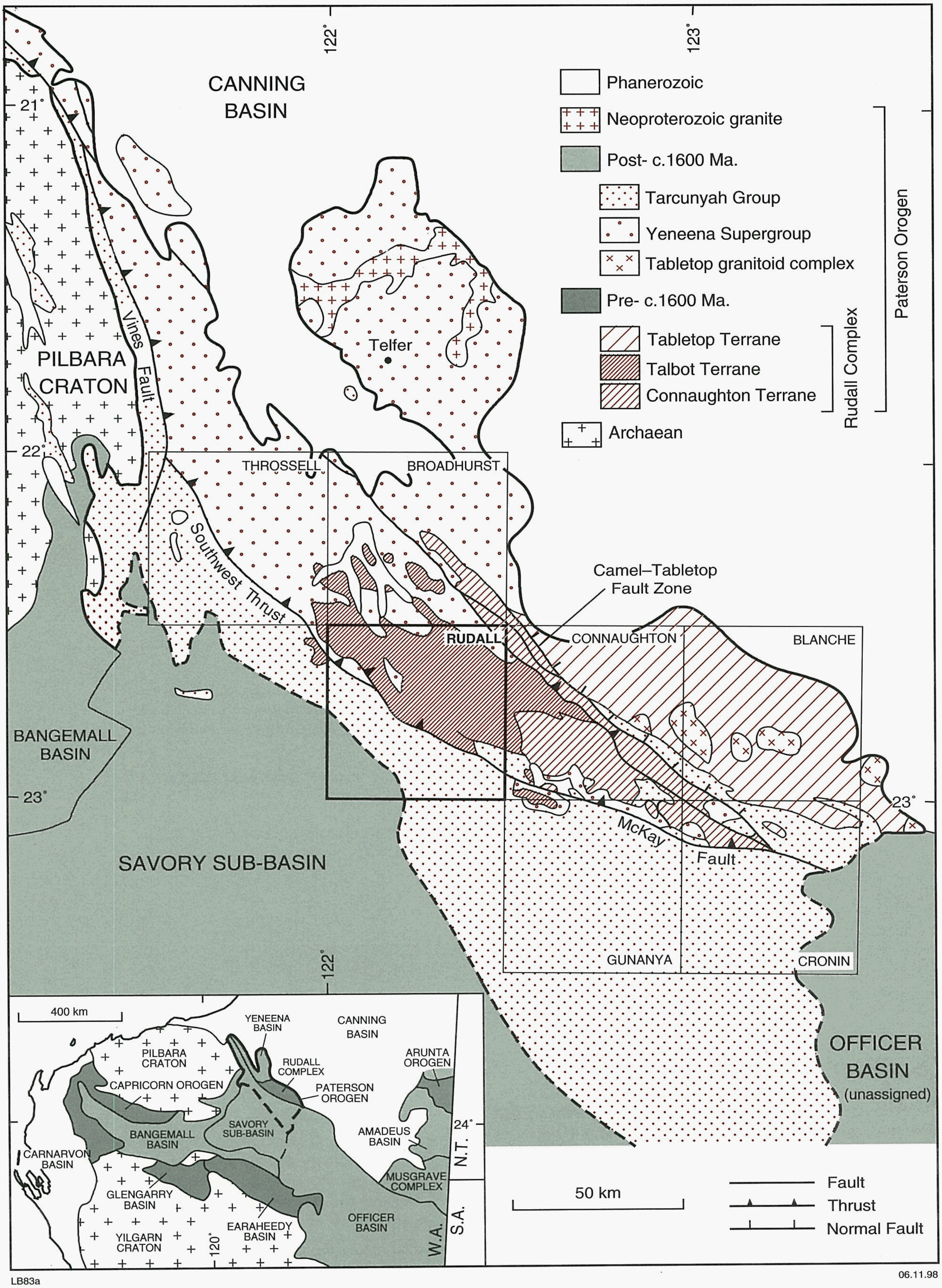

Figure 1. Regional geological setting of Rudall

Climate and vegetation

The climate is arid, with potential evaporation far in excess of precipitation. Average rainfall is 200 mm per year, mainly derived from storm and cyclone activity between November and March. Average summer temperatures range from daily minima of about 24°C to maxima of 39°C, whereas daily winter temperatures typically vary between 6 and 24°C. Average annual evaporation is about 4400 mm, and prevailing winds blow from the east and southeast.

The area forms part of the Great Sandy Desert and Little Sandy Desert natural regions of Beard (1970). Spinifex (*Triodia*) is present across the entire area, whereas other forms of vegetation are associated with different types of terrain; for example, sandplains also contain *Grevillia*, wattles, soft shrubs (*Crotalaria*), eucalypts, tea tree, and desert oak. Major drainages, such as the Rudall River, contain large eucalypts and grasses, and areas of rock outcrop include small scrub, grasses, mulga, and small eucalypts.

Physiography

The physiography of RUDALL (Fig. 2) is a product of several periods of erosion and deposition. However, the most important events during this history appear to have been Permian glaciation, Tertiary peneplanation, and Cainozoic erosion and deposition. The physiographic subdivision outlined below is an extension of that used by Hickman and Clarke (1994) on BROADHURST.

Permian land surface

Remnants of the Permian land surface (Fig. 2) are present in areas covered by Permian fluvial–glacial sediments (benches and mesas), and in northerly trending glacial valleys (dissected valley deposits).

Tertiary land surface

The laterite, ferruginous duricrust, and silcrete deposits capping the dissected plateaus represent essentially unmodified remnants of a Tertiary peneplain. The precise age of the peneplain is currently uncertain. However, the surface could be correlated with the Hamersley Surface in the Hamersley Ranges (Campana et al., 1964; Chin et al., 1982) or the Ashburton Surface of central Australia (Jennings and Mabbutt, 1971). Smaller areas of laterite, duricrust, and silcrete deposits cap hills and ridges in the dissected plateaus. These are typically preserved in areas underlain by arenite and quartzite of the Rudall Complex, Yeneena Supergroup, and Savory Group. The ridges are commonly bevelled to a height of about 450 m above sea level in the western part of the Fingoon Range, and about 400 m above sea level east of May Creek (Fig. 2).

The calcrete valley floor deposits southeast of Rooney Creek, south of May Creek, and in the southwestern part of the map sheet pre-date the sandplains that partially cover them, and are probably related to channels and lakes that were active during the Tertiary. These deposits form low mounds in low-lying areas, and are composed of massive, nodular, and vuggy limestone partly replaced by chalcedony.

Recent erosional land surface

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

The ridges unit includes the Fingoon Range and Connaughton Hills with dissected and, in part, sinuous quartzite ridges rising 100 to 150 m above the general level of the valleys and plains (Fig. 2). Pelite and psammitic units typically underlie valleys between the ridges.

The northern and eastern parts of RUDALL contain large expanses of the low hills unit. Geology influences the topography of the hills: orthogneiss and paragneiss characteristically produce rounded hills, and quartzite produces more rugged country. The low hills unit is subjected to active erosion by headwater systems and constitutes an intermediate stage of peneplanation.

The rock pavement and low outcrop unit is mainly present in the sandplain country in the southwestern part of RUDALL, but also includes small areas within the low hills unit. Erosion is restricted to wind action and water movement in small streams, and represents the last stage in the formation of a new peneplain.

Recent depositional land surface

Sandplains have been divided into seif (longitudinal) dune and dune-free sandplains, and together these cover about 40% of RUDALL (Fig. 2). The northeastern margin of the area includes the western edge of the Great Sandy Desert. The southwestern part of RUDALL includes the eastern edge of the Little Sandy Desert.

The seif dune sandplains form predominantly flat country containing easterly to southeasterly trending seif dunes with maximum heights of 30 m that are many kilometres long and spaced up to 3 km apart. The longitudinal profiles are consistent with prevailing winds from the east-southeast. Not only do individual dunes tend to increase in height towards the west-northwest, but active depositional slopes also face this direction. Many of the dunes are asymmetrical, with steep southern slopes. Crowe (1975) provided further descriptions of seif dunes. The dune-free sandplains and the leeward sides of hills are areas subjected to periodic flooding.

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

The scree, colluvium, sheetwash fans, and playa lakes unit commonly flanks sandplains, and represents locally derived clastic detritus from streams and channels draining hilly areas. The present drainage dissects some of these deposits.

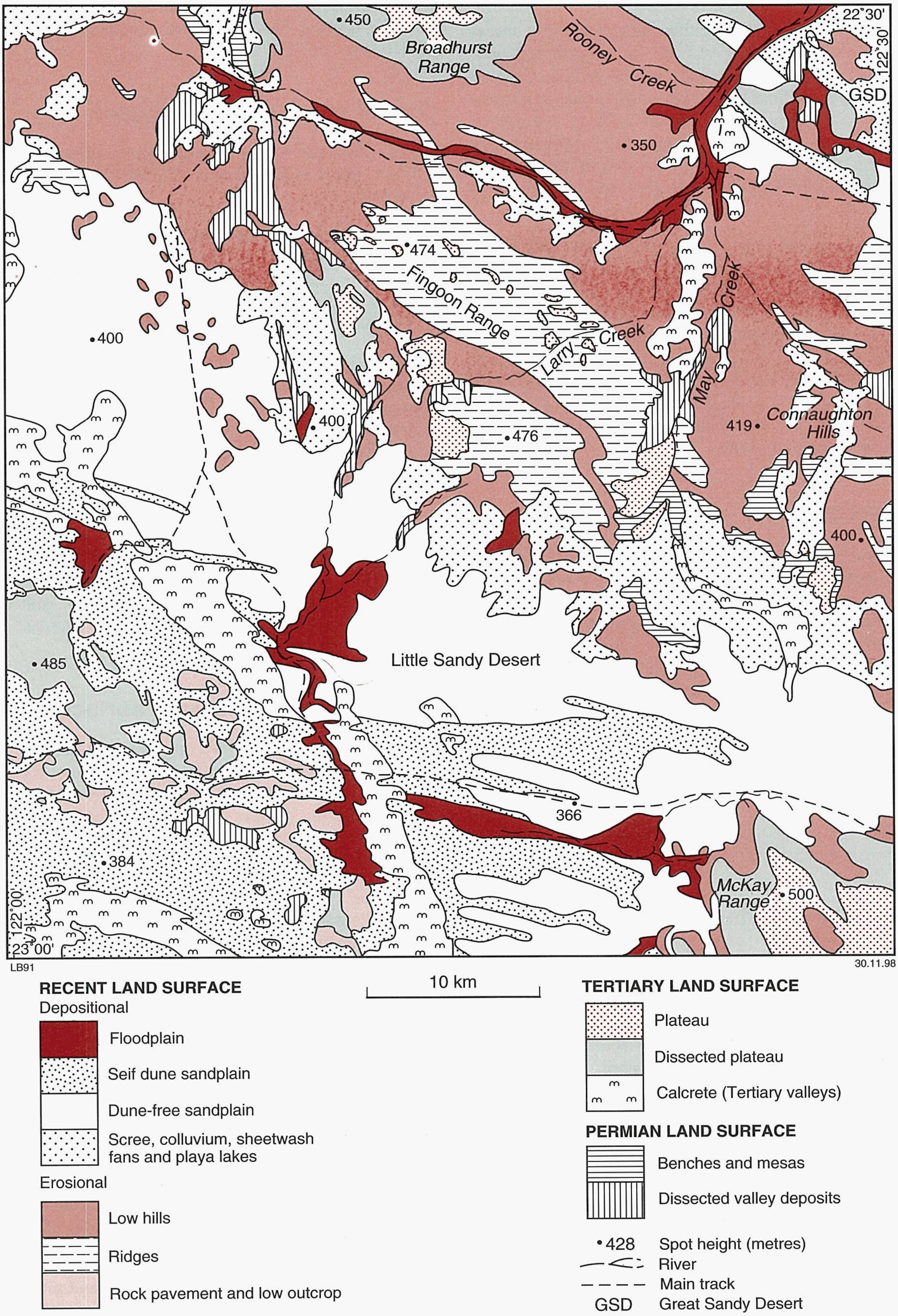

Figure 2. Physiography and access on Rudall

Previous investigations

W. F. Rudall wrote the first report on the region (Rudall, 1897) and searched unsuccessfully for the lost Wells expedition in 1896. F. H. Hann, who accompanied W. F. Rudall in 1896, returned the following year searching for grazing land and prospecting for gold. In 1898, F. H. Hann named the Rudall River after his co-explorer.

The first geological reconnaissance of RUDALL was made by H. W. B. Talbot and A. W. Canning in 1908–09 along the Canning Stock Route. The geological reports and maps produced (Talbot, 1910, 1920) describe gneiss (Rudall Complex), the 'Nullagine Series' (Yeneena Supergroup and Bangemall Group), and the 'Paterson Range Series' (Paterson Formation).

The Bureau of Mineral Resources (BMR, now known as the Australian Geological Survey Organisation) mapped a large part of the Canning Basin in 1954 (Traves et al., 1957), resulting in the publication of the PATERSON RANGE and TABLETOP 4-mile sheets. In 1965, BMR completed a regional gravity survey of RUDALL, with 11-km station spacing. The coarse station spacing is insufficient to permit interpretations appropriate to 1:100 000-scale mapping.

L. E. de la Hunty and J. G. Blockley, of the Geological Survey of Western Australia (GSWA), made reconnaissance trips in 1966 and 1969 to assist in the preparation of the 1966 and 1973 editions of the State Geological Map.

The isolation of the Paterson Orogen and the lack of a permanent water supply impeded mineral exploration in the area until 1971, when gold was discovered at the Telfer gold deposit on PATERSON (see **Economic geology**).

Reconnaissance mapping of the RUDALL 1:250 000 sheet was carried out in 1975 (Chin et al., 1980) as part of the systematic 1:250 000-scale geological mapping of Western Australia. This work confirmed the unconformable relationship between the Yeneena Supergroup (Williams and Bagas, in prep.a) and the Rudall Complex. The prospectivity of the region for uranium mineralization, analogous to that in the Alligator River and South Alligator River regions of the Northern Territory and the Athabasca Basin of northern Saskatchewan, Canada, was also increased.

In 1984, BMR flew a regional airborne magnetic survey over the RUDALL 1:250 000 sheet at a nominal altitude of 150 m above ground level and a line spacing of 1.6 km. Total magnetic intensity readings were acquired with a fluxgate magnetometer at a sample interval of 60 m, and recorded on analogue charts. In 1985, uranium was discovered at Kintyre on BROADHURST adding new impetus to exploration. Since then, exploration companies have completed more detailed magnetic and radiometric surveys.

In 1989, GSWA commenced a program of detailed 1:100 000-scale geological mapping of the Rudall Complex, and by 1998 BROADHURST (Hickman and Clarke, 1994), RUDALL, THROSSELL (Williams and Bagas, in prep.a), POISONBUSH (Williams and Bagas, in prep.b), GUNANYA (Bagas, 1998), CONNAUGHTON (Bagas and Smithies, 1998a), and BLANCHE–CRONIN (Bagas and Smithies, 1998b) had been completed.

This report and the accompanying 1:100 000 geological map are based on detailed regional mapping by A. H. Hickman and L. Bagas during 1991 and 1992, and their interpretation of available regional magnetic and radiometric data. Mapping was carried out using 1985 1:25 000 colour aerial photographs and 1988 1:50 000 black-and-white aerial photographs.

Regional geological setting

RUDALL occupies part of the Paterson Orogen (Williams and Myers, 1990), which was previously referred to as the Paterson Province (Daniels and Horwitz, 1969; Blockley and de la Hunty, 1975). The Savory Sub-basin of the greater Officer Basin (Williams and Bagas, in prep.a; previously called the Savory Basin by Williams, 1990) occupies the southwestern part of the area (Fig. 1). Permian sedimentary rocks of the Canning Basin form local outliers, which are too small to show on Figure 1.

The Paterson Orogen is a northwesterly trending belt of folded and metamorphosed Proterozoic igneous and sedimentary rocks. On RUDALL, there are three major subdivisions of the Paterson Orogen: the Rudall Complex, Throssell Group, and Tarcunyah Group. Each group of rocks was deformed and metamorphosed by Mesoproterozoic to Neoproterozoic orogenies, but the Rudall Complex, which unconformably underlies the Throssell Group and the Tarcunyah Group, was also subjected to a Palaeoproterozoic orogenic event.

The Rudall Complex is composed of gneiss, schist, and quartzite, representing a range of igneous and sedimentary rocks deformed and metamorphosed during at least two pre-Throssell Group events of northeast–southwest plate collision, fold and thrust belt formation, and partial melting. Orthogneiss constitutes about 50% of the Rudall Complex and was derived by metamorphism of a range of granitoid protoliths. An early suite, forming part of a complex lithologically layered orthogneiss, crystallized at about 2015 Ma (see **Geochronology**) and may predate the metasedimentary succession (Table 1). Deposition of a 5000 m-thick siliciclastic succession comprising the Larry Formation and Butler Creek Formation is known to have occurred prior to 1780 Ma because it was intruded by granitoids of this age. The succession indicates shoreline–shelf–slope environments in a subsiding foreland basin on the eastern margin of a continent.

The lowest part of the Poynton Formation (Table 1) consists of well-sorted quartz sands and minor pebble beds, and is a shallow-shelf facies quite distinct from the underlying turbidite units of the Butler Creek Formation. No angular unconformity has been observed, but a disconformity could be present.

The stratigraphic succession of the Rudall Complex on RUDALL contains no mafic volcanic rocks, but sheared serpentinized ultramafic bodies (peridotite) associated with

Table 1. Stratigraphy of the metasedimentary rocks of the Rudall Complex

Unit and symbol	*Maximum thickness*	*Name derivation; type area; distribution*	*Lithology*	*Relationships[(a)]*
Poynton Formation, *ERo*	>1000 m	Poynton Creek (AMG 330051); Poynton Creek (AMG 330070); northeastern and northern RUDALL — almost entirely restricted to the Poynton Domain	Basal quartzite passes upward into interlayered psammitic gneiss, quartzite, and quartz–muscovite schist. The upper part of the formation is dominantly quartz–feldspar–muscovite gneiss with minor semi-pelitic schist and local biotite–plagioclase–quartz schist and banded iron-formation	Unconformably overlain by the Coolbro Sandstone (Yeneena Supergroup), and pervasively intruded by porphyritic granitoid protoliths (*ERga*)
Conformity or disconformity				
Butler Creek Formation, *ERc*	>1000 m	Butler Creek (AMG 400961); Butler Creek (AMG 400900); eastern RUDALL, north of Rudall River, and northwestern Fingoon Range	Banded paragneiss containing thin layers of quartz–feldspar(–biotite) gneiss, quartz–biotite schist, and minor amphibole–chlorite schist. Local micaceous psammitic gneiss, banded iron-formation, and muscovitic quartzite	Pervasively interlayered with *ERga* and includes tectonite zones of intricately interleaved paragneiss and orthogneiss.
Conformable and tectonic contact				
Cassandra Member of Yandagooge Formation, *ERyp*	<230 m	Cassandra mineral prospect (AMG 323853); around AMG 287895 to AMG 291902; around headwaters of Larry Creek (central RUDALL)	Iron-rich graphitic, pelitic schist, banded iron-formation, and chert.	Member in upper part of Yandagooge Formation
Yandagooge Formation, *ERy*	1500 m	Yandagooge Creek (AMG 053310); northwestern Fingoon Range (AMG 175005); southwestern BROADHURST (3353) and in the Fingoon Range area	Dominantly a pelitic to semipelitic assemblage of quartz–muscovite schist with hematitic biotite schist and thin intercalations of muscovitic quartzite.	Extensively intruded by porphyritic granitoid protoliths of *ERga*
Conformable and tectonic contact				
Fingoon Quartzite, *ERf*	1500 m	Fingoon Range, central RUDALL; around AMG 244932 to 248938 and AMG 289945 to 296955); Fingoon Range, northwestern RUDALL and southwestern BROADHURST	Dominantly massive or layered quartzite, but including quartz–muscovite schist with minor micaceous quartzite muscovitic quartzite with intercalations of quartz–muscovite schist	Boundary contacts with orthogneiss in some areas, but the formation's composition has precluded internal granitoid intrusion
Conformable and tectonic contact				
Larry Formation, *ERw*	>1000 m	Larry Creek (AMG 288914); around AMG 236854 to 250870 and AMG 288914; Fingoon Range area	Quartz–feldspar–mica paragneiss containing quartz–mica schist and minor muscovitic quartzite. Pebbly beds locally near the top of the formation	Lowest formation of the succession. Base not exposed. Transitional contact with the Fingoon Quartzite

NOTE: (a) excludes tectonic contacts pelitic schist and turbiditic metasedimentary rocks are present in three west-northwesterly trending zones. Lithologically, the assemblage is similar to compressed and attenuated ophiolitic units in many of the world's orogenic belts, and Carr (1989) concluded that they represent slices of Proterozoic oceanic crust.

The main suite of orthogneiss represents metamorphosed sheets of porphyritic granite to monzogranite. Zircon U–Pb ages (see **Geochronology**) have established that intrusion of these sheets occurred between 1787 and 1765 Ma. This orthogneiss suite does not contain S_1 foliation, which is present in the early orthogneiss and the metasedimentary succession. The D_1 deformation event responsible for S_1 probably involved subhorizontal thrusting and crustal thickening, leading to partial melting and intrusion of the 1787–1765 Ma granitoids. These could have originated in either magmatic arc or fold and thrust belt environments (Smithies and Bagas, 1997).

The Yeneena Supergroup, as defined by Bagas et al. (1995), consists of the Throssell and Lamil Groups. The Lamil Group is not present on RUDALL. The age of the Throssell Group is very poorly constrained, but is probably between 1250 and 900 Ma. The Throssell Group is essentially a sandstone–shale–carbonate succession, representing depositional environments ranging from fluviatile–deltaic to shelf. Deposition commenced in a strike-slip basin system, which later evolved into a northeasterly deepening shelf environment responsible for the Lamil Group in the Telfer area. Abundant palaeocurrent data and lateral facies changes indicate that a continental landmass lay to the southwest. Deformation of the Yeneena Supergroup included northeast–southwest compression and upright folding and thrusting from the northeast, as in the Rudall Complex. These similarities suggest that the evolution of the Yeneena Basin might represent later stages in progressive stages of the northeast–southwest convergence (Hickman and Bagas, 1995).

Tectonic closure of the Throssell Group strike-slip basins was followed by deposition of the Tarcunyah Group at c. 800 Ma (Bagas et al., 1995), which represents deltaic to shallow-shelf sedimentation along the eastern margin of the Pilbara Craton.

Deformation of the Tarcunyah Group involved a combination of upright folding, thrusting, and dextral strike-slip movements along a northwesterly trending zone from the McKay Range to the eastern part of THROSSELL (Williams and Bagas, in prep.a), and further north to the eastern margin of the Gregory Range.

The Savory Sub-basin has been interpreted as partly a marginal sag basin and partly an interior continental sag basin that was deposited sometime between 900 and 600 Ma (Williams, 1992). It is now considered part of the greater Officer Basin (Bagas et al., 1995; Perincek, 1996).

The upper part of the Savory Group unconformably overlies the Tarcunyah Group, and Williams (1992) provided a detailed description of its relationships to the Paterson Orogen. Williams (1992) stated that sedimentation in the northeastern part of the Savory Sub-basin was directly linked to erosion of uplifted areas in the Paterson Orogen (D_6). Thus, the eastern part of the Savory Sub-basin is interpreted as a foreland basin produced by downward flexuring of its basement (mainly Bangemall Group).

Permian fluvioglacial sediments and tillite, forming part of the Canning Basin succession, unconformably overlie the Proterozoic rocks and mainly outcrop in northerly trending glacial valleys.

Proterozoic geology

Proterozoic rocks on RUDALL comprise the Rudall Complex, Yeneena Supergroup (Throssell and Tarcunyah Groups), and Savory Group. Descriptions of the Throssell, Tarcunyah, and Savory Groups are entirely stratigraphic, whereas the section on the Rudall Complex includes discussion of unassigned sedimentary units and igneous rocks. Figure 3 is a simplified map of the Proterozoic geology.

Rudall Complex

The Rudall Complex (Williams, 1990) outcrops in the northern and eastern parts of RUDALL, where it consists of an arenaceous and pelitic succession (now paragneiss) intruded by granitoids (now orthogneiss). Beyond RUDALL, these rocks extend for about 150 km from BROADHURST to SURPRISE (Chin et al, 1980; Crowe and Chin, 1979; Yeates and Chin, 1979; Williams and Williams, 1980). The present mapping placed emphasis on field identification of protoliths of metamorphic rocks of the Rudall Complex. Mapping was initially lithological, but following map compilation it was evident that stratigraphic successions could be recognized.

On RUDALL, the Rudall Complex is tectonically divided into ten crustal segments referred to as 'tectono-stratigraphic domains'. The boundaries of these domains are principally major D_2 faults, but D_4 faults and the unconformity at the base of the Throssell Group also form some boundaries (Fig. 4, and the geological map).

Figure 5 presents lithological columns for ten areas, and relates these local successions to a possible regional stratigraphic succession. The stratigraphy of the Poynton and Rooney Domains may not be related to that of the Fingoon, Warturnkurru, and Butler Domains. In particular, a major tectonic break separates the Poynton Domain from the Fingoon and Butler Domains, precluding confident stratigraphic correlations between those areas. No stratigraphic succession has been established in the tectonically fragmented Clayton Domain, and the successions of the Lalapa, Martu, and Parnngurr Domains are not correlated with the stratigraphic succession in the central part of RUDALL.

The stratigraphic subdivision of the metasedimentary rocks in the Rudall Complex follows that of Hickman et al. (1994). Certain areas on RUDALL contain insufficient evidence for lithostratigraphic correlation, and the

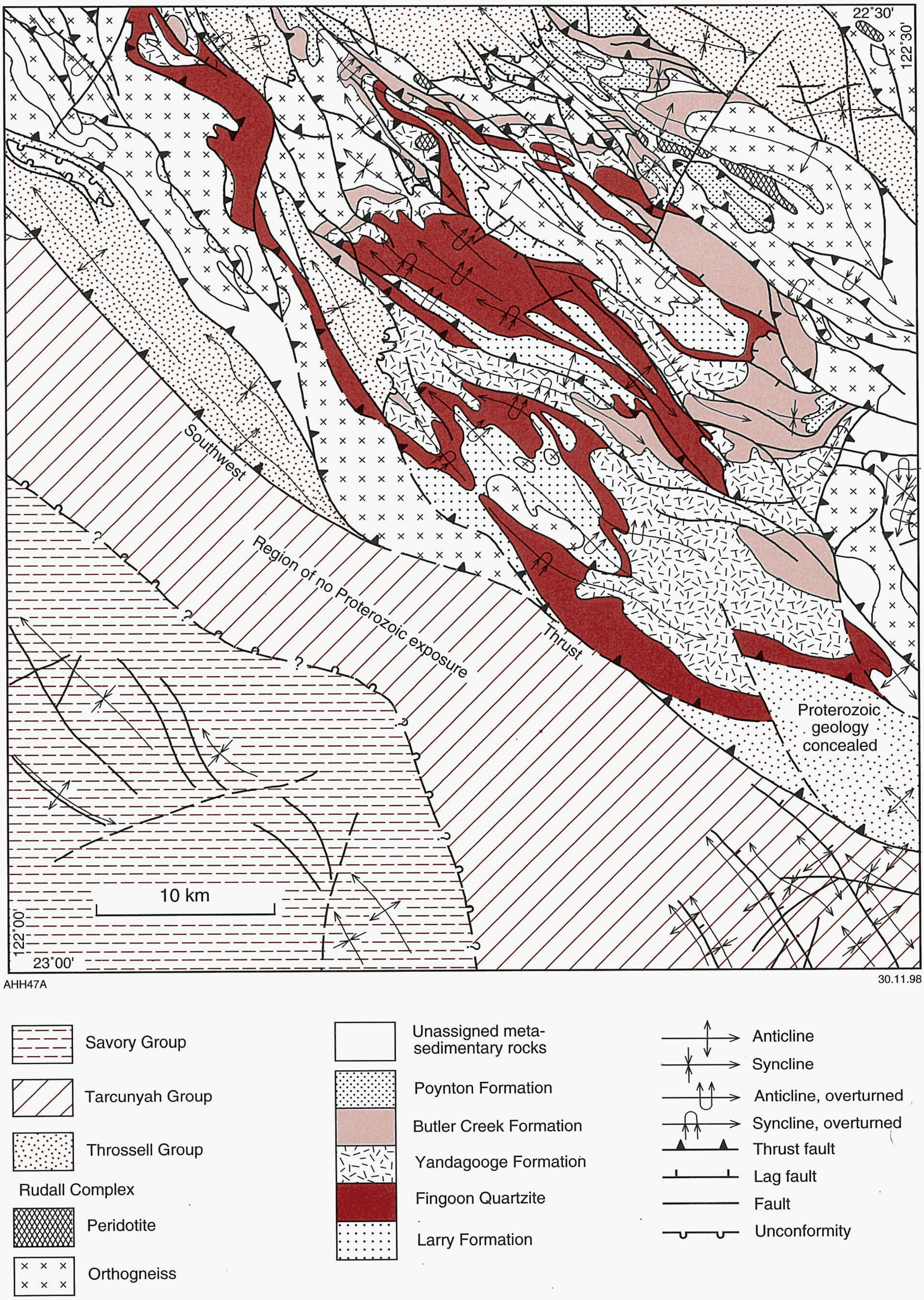

Figure 3. Simplified geological map of RUDALL, showing major structures and Proterozoic stratigraphy

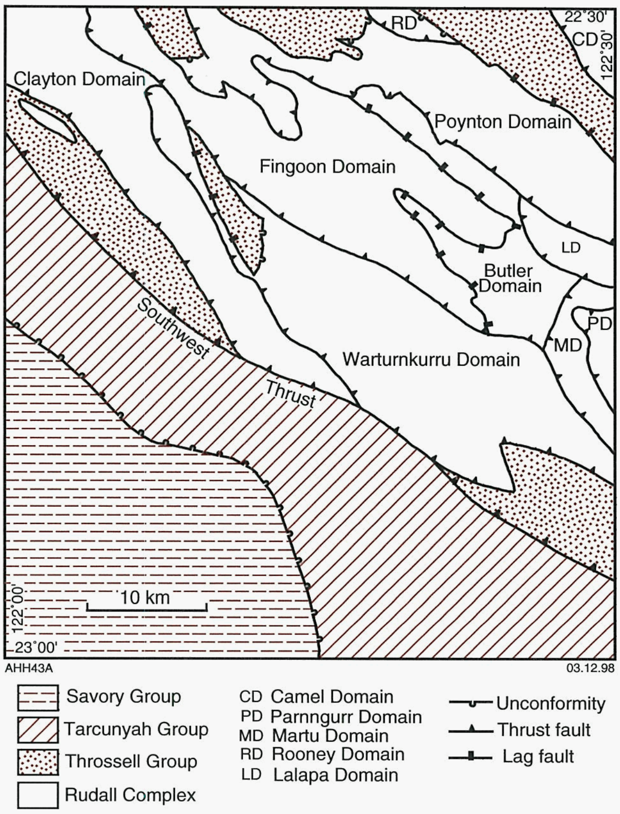

Figure 4. Major tectono-stratigraphic units on Rudall

stratigraphic positions of some paragneiss units are therefore left unassigned (see **Unassigned metasedimentary rocks**). Principal stratigraphic and lithological features of the succession, including derivation of name, type area, and distribution, are summarized in Table 1.

Larry Formation (*ꝐRw, ꝐRwa*)

The Larry Formation (*ꝐRw*) is exposed in the cores of the Fingoon Anticlinorium and anticlinoria south of the Rudall River, and south of the Cassandra Prospect, and is the lowest stratigraphic unit recognized in the area. The formation forms low, poorly exposed, undulating terrain and consists of a highly weathered, tectonized, and monotonous succession of quartz–feldspar–mica paragneiss, quartz–mica schist, and minor amounts of variably micaceous quartzite (*ꝐRwa*). The paragneiss (recrystallized quartzofeldspathic sedimentary rock) contains abundant quartz, feldspar (both microcline and oligoclase), and biotite, with accessory sericite and epidote.

The succession is interpreted to represent a metamorphosed assemblage of argillaceous rocks (siltstone and mudstone) and arenites (greywacke and variably clayey sandstone). The depositional setting for this succession may have involved fluviatile or shallow-water marine environments. The feldspathic nature of the metasedimentary rocks indicates that they were partly derived from granitoid source rocks.

The base of the Larry Formation is not exposed, and the formation is transitionally overlain by the Fingoon Quartzite. There is an increase in the proportion of quartzite units towards the top of the formation (e.g. AMG 250870*), but this may be due to tectonic interleaving.

Poorly preserved graded bedding and fine-scale cross-laminations are present in paragneiss north and south of the Rudall River (AMG 240038 and 242005 respectively). Taking local structure into account, these observations indicate younging towards the Fingoon Quartzite.

Fingoon Quartzite (*ꝐRf, ꝐRfq, ꝐRfm ꝐRfs*)

The Fingoon Quartzite (*ꝐRf*) transitionally overlies the Larry Formation and includes quartzite, micaceous quartzite, and quartz–mica schist. On Broadhurst an arenaceous succession previously assigned to the 'Tjingkulatjatjarra Formation' (Clarke, 1991), is here correlated with the Fingoon Quartzite. It should be noted, however, that Clarke's definition of the Tjingkulatjatjarra Formation at Number 11 Pool included upper units of mica schist and banded iron-formation, which are now included in the Yandagooge Formation.

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

About 200 m from the top of the formation a flaggy, well-layered succession of muscovite-rich quartzite is intercalated with minor amounts of muscovite schist (*ꝐRfq*), and muscovite schist is intercalated with minor amounts of muscovite-rich quartzite (*ꝐRfm*). Psammitic quartz–feldspar–muscovite schist and gneiss (*ꝐRfs*) is developed near the top of the formation.

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

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

* 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.

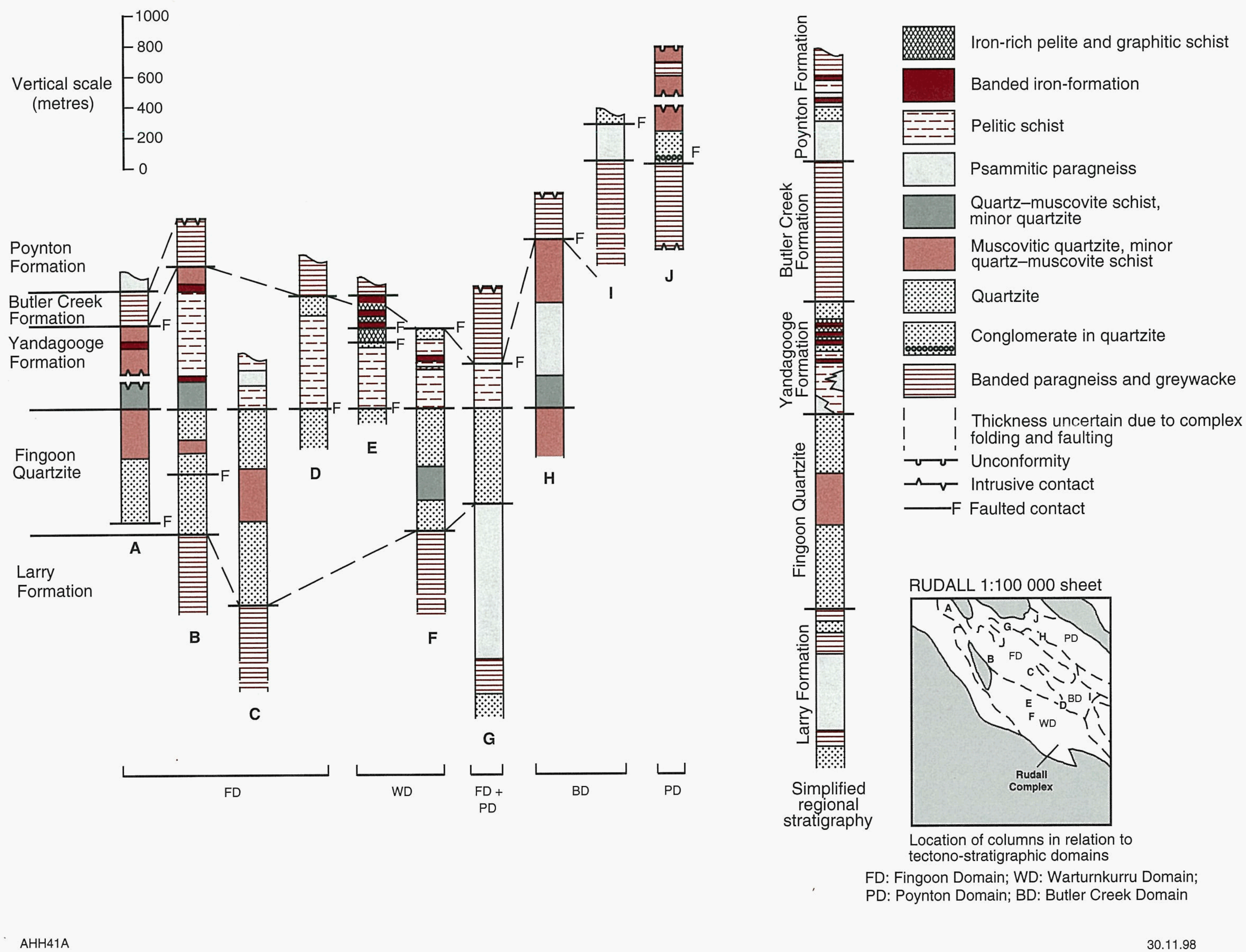

Figure 5. Simplified sections through the stratigraphic succession of the Rudall Complex, RUDALL

Yandagooge Formation (*ЕRy, ЕRyq, ЕRyi, ЕRys, ЕRya*)

The Yandagooge Formation (*ЕRy*) is a widespread and lithologically distinctive unit of the Rudall Complex. Except for thin units of quartzite (*ЕRyq*), the formation includes metamorphosed pelitic and semi-pelitic rocks with laterally lenticular layers of banded iron-formation, chert, graphitic schist, and biotite schist (*ЕRyi*). The dominant rock type of the formation is quartz–muscovite schist containing thin layers of muscovitic quartzite (*ЕRys*). A relatively psammitic facies of the formation is present north of the Rudall River where muscovite–feldspar–quartz gneiss (*ЕRya*) represents metamorphosed feldspathic sandstone. However, the formation is commonly 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 less than 1500 m thick, transitionally overlies the Fingoon Quartzite, and is interlayered with orthogneiss.

The quartz–mica schist is interlayered with thin units of banded iron-formation, quartzite, micaceous quartzite, and chert. The quartz–mica schist contains varying amounts of quartz, muscovite, and biotite, with minor amounts of feldspar (predominantly plagioclase), finely disseminated opaque minerals, and garnet. In places this rock is rich in limonite and clay, as weathering products. The chert is composed of deformed and recrystallized quartz, with minor amounts of mica (predominantly muscovite) and opaque minerals, and rare sericitized plagioclase. The banded iron-formation is finely laminated, consisting of quartz, oxide material (possibly after amphibole), aligned magnetite, clay, accessory muscovite, and rare relict garnet. The Cassandra Member (*ЕRyp*) structurally overlies the quartz–mica schist.

Cassandra Member (*ЕRyp, ЕRypi*)

A 230 m-thick succession of iron-rich and graphitic pelite (metamorphosed mudstone and siltstone), banded iron-formation, and chert near the headwaters of Larry Creek has been subdivided as the Cassandra Member (*ЕRyp*) of the Yandagooge Formation. The lithology of the member is summarized in Table 1.

The Cassandra Member is interpreted as a succession of metamorphosed chemical deposits and pelite laid down in a low-energy environment during periods of low clastic supply. The banded iron-formation (*ЕRypi*) and chert probably accumulated as gels. The Cassandra Member is overlain by the Butler Creek Formation, a metagreywacke and pelite succession probably deposited by turbidity currents in deep water.

Butler Creek Formation (*ЕRc, ЕRcs, ЕRcq, ЕRci*),

The Butler Creek Formation (*ЕRc*) is a monotonous succession of banded paragneiss that is present in many areas of northern and eastern RUDALL. The unit provides the only stratigraphic link between the successions of the Fingoon and Warturnkurru Domains and that of the Poynton Domain, but its relative incompetence during deformation has resulted in complex internal folding and major faulting. Thus, the upper and lower contacts of the formation are commonly tectonic.

The formation consists of grey or brown schist (pelite derived from a shale or muddy sandstone) intercalated with fine to coarse paragneiss (metamorphosed feldspathic greywacke) local banded iron-formation (*ЕRcs*), and rare units of light-grey to white quartzite or argillaceous quartzite (*ЕRcq*). These rock types are commonly intercalated in 0.1 to 2 m-thick bands. Pelitic units contain quartz, biotite, muscovite or sericite, secondary chlorite, and minor amounts of plagioclase (usually albite or oligoclase). The metagreywacke is fine grained and contains quartz, muscovite, elongate aggregates of microcline, subordinate albite, minor biotite, and secondary sericite. Quartzite is commonly thinly banded, fine to medium grained, and contains quartz, minor amounts of biotite and sericite, and accessory tourmaline. Pebble bands are rare, with clasts being entirely composed of vein quartz. Banded quartz–magnetite rock (*ЕRci*), representing metamorphosed banded iron-formation, locally forms units large enough to show on the map.

Near major D_2 faults, the unit contains belts of tectonically interleaved paragneiss and orthogneiss, and local megaboudins of ultramafic and mafic rocks.

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

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

Poynton Formation (*ЕRo, ЕRoq, ЕRom, ЕRos, ЕRot*)

The Poynton Formation (*ЕRo*) is a succession of quartzite, metagreywacke, quartz–muscovite schist, and minor amounts of pelitic schist and banded iron-formation structurally overlying rocks correlated with the Butler Creek Formation. The formation is present in the Poynton, Rooney, and Butler Domains, and is thought to extend into the Lalapa Domain.

North of Poynton Creek the lower part of the formation is a 100 m-thick unit of quartzite (*ЕRoq*) containing minor intercalations of quartz–feldspar–muscovite paragneiss and 1–2 m-thick layers interpreted to be metamorphosed conglomerate. The clast-like structures of the conglomerate are well rounded and 20 to 50 mm across. Microscopic examination shows no clear clast boundaries, but the clasts are composed entirely of coarse quartz or quartz and muscovite, whereas the matrix material is finer grained and includes minor amounts of biotite and plagioclase. Above the basal quartzite is a 100–200 m-thick unit of interlayered quartzite and quartz–feldspar–muscovite paragneiss and schist (*ERom*). This is interpreted as metamorphosed arkosic sandstone, but it could be a felsic volcanogenic sedimentary rock. A 100–200 m-thick sheet of orthogneiss separates the arkosic unit from the upper part of the formation, which is best exposed in a tributary of Poynton Creek (AMG 285090). The upper unit is at least 400 m thick and consists of compositionally layered quartz–feldspar–biotite paragneiss with numerous thin units of quartzite and quartz–biotite schist (*ERos*). Some creeks in the upper part of this section of the formation expose 0.5–1.0 m-thick compositionally layered rhythmic units. The units consist of feldspathic quartzite layers grading upward into plagioclase–quartz–muscovite–biotite gneiss overlain by 50–100 mm-thick layers of biotite–epidote–quartz microgneiss. These rhythmic units are interpreted to be metamorphosed sandstone–greywacke–shale graded beds of a turbidite succession. Biotite–plagioclase–quartz schist (*ERot*), probably representing metamorphosed silty shale, is locally present within the upper part of the formation westward from Rooney Creek.

In the southern part of the Rooney Domain (AMG 300100), the formation is in tectonic contact with the Butler Creek Formation. The most southwesterly exposures are interpreted to be the stratigraphically lowest, and include sheared pebbly greywacke, passing north-eastward into banded feldspathic paragneiss containing scattered small pebbles of quartz and feldspar. Northward to the unconformity with the Throssell Group, the Poynton Formation is dominantly a banded quartz–feldspar–biotite–muscovite gneiss without mappable quartzite or pelitic schist units. North of Rooney Creek, sills of granitic orthogneiss and veins of pegmatite extensively sheet the formation.

Other large outcrops of the Poynton Formation are located along the Rudall River (AMG 355000) and 5 km north-northeast of Rudall Crossing. The outcrops north of Rudall Crossing are composed of muscovite-rich psammitic paragneiss, muscovite–quartz schist, and minor amounts of quartzite. The entire assemblage contains sheets and lenses of gneissic pegmatite, possibly associated with K-feldspar augen orthogneiss to the southeast.

Most of the Rudall River outcrops contain banded psammitic paragneiss typical of the Rooney Creek and Poynton Creek areas, but muscovite quartzite forms a small area of hills (AMG 340020). This quartzite overlies the Butler Creek Formation, and is probably the same basal unit as in the Poynton Creek area. A notable feature of the quartzite here is the presence of a stratabound, 1–5 m-thick, kaolinized, fine-grained, massive leucocratic rock. Chemical analyses of four samples reveal extensive leaching, probably of a felsic–intermediate, fine-grained, volcanogenic sedimentary rock (Hickman and Bagas, in prep.).

Unassigned metasedimentary rocks (*ERs, ERss, ERsm, ERq, ERi, ERm, ERb*)

Figure 3 shows that large metasedimentary enclaves in the orthogneiss of northwestern RUDALL are not correlated with the main succession, and are mapped as lithological units.

Psammitic paragneiss (*ERs*) representing metamorphosed sandstone and subordinate argillaceous siltstone consists of quartz–feldspar–muscovite gneiss with minor amounts of quartz–muscovite schist and quartzite. The main outcrop on RUDALL is southwest of Watrara Pool (AMG 000080). Originally homogeneous feldspathic sandstone is now represented by flaggy psammitic paragneiss (*ERss*) with only rare thin intercalations of pelitic schist. This unit outcrops 7 km northwest of Rudall Crossing, and overlies the Butler Creek Formation. The contact is obscured by scree, but appears to be an angular discontinuity, casting doubt on a correlation with the Poynton Formation.

Muscovite-rich psammitic paragneiss containing layers of quartzite and quartz–muscovite schist (*ERsm*) outcrops southwest of Watrara Pool (AMG 000090). The protoliths of this unit were intercalated sandstone, siltstone, and argillaceous siltstone.

Quartzite (*ERq*) is widespread in the northwestern part of RUDALL and in the Connaughton Hills. The rock is either massive or layered, with a pervasive foliation along recrystallized quartz grains or muscovite-rich planes. The protolith was silica sand, but no sedimentary structures are preserved.

Banded iron-formation (*ERi*) is present in the Camel Domain of northeastern RUDALL, where the unit is at least 50 m thick and contains minor amounts of quartzite. The banded iron-formation is a quartz–magnetite rock occupying an enclave within orthogneiss.

An isolated outcrop (AMG 890130) of quartz–muscovite and quartz–chlorite schist (*ERm*) is extensively veined by quartz, and flanked to the east by sheared quartzite (*ERq*) and minor psammitic paragneiss.

The Connaughton Hills consist predominantly of thick units of psammitic paragneiss intercalated with quartzite. High in the succession the paragneiss contains micaceous quartzite, and thinner members of quartz–muscovite schist (*ERm*) and banded iron-formation (*ERi*) are in the uppermost stratigraphic level. The quartzite is moderately foliated, with variable amounts of sericite or muscovite and traces of tourmaline and feldspar. This rock is interpreted as metamorphosed slightly clayey sandstone. However, it is remarkably clean and could have been a clayey chert. The quartzite is interlayered with crenulated quartz–mica schist and biotite–plagioclase–quartz schist. The finer grained quartz–mica schist essentially has the same mineralogy as the quartzite, but with more abundant muscovite and accessory tourmaline. The biotite–plagioclase–quartz schist contains quartz, biotite, muscovite, and plagioclase (albite to oligioclase). This pelitic schist was probably a lithic sandstone containing clay, feldspar, and iron oxides. The quartzite just north of

Butler Creek contains relict kyanite and sillimanite, and is interpreted as either metamorphosed argillaceous sandstone or a lithic quartzite. This quartzite is intercalated with thin amphibolite units.

Banded paragneiss (*ERb*), lithologically indistinguishable from much of the Butler Creek Formation, is widespread in the Martu, Parnngurr, and Lalapa Domains of eastern RUDALL. Stratigraphic correlation between the Butler Creek Formation and this paragneiss may be justified, but it has not been possible to confirm this on CONNAUGHTON (Bagas and Smithies, 1998a).

Minor intrusions (*ERa, ERaa, ERu*)

The Rudall Complex contains minor amounts of felsic, mafic, and ultramafic metamorphosed intrusive rocks, most of which contain S_2 structures and therefore clearly pre-date the Throssell Group (see **Structure**). Felsic intrusive rocks such as aplite and microgranite are noted in the orthogneiss (*ERga)* unit.

Layers and pods of ultramafic (metamorphosed dunite, peridotite, and pyroxenite) rocks (*ERu*) are present in both the orthogneiss and metasedimentary rocks of the Rudall Complex. The pods are several hundred metres wide and composed of serpentine–tremolite–chlorite rock with serpentine pseudomorphs after olivine and pyroxene. These lenticular masses invariably occupy fold cores and represent the tectonically thickened parts of sheets. Between these fold closures the sheets are commonly sheared out or reduced to 1–2 m of ultramafic schist. From a geochemical study of these rocks, Carr (1989) concluded that the ultramafic rocks had komatiitic affinities. As discussed in **Structure**, the ultramafic bodies are present in three main zones on RUDALL. The most important zone is in the valley of the Rudall River, and strikes west-northwesterly over about 50 km. A zone of D_2 shearing and attenuation structurally controls its central and western sections, whereas further east the ultramafic remnants indicate that the original intrusion transgressed stratigraphic boundaries.

Ortho-amphibolite (*ERa*) representing metamorphosed gabbro and dolerite is present as numerous small enclaves within the orthogneiss complex and in sheets and mega-boudins in paragneiss. The largest bodies are sheets of metagabbro 4 to 8 km south-southwest of Rudall Crossing. These sheets have intruded the Fingoon Quartzite and are intruded by lithologically layered gneiss (*ERgx*) and veins of microgranite. Much of the amphibolite in this area is sheared and metasomatized, locally resulting in zones of calc-silicate gneiss (AMG 105020). The original composition of these mafic intrusive rocks varied from leucogabbro to dolerite.

A zone of mafic enclaves and lenses strikes west-northwesterly along the valley of the Rudall River, parallel to, and about 1–2 km south of, the ultramafic zone described above (*ERu*). These rocks are extensively altered (sheared and metasomatized), but originally varied from fine-grained gabbro to dolerite. Alteration minerals include epidote, clinozoisite, scapolite, carbonate, and phlogopite, and metasomatism has locally produced calc-silicate gneiss. Extensively altered amphibolite, now represented by calc-silicate gneiss (*ERaa*; AMG 215045) has undergone major chemical changes, with enrichment of alumina (28% Al_2O_3) and loss of Fe, Mg, and V. This alteration is discussed in **Metamorphism**.

Orthogneiss (*ERga, ERgx, ERge, ERgb, ERgg, ERgd, ERgm, ERgp*)

On RUDALL, about 50% of the exposed Rudall Complex is composed of orthogneiss derived from granitoid protoliths. About 80% of the orthogneiss is a microcline–quartz–plagioclase–biotite gneiss (*ERga*) containing numerous augen (deformed megacrysts) of K-feldspar. A further 10% of the orthogneiss is a lithologically layered gneiss (*ERgx*) with inclusions (mainly xenoliths) of amphibolite, serpentinite, banded iron-formation, and various types of paragneiss. This relatively complex orthogneiss is pervasively intruded by sheets and veins of augen orthogneiss (*ERga*), suggesting that the granitoid protoliths of these two varieties of gneiss crystallized during separate intrusive events, consistent with current geochronological data. Furthermore, the layer-parallel foliation (S_1) of the lithologically layered gneiss (*ERgx*) is tightly folded (F_2), but no S_1 foliation has been recognized in the augen orthogneiss (*ERga*). Zircons extracted from orthogneiss in the lithologically layered gneiss (*ERgx*; GSWA 104932*, AMG 035158) include a zircon population with an age of 2015 ± 26 Ma. Zircons extracted from several augen orthogneiss (*ERga*) samples have single zircon populations with ages between 1765 and 1790 Ma. Biotite granodioritic orthogneiss (*ERgd*; GSWA 111854, AMG 270003) intruding the Larry Formation in the core of the Dunn Antiform has been dated at 1778 ± 17 Ma, indicating that it is probably a variant of the augen orthogneiss (*ERga*) suite. Xenocrystic zircons in various samples of orthogneiss have a maximum age of 2715 Ma (Nelson, 1995), indicating a complex assemblage of source rocks and crustal contaminants.

Protoliths for the augen orthogneiss (*ERga*) intruded all levels of the paragneiss succession, with the possible exception of flaggy psammitic paragneiss (*ERss*) in the northwestern part of RUDALL. Lithologically layered gneiss (*ERgx*) is almost entirely restricted to the Clayton Domain, where contacts with unassigned metasedimentary units of the Rudall Complex are intrusive. However, it is possible that these metasedimentary rocks are older than the stratigraphic succession from the Larry Formation to the Poynton Formation. At no localities do units of the paragneiss succession unconformably overlie any types of orthogneiss, and no conglomerates containing orthogneiss clasts have been identified. In summary, field evidence on RUDALL indicates that most augen orthogneiss (*ERga*) protoliths were younger than the paragneiss succession, whereas lithologically layered gneiss (*ERgx*) includes c. 2000 Ma granitoid protoliths and is therefore older than the c. 1790 Ma Fingoon Quartzite. The contact between the Fingoon Quartzite and the Larry Formation is

* Six-digit numbers refer to samples held in the Geological Survey of Western Australia's petrology collection.

transitional; therefore, it is concluded that the oldest orthogneiss components of the lithologically layered gneiss (*ERgx*) are older than the entire sedimentary succession now represented by paragneiss in the central part of RUDALL.

Microcline–quartz–plagioclase–biotite gneiss (*ERga*) containing numerous augen of K-feldspar is commonly well exposed, and forms low rocky hills with only sparse vegetation. The rock is variably foliated by S_2 (see **Structure**) mica alignment, and ranges from a poorly foliated porphyritic granite or monzogranite to a quartz–feldspar–muscovite schist. The mica foliation is commonly folded by F_4 folds or crenulated by S_4 (see **Structure**). Microscopic examination reveals a strongly foliated, granoblastic mosaic of microcline, plagioclase, and quartz with variable biotite and muscovite. Other minerals include minor amounts of sphene, allanite, and epidote, with apatite, zircon, and opaque minerals as accessory phases. Plagioclase is sericitized or saussuritized, and microcline forms elongate to lenticular coarse-grained mosaics. Microcline augen commonly enclose small crystals of plagioclase and biotite. Where the rock composition is granodiorite, the feldspar augen are chiefly composed of oligoclase.

Various outcrops of augen orthogneiss (*ERga*) contain xenoliths of orthogneiss (AMG 358005) or paragneiss (AMG 297998), or have been intruded by aplite veins (AMG 245035). Zircon U–Pb dating (Nelson, 1995) indicates that crystallization ages for the augen orthogneiss (*ERga*) probably ranged from 1790 to 1765 Ma. However, some samples (e.g. GSWA 110056, from 5 km southwest of the Rooney Creek – Rudall River confluence) include xenocrystic zircons with a maximum age of 2425 Ma (Nelson, 1995).

A broad zone of aplite and microgranite veins and stockworks in augen orthogneiss (*ERga*) is present southeast and southwest of, and within a radius of 10 km from, Rudall Crossing. None of these units are sufficiently large to show on the 1:100 000 map sheet, but the main area of microgranite is 8 km south of Rudall Crossing (AMG 145000). The microgranite does not contain S_2, and other felsic units of this late intrusive suite either cut S_2 or intrude D_2 shear zones. A stock of weakly foliated biotite–muscovite monzogranite (AMG 280860; *ERge*) could be related to these late-stage granitic intrusions.

Where augen orthogneiss (*ERga*) has been extensively leached and subsequently silicified above a Cainozoic water table, the rock has been mapped as silicic caprock (*Czzg*). This unit now forms numerous mesas in the Rudall River valley. This extensively altered orthogneiss retains its metamorphic foliation, but feldspar has been removed to leave a rock outwardly resembling psammitic paragneiss. However, at the level of the ancient water table the foliated siliceous schist passes abruptly into typical augen orthogneiss (*ERga*).

Orthogneiss with lithological, and therefore compositional, layering (*ERgx*) is mainly exposed in the northwestern part of RUDALL, but similar rocks included in this unit are found south of Larry Creek (AMG 290810). The unit is conspicuously banded, which can be seen both in outcrop and on aerial photographs. Layers of quartz–feldspar–muscovite gneiss alternate with biotite-rich gneiss, quartz–feldspar gneiss, and gneissic pegmatite. Quartzite, paragneiss, amphibolite, serpentinite, and banded iron-formation are included in lithologically layered gneiss (*ERgx*), and range in size from centimetre-wide xenoliths at outcrop scale to large enclaves several hundred metres in length.

Lithologically layered gneiss (*ERgx*) includes several granitoid protoliths ranging in composition from granite and syenogranite to granodiorite. Zircon U–Pb dates of 1787 ± 12 Ma (GSWA 104934, AMG 059022), and 2015 ± 26 Ma and 2717 to 2577 Ma in a mixed zircon population (GSWA 104932, AMG 035158) have been obtained (Nelson, 1995). The sample providing the 1787 Ma age is from drillcore and precise relationships are not clear, but it appears to have been from an augen orthogneiss (*ERga*) intrusion within lithologically layered gneiss (*ERgx*).

Lithologically layered orthogneiss derived from fine- to medium-grained granite or monzogranite (*ERgg*) outcrops north of the Rudall River (AMG 260045). The unit contains nebulitic biotite-rich layers defining complex fold structures, and outwardly resembles parts of the lithologically layered gneiss (*ERgx*). Sheared and boudinaged amphibolite-facies metadolerite layers are interpreted to be early dykes. One sample of the orthogneiss (GSWA 112310) contains two zircon populations dated at 1972 ± 4 Ma and 1802 ± 14 Ma (Nelson, 1995). Field evidence suggests lit-par-lit injection of an older orthogneiss by leucocratic layers and veins.

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

Even-grained granitic to monzogranitic orthogneiss (*ERge*) is a minor, but widespread, constituent of the Rudall Complex. The larger outcrops are found in the northeastern part of RUDALL, adjacent to outcrops of banded garnetiferous granodioritic orthogneiss (*ERgb*) and south of Larry Creek (AMG 260830). South of Larry Creek the rock is a non-foliated to foliated monzogranite containing quartz, microcline, oligoclase, and muscovite. In the northeastern part of RUDALL, foliated, medium- to coarse-grained, granitic to monzogranitic orthogneiss (*ERge*) is veined by pegmatite.

Biotite granodioritic orthogneiss (*ERgd*) outcrops in the Rudall River valley (AMG 270003) as a dark-grey gneiss spotted with blebs of quartz, and occupies a large dyke or stock within quartzite, metagreywacke, and pelitic schist of the Larry Formation. In thin section, elongate blebs of coarsely polygranular quartz are set in an andesine–biotite matrix, with minor muscovite, opaque minerals, microcline, and secondary epidote and carbonate. Most of the quartz probably represents clasts from the quartzite host.

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

Pegmatite (*ERgp*) is a common constituent of the Rudall Complex, but outcrops are commonly too small to distinguish on the 1:100 000 map sheet. Much of the pegmatite is strongly deformed and may be related to pre-D_1 granitoid protoliths of the orthogneiss. Elsewhere, close interlayering of pegmatite with both orthogneiss and certain types of paragneiss, commonly in association with numerous quartz veinlets, indicates derivation from relatively proximal partial melting. The main mineral constituents are quartz, plagioclase, and muscovite, with quartz-rich varieties commonly containing tourmaline.

Yeneena Supergroup

The stratigraphic name 'Yeneena Group' (Williams et. al., 1976) encompassed three geographically separate packages of fluviatile–marine sedimentary rocks (Williams, 1990). Subsequently, Bagas et al. (1995) redefined these assemblages into the Yeneena Supergroup (composed of the Throssell and Lamil Groups) and the Tarcunyah Group. In the northern part of BROADHURST, Hickman and Clarke (1994) noted that a discontinuity of unknown type (fault or unconformity) separates the Throssell Group from the Lamil Group. On RUDALL, the contact between the Throssell Group and the Tarcunyah Group is tectonic.

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

Throssell Group

Coolbro Sandstone (ETc, ETcp, ETcs, ETcd)

The Coolbro Sandstone (*ETc*) was named and defined by Williams et al. (1976). The succession on RUDALL is the southern continuation of the same formation on BROADHURST (Hickman and Clarke, 1994). Southeasterly stratigraphic thinning recorded on BROADHURST continues onto the northern part of RUDALL, where the sandstone succession is about 2 km thick. The Coolbro Sandstone is absent in the southern part of RUDALL, and northerly directed palaeocurrents in the southern part of the Broadhurst Range and on Miles Ridge suggest that this is due to onlap against a basement topographic high. The latter would partly coincide with the northeasterly trending culmination in the Rudall Complex of the Fingoon Range (D_4; see **Structure**).

The Coolbro Sandstone unconformably overlies the Rudall Complex, and its lowest beds are commonly polymictic conglomerate (*ETcp*) containing rounded boulders and pebbles of gneiss, quartzite, and vein quartz. These conglomerate units are lenticular, particularly where boulder-sized clasts are present, and interpreted as channel-fill deposits. Well-sorted, matrix-supported, vein quartz conglomerate beds locally display crude vertical grading and are commonly ferruginous, indicating a pyrite component in the fresh rock. However, geochemical analysis has not revealed anomalous gold, uranium, or base-metal values.

Shale or pelitic schist (*ETcs*) forms units up to 50 m thick in the Miles Ridge area in northeastern RUDALL and also forms parts of faulted isoclinal outliers in the Rudall Complex. Shale units have commonly reacted incompetently to stress during the Paterson Orogeny, and are partly converted into carbonaceous schist veined by quartz. Some of the quartz veins contain highly anomalous gold and silver contents (see **Economic geology**).

Interbedded sandstone, siltstone, and shale (*ETcd*) form a 500 m-thick unit in the lower part of the Coolbro Sandstone at Miles Ridge (AMG 360100). The unit overlies basal conglomerate and represents a southeasterly lateral facies change from sandstone in the northwest to more argillaceous rocks, and may coincide with the edge of a deltaic sand wedge to the northwest. Palaeocurrent data in the Miles Ridge area show northerly flowing currents in the Coolbro Sandstone (Fig. 6), conforming to similar observations on BROADHURST (Hickman and Clarke, 1994).

Broadhurst Formation (ETb, ETbs, ETbk, ETbq)

The Broadhurst Formation (*ETb*) was named (Williams et al., 1976) after Broadhurst Range, and its type locality is on BROADHURST. The unit conformably overlies the Coolbro Sandstone, and is exposed west of Fingoon Range and southwest of the Southwest Thrust in the northeastern part of RUDALL. Near the Fingoon Range only the lower 500 m of the formation is exposed, and is composed of carbonaceous, graphitic, or sulfidic shale and minor amounts of sandstone, dolostone, and limestone.

Pelitic schist or shale (*ETbs*) is the dominant rock type of the Broadhurst Formation and is intercalated with sandstone in the basal transitional zone with the underlying Coolbro Sandstone. The schist is dark grey, carbonaceous, and poorly exposed. This basal part of the formation has a strong magnetic signature, probably due to a high pyrrhotite content. The shale is interbedded with limestone and dolostone beds (*ETbk*) between 120 and 220 m from the base. This is overlain by less than 300 m of shale (*ETbs*), which in turn is overlain by sandstone (*PTbq*) similar in appearance to the Coolbro Sandstone.

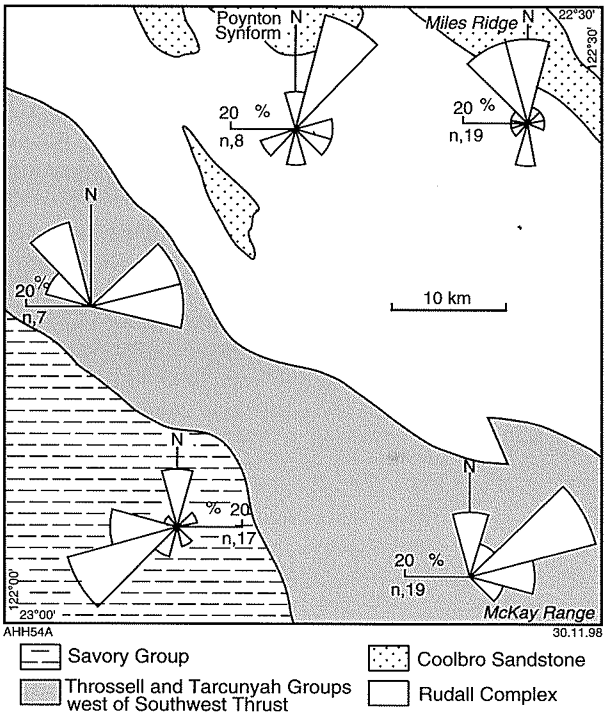

Figure 6. Palaeocurrent analysis of the Throssell, Tarcunyah, and Savory Groups, RUDALL

Southwest of the Southwest Thrust in the northwestern part of RUDALL, the Broadhurst Formation contains numerous sandstone units within a dominantly shale–siltstone succession.

Taliwanya Formation (ꝐTt)

On CONNAUGHTON the Taliwanya Formation (*ꝐTt*) unconformably overlies the Rudall Complex and is where the unit is best developed and formally defined (Bagas and Smithies, 1998a). On RUDALL the unit is restricted to local outcrops of conglomerate north of the McKay Range.

Pungkuli Formation (ꝐTp)

Shale and carbonate rocks correlated with the Pungkuli Formation (*ꝐTp*) of CONNAUGHTON (Bagas and Smithies, 1998a) are locally exposed north of the McKay Range in the southeastern part of RUDALL. On CONNAUGHTON, the formation is assumed to be disconformably overlain by the Gunanya Sandstone of the Tarcunyah Group

Stratigraphic relationships between the Taliwanya and Pungkuli Formations of the McKay Range and the Coolbro Sandstone and Broadhurst Formation of the Throssell and Broadhurst Ranges are problematical, but the units are tentatively grouped together lithostratigraphically.

Tarcunyah Group

The Tarcunyah Group is formally defined on THROSSELL (Williams and Bagas, in prep.a). Recent work supports a Neoproterozoic age for the group, and it is now considered to be partly coeval with the Savory Group (Bagas et al., 1995). Palaeontological evidence from stromatolites and acritarchs suggest that the Tarcunyah Group is equivalent to Supersequence 1 of the greater Officer Basin (Walter et al., 1995; Bagas et al., 1995; Perincek, 1996).

Only two formations of the Tarcunyah Group are exposed on RUDALL — the Gunanya Sandstone and the Waters Formation — both of which outcrop in the McKay Range.

Gunanya Sandstone (*ꝐUu, ꝐUup, ꝐUua*)

The Gunanya Sandstone (*ꝐUu*) is 500 m thick, consists of coarse- to medium-grained arkosic sandstone, and exhibits abundant trough cross-bedding. The upper 100 m of the formation contains thin pebbly horizons and beds of feldspathic grit. Palaeocurrent data (Fig. 6) indicate that deposition was from northeasterly flowing currents, presumably in a fluviatile to deltaic environment. Conglomerate (*ꝐUup*) within the formation (AMG 485630) is 10–20 m thick, and contains well-sorted, matrix-supported, rounded, vein-quartz pebbles 10–20 mm in diameter. Elsewhere, conglomerate beds of this type are less than 1 m thick. On the western side of the McKay Range the sandstone includes a unit of interbedded sandstone and siltstone (*ꝐUua*), marking a local interval of fine-grained clastic sedimentation.

Waters Formation (*ꝐUt, ꝐUts, ꝐUta, ꝐUtw, ꝐUtc, ꝐUtk*)

A 50–100 m-thick carbonaceous shale unit (*ꝐUts*) of the Waters Formation (*ꝐUt*) conformably overlies the Gunanya Sandstone. The most extensive exposures of this basal unit of the Waters Formation are on the northern side of the McKay Range (AMG 485615 and 450580). The shale (*ꝐUts*) varies from reddish-brown to grey, contains some thin sandstone beds in its lower part, and is locally sulfidic (gossanous at the surface). At higher stratigraphic levels the shale unit contains thin carbonate beds and is overlain by a 20 m-thick sandstone unit (*ꝐUta*). The sandstone unit exhibits cross-bedding and upward fining, and is overlain by 100 m-thick, brown-grey, silty shale containing nodular limonite layers. On the northwestern side of the McKay Range this shale unit is overlain by a 100 m-thick arenite composed of 10–20 m-thick sandstone–siltstone–shale rhythmic units (*ꝐUtw*). Basal parts of the sandstone units are in abrupt, conformable contact with shale units at the top of the previous rhythmic unit. The lowest sandstone beds are coarse grained and commonly gritty or pebbly. Planar and trough cross-bedding indicate northerly to northeasterly flowing palaeocurrents. Overlying siltstone beds are flaggy and locally ferruginous, and fine upward to 1–2 m-thick shales at the top of each rhythmic unit. These shales are reddish-brown and contain 10–50 mm-thick gossanous layers (oxidized sulfidic shale). Exposures above the rhythmic member are limited to two low, altered (calcrete or silcrete) outcrops of finely laminated grey carbonate and shale (AMG 360625 and 330585). The more northeasterly exposure indicates the presence of a carbonate unit (*ꝐUtc*) at least 50 m thick, but a calcrete caprock obscures most of the unit. Parts of the carbonate are dark grey and include thin gossanous layers. The other exposure is almost entirely covered by silcrete, and consists principally of shale with minor silicified carbonate layers (*ᵽUtk*).

Carbonate (*ᵽUtc*) and carbonate–shale (*ᵽUtk*) units (AMG 465620) in the upper part of the formation are probably equivalent to other carbonate units (AMG 360625). Boulders of stromatolitic carbonate are present (AMG 465620), although no stromatolites were found in the bedrock.

Outcrops of purple feldspathic arenite, 13 km east-northeast of White Gums Bore, are tentatively assigned to the Waters Formation and labelled *ᵽUta*. Bedding here is ripple marked, and siltstone contains pebbles of vein quartz.

Savory Group

Stratigraphic subdivision of the Savory Group follows that of Williams (1992). In the southwestern part of RUDALL, the group is represented by formations belonging to three of the depositional sequences recognized by Williams (1992). The oldest unit, the Mundadjini Formation, is interpreted to be a deltaic to shallow-marine sandstone, about 840–815 Ma in age. The age of the overlying Boondawari Formation is considered to be 670 Ma, based on a correlation with the glacigenic Olympic Formation of the Amadeus Basin in central Australia (Williams I. R., 1993, pers. comm.). The McFadden and Tchukardine Formations are interpreted to have been deposited in the Wells Foreland Basin, to which Williams (1992) assigned an age of about 620–600 Ma based on its genetic relationship to the Paterson Orogeny. Williams (1992) stated that the Tchukardine and McFadden Formations disconformably overlie the Mundadjini and Boondawari Formations, and that the Boondawari Formation disconformably or unconformably overlies the Mundadjini Formation. The contact between the Tchukardine and McFadden Formations is a north-northeasterly striking fault in the Emu Range area of RUDALL.

Mundadjini Formation (*ᵽSm*)

The Mundadjini Formation (*ᵽSm*), named and defined by Williams and Tyler (1991), outcrops in the core of an anticline (AMG 990675). The formation is composed of medium-grained, cross-bedded sandstone. Except on very large outcrops, the cross-bedding is difficult to measure as a consequence of the individual cross-beds being 5–10 m thick. By far the most visible sedimentary layering is foreset lamination, spaced at 50–300 mm intervals. Palaeocurrent analyses from observations at two localities indicate southwesterly flowing currents.

Boondawari Formation (*ᵽSb, ᵽSbm, ᵽSbh*)

The Boondawari Formation (*ᵽSb*) of Williams and Tyler (1991) is composed of glacigenic diamictite (*ᵽSbm*), shale and mudstone (*ᵽSbh*), and sandstone–siltstone (included in *ᵽSb*). The diamictite consists of well-rounded and striated pebbles and smaller lithic clasts in a ferruginous mudstone matrix. The best exposures are 8 km south of White Gums Bore in the southern part of RUDALL (AMG 165670), where a 15 m-thick sandstone unit separates two diamictite units. The lower diamictite is 30 m thick and the upper unit is 4 m thick, with quartzite and silicified shale clasts up to 300 mm in diameter. Underlying the lower diamictite is sandstone (*ᵽSb*) with well-preserved ripple marks indicating westerly to west-northwesterly flowing currents. Shale (*ᵽSbh*) above the upper diamictite has varve-like laminations and fine-scale cross-bedding in silty beds. The diamictite of the Boondawari Formation is poorly and intermittently exposed over a strike length of 8 km on RUDALL. Identification of the unit from 'float' (residual clasts) is complicated by the presence of Paterson Formation tillite in the same area.

Tchukardine Formation (*ᵽSt*)

The Tchukardine Formation (Williams, 1992) is predominantly composed of medium-grained, cross-bedded sandstone (*ᵽSt*), with rare silty shale, conglomerate, and siltstone. Cross-bed sets are locally so large as to be visible on 1:50 000-scale aerial photographs. The dominant palaeo-current direction is westerly or southwesterly, confirming the observations of Williams (1992). On RUDALL the formation is at least 200 m thick.

McFadden Formation (*ᵽSf*)

On RUDALL the McFadden Formation (Williams, 1992) is confined to the Emu Range, where it is in faulted contact with the Tchukardine Formation. However, south of RUDALL, Williams (1992) mapped the formation over a distance of 400 km.

In the Emu Range the formation is composed of alternating units of medium-grained sandstone and flaggy, fine-grained sandstone (*ᵽSf*). Cross-bedding is on a large scale, with individual cross-beds being 1–10 m thick. Palaeocurrent directions are commonly northerly in Emu Range, but a regional survey by Williams (1992) indicated a westerly to southerly flow regime further south.

Dykes, veins, breccia, and gossan (*d, q, b, fb, go*)

Minor intrusive rocks of unknown age consist of dolerite dykes (*d*), quartz veins (*q*), and barite(–hematite) veins (*b*). Also included in this group are gossan (*go*) units (although these have various origins ranging from intrusion-related to stratiform and syngenetic) and fault breccia (*fb*).

Dolerite dykes (*d*) intruding the Rudall Complex in the northwestern part of RUDALL have varying trends from west-northwest to north-northwest. The dolerite exhibits low metamorphic grade and the dykes clearly post-date D_2 and D_4 structures. The later relationship establishes that they are younger than the Throssell Group, but no intrusion of the Throssell Group has been observed.

Quartz (*q*) veins are widespread on RUDALL, and are commonly located in faults and shear zones. Some veins are limonitic, particularly along their margins, indicating wallrock sulfidation reactions. Other veins contain limonite and goethite in late fractures, suggesting precipitation from groundwater during Cainozoic lateritization. Chemical analyses of vein quartz locally establish hydrothermal mineralization containing highly anomalous contents of Ce, La, Ba, Cu, As, Ag, and Au (Hickman and Bagas, in prep). Some veins also contain visible tourmaline or rutile.

Barite (*b*) veins, locally including up to 50% massive hematite, are present in the northwestern part of RUDALL (AMG 012088 and 020048). At the northern locality the veins are up to 4 m thick and consist of layers of grey and cream-coloured barite containing hematite and grains of silica. Separate layers of granular hematite and chert are commonly minor constituents of the veins. Late, salmon-coloured barite veinlets transgress the layered barite. The barite veins truncate the main foliation (S_2) in banded orthogneiss and quartz–muscovite schist of the Rudall Complex. However, hematite layers in the veins are isoclinally folded by northwesterly plunging folds, which could be related to either D_4 or D_6 deformation events. At both the northern and southern occurrences there are two sets of barite–hematite veins, one striking west-northwest and another set striking north-northeast. Both areas are adjacent to a north-northwesterly striking D_6 fault, and it is probable that the barite veining is related to the D_6 event and associated hydrothermal activity.

Gossan or gossanous rock (*go*) units are limonite–goethite concentrations formed by surface oxidation of sulfide mineralization. Such sulfide mineralization is either epigenetic (commonly accompanying quartz veining), or syngenetic and stratiform. All gossans identified during the mapping were sampled, and analytical results are discussed in Hickman and Bagas (in prep.)

Silicified fault breccia (*fb*), shown by an overprint on the map, is mainly associated with brittle D_6 faults. Accessible examples are in the Rudall River valley (AMG 150050 and 160030) and on the northern slopes of the McKay Range (AMG 485640). Angular fragments of country rock are enveloped by a siliceous, and commonly ferruginous, comminuted matrix of rock flour, and some microcrystalline pseudotachylyte veinlets are locally present.

Permian geology

Figure 7 shows the location of Permian glacial valleys, which are probably shallower than similar valleys on BROADHURST (Hickman and Clarke, 1994). Limited glacial striae on adjacent Proterozoic rocks indicate that ice movement was northerly, as on BROADHURST. These valleys contain fluvioglacial sediments and tillite, and where these deposits outcrop they form isolated mesas or partially dissected benches flanking larger hills.

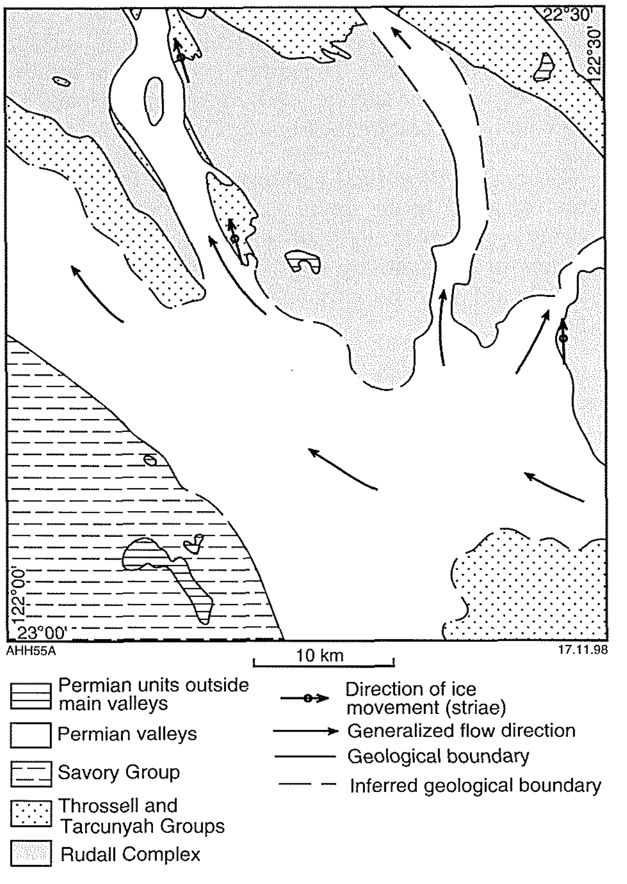

Figure 7. Permian valleys on RUDALL

Paterson Formation (*Pa*)

The Permian sediments are assigned to the Paterson Formation (*Pa*), previously described by Traves et al. (1957) and Chin et al. (1980, 1982). The areas labelled as dissected valley deposits on Figure 2 contain well-rounded boulders within tillite deposits. These boulders locally exceed 5 m in diameter and include quartzite, orthogneiss, and paragneiss.

The tillite deposits pass upward into cross-bedded, medium- to coarse-grained sandstone, siltstone, and mudstone, with ripple marks, trace fossils (AMG 237897 and 446814), and graded laminae. Sandstone, siltstone, and mudstone south of Fingoon Range, near Larry Creek, and around the headwaters of May Creek show no evidence of a glacial origin, and may include Mesozoic units of the Canning Basin.

Cainozoic geology

Recent sediments that are presently being deposited are mapped as Quaternary (*Q*), while older more dissected sediments are mapped as Cainozoic deposits (*Cz*).

Gently undulating cappings of duricrust, including ferricrete or ironstone deposits (*Czl*), silcrete deposits (*Czz*), and silicified sandstone caprock (*Czzc*) expose underlying bedrock where dissected. The duricrust represents remnants of Cainozoic weathering profiles in which the original rock structures or textures are poorly preserved. The ferricrete grades downward into leached and kaolinized deeply weathered rock. These sediments are probably Tertiary in age and may represent a Tertiary continent-wide weathering event (Idnurm and Senior, 1978). Silicified augen orthogneiss (*Czzg*) in the Rudall River valley is shown on the map as a Cainozoic unit, although it is clearly an in situ alteration product of the orthogneiss.

Colluvium, sheetwash, fan deposits, and talus (*Czc*) are composed of red-brown, ferruginous gravel, sand, and silt. They are derived from various rock types, but mainly from those relatively resistant to weathering and erosion, which now form adjacent hilly areas. Colluvium derived from Permian fluvioglacial sediments and tillite (*Czcg*) exhibits a distinctive light photo pattern east of May Creek and around the Rudall airstrip.

Consolidated alluvial conglomerate (*Czag*) along the Rudall River and Poynton Creek is dissected by the present drainage, and forms banks 5–10 m above modern equivalents in the beds of the watercourses. The unit is variably indurated by siliceous or ferruginous cement.

Calcrete (*Czk*), consisting of massive, vuggy, or nodular sandy limestone, is only a few metres thick and present in old drainage channels in the eastern and southwestern parts of RUDALL. Secondary silicification locally results in incomplete replacement by a vuggy and opaline silica caprock. In the southwestern part of RUDALL, calcrete of an old major drainage course is transgressed and overlain by seif dunes.

Quaternary deposits

Locally derived colluvial sands, soil, and gravel (*Qc*) form gently sloping scree and outwash fans alongside ridges and hills. Watercourses, forming banks up to 3 m high, weakly incise the colluvium. Extensive colluvial fans locally grade downstream into alluvium.

Sand containing laterite granules and pebbles (*Qp*) forms characteristic dark photo patterns in the southwestern and southeastern parts of RUDALL. This unit is a mixture of partly residual and partly transported ferricrete granules, pebbles, and eolian sand. Being partly residual in origin, the unit indicates relatively high iron content in bedrock, and commonly overlies shale, pelitic schist, or nodular laterite.

Flat to undulating sandplain (*Qs*) covers most of the southwestern and northeastern-most parts of RUDALL. The sandplain and seif dunes consist of dark-red eolian sand and clayey sand. The sand is composed of iron-stained quartz grains up to 0.5 mm in diameter. The dunes are up to 30 m in height, many kilometres long, and have a pronounced west to northwest orientation in the direction of the prevailing winds. Sand movement is confined to the dune crests, and a cover of spinifex (*Triodia sp.*) and small bushy eucalypts stabilizes their sides. Some dunes terminate on the eastern sides of outcrops or where cut by drainage channels. The depth of the sand between dunes is commonly less than 2–3 m, as revealed by exposed pediments and an absence of trees (shallow soil).

Poorly developed red-earth soils (*Qw*) cover the central part of RUDALL between the Fingoon Range and the eolian sands in the southwest. This unit is covered with dense mulga, which has grown in a distinctive curved pattern. The soils have formed over mature, deeply weathered plains or after mature alluvium, and contain varying amounts of ferricrete granules and, in places, calcareous soils.

The present drainage courses and associated floodplains contain alluvium (*Qa*) consisting of unconsolidated clay, silt, sand, and gravel. The floodplain deposits also contain sand and clay mixed with eolian sands. As on BROADHURST (Hickman and Clarke, 1994) the drainage leaving hilly areas eventually terminate in floodplains, where floodwaters are absorbed by eolian sands.

Playa lake deposits (*Ql*) consist of clay, silt, and evaporites occupying low-lying areas marginal to drainage channels or at the termination of creeks against sand dunes. Beneath the surface of these lake areas is a mixture of black to brown mud, evaporites, and sand. Lake surfaces are not vegetated except for seasonal grasses and scattered eucalypts.

Structure

An outline of the regional structural setting of RUDALL is provided under **Regional geological setting**. Table 2 summarizes structures of the various deformation events that have affected RUDALL. The area's major structures are illustrated on Figure 3.

Pre-Yeneena Supergroup deformation

D_1 structures

No major D_1 fold structures were identified during mapping, but the widespread existence of layer-parallel penetrative schistosity folded by F_2 isoclines, and in places visibly deformed by cross-cutting S_2 foliation, establishes regional deformation prior to the D_2 event. The observation that S_1 is parallel to compositional layering in the paragneiss and quartzite units suggests that it may be the axial plane foliation of major isoclinal (possibly recumbent) folds. However, it could also be associated with subhorizontal tectonic interleaving (thrusting). The D_2 event obliterated any linear fabrics that could have been used to establish the orientation of D_1 strain.

D_2 structures

The D_2 event was not a single short-term event affecting all parts of the Rudall Complex at precisely the same time. This is established by D_2 thrust-stacking, with structures in the northeast and east apparently over-riding earlier structures to the southwest.

Table 2. Summary of deformation episodes on RUDALL

Event, age, and magmatism	*Major structures*	*Minor structures*	*Metamorphism*
D_1: Early Yapungku Orogeny, c. 2015–1787 Ma. Regional layer-parallel shear, direction unknown	Identified on BROADHURST	S_1: Penetrative layer-parallel schistosity; alignment of mica, quartz, and feldspar	M_1: Low-pressure, mid-amphibolite facies conditions (on BROADHURST); local melting; granitoid intrusion.
D_2: Late Yapungku Orogeny, c. 1787–1765 Ma. Southwesterly and westerly directed thrusting and overfolding	Tight to isoclinal F_2 folds (axes trend west-northwest to north and are overturned towards the south-southwest); D_2 thrust zones	F_2: Isoclinal folds. S_2: Schistosity due to alignment of mica and quartz. L_2: Stretching lineation within S_2	M_2: Medium-pressure amphibolite facies; some melting of pelitic rocks. Granitoid magmatism and pegmatite mineralization.
D_3: Early Miles Orogeny. Local westerly or northwesterly directed isoclinal–recumbent folding	F_3 recumbent folds with east–west to northeast–southwest axes; only on BROADHURST	Local faulting and quartz veining of the Rudall Complex – Throssell Group unconformity	None identified
D_4 : Miles Orogeny, c. 900–800 Ma. Regional deformation in response to southwesterly directed compression	Upright, tight to isoclinal F_4 folding about northwesterly trending axes. Strike-slip fault system	S_4: Axial surface cleavage inclined steeply to northeast L_4: Stretching lineations plunge down-dip on S_4	M_4: lower greenschist facies; locally intense cataclasis and dynamic recrystallization. Hydrothermal mineralization.
D_5: Local deformation. ?Northeasterly directed stress release after D_4	None identified on RUDALL	Open recumbent F_5 crenulation; S_5 strike-slip cleavage; only on BROADHURST	None identified on RUDALL
D_6: Paterson Orogeny, c. 620–530 Ma. Brittle deformation in response to north-northeast – south-southwest compression	East-northeasterly and northerly striking near-vertical strike-slip faults	S_6: Strain-slip cleavage, axial to conjugate kink bands, deforming S_4	None identified on RUDALL. Granite magmatism in the Telfer region

Complex tight to isoclinal F_4 folding in the central part of the Fingoon Domain and in the Warturnkurru Domain have obscured the original orientation of D_2 structures, although F_2 folds have also been observed in F_4 axial regions (AMG 256906). These folds are isoclinal and plunge shallowly towards the north. To the southeast, away from the F_4 axial regions and in areas of shearing (AMG 265903), F_2 folds are parallel to F_4 folds. This observation suggests that F_2 folds have most likely been rotated towards parallelism with F_4 folds during progressive shearing. Therefore, the local F_4 effects on F_2, especially in the Fingoon Quartzite, are difficult or impossible to determine in the field.

The D_4 shear zones would have been incompetent units subjected to reactivation during the D_4 event. Consequently, the recognition of D_2 shear zones within D_4 lags and thrusts depends on the following criteria: extreme attenuation inconsistent with adjacent F_4 folds; associated minor F_2 folds and faults; or sheared pre-D_4 intrusions of microgranite, aplite, or pegmatite.

The D_2 event included emplacement of sheets of ultramafic rocks parallel to S_2 and apparently partly controlled by D_2 shear zones.

Post-Yeneena Supergroup deformation

On BROADHURST (Hickman and Clarke, 1994) four phases of deformation, D_3–D_6, were recognized in the Throssell Group. The D_4 event was the dominant event responsible for the major northwesterly trending folds visible on maps and aerial photographs. Of these four phases, D_4 and D_6 are well developed on RUDALL, and local pre-D_4 movement along the Rudall Complex – Throssell Group unconformity probably represents the D_3 event. The D_3 and D_4 events are considered to be progressive deformation events forming the Miles Orogeny (Bagas et al., 1995). Post-D_4 folds, faults, and cleavage in the Savory Group on RUDALL are here assigned to the D_6 event, which was redefined as the Paterson Orogen by Bagas et al. (1995). These Savory Group structures were formed under a very similar stress regime to D_6 in the Throssell Group (north-northeast to south-southwest compression) and are of the same type as those in the Throssell Group. Williams (1992) presented sedimentological and structural evidence that these Savory Group structures formed after the D_4 event and that they are younger than 670 Ma, the probable depositional age of the Boondawari Formation.

D_3 structures

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

D_4 structures

The most easily recognizable deformation event in both the Rudall Complex and Throssell Group produced D_4 structures trending about 300–320°. These structures represent the main phase of post-Throssell Group deformation and, subsequent to mapping on RUDALL and CONNAUGHTON, have been included with D_3 in the Miles Orogeny (Bagas et al., 1995). The dominant tectonic structures of the Throssell Group are major, upright to overturned, tight to isoclinal, northwesterly to west-northwesterly trending folds, commonly with intervening northwesterly striking faults and shear zones. Most folds are overturned to the southwest, and contain a variably developed axial plane cleavage, S_4, dipping steeply to the northeast. Individual faults extend laterally for tens of kilometres and exhibit both down-dip and strike-slip movement. In terms of vertical movement, the southwestern limbs of the anticlines are associated with high-angle thrusts, and complimentary lag faults (normal) are present on their northeastern limbs. On a regional scale the faults intersect at acute angles and, overall, present an anastomosing system.

The F_4 fold geometry in the Rudall Complex is complicated by the fact that the D_4 event was superimposed on a pre-existing structural complex in which lithological layering and metamorphic foliations were inclined. The most obvious consequence of this superimposition is that minor F_4 folds in the Rudall Complex commonly plunge far more steeply than F_4 folds in the Throssell Group. Plunge directions (northwest or southeast) are far less affected because F_4 axial surfaces are steeply inclined. The variable plunge of F_4 folds in the Rudall Complex and the fact that, like F_2 folds, F_4 folds are tight to isoclinal, locally cause problems in distinguishing between minor F_2 and F_4 folds in the field. Minor F_4 folds can best be distinguished where they deform S_2 foliation.

A regional reversal of plunge of F_4 folds is present across a northeasterly trending zone between Talbot Soak (AMG 370060) and the centre of the map sheet (Fig. 4). This culmination is unlike local F_4 culminations in the Throssell Group on BROADHURST in that it is not restricted to an individual fold, but equally affects all F_4 folds in the area. Therefore, the reversal must result from either uniformly high southwesterly axial strain (stretching) in this area, or from interference with a northeasterly trending antiform.

Mapping on RUDALL indicates that vertical displacement along the thrusts and lags range from a few hundred metres to at least 3 km (e.g. Clayton Thrust, AMG 070010). However, the Southwest Thrust (Fig. 3), which is a relatively low-angle fault, has brought older units of the Rudall Complex into contact with the Broadhurst Formation and is clearly a major regional structure (Fig. 1). This conclusion was also reached by Chin et al. (1980), who noted a coincidence between this fault and the steep gravity gradient on the southwestern margin of the Warri Gravity Ridge.

South of Junction Creek (AMG 000030), the Southwest Thrust dips northeasterly at 30–40°, an inclination markedly shallower than structurally overlying thrusts to the northeast. There has been at least 4 km of movement along the Southwest Thrust in the northwestern part of RUDALL since the Coolbro Sandstone is absent to the west. The Southwest Thrust is probably a sole thrust, flattening to the northeast.

D_6 structures

As on BROADHURST (Hickman and Clarke, 1994) D_6 structures on RUDALL consist of northerly to northwesterly striking dextral faults, east-northeasterly striking sinistral faults, and the associated strain-slip cleavage, S_6. In northeastern RUDALL and southeastern BROADHURST, easterly to east-southeasterly trending open folds are present between northwesterly striking D_4 faults. Many D_4 faults were reactivated during the D_6 event, as confirmed by the observation that northerly striking D_6 faults commonly branch off the D_4 faults. D_6 stress (maximum compression from the north-northeast) is likely to have resulted in D_6 dextral movement along the D_4 faults, and this movement was accompanied by the formation of easterly trending, oblique, transpressional F_6 folds. The D_6 stress regime was similar to the D_4 stress regime, but D_6 folding and faulting on RUDALL was far less intense than during the D_4 event. In the northwestern part of RUDALL, the Southwest Thrust is displaced by northwesterly striking D_6 dextral faults south of Junction Creek (AMG 020025).

In the southwestern part of RUDALL, fault, fold, and cleavage structures in the Savory Group are consistent with generation by the D_6 event. The folds of this area are open and plunge at about 10° to the northwest or southeast. Faults are steep to vertical, and most appear to be minor. Williams (1992) noted that the northerly striking faults are dextral, whereas the east-northeasterly striking faults are sinistral.

In the southeastern part of RUDALL, the Gunanya Sandstone is extensively silicified, brecciated, and veined by quartz and hematite against a major high-angle fault along the northeastern edge of the McKay Range. Upthrow on the northeastern side of this fault is established by the juxtaposition of the Gunanya Sandstone and Pungkuli Formation.

Metamorphism

The Miles Orogeny (D_3–D_4) produced the dominant structural and metamorphic features of the area with the result that earlier structures and metamorphic mineral assemblages are overprinted and incompletely preserved. Even so, there is abundant evidence that the Rudall Complex was metamorphosed to amphibolite facies prior to deposition of the Yeneena Supergroup, and that this metamorphism was principally related to the D_2 event. The M_1 (D_1) mineral assemblages are extremely poorly preserved. Greenschist metamorphism associated with the D_4 event affected both the Rudall Complex and Throssell Group, but it is also possible that some greenschist assemblages in the Rudall Complex represent late M_2 retrogression. No significant metamorphism has affected the Tarcunyah Group.

The sedimentary formations of the Savory Group show no evidence of recrystallization after diagenesis (Williams, I. R., 1993, pers. comm.), indicating no significant burial metamorphism.

Metamorphism on Rudall is discussed in more detail in Hickman and Bagas (in prep.).

Rudall Complex

The Rudall Complex was metamorphosed to amphibolite facies preceding deposition of the Yeneena Supergroup, since all units of the Yeneena Supergroup exhibit only greenschist facies effects. However, D_4 deformation of the Rudall Complex resulted in structural juxtaposition of segments from different positions in the crust. Thus, any pre-D_4 regional metamorphic zonation has been fragmented.

As noted by Clarke (1991), it is difficult to identify M_1 mineral assemblages because of M_2 recrystallization. Retrograde metamorphism possibly late in the D_2 and D_4 events has also partially replaced M_2 assemblages. Even so, M_2 prograde metamorphic minerals are locally preserved, particularly in pelitic and semipelitic schists.

The distribution of diagnostic metamorphic minerals in the Rudall Complex on RUDALL is shown on Figure 8. Most of the Rudall Complex has been subjected to prograde amphibolite-facies metamorphism, with maximum grade possibly reaching the amphibolite-granulite transition. However, most of the present mineral assemblages were formed by greenschist-facies retrogression, and relics of diagnostic medium- to high-grade prograde minerals are too infrequent for reconstruction of regional metamorphic patterns. Retrogression was probably post-peak M_2 and syn-M_4.

Lithology and metamorphic mineral assemblages

Pelitic schist

Most pelitic schist consists of quartz (with undulose extinction) and muscovite (commonly sericite) with variable chlorite, biotite, epidote, plagioclase, and magnetite, and rare tourmaline. Clumps of sericite up to 10 mm in diameter commonly contain relict kyanite, sillimanite, or staurolite, and plagioclase is extensively sericitized.

Biotite is variably retrogressed to chlorite, sericite, epidote, and iron oxides. It forms part of an early foliation (probably S_2) at an angle to, and cross-cut by, a later foliation (S_4). The later foliation is defined by lineated and usually undisturbed sericite flakes that are locally slightly bent.

Garnet (mostly almandine) is present with or without staurolite, but has not been found in association with kyanite or sillimanite. The garnet is highly fractured, with sericite, quartz, and iron oxide infillings, and is enveloped or wrapped by schist fabrics containing chlorite, sericite, quartz, or iron oxides (probably ilmenite). Some garnets show 'snowball' textures (S_2) with schist fabrics (S_4) wrapping around them.

Paragneiss and quartzite

Quartzite commonly provides little evidence of metamorphic grade, being composed of an oriented quartz mosaic with minor amounts of muscovite or sericite. However, some samples contain hornblende and others contain sericite, chlorite, or clay apparently pseudomorphing sillimanite (GSWA 106829, AMG 298956).

Small relics of staurolite are enveloped by sericite and quartz and relics of biotite are altered to sericite and chlorite (AMG 275872, GSWA 106816). The biotite defines an early foliation (S_2) that is cross-cut by later and little deformed sericite (S_4).

Chlorite has commonly replaced (post-peak M_2) hornblende or actinolite, leaving relics of these medium-grade metamorphic minerals. Garnet (almandine) is common, but staurolite and kyanite are rare, reflecting the relatively low aluminium contents of most paragneiss protoliths.

Amphibolite

Amphibolite units on RUDALL are principally ortho-amphibolite, and represent metamorphosed dolerite, gabbro, and pyroxenite. The main mineral constituents are now hornblende or actinolite and plagioclase (andesine to anorthite), with minor amounts of quartz and variable amounts of epidote, clinozoisite, chlorite, biotite, scapolite, apatite, sphene, rutile, and iron oxides. Metamorphosed pyroxenites contain no plagioclase or quartz. Para-amphibolite within the paragneiss units probably represents metamorphosed calcareous sedimentary rock, and contains some quartz and apatite.

Banded iron-formation

Metamorphosed banded iron-formation consists of layers of quartz mosaic alternating with granular magnetite or magnetite–quartz layers. Grunerite is commonly present in the iron-rich layers, indicating metamorphism at a grade between the garnet and sillimanite zones of pelitic rocks (amphibolite metamorphic facies; Turner and Verhoogen, 1960).

Metamorphosed ultramafic bodies

Ultramafic bodies have been metamorphosed to produce rocks ranging from serpentinite to serpentine–tremolite–chlorite(–talc) and actinolite–epidote rocks. The most common rock type is serpentinized peridotite. Opaque minerals are abundant and outline olivine cumulate textures. Anthophyllite is locally present, suggesting amphibolite facies, hornblende-hornfels facies, or metasomatic conditions, but the other minerals present are characteristic of greenschist-facies metamorphism.

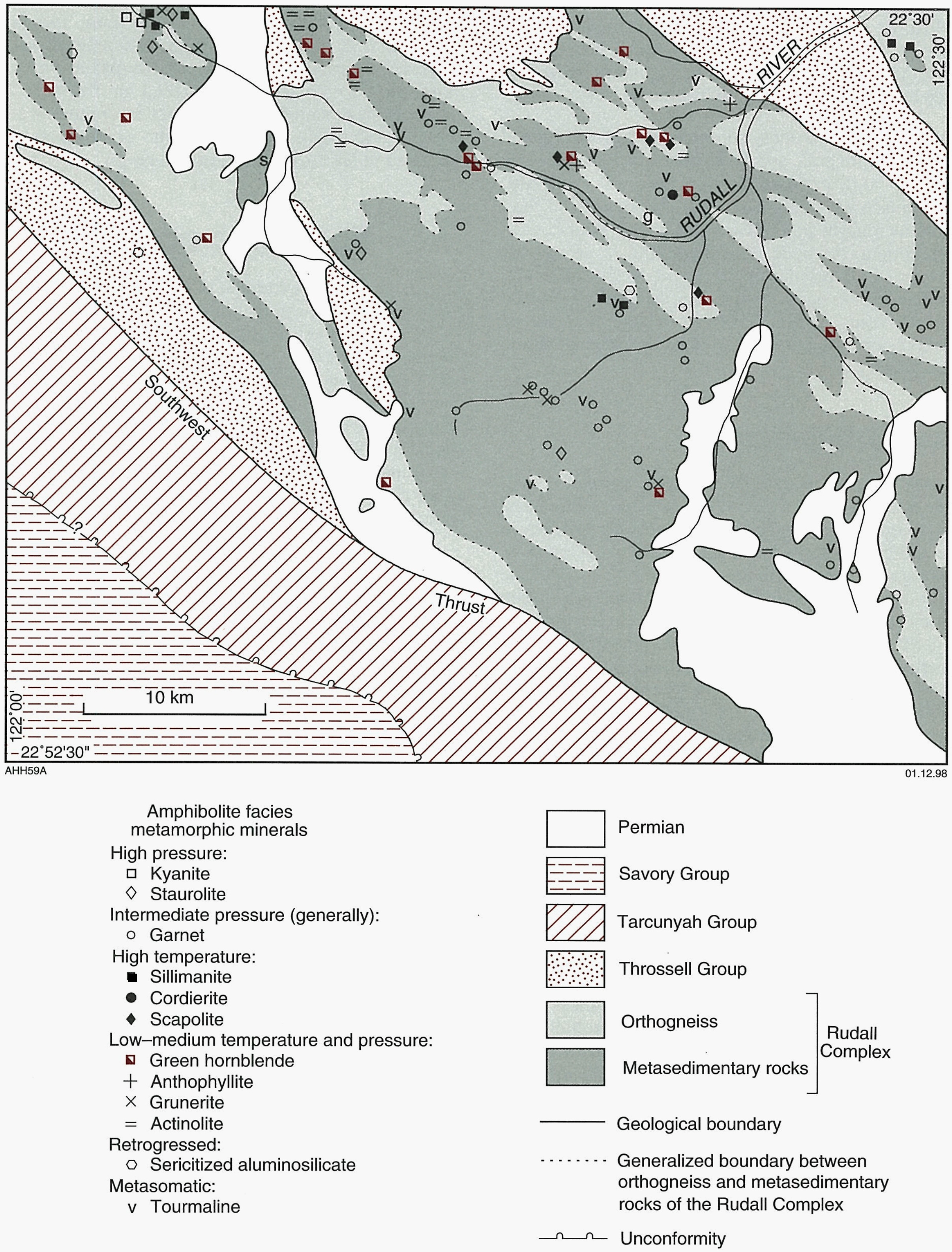

Figure 8. Prograde metamorphic minerals of the Rudall Complex

Metasomatized rocks

Sheet-like bodies of granitoid magma have extensively intruded the metamorphosed sedimentary rocks of the Rudall Complex so that large proportions of such rocks are close to granitoid contacts. Contact metamorphic effects are partly obscured by superimposed regional metamorphism, but preserved metasomatic minerals include tourmaline, scapolite, and sulfides.

Tourmaline is the most conspicuous and widespread metasomatic mineral, and is present not only in veins of quartz and pegmatite, but also in quartzite, quartz–muscovite schist, banded iron-formation, and tourmaline–quartz pods near orthogneiss contacts. In metasedimentary rocks the tourmaline is present as grains or small prisms up to 3 mm long, and black tourmaline crystals up to 200 mm long are locally preserved in quartz veins (AMG 350073). These tourmaline occurrences indicate introduction of boron during granitoid emplacement.

Yeneena Supergroup

Greenschist-facies metamorphism (M_4), associated with the D_4 event (Miles Orogeny), has affected the Yeneena Supergroup on RUDALL. The effects, most clearly seen in pelite and carbonate rocks of the Broadhurst Formation, are not readily apparent in the quartz-rich arenites of the Coolbro Sandstone, although only a small number of thin sections have been prepared from both formations. Characteristic metamorphic features in the Broadhurst Formation are sericite growth and recrystallization of quartz in metasiltstone, and chlorite growth and calcite and dolomite regrowth along S_4 foliation in carbonate rocks. Metamorphism of the Tarcunyah Group is of very low grade on RUDALL and mainly restricted to dynamic effects close to faults.

Dynamic metamorphism is an important feature of shear zones, and fault-bounded synclinal enclaves within the Rudall Complex locally exhibit evidence of elevated metamorphic grades.

Summary of metamorphism

Prograde mineral assemblages in the pelitic schist in the Rudall Complex are consistent with amphibolite-facies metamorphism (Barrovian metamorphism with grades spanning the garnet and sillimanite zones). The apparent absence of cordierite and andalusite combined with the common abundance of garnet indicate medium- to high-pressure conditions (Yardley, 1991). Retrogressive mineral assemblages are indicative of metamorphism at greenschist facies (M_4).

The mineral assemblages of amphibolite units indicate upper greenschist- to amphibolite-facies metamorphism. In these rocks the absence of garnet suggests low- to medium- pressure conditions, and the relatively calcic compositions of plagioclase are consistent with medium-temperature, amphibolite-facies metamorphism.

Geochronology

Nelson (1995) published high-precision geochronological data for the Rudall Complex, but there is almost no reliable isotopic data for the Yeneena Supergroup, Tarcunyah Group, and Savory Group. The geochronological results, sources of data, and cited interpretations obtained from the Paterson Orogen are summarized in Table 3. The chronological sequence of events is summarized in Table 4, and the implications of the available data are discussed in Hickman and Bagas (in prep.).

Economic geology

The first reported exploration in the Rudall River area was a search for nickel and platinum group elements (PGE) in 1971 by Northwest Oil and Minerals Company in large ultramafic pods (*ERu*) near the Rudall River. The company considered the ultramafic rocks to be prospective for PGE, chromite, or cumulate-associated nickel deposits, and announced the discovery of significant platinum values. Blockley (1972) investigated the validity of these results and found negligible quantities of platinum. However, some alluvial samples did contain gold, although their source was not identified.

In 1972, Otter Exploration located gossans containing subeconomic base metals at Mount Cotton (on CONNAUGHTON) and Yandagooge – Lead Hills (on BROADHURST). Gold-bearing gossans were identified on PATERSON RANGE by Day Dawn Minerals in 1971 and in 1972 the Telfer gold deposit was delineated by Newmont Holdings. This discovery initiated considerable exploration activity in the region.

The earliest uranium exploration in the region was undertaken in 1974 by Esso Exploration. Helicopter-borne radiometric surveys were flown and selected areas were followed up with a fixed-wing spectrometer survey. Surface sampling of anomalies failed to detect significant uranium deposits.

In 1977, CRAE completed an airborne radiometric and magnetic survey over the Rudall Complex on CONNAUGHTON and the southeastern part of RUDALL. The company was exploring for pegmatite and metamorphic–hydrothermal-related uranium mineralization, analogous to the Alligator Rivers region of the Northern Territory and the Athabasca region of northern Saskatchewan in Canada. A number of radiometric anomalies were detected, but subsequent investigation failed to detect economic mineralization. The uranium mineralization observed was thought to be the result of secondary enrichment in calcrete.

Occidental Minerals explored the Coolbro Sandstone and Broadhurst Formation contact (Yeneena Supergroup) for uranium and base metals in 1978. Subsequent drilling of anomalies in the Mount Sears Range, Sunday Creek, Coolbro Creek, and the Broadhurst Range failed to detect economic mineralization.

During 1978–84 the region was explored for kimberlites using magnetic and geochemical anomalies. In 1980,

Table 3. Geochronological results for intrusive rocks of the Paterson Orogen

Age (Ma)	*Rock suite*	*Dating method*	*Reference*	*Interpretation in reference*[(a)]
2715–2577	Orthogneiss (*ERgx*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Crystallization age of xenocrystic zircons
2425 ± 7	Orthogneiss (*ERga*)[(b)]	Ion microprobe U-Pb	Nelson (1995)	Crystallization age of xenocrystic zircons
2015 ± 26	Orthogneiss (*ERgx*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1972 ± 4	Orthogneiss (*ERgg*)[(b)] (GSWA 112310)	Ion microprobe U–Pb	Nelson (1995)	Age of crystallization of early granitoid component of rock
1802 ± 14	Orthogneiss (*ERgg*)[(b)] (GSWA 112310)	Ion microprobe U–Pb	Nelson (1995)	Age of crystallization of late granitoid veins
1801 ± 4	Orthogneiss (*ERge*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1795 ± 17	Orthogneiss (*ERge*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1790 ± 17	Orthogneiss (*ERga*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1787 ± 5	Orthogneiss (*ERga*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1787 ± 12	Orthogneiss (?*ERga* in *ERgx*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1778 ± 17	Orthogneiss (*ERgd*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1775 ± 10	Orthogneiss (*ERga*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1778 ± 16	Aplite dyke[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of aplite crystallization
1765 ± 15	Orthogneiss (*ERga*)[(b)]	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
1533 ± 29	Randomly selected samples from the Rudall River headwaters	Rb–Sr	Chin and de Laeter (1981)	Uncertain
1333 ± 44	Orthogneiss on CONNAUGHTON	Rb–Sr	Chin and de Laeter (1981)	Age of D_2; maximum age of Yeneena Supergroup
1291 ± 10	Pegmatite on CONNAUGHTON	Ion microprobe U–Pb	Nelson (1995)	Crystallization age of pegmatite; pre- or syn-D_2; maximum age of Yeneena Supergroup
1132 ± 21	Pegmatite veins intruding the Rudall Complex[(b)]	Rb–Sr	Chin and de Laeter (1981)	Possibly related to D_4; minimum age of Yeneena Supergroup
1080	Runton Adamellite on TABLETOP (1:250 000)	Two-point Rb–Sr	Chin and de Laeter (1981)	Post-dates D_4; post-dates Yeneena Supergroup
1067 ± 260	Runton Adamellite on TABLETOP (1:250 000)	Pb–Pb	N. McNaughton and G. L. Clarke (unpublished data)	Post-dates D_4 and Yeneena Supergroup
940	Warrabarty prospect on BRAESIDE	Pb–Pb	I. Fletcher (1993, pers. comm.,)	Age of epigenetic galena in Broadhurst Formation
900	Nifty deposit on LAMIL	Pb–Pb	I. Fletcher (*in* Blockley and Myers, 1990)	Age of epigenetic galena in Broadhurst Formation
692 ± 6	Mafic intrusion on BROADHURST	K–Ar	CRAE unpublished data	Age of crystallization
690 ± 48	Mount Crofton Granite 'Complex'	Pb–Pb	Goellnicht et al. (1991)	Post-dates D_4
633 ± 13	Minyari monzogranite, Telfer area	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
c. 620	Mount Crofton Granite 'Complex'	Ion microprobe U–Pb	Nelson (1995)	Age of granitoid crystallization
601 ± 42	Granite at Mount Crofton	Rb–Sr	Williams (1992; data from Trendall, 1974)	Post-dates D_4
595 ± 27	orthogneiss (*ERga*)[(b)]	Rb–Sr	Chin and de Laeter (1981)	Alteration event post-dating D_4

NOTES: (a) Not necessarily accepted in this report
(b) On RUDALL

Occidental Minerals reported uranium mineralization close to the Coolbro Sandstone – Broadhurst Formation contact at Sunday Creek and Mount Sears Range (Hickman and Clarke, 1994).

Aquitaine Australian Minerals completed an airborne radiometric survey during 1981–82 in the Watrara Creek and May Creek areas. Ground investigation of uranium anomalies failed to outline any significant mineralization.

In 1981, Seltrust Mining Corporation reappraised Northwest Oil and Minerals Company's ground near the Rudall River for platinoids, copper, and gold, but failed to detect any mineralization.

In 1981–82, Agip Australia discovered uranium mineralization in core drilled by Newmont at Mount Cotton in 1978. Minor base-metal mineralization was detected in subsequent exploration.

CRAE acquired title to the Kintyre area for diamond exploration in 1983 and discovered the Kintyre uranium deposit on BROADHURST in 1985. This discovery resulted from following up radiometric anomalies that were

Table 4. Geochronological data relevant to the evolution of the Paterson Orogen

Isotopic age (Ma)	*Geological event*
2015 ± 26	Crystallization of some *ERgx* granitoid protoliths
pre-1800	Deposition of Larry Formation
c. 1800	Crystallization of some *ERge* and *ERgg* protoliths
1790–1765	Crystallization of *ERga* and *ERgd* protoliths
pre-1780	Deposition of Rudall Complex sedimentary protoliths
c. 1765–1700	Metamorphism, M_2; accompanying D_2
1333 ± 44	Metamorphism of an orthogneiss on CONNAUGHTON
1291 ± 10	Crystallization of a pegmatite dyke on CONNAUGHTON
c. 1300	Deposition of Manganese Subgroup of the Bangemall Group, unconformably underlying the Tarcunyah Group
c. 1200	Metamorphic biotite, unconformably underlying the Tarcunyah Group
1132 ± 21	Crystallization or metamorphism of pegmatite dykes
1080	Crystallization or metamorphism of the Runton Adamellite
940–820	Galena mineralization in Throssell Group
800–600	Evolution of the Savory Sub-basin
c. 620	Minimum age for emplacement of post-D_4 granitoids

detected during airborne geophysical surveys flown during diamond exploration (Jackson and Andrew, 1990). After the discovery of Kintyre, it was considered that the potential for discovering further unconformity vein-style uranium deposits was high, and that the Rudall Complex had potential for Palaeoproterozoic-style stratiform and stratabound base-metal and gold deposits, and for ultramafic-related PGE. This initiated considerable exploration activity in the region by various companies, which led to the discovery of 'blind' uranium mineralization in the Sunday Creek area on BROADHURST by Scomac Management Services in 1992. Following Scomac's discovery of pitchblende at the base of the Coolbro Sandstone near Sunday Creek, recent exploration for uranium has been concentrated near outcrops of the Coolbro Sandstone.

In 1984, Stockdale Prospecting completed a stream-sediment geochemical survey in search of diamonds on RUDALL and CONNAUGHTON. Kimberlites were not detected, although a number of samples from Larry Creek and May Creek were found to contain visible gold. Further sampling failed to locate the source of the gold.

Geochemical investigation

In view of the limited knowledge of mineralization on RUDALL the present mapping included routine sampling of gossans, gossanous or sulfidic vein quartz, and visibly mineralized rock observed during fieldwork. All 395 samples collected were analysed for trace elements, and 31 samples were analysed for major elements. Hickman and Bagas (1995) summarized preliminary conclusions on the mineral potential of RUDALL, and a full listing of the analytical data, with conclusions, is provided by Hickman and Bagas (in prep.). Figure 9 shows locations of the anomalous samples.

Gold

Stockdale Prospecting Limited, in 1984, reported visible gold in stream-sediment samples along Larry Creek and May Creek (Fried, 1984). Subeconomic gold mineralization is also associated with a few of the uranium prospects around the headwaters of Larry Creek, where veins occupying D_4 faults have up to 3 ppm gold.

At Poynton Creek routine gossan analyses following the present field mapping revealed gold contents up to 4.07 ppm. However, results of a follow-up sampling program were largely negative, and indicate that gold mineralization is of low grade and erratic. About 3 km east of Talbot Soak a sulfidic semipelitic member of the Coolbro Sandstone contains between 0.53 and 1.10 ppm gold, and certainly merits further examination.

Uranium (and associated Cu, Pb, and Zn)

Exploration companies have explored RUDALL for uranium and other mineral commodities since the discovery of the Kintyre deposit on BROADHURST in 1985. This exploration targeted unconformity vein-style uranium, base-metal, gold, and platinum-group element (PGE) mineralization using airborne geophysics and stream-sediment geochemistry.

Most radiometric anomalies coincide with surface uranium minerals in ironstone developed on ferruginous metapelite and graphitic schist of the Cassandra Member (Yandagooge Formation). Other anomalies are in calcrete or silcrete developed on orthogneiss, and in fractured or faulted arenite of the Coolbro Sandstone (Fandango prospect). Subsequent drilling has shown that the mineralization is uneconomic, with maximum uranium levels of 500 ppm U_3O_8, but commonly less than 100 ppm U_3O_8. Anomalous, but subeconomic, copper, lead, zinc, silver, gold, molybdenum, chromium, nickel,

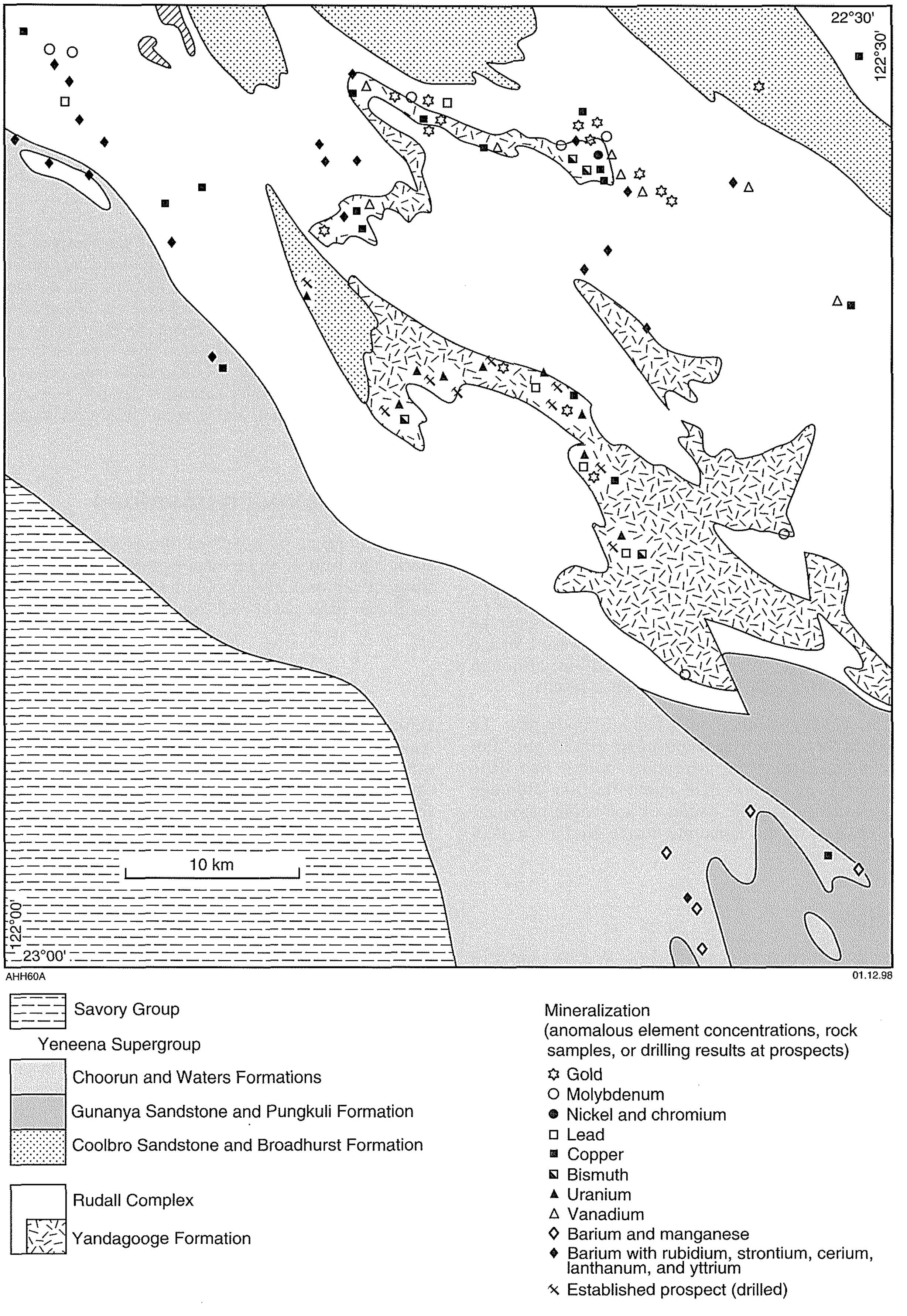

Figure 9. Economic geology of RUDALL

and PGE have also been noted in association with uranium. The mineralization is probably due to secondary or recent mobilization and subsequent precipitation in regolith. The geology of uranium prospects shown on the map is summarized by Hickman and Bagas (in prep.).

Copper, lead, and zinc

Elsewhere, the Broadhurst Formation of the Throssell Group hosts stratabound and stratiform copper, lead, and zinc mineralization resembling Mt Isa-style base-metal deposits. Examples outside RUDALL include the widely separated Nifty and Maroochydore deposits, indicating that the Broadhurst Formation is prospective over a large area.

The Camelot Syncline includes the only outcrops of the Broadhurst Formation on RUDALL. The formation contains elevated As, Pb, U, Cu, Zn, and Fe and traces of Au in chloritic shale, graphitic schist, and carbonate. The western extension of the Camelot Syncline merits further exploration beneath the Permian cover.

Platinum-group elements

In 1971 North West Oil and Minerals NL undertook PGE exploration by drilling ultramafic rocks (*ERu*) around the Rudall River. They announced values of between 1.99 and 6.65 ppm Pt from depths of up to 240 m, although Blockley (1972) could not duplicate these results.

Carr (1989) sampled an ultramafic body near the Rudall River, which assayed up to 0.036 ppm Pd. He concluded that the ultramafic bodies had little potential for economic PGE mineralization, although differentiated ultramafic bodies of komatiitic parentage were prospective for komatiite-hosted Ni–Fe–Cu–PGE mineralization.

Barite

Barite veins up to 0.3 m wide are present 4 km southwest of Watrara Pool (AMG 041112), and there is additional mineralization between this locality and about 65 km to the southwest (AMG 020048). A description of the veins is given under **Dykes, veins, breccia, and gossan.**

The barium sulfate content of the veins reaches up to about 80% (47% Ba), the chief impurities being iron (hematite) and silica. Although the largest vein is over 100 m long and up to 4 m thick, the level of impurities and the remote location make the deposits subeconomic. Analytical data (Hickman and Bagas, in prep.) reveal no significant base- or precious-metal mineralization.

Gypsum

During the mapping gypsum deposits were located about 2 and 3 km (the main outcrop) north of Rudall Crossing. The gypsum deposits are mixed with clay and silt, appear to be of low grade, are covered by 2–3 m of gravel, and may extend over an area of about 10 km^2. At the main outcrop, gypsum forms beds 1–2 m thick between Permian fluvioglacial deposits and overlying Cainozoic colluvium, and is probably a Tertiary lacustrine deposit. The second outcrop is 1.5 m thick and contains minor carbonate in nodules.

Semi-precious gemstones

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

Water resources

Permanent and semi-permanent pools are present along the major rivers where alluvium is sufficiently thick and extensive to hold groundwater resources. Areas containing calcrete may contain large, although saline, groundwater supplies. Significant groundwater supplies are likely to be found in fractured and sheared Coolbro Sandstone and Gunanya Sandstone. Permian sandstone units in the buried glacial valleys may be potential aquifers, although salinity levels are untested. CRAE drilled seven water bores between 1988 and 1991 in search of shallow (less than 65 m depth), potable water resources. Salinities ranged from 1180 to 7100 mg/l, and the best yield was obtained from the White Gums Bore, which intersected calcrete. The Western Australian Water and Rivers Commission holds records of these bores.

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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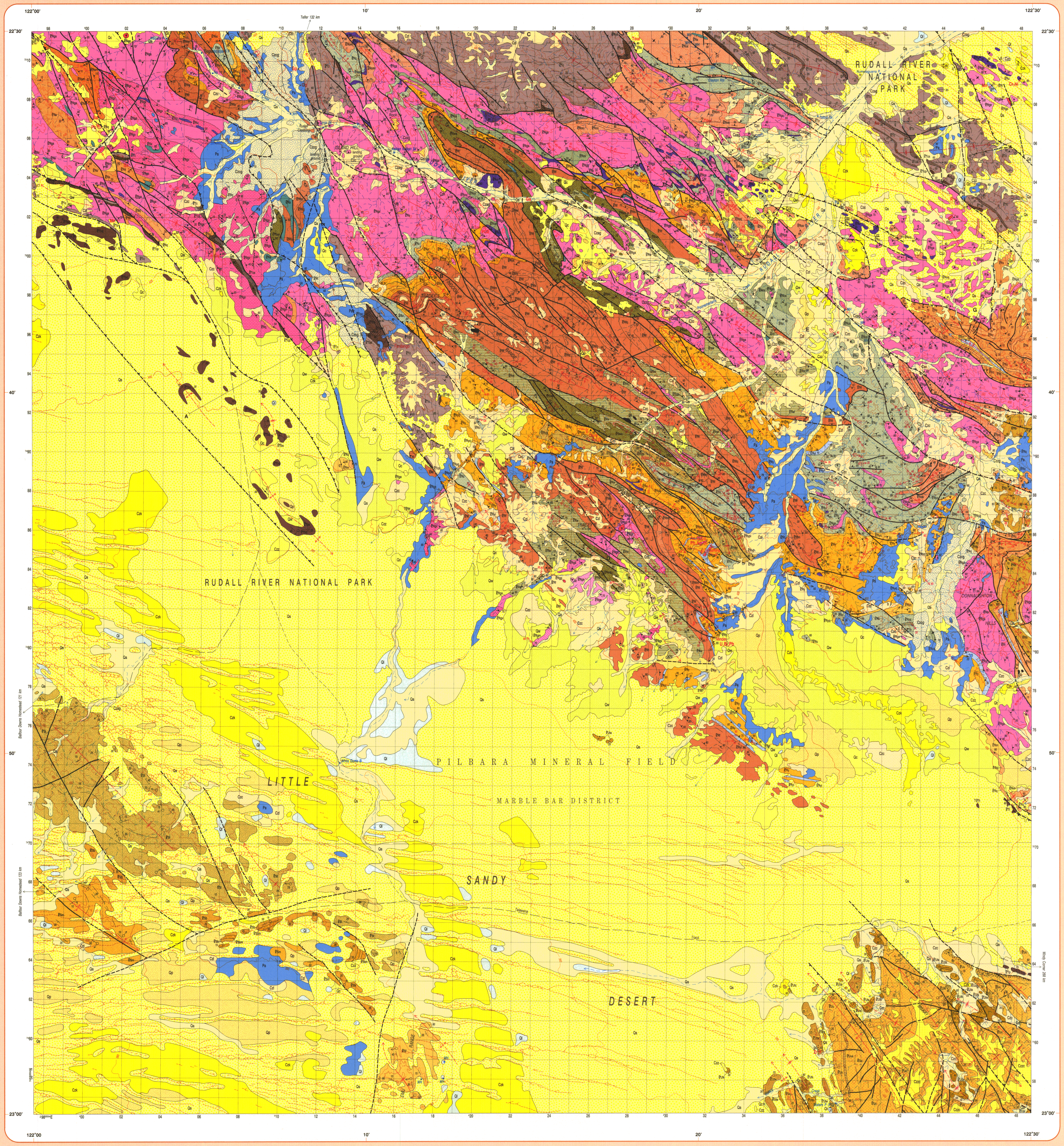
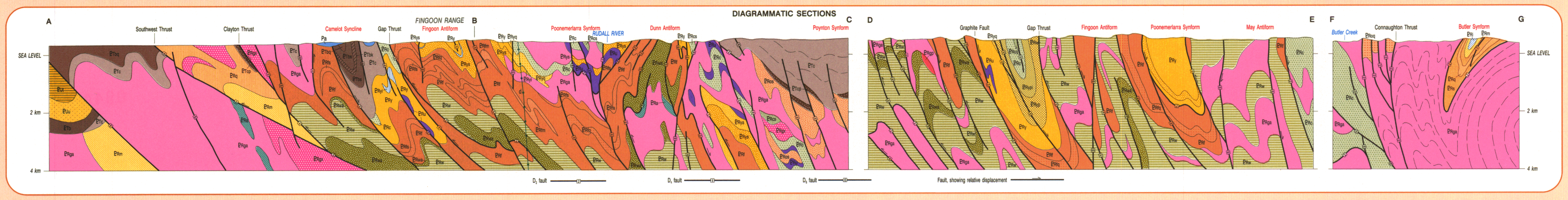


DIAGRAMMATIC SECTIONS



PHANEROZOIC — CAINOZOIC — QUATERNARY

Symbol	Description
Qa	Alluvium — sand and gravel in drainage channels, and sand, partly reworked by wind action, on floodplains
Ql	Playa and claypan deposits — clay and silt; saline and gypsiferous in part
Qs	Eolian deposit — sand; includes seif dunes and intervening sandy valleys
Qp	Lag and eolian deposits — laterite pebbles and eolian sand; chiefly overlies sulfidic shale
Qc	Colluvium — locally derived sand and gravel; in scree and outwash-fan deposits
Qw	Colluvium and alluvium — silt, sand, and gravel on low slopes and sheetwash areas; numerous small claypans
Czag	Colluvium and alluvium — gravel and boulder beds; dissected by present-day drainage
Czc	Colluvium — variably cemented outwash talus, dissected by present-day drainage
Czcg	Colluvial and eluvial pebbly sand, silt, and clay overlying PATERSON FORMATION; partly consolidated
Czl	Laterite — ferruginous duricrust on tops of hills; remnants of Tertiary peneplain
Czk	Calcrete — massive, nodular, and cavernous sandy limestone
Czz	Silcrete — siliceous caprock with angular quartz grains
Czzc	Silicified sandstone caprock with thin veneer of colluvium; restricted to tops of hills
Czzg	Leached and variably silicified granitic orthogneiss; alteration product of ᵽRga

PERMIAN — CANNING BASIN

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

Symbol	Description
d	Dolerite dyke
q	Quartz vein
fb	Fault breccia and silicified rock adjacent to faults
go	Gossan, or zone of gossanous rock
b	Barite vein, locally associated with hematite

PROTEROZOIC — Savory Group — SAVORY BASIN

Symbol	Description
ᵽSf	McFADDEN FORMATION: sandstone, quartz wacke; minor conglomerate and siltstone
ᵽSt	TCHUKARDINE FORMATION: sandstone, quartz wacke; minor conglomerate, siltstone, and shale
ᵽSb	BOONDAWARI FORMATION: sandstone, siltstone, and shale; minor conglomerate and diamictite
ᵽSbh	Shale and mudstone; varve lamination and fine-scale cross-bedding; local diamictite
ᵽSbm	Diamictite; mudstone containing striated and rounded pebbles and boulders; glacigene deposit
ᵽSm	MUNDADJINI FORMATION: sandstone; minor siltstone, conglomerate, and shale

Tarcunyah Group

Symbol	Description
ᵽUt	WATERS FORMATION: shale, carbonate rocks, and upward-fining sandstone-siltstone-shale rhythmic units (section only)
ᵽUts	Shale, reddish brown to grey; minor sandstone, carbonate, and sulfidic beds
ᵽUta	Sandstone and siltstone, cross-bedded
ᵽUtw	Upward-fining sandstone-siltstone-shale rhythmic units
ᵽUtc	Carbonate rock, grey to cream and finely laminated; locally stromatolitic
ᵽUtk	Shale and carbonate rock intercalated

GUNANYA SANDSTONE

Yeneena Supergroup — Throssell Group

PUNGKULI FORMATION

BROADHURST FORMATION

COOLBRO SANDSTONE

PATERSON OROGEN — Rudall Complex

POYNTON FORMATION

BUTLER CREEK FORMATION

YANDAGOOGE FORMATION

FINGOON QUARTZITE

LARRY FORMATION

Geological boundary
- exposed
- approximate

Fault
- exposed
- concealed
- concealed, position uncertain
- thrust or reverse, showing dip
- lag, showing dip
- with quartz vein, breccia
- horizontal relative displacement

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

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

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

Glacial striae, showing direction of ice movement

Way-up indicator
- graded bedding
- cross-bedding

Direction and sense of movement of sediment-bearing currents
- asymmetrical ripple marks

Metamorphic foliation, showing strike and dip
- inclined
- vertical
- trend (section only)

Cleavage, showing strike and dip
- inclined
- intersecting bedding

Lineation, showing direction of plunge
- unspecified, inclined
- unspecified, on foliation plane
- mineral lineation
- axis of crenulation

Fracture, joint, extension vein, showing strike and dip
- inclined

Airphoto lineament
- structural trend

Trace fossil locality

Major track, maintained

Track

Horizontal control, minor

National park boundary

Sand dune

Contour line, 20 metre interval

Watercourse, ephemeral

Bore — B

Pool, Waterhole — P, WH

Rockhole — RH

Soak — Sk

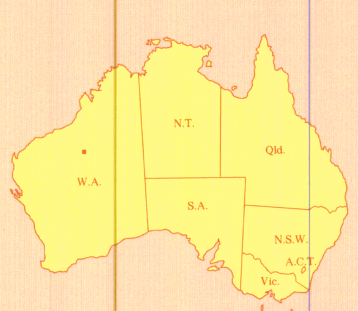
Position doubtful — (PD)

Prospect — Cassandra

Mineral occurrence

Geochemical anomaly from gossan assay (anomaly criteria: > 1000 ppm, except for Ba > 1%; Mn > 10%; Au > 0.5 ppm; PGE > 1 ppm) — *

Mineral	Symbol
Asbestos (chrysotile)	Ac
Barite	Ba
Bismuth	Bi
Chromium	Cr
Copper	Cu
Garnet	Ga
Gold	Au
Gypsum	Gp
Kyanite	Ky
Lead	Pb
Manganese	Mn
Nickel	Ni
Platinum Group Elements	PGE
Rutile	R
Silver	Ag
Strontium	Sr
Tourmaline	Tour
Uranium	U
Zirconium	Zr



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GRID CONVERGENCE 0.3°

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 seven years.

DEPARTMENT OF MINERALS AND ENERGY

DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SCALE 1:100 000

TRANSVERSE MERCATOR PROJECTION

Geology by A.H. Hickman and L. Bagas 1991-92

Edited by D. Ferdinando, C. Strong, and G. Loan

Cartography by S. Collopy and K. Greenberg

Topography from the Department of Land Administration Sheet SF 51-10, 3352, with modifications from geological field survey

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This map is also available in digital form

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