EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

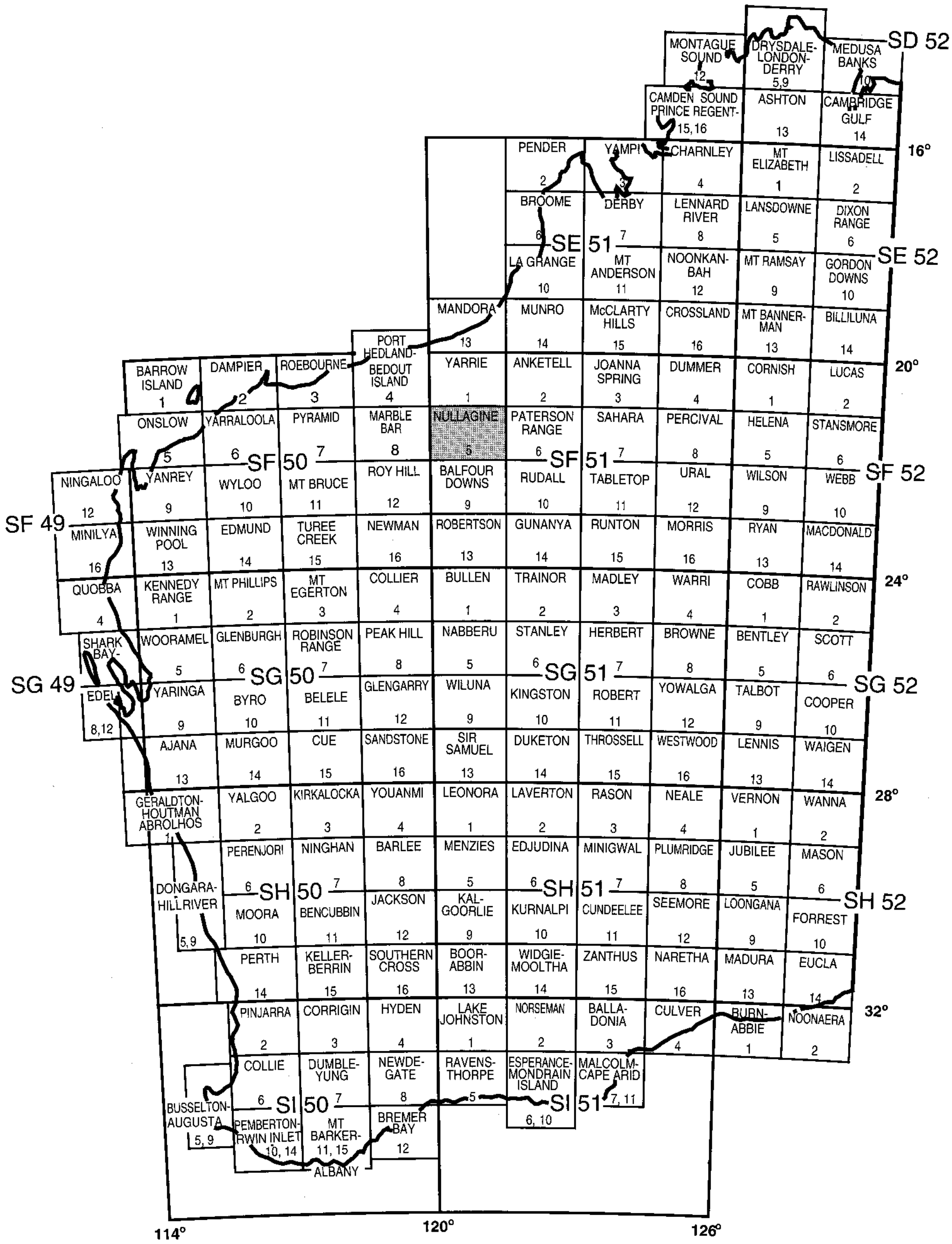
GEOLOGY OF THE PEARANA 1:100 000 SHEET

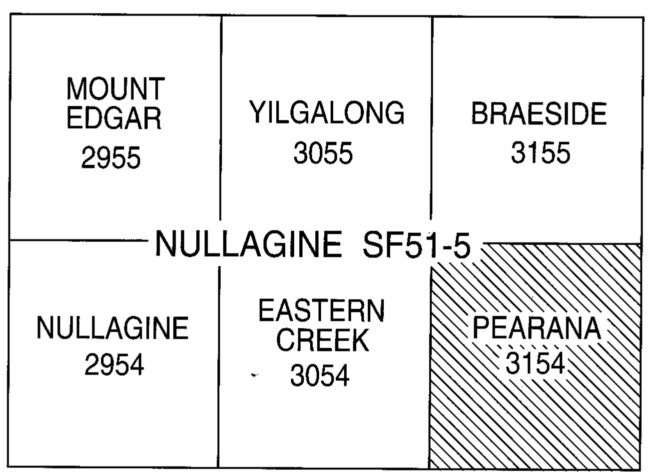
by I. R. Williams and A. F. Trendall

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY





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Perth 1998

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Cover photograph:

View of the Gregory Granitic Complex (right side of picture) and the overlying, unconformable, basal Googhenama Formation of the Tarcunyah Group (escarpment on left), looking south.

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Geology of the Pearana 1:100 000 sheet

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Introduction

The PEARANA* 1:100 000 geological sheet (SF51-5-3154) is bounded by latitudes 21°30' and 22°00'S and longitudes 121°00' and 121°30'E. It occupies the southeastern corner of NULLAGINE (1:250 000), and straddles the boundary between the Pilbara and Great Sandy Desert regions. PEARANA takes its name from the Pearana Rock Hole (AMG† 171762) in the southern part of the sheet area.

There are no homesteads or permanent settlements on PEARANA. However, the exploration, development, and mining of manganese deposits in the Woodie Woodie and Skull Springs areas has resulted in mining camps with fluctuating populations since the early 1950s. Over the last seven years openpit manganese mines have operated at the Radio Hill, Lox, Cracker, and Green Snake pits in the Woodie Woodie area. Centralized beneficiation and loading facilities, operated by Portman Mining between 1990 and 1996, are located at the old Woodie Woodie mine site. These were acquired by Valiant Consolidated in 1996. Valiant Consolidated also began operations in 1994 at the Mike openpit manganese mine. The mine and beneficiation plant, which lie 12 km south of Woodie Woodie, were operated between 1994 and October 1997. The nearest occupied pastoral homestead is Warrawagine, 94 km to the northwest, and the small town of Nullagine lies 94 km due west of PEARANA.

A good graded road, used for ore cartage and transporting mine supplies, links the Woodie Woodie area to Port Hedland, 386 km to the northwest. Other graded roads, maintained by mining companies, link Western Mining Corporation's Nifty copper mine (52 km east of Woodie Woodie and 12 km east of the sheet boundary) and the Mike mine to the Woodie Woodie – Port Hedland road 8 km west of Woodie Woodie. A graded road, suitable for light traffic only, links Woodie Woodie west to Nullagine. A bulldozed track, locally called the 'Esso track', connects the Nifty road, east of the Gregory Range, to the Balfour Downs – Rudall road, which crosses the southeastern corner of PEARANA. The latter, graded road gives access to the Rudall River National Park and the mineral-prospective Rudall region. A network of bulldozed exploration tracks in the north-eastern corner of PEARANA provides good access to the Great Sandy Desert area north of the Nifty road. A recently upgraded track links the Woodie Woodie area with Pearana Rock Hole. An old pastoral track continues south from Pearana Rock Hole to link up with Balfour Downs Station tracks on WOBLEGUN. A rough bulldozed track also connects Skull Springs to Pearana Rock Hole, then continues eastwards to join the 'Esso track' (AMG 408851). The Skull Springs area is linked westward to the Nullagine – Woodie Woodie road by an old mining track. Other old, poorly maintained, mining tracks connect abandoned manganese prospects and the upper Carawine Pool area to the Nullagine – Woodie Woodie or Port Hedland – Woodie Woodie roads. Despite the broad track-network on PEARANA, many areas in the south-central, and along the south and west margins, are inaccessible to four-wheel drive vehicles because of the rugged, dissected terrain.

Previous and current investigations

A bibliography covering the NULLAGINE and MARBLE BAR 4-mile geological series maps (Noldart and Wyatt, 1962) contains a number of early references to the PEARANA area. Further references are given in Hickman (1978) and Hickman (1983).

As with the adjacent BRAESIDE sheet to the north, PEARANA was traversed by several early exploratory expeditions. In 1861, F. T. Gregory crossed the north-eastern part of PEARANA looking for a route through the sand dune country to the east. He traversed as far as Mount Macpherson in the Throssell Range, 10 km east of the PEARANA boundary, before being forced to return to the Oakover River through lack of water (Gregory and

* 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.

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

Gregory, 1884; Feeken et al., 1970). Later, in 1897, W. F. Rudall made several traverses south, southeast, and east across PEARANA in an unsuccessful attempt to locate the missing members of the Calvert Scientific and Exploring Expedition (Rudall, 1898). A. W. Canning examined the country east of the Gregory Range in 1903 for a possible route for the proposed Rabbit Proof Fence (No. 1 Vermin Fence). He surveyed the route in 1904, and the fence was constructed across PEARANA in 1906–07 (Broomhall, 1991). The fence was abandoned in the late 1940s.

Geological information on PEARANA was initially described by Maitland (1908) in a geological sketch map covering the Pilbara Goldfield (declared in 1889). Talbot (1920) corrected, revised, and added to this early work. The first reference to mineralization on PEARANA can be found in Maitland (1919). He recorded the discovery of lead and copper '7 miles southwest of the 750 mile peg on the Rabbit Proof Fence'. If this locality was identified correctly then the lead mineralization is nearly 60 km south of what later became known, in the 1920s, as the Braeside Lead Field (Blatchford, 1925). Recent prospecting activity in the area located small amounts of galena in quartz veins cutting the Warri Warri Member of the Hardey Formation (see **Fortescue Group**). Although manganese was recorded in the district by Blatchford (1925) and Finucane (1938), it was not until around 1950 that the high-grade Woodie Woodie manganese deposits were discovered (Owen, 1953).

The first regional geological coverage of PEARANA can be found in the NULLAGINE 4-mile geological series map published in GSWA Bulletin 115 (Noldart and Wyatt, 1962). A more detailed geological map, covering the northwestern quadrant of PEARANA, accompanied the report on the newly discovered manganese deposits in the Mount Sydney – Woodie Woodie area (de la Hunty, 1965), and a revised stratigraphic and structural interpretation of the area is given in Hickman (1978). The Bureau of Mineral Resources (BMR), now the Australian Geological Survey Organisation (AGSO), released a preliminary Bouguer Anomaly map for NULLAGINE (1:250 000) in the late 1970s (undated publication) and a Total Magnetic Intensity contour map in 1987.

There are very few records of prospecting on PEARANA during the first half of this century. It was not until the discovery of manganese at Woodie Woodie around 1950 that mining syndicates and larger exploration companies began to take an interest in the area. Following favourable reports from GSWA and BMR (Owen, 1953), the Northern Mining Syndicate commenced manganese mining at Woodie Woodie in 1953. This was followed, in 1956, by the opening of the Skull Springs manganese deposits. A manganese-driven 'mining boom' soon developed, which peaked around 1962, then gradually declined until 1972 when operations on PEARANA ceased. However, interest in the manganese potential of the area remained due to the high ore-grades and ease of extraction. New gravity data, followed by drilling, outlined new orebodies in the 1980s, and in 1990 Portman Mining commenced openpit mining at the Radio Hill and Lox pits in the Woodie Woodie area. Openpit mining continued in a number of other pits until 1996 when Portman Mining sold out to Valiant Consolidated. Valiant Consolidated commenced openpit mining operations at the Mike mine in 1994 and closed all operations in October 1997.

Following the discovery of gold at Telfer in 1971, and high-grade copper mineralization at Nifty in 1983, exploration companies turned their attention to the base-metal and gold potential of PEARANA. Exploration reports (from 1952 onward) for PEARANA (Appendix 1) can be obtained from the Western Australia Mineral Exploration Index (WAMEX) open-file system held in the GSWA library.

Initially, detailed field work of the present survey (carried out by A. F. Trendall between 1987 and 1991) was directed towards reassessment of the Archaean Fortescue Group and the associated Gregory Granitic Complex. The remainder of the sheet area, which covers the Archaean lower Hamersley Group and the Proterozoic Paterson Orogen, was mapped by I. R. Williams in the 1990–1992 field seasons. PEARANA was mapped in conjunction with the adjoining BRAESIDE and ISABELLA sheets. Black-and-white 1:40 000 airphotos, flown in 1972, were used for field work.

Climate, vegetation, and physiography

The climate on PEARANA is arid (desert) with summer rainfall peaking between January and March. Most rain comes from summer thunderstorms, rain associated with monsoonal troughs, or waning southerly to southeasterly moving tropical cyclones. Lighter winter rains may occur between May and July. The mean annual rainfall is around 220 mm, decreasing southeastward across PEARANA. Apart from the cyclone season (December to April), humidity is low, and the evaporation rate is up to 3900 mm per annum. Summers are very hot, with mean maximum temperatures above 40°C, and winters are mild, with mean minimum temperatures around 12°C (Pink, 1992).

PEARANA is unequally divided along a north-northwest trending boundary between the Fortescue Botanical District to the west, the Canning Botanical District to the east, and the Keartland Botanical District in the extreme southeast corner (Fig. 1). All three units belong to the Eremaean Botanical Province (Beard, 1975). The larger Fortescue Botanical District covers a variety of vegetation regions. These include a tree steppe of Snappy Gum (*Eucalyptus brevifolia*) and buck spinifex (*Triodia wiseana*) on rugged hills with siliceous soils, and a shrub steppe of *Acacia pachycarpa* and *Acacia victoriae* with spinifex (*Triodia pungens, Triodia wiseana*) on low hills with calcareous soils. Both these regions are associated with the upper reaches of the Oakover Valley. Shrub steppe of Kanji (*Acacia pyrifolia*) and spinifex (*Triodia pungens*) together with sparse Snappy Gum and Bloodwood *(Eucalyptus dichromophloia)* grow on the

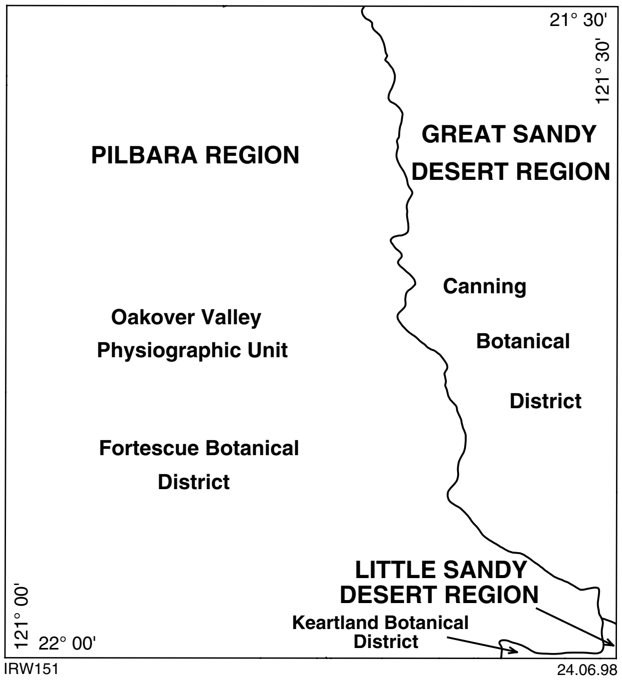

Figure 1. Natural regions and botanical districts on Pearana (after Beard, 1975)

volcanic soils of the Gregory Ranges. Scattered *Hakea* and *Grevillea* species are also found throughout the shrub steppes. A sparse shrub steppe of *Acacia bivenosa* and spinifex (*Triodia brizoides*) overlies mainly Permian rocks in the broad Oakover River valley. River Gum (*Eucalyptus camaldulensis*) and Paperbark (*Melaleuca* sp.) line the larger drainage systems (Beard, 1975).

The Canning Botanical District, corresponding to part of the Great Sandy Desert, consists of a monotonous shrub steppe between spinifex-covered longitudinal dunes. Shrubs in this district consist of mixed *Acacia*, *Grevillea,* and *Hakea* species, whereas the ground cover is comprised of feather top spinifex *(Plectrachne pungens)* and *Triodia* species. Spinifex-covered low hills in this district tend to be treeless.

The vegetation in the Keartland Botanical District is similar to the Canning Botanical District, except spinifex (*Triodia basedowii*) is the dominant ground cover (Beard, 1975).

The Great Sandy Desert Natural Region (Beard, 1970), also called the Great Sandy Desert Dunefield (Jennings and Mabbutt, 1986), occupies the eastern third of Pearana (Fig. 1). The dunefields on Pearana are more varied than those found further north on Braeside. Although simple- and chain-longitudinal dunes still predominate, there are small net-dune complexes in the broad early Cainozoic palaeovalleys that lie along the eastern margin of Pearana. Longitudinal dunes along the northern boundary of Pearana are over 20 m high, but decrease southward to 8–12 m in height. Dune density is more variable and ranges from less than 100 m spacing in net dune complexes to 2–3 km spacing over the Gregory Granitic Complex. Dune frequency also decreases southward. The longitudinal dunes trend consistently around 290°. East and southeast of Woodie Woodie, dunes have crossed the drainage divide and penetrated the Oakover Drainage Basin for a distance of over 2 km. A prominent hogback ridge, marking the unconformity between the Tarcunyah Group and the Gregory Granitic Complex, forms a barrier between a sand-rich desert to the east and a sand-depleted desert area to the west.

The Oakover Valley physiographic unit on Pearana is a component of the Pilbara Natural Region (Beard, 1970). Although the unit on Pearana is dominated by the Oakover River, it also includes a number of large tributaries, which join it from the southeast, east, and west (Fig. 2). The Davis River, flowing from the southwest, occupies a separate drainage basin (Fig. 2). The eastern limit of the Oakover Drainage Basin roughly corresponds to the western edge of the Great Sandy Desert (Fig. 2). The Oakover River flows through a series of gorges including the Upper Carawine and Tarra Tarra gorges, and permanent pools and springs lie in these gorges and elsewhere along the Oakover and Davis rivers. Semi-permanent pools and rock holes are also scattered along the numerous tributaries flowing northwest into the Oakover River from the Gregory Range. These creeks show a pattern of strong bedrock-control in their upper reaches.

South of the Davis–Oakover river confluence the Oakover Formation, which caps mesas, buttes, and tablelands on Braeside, becomes the floor of a broad palaeovalley east of Skull Springs. The average gradient of the Oakover River on Pearana is 1 in 687 (0°05' fall), whereas the gradient of the Oakover Formation is only 1 in 1145 (0°03' fall). The Oakover Formation has been described as a lacustrine deposit of Miocene to Holocene age (Cockbain, 1978), thus the gentle gradient of the formation implies a slight northward tilt.

The lower Permian fluvioglacial rocks, also described on Braeside, occupy a well-defined glaciated palaeo-valley, trending 345°, between 4 and 8 km east of the present day Oakover River.

The highest land elevation is Mount Traine (480 m AHD; Australian Height Datum) in the southwestern corner of Pearana. A broad area of high ground also occupies the southeastern part of Pearana where a number of ridges and peaks reach 460 m. Although the Oakover River drops to 240 m in the Carawine Gorge, the greatest local relief (150 m) is in the Tarra Tarra Gorge upstream from the Davis River junction. Except for the Great Sandy Desert and the broad Oakover Valley region west and northwest of Woodie Woodie, Pearana has a rugged terrain with a well-developed drainage system. In contrast, the Great Sandy Desert is a broad, undulating plain falling gently to the northeast. The desert is characterized by prominent inselbergs (or bornhardts) of granitic rock where it overlies the Gregory Granitic Complex. A prominent hogback ridge, up to 80 m high and traceable for over 55 km along the eastern margin

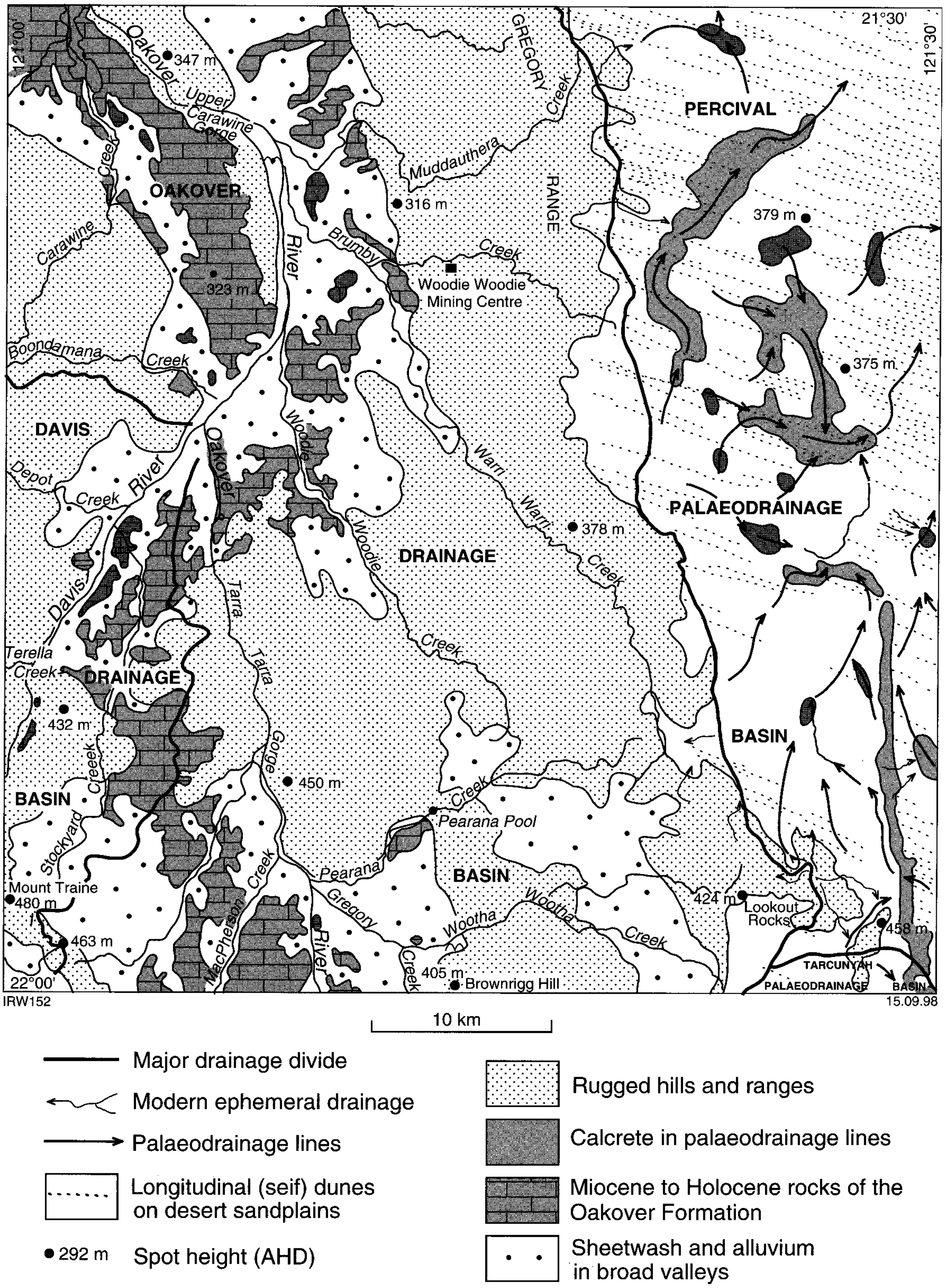

Figure 2. Physiographic and drainage sketch map of Pearana

of PEARANA, marks the western edge of the Tarcunyah Group.

The palaeodrainage system in the Great Sandy Desert indicates a north-northeastward flow toward the Percival Palaeoriver (van de Graaff et al., 1977). The system is marked by intermittent outcrops of trunk valley calcrete (Fig. 2). A smaller system in the southeast drained southeastward into the Tarcunyah Palaeodrainage Basin (Williams and Bagas, in prep.).

All these palaeodrainage systems are believed to have been active during the Late Cretaceous and early Cainozoic. Significant flow probably stopped after the onset of arid climatic conditions during the Middle Miocene (van de Graaff et al., 1977).

Regional geological setting and geological summary

Components of four major tectonic units, the Pilbara Craton, Bangemall Basin, Paterson Orogen, and Canning Basin, are present on PEARANA. The distribution of these tectonic units is shown on Figure 3.

The Koongaling Volcanic Member of the Hardey Formation, the basal unit of the Fortescue Group in this region, includes the oldest dated rocks on PEARANA (c. 2764 Ma, Arndt et al., 1991). The Fortescue Group is part of the Hamersley Basin of the Pilbara Craton (Trendall, 1990). Metamorphosed volcanic and sedimentary rocks of the Fortescue Group occupy a broad northerly trending and generally west-dipping zone in the central part of PEARANA. This zone wedges out between the north-trending Baramine Fault and Southwest Fault on the southern boundary of the sheet area (Fig. 4). Fortescue Group rocks also occupy a southeast dipping segment along the central-western margin of PEARANA (Fig. 5), due west of the Woodie Woodie mining centre. A discontinuous zone of medium-grade metamorphosed and strongly deformed microporphyritic rocks are present on the eastern side of the Gregory Granitic Complex and adjacent to the unconformably overlying Neoproterozoic Tarcunyah Group. These metamorphosed microporphyritic rocks, although included within the Gregory Granitic Complex, are possible high-grade metamorphic correlatives of the Koongaling Volcanic Member. The Fortescue Group rocks in the central part of PEARANA are disrupted by a series of subparallel, steep, easterly dipping, reverse, and transpressional faults.

The Gregory Granitic Complex (c. 2760 Ma) occupies a broad continuous north-trending zone in the eastern half of PEARANA (Fig. 5). As on BRAESIDE its relationship to the overlying Fortescue Group, particularly the felsic volcanic rocks of the basal Koongaling Volcanic Member, is controversial. However, recent geochemical and geochronological investigations indicate the Koongaling Volcanic Member and the Gregory Granitic Complex are comagmatic and coeval (Williams and Trendall, 1998b). All contacts between the Koongaling Volcanic Member and the granitoid rocks on PEARANA are faults. Trendall (1991) suggested that the boundary might be gradational, indicating that the Gregory Granitic Complex was the contemporaneous plutonic component underlying the vents from which the lavas of the Koongaling Volcanic Member were erupted. The surface exposure of the coarse-grained, gneissic syenogranite and orthogneiss is the result of uplift along east-dipping reverse faults.

Most of the western half of PEARANA is underlain by the Carawine Dolomite (≥2500 Ma, Jahn and Simonson, 1995), which is part of the Hamersley Group of the Hamersley Basin in the Pilbara Craton. The Carawine Dolomite occupies the regional Oakover Syncline (Hickman, 1978; Fig. 5). It is a platformal carbonate unit (Simonson et al., 1993b), that disconformably overlies the Jeerinah Formation of the Fortescue Group. In many areas the Carawine Dolomite is unconformably overlain by the Pinjian Chert Breccia, a residual deposit formed on a Proterozoic karst topography.

Several small, faulted outliers of the marine sedimentary Woblegun Formation unconformably overlie the Carawine Dolomite and Pinjian Chert Breccia in the Brownrigg Hill area (southern margin of PEARANA). This formation is the basal unit of the (c. 1300 Ma) Manganese Subgroup (Williams, 1989), and these localities represent the most northeasterly known extent of Bangemall Basin rocks.

The eastern margin and two small areas around Brownrigg Hill on the southern margin of PEARANA are occupied by fluvial and shallow-marine sedimentary rocks belonging to the older, low-grade metasedimentary Throssell Group (900–1300 Ma) of the Yeneena Basin (Williams and Bagas, in prep.) and the younger, sedimentary Tarcunyah Group (c. 800 Ma) of the Officer Basin (Bagas et al., 1995; Perincek, 1996; Williams and Bagas, in prep.). The Tarcunyah Group unconformably overlies the Gregory Granitic Complex along the eastern margin of PEARANA, and the Manganese Subgroup, and Fortescue and Hamersley Groups on the southern margin of the sheet area. In northeastern PEARANA, the Tarcunyah Group is separated from the Throssell Group, which lies in the northeastern corner, by the steep, east-dipping Vines Fault, a reverse fault with a dextral strike-slip component (Williams, 1990b). Both the Throssell and Tarcunyah Groups belong to the Paterson Orogen tectonic unit.

The Waltha Woora Formation, a correlative of the lower part of the Tarcunyah Group, lies north and west of Woodie Woodie in the northern-central part of PEARANA. The formation unconformably overlies the Pinjian Chert Breccia, Carawine Dolomite, and upper units of the Fortescue Group. It was deposited in channels and small depressions eroded in the underlying rocks. Preliminary studies of abundant stromatolite taxa in the Waltha Woora Formation (Grey, 1978) revealed that they are similar to taxa described from the Waroongunyah Formation on BALFOUR DOWNS (1:250 000). Although the stromatolites support coeval development, there is no direct evidence for a physical link between the two formations.

A linear, narrow, and discontinuous outcrop of the Permian, fluvioglacial Paterson Formation trends north-

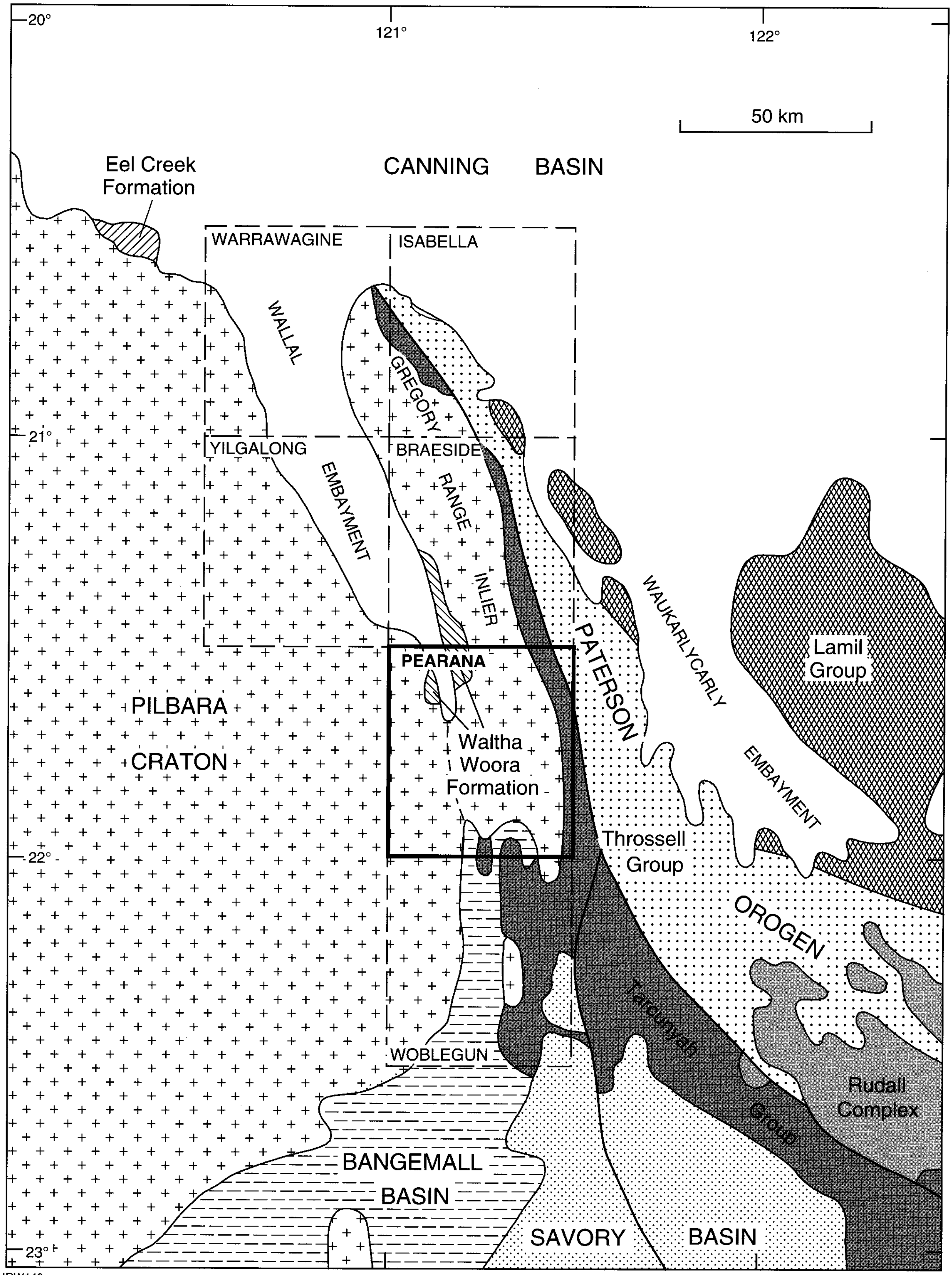

Figure 3. Regional geological setting of PEARANA

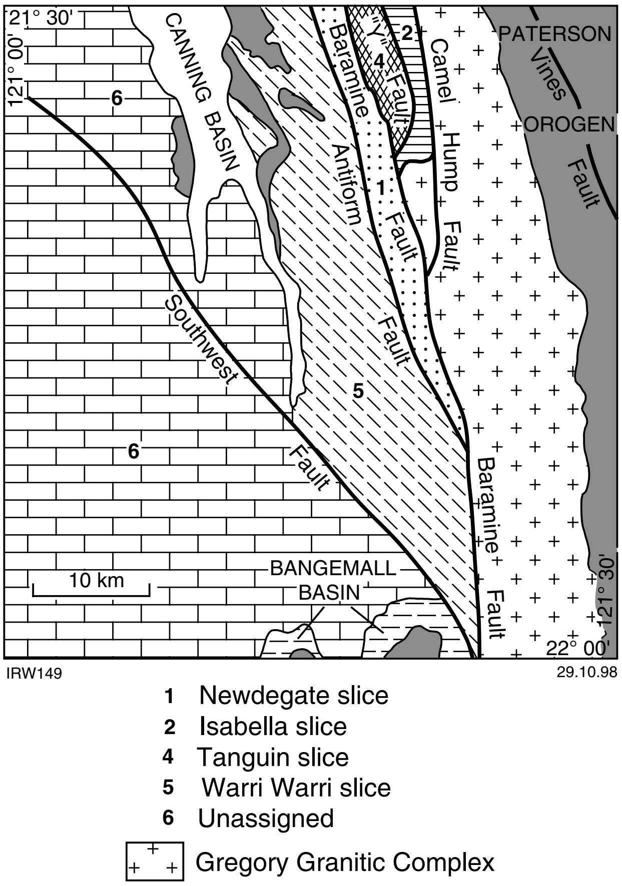

Figure 4. Structural fault slices on PEARANA (after Trendall, 1991)

northwesterly across PEARANA (Fig. 5). The restricted nature of the outcrop adjacent to striated glaciated pavements, particularly on the Pinjian Chert Breccia, strongly suggests that these Permian rocks were largely confined to glaciated valleys. The glaciers moved northwards towards the Wallal Embayment of the Canning Basin.

A comparative tabulation of previously published Precambrian stratigraphy (Hickman, 1978) with this survey is given in Figure 6. It should be noted that the revised and consolidated stratigraphic nomenclature for the Fortescue Group used by Thorne and Trendall (in prep.) has been adopted on PEARANA. The main changes to be noted from previous publications are the replacement of the name Lewin Shale (Hickman, 1978) by Jeerinah Formation, and the name Pearana Basalt (Hickman, 1978) by Maddina Basalt. The Hardey Formation applies to Fortescue Group units beneath the Kylena Basalt.

Archaean rocks

Archaean rocks on PEARANA are part of the Pilbara Craton. This craton consists of a granite–greenstone terrain (c. 3600–2850 Ma) and the younger volcano–sedimentary sequence of the Hamersley Basin (c. 2770–2400 Ma; Trendall, 1990). Only the latter unit is present on PEARANA.

Hamersley Basin

Gregory Granitic Complex

The late Archaean Gregory Granitic Complex (Hickman, 1975, 1978, 1983) occupies a 6–14 km wide, roughly north-trending zone across the eastern half of PEARANA. The complex, part of the Gregory Range Inlier, forms a narrow belt 160 km long that extends along the eastern margin of the Pilbara Craton southward, from ISABELLA to WOBLEGUN.

Understanding the relationships between components of the complex has been hindered by poor exposure and difficult access. The present detailed study has recognized four major components in the Gregory Granitic Complex: a widespread medium- to coarse-grained metamorphosed syenogranite or alkali granite (*ARm*); small plutons of porphyritic to seriate, coarse-grained, rapakivi-textured, and metamorphosed syenogranite (*ARr*); a strongly metamorphosed, fine-grained to microporphyritic granitoid rock, which may be a recrystallized felsic lava (*ARp*); and a metamorphosed granophyre body (*ARy*).

Medium- to coarse-grained syenogranite (ARm)

Scattered outcrops of metamorphosed medium- to coarse-grained syenogranite (*ARm*) form low inselbergs and tor-covered, flat rock surfaces in the north, and rugged weathered hills in the Lookout Rocks – Fletchers Find area near the southern margin of the sheet area. The metamorphosed syenogranite includes leucocratic to mesocratic varieties, the former abundant in southern PEARANA. Although dominantly an alkali granite, quartz-poor varieties approach syenite in composition, and biotite- and plagioclase-rich varieties place some samples in the monzogranite range.

The metamorphosed syenogranite is dominated by alkali feldspar (albite, microcline, and perthite), with lesser amounts of quartz and plagioclase (commonly oligoclase). The dominant mafic mineral is hastingsite, with lower amounts of biotite and minor amounts of aegirine–augite. Titanite and opaque minerals — most probably a mixture of magnetite and ilmenite — are ubiquitous, whereas zircon, apatite, allanite, and (very rarely) fluorite are accessory phases. Secondary minerals include saussurite, epidote, and sericite.

The unit is intersected by several anastomosing faults trending north to north-northwest. The faults are commonly indicated by quartz-breccia or quartz-filled mylonite zones, which sometimes carry minor copper mineralization. These faults have large vertical and sinistral strike-slip movements that, as described by Trendall (1991), transported deeper crustal material up and towards the west. Rocks originating at deeper crustal levels are exposed southwards across the complex, and this is expressed in the textures of the granitic rocks, which change from allotriomorphic granular texture with

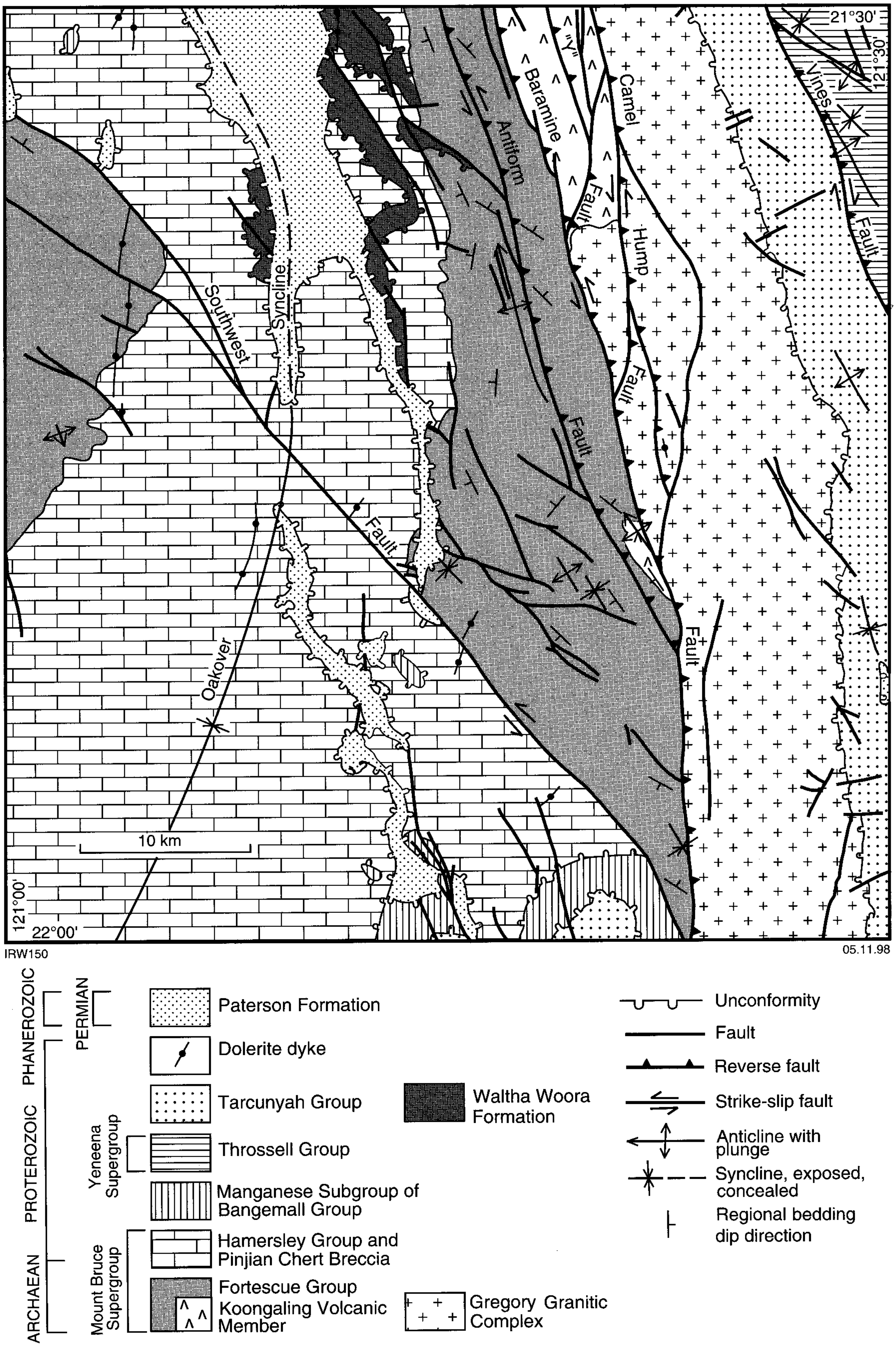

Figure 5. Structural sketch map of Pearana

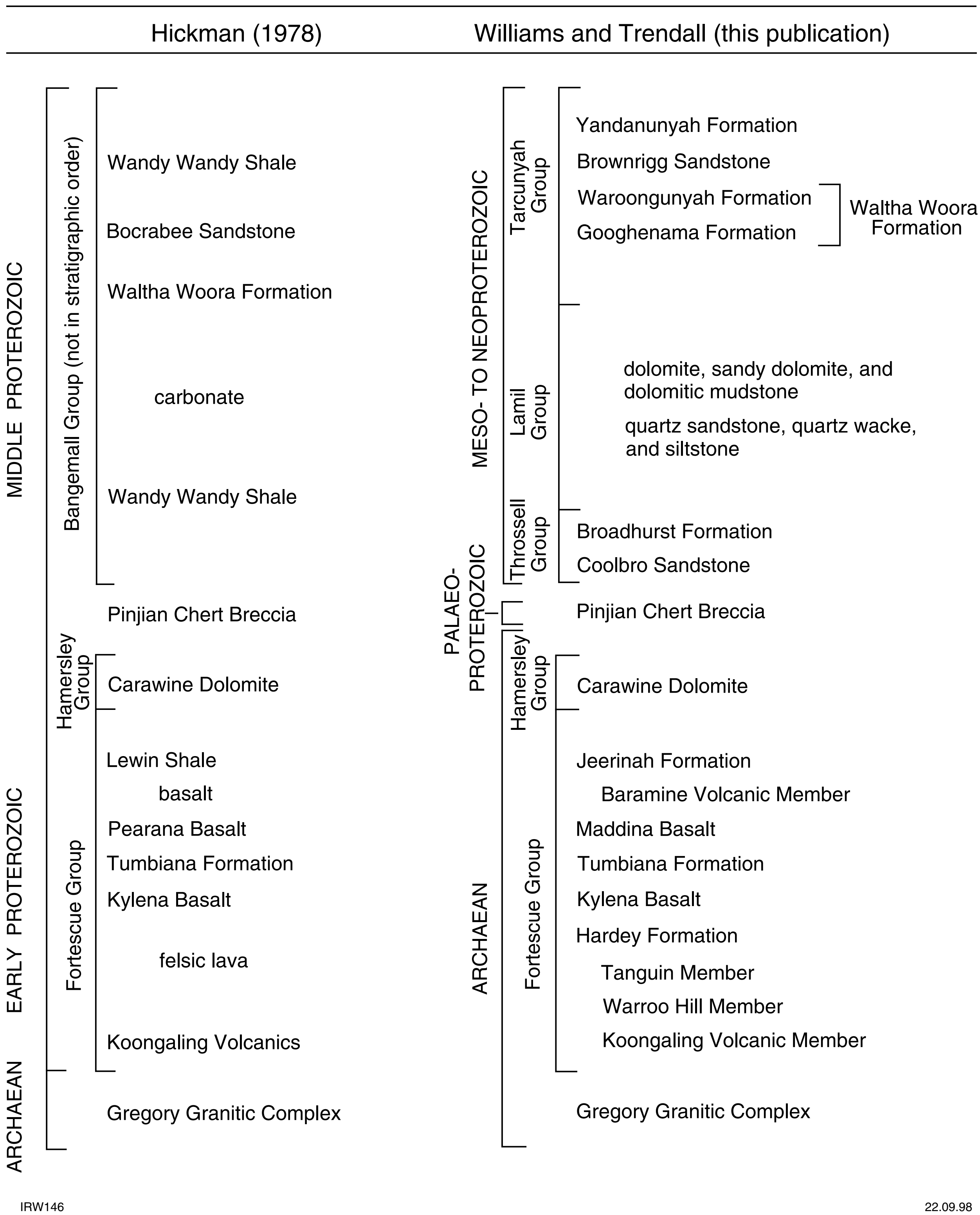

Figure 6. Comparative Precambrian stratigraphy on Pearana

a weak foliation in the north to pervasive protomylonitic, mylonitic, and gneissic fabrics in the south. There appears to be at least two phases of metamorphism: early low to medium amphibolite facies (a ductile regime) with coarse crystalloblastic textures; and later lower grade metamorphism (a more brittle regime) with intergranular deformation, quartz straining, and brecciation.

Granophyre (ARy)

Metamorphosed granophyre on PEARANA is restricted to one large outcrop at the base of the Isabella slice 9 km east of Woodie Woodie where it is faulted against the Koongaling Volcanic Member, and two minor occurrences (AMG 270070) on the western margin of the microporphyritic granitoid rock (*ARp*) 2 km north-northwest and 21 km north of Fletchers Find. These latter occurrences, identified in thin section, appear to be a phase of the granitoid rock (*ARp*). This is significant because on BRAESIDE the metamorphosed granophyre appears to grade into the overlying felsic volcanic rocks of the Koongaling Volcanic Member.

The metamorphosed granophyre consists of non-granophyric aggregates of alkali feldspar and rounded to ovoid grains of quartz and feldspar set in a granophyric groundmass. Scattered grains of hastingsite, biotite, and aegirine–augite are also present. Titanite-fringed opaque minerals (magnetite and ilmenite) are abundant, and zircon and apatite are accessory minerals. Large anhedral poikiloblastic granular garnets are a feature of the granophyre at the base of the Isabella slice. The mineral assemblage is similar to that in the other components of the Gregory Granitic Complex.

Porphyritic to seriate syenogranite (ARr)

Faulted and deformed elongated plutons of metamorphosed porphyritic to seriate syenogranite straddle the Nifty road 12.5 km southeast of Woodie Woodie (AMG 302090), the ‘Esso track’ 16.5 km southeast of Woodie Woodie (AMG 313974), and extend across the southern boundary onto BALFOUR DOWNS (1:250 000) 8.5 km southeast of Fletchers Find (AMG 350670). A poorly exposed fourth pluton (AMG 269054) has intruded the metamorphosed granophyre (*ARy*) 9.5 km east of Woodie Woodie. The syenogranite (*ARr*) exposure is characterized by widely scattered prominent rocky hills and tors. In hand specimen, the original megacrysts — now commonly augen — appear as composites of grey and white feldspar, peppered with mafic minerals and partly surrounded by mantles of pink feldspar, set in mafic-rich matrices. In thin section, the large megacrysts consist of plagioclase (typically albite), microcline, and perthite, all containing small scattered crystals of hastingsite, and biotite. The megacrysts are set in a coarse-grained matrix of quartz, microcline, plagioclase, hastingsite, and lesser biotite. The large megacrysts are incompletely surrounded by fine-grained rims of microcline and plagioclase. However, it is not clear whether this is an igneous feature (i.e. rapakivi-style texture) or due to later metamorphism and deformation. Aggregates and schlieren of mafic minerals, which have recrystallized during metamorphism, include hastingsite, biotite, epidote, titanite, and opaque minerals (apparently a mixture of magnetite and ilmenite). Allanite, zircon, and apatite are accessory minerals.

The plutons are typically more deformed than those on BRAESIDE, although deformation is still heterogeneously distributed. Deformation ranges from breccia zones to pervasive shearing, with a mylonitic fabric in some areas. There are narrowly spaced shear zones in some thin sections, together with kinked and broken larger crystals. Grains within the augens are generally less deformed than those in the matrix. The mafic minerals normally wrap the augens, which in some cases have tails of quartz and feldspar. Metamorphism appears to have reached low to middle grade, although retrograde effects (including saussuritized plagioclase) are also present.

Equigranular, fine-grained to microporphyritic granitoid rock (ARp)

Metamorphosed, fine-grained to microporphyritic granitoid rock (*ARp*) occupies an almost continuous, narrow belt adjacent to the Tarcunyah Group unconformity, extending from 10 km east-southeast of Thursday Hill to the southern boundary of PEARANA. A second, small area 3.5 km east of Mount Gregory (AMG 325920) lies adjacent to a large fault on the western side of the Gregory Granitic Complex. This unit was mapped as a felsic porphyry on BALFOUR DOWNS (1:250 000).

The microporphyritic granitoid has undergone complex deformation and metamorphism similar to that of other components of the Gregory Granitic Complex.

The distinctive, microporphyritic texture of the rock is similar to the porphyritic rhyolite and rhyodacite of the Koongaling Volcanic Member. However, in thin section, both the matrix and phenocrysts consist of a mosaic of alkali feldspar and quartz, and plagioclase locally. The rock is a porphyroidal microgneiss, with a groundmass consisting of fine-grained, granoblastic alkali feldspar (microcline, albite, and perthite), sodic plagioclase, and quartz. Segregations of hastingsite, biotite, titanite, and opaque minerals constitute the mafic component. Apatite, allanite, and zircon are accessory minerals, and epidote and (rare) stilpnomelane are secondary minerals.

Rafts and xenoliths of schistose metasedimentary rocks (Alqm)

The metamorphosed medium- to coarse-grained syenogranite (*ARm*) and fine-grained, microporphyritic granitoid rock (*ARp*) locally contain schistose metasedimentary rock (*Alqm*) as scattered xenoliths or extensive rafts up to 2 km^2 in area. These large metasedimentary rafts are concentrated close to the boundary between the syenogranite (*ARm*) and microporphyritic granitoid (*ARp*) units. East of Fletchers Find, this boundary is a quartz mylonite zone.

The metasedimentary rafts and xenoliths contain quartz–muscovite–biotite, quartz–muscovite–biotite–sillimanite(–cordierite), and muscovite–biotite–

chlorite assemblages. A metamorphosed quartz-pebble conglomerate and a quartz–muscovite schist lie 1.5 km northwest of Fletchers Find.

The metasedimentary rafts initially reached middle to upper amphibolite facies before retrograding to greenschist facies. This metamorphic history is reflected in the host granitoid rocks of the Gregory Granitic Complex.

Relationships of the complex

Faults form all contacts between the complex and the overlying Fortescue Group on PEARANA. The maximum vertical displacement (east block up) along the Baramine Fault lies west of Lookout Rocks where the metamorphosed medium- to coarse-grained syenogranite (*ARm*) — deformed and metamorphosed to a granite gneiss — is faulted against the Jeerinah Formation. The granophyre (*ARy*) 9 km east of Woodie Woodie (AMG 270070) is in faulted contact with the overlying Koongaling Volcanic Member in the Isabella slice. However, exposures of this contact on BRAESIDE show gradational and intrusive relationships. The contact between the metamorphosed granophyre and other components of the complex on PEARANA is masked by sand, except at AMG 269054 where it appears to be intruded by metamorphosed porphyritic to seriate syenogranite (*ARr*). The plutons of metamorphosed porphyritic to seriate syenogranite (*ARr*) also contain large rafts and xenoliths of medium- to coarse-grained syenogranite (*ARm*), supporting observations on BRAESIDE that the porphyritic syenogranite is slightly younger than the syenogranite (*ARm*). The fine-grained to microporphyritic granitoid rock (*ARp*) outcrops extensively along the eastern margin of the complex, and is unconformably overlain by the Tarcunyah Group. Its intrusive relationship to the syenogranitic unit (*ARm*) is unclear because contacts, where exposed, are mylonitized (*qm*). The Gregory Granitic Complex displays a complex metamorphic history and is heterogeneously deformed. Metamorphic grade and deformation complexity increase southward across the sheet. Metamorphic grade in metasedimentary xenoliths attained middle to upper amphibolite facies.

Trendall (1990, 1991) suggested that the Gregory Granitic Complex may be the contemporaneous plutonic body (intrusion?) underlying the volcanic centres that sourced the Koongaling Volcanic Member. Only the granophyre was previously considered to be related to the volcanic rocks (Hickman, 1983). Later transpressional faulting and uplift followed by deep erosion led to the present configuration of the units. Geochemical data (Appendix 2) show the felsic lavas of the Koongaling Volcanic Member and the components of the Gregory Granitic Complex have similar chemistry, possibly implying a comagmatic igneous suite. Evidence for this conclusion is presented in detail in the BRAESIDE Explanatory Notes (Williams and Trendall, 1998b). In summary, the suite is both petrologically and chemically alkaline. The suite is also anhydrous, silicic, and potassic, and on tectonic discrimination diagrams (Smithies, R. H., 1998, pers. comm; Williams and Trendall, 1998b) plots specifically within the 'A_2' group field of the 'A' type felsic igneous category (Eby, 1992). Such granitoids are the result of crustal melting of a source that has been through previous subduction or collision in an anorogenic setting under a tensional tectonic setting. These data also support the original hypothesis proposed by Trendall (1990, 1991) that the Gregory Granitic Complex and volcanic rocks of the Koongaling Volcanic Member are genetically related.

Speculation on the age of the Gregory Granitic Complex followed publication of a 12 point total-rock Rb–Sr isochron age of 2651 ± 60 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7086 ± 0.0048 from gneissic syenogranites 1.5 km north-northwest of Lookout Rocks (AMG 340731; de Laeter et al., 1977). Two discordant biotite samples gave a mean age of around 1200 Ma, which may be the age of major uplift in the region (Hickman et al., 1994). Trendall (1991) suggested that the Koongaling Volcanic Member and the Gregory Granitic Complex may have similar ages. Subsequently, Sensitive High-Resolution Ion Microprobe (SHRIMP) zircon U–Pb geochronology (Nelson, 1996) gave results of 2757 ± 5 Ma for the metamorphosed porphyritic to seriate syenogranite (*ARr*), 2762 ± 4 Ma for the metamorphosed medium- to coarse-grained syenogranite (*ARm*), and 2763 ± 8 Ma for the granophyre (*ARy*) (Table 1).

The similarity of these ages to SHRIMP U–Pb zircon dates from the Koongaling Volcanic Member (2764 ± 8 Ma) and a rhyolite porphyry sill in the Warri Warri Member (2760 ± 10 Ma) on PEARANA (Arndt et al., 1991) is significant, and leaves little doubt as to the coeval relationship of these rocks. The results are summarized in Table 1.

Exposure of the Gregory Granitic Complex is attributed to uplift along a series of steep reverse faults with a sinistral strike-slip component. The successive tectonic events, which contributed to this picture, are discussed in Williams and Trendall (1998b).

Fortescue Group

The Fortescue Group outcrops in two areas on PEARANA, west of the Oakover River valley, and north–south down the centre of the sheet. The western area is the easternmost outcrop of the main Fortescue Group, which extends hundreds of kilometres over much of the southern part of the Pilbara Craton. Only the Maddina Basalt and Jeerinah Formation are present in this part of PEARANA. Outcrop down the centre of the sheet is the southern end of a narrow belt forming the Gregory Range Inlier of the Fortescue Group (Fig. 3). This belt extends northward onto BRAESIDE and ISABELLA; small areas of the inlier are also present on WARRAWAGINE and YILGALONG. The inlier is cut by numerous faults subparallel to its north-northwesterly trending length. Trendall (1991) identified a number of these as major faults, dividing the rocks into discrete elongate belts, or tectonic slices. Although mapping since 1990 has shown that the number of subparallel faults is greater than originally thought, and that many of the minor faults approach the importance

Table 1. Summary of geochronology on PEARANA

GSWA Sample no.	*Locality*	*Lithology*	*Method*	*Age*	*Interpretation*	*Reference*
Samples not collected by GSWA	Near Woodie Woodie, Oakover River Ford (Nullagine Road), and upper and lower Carawine Pools	Carawine Dolomite (*AHc*)	Pb isotopic analysis, carbonate Pb–Pb isochron age	2541 ± 32 Ma	Diagenesis of the Carawine Dolomite	Jahn and Simonson (1995)
94760	Base of cliffs on south side of Warri Warri Creek, 4.5 km southwest of Mount Gregory (AMG 248901)	Metarhyolitic porphyry (*AFhp*) sill in Hardey Formation, between Kylena Basalt and Warri Warri Member	SHRIMP (U–Pb zircon)	2760 ± 10 Ma	Age of crystallization, emplacement	Arndt et al. (1991)
94759	Top of the Koongaling Volcanic Member beneath Warri Warri Member, 3 km south-southeast of Mount Gregory (AMG 296897)	Metarhyolite (*AFhi*) of Koongaling Volcanic Member	SHRIMP (U–Pb zircon)	2764 ± 8 Ma	Age of crystallization, emplacement	Arndt et al. (1991)
45756 45757	1.5 km north-northwest of Lookout Rocks (AMG 34073)	Foliated alkali granite, medium- to coarse-grained sheared and metamorphosed Gregory Granitic Complex (*ARm*)	Rb–Sr whole-rock isochron	2651 ± 60 Ma 12 point isochron	Originally interpreted as age of emplacement, now interpreted as the age of metamorphic event	de Laeter et al. (1977) Trendall (1991)
45756D 45756E	1.5 km north-northwest of Lookout Rocks (AMG 340731)	Biotite from alkali granite, metamorphosed Gregory Granitic Complex (*ARm*)	Rb–Sr mineral isochron Two samples of biotite	1226 Ma 1194 Ma	Originally attributed to shearing in granite, now interpreted to correspond to uplift associated with Miles Orogeny (D_4), Paterson Orogen	de Laeter et al. (1977) Hickman et al. (1994) Bagas et al. (1995)
118920	5.5 km SE of Thursday Hill (AMG 297175)	Alkali granite gneiss, Gregory Granitic Complex (*ARm*)	SHRIMP (U–Pb zircon)	2762 ± 4 Ma	Age of crystallization of the granite precursor	Nelson (1996)
118924	'Esso track', 16.5 km southeast of Woodie Woodie (AMG 313974)	Hornblende–biotite granite augen gneiss, Gregory Granitic Complex (*ARr*)	SHRIMP (U–Pb zircon)	2757 ± 5 Ma	Age of crystallization of the granite precursor of the augen gneiss	Nelson (1996)
118923	Nifty access road, 9 km east of Woodie Woodie (AMG 262070)	Porphyritic granophyre, metamorphosed Gregory Granitic Complex (*ARy*)	SHRIMP (U–Pb zircon)	2763 ± 8 Ma	Age of crystallization of the granophyre	Nelson (1996)

NOTE: SHRIMP: Sensitive High-Resolution Ion Microprobe of those previously named, it is convenient to retain the names of the major faults and slices, which are present on PEARANA, and to describe Fortescue Group stratigraphy in terms of these subdivisions (Fig. 4).

The southern part of the Gregory Range Inlier on PEARANA includes the westernmost three of the five major faults named by Trendall (1991): the Southwest, Antiform, and Baramine Faults (from west to east). Other faults east of the Baramine Fault may represent southern extensions of the 'Y' and Camel Hump Faults, which are better defined on BRAESIDE and ISABELLA. The Southwest, Antiform, and Baramine Faults delimit the southernmost parts of the Warri Warri and Newdegate slices (Fig. 4). Possible southern extensions of the Tanguin, Isabella, and Lochinvar slices are poorly defined on PEARANA, and cannot be clearly delineated within the Gregory Granitic Complex, which occupies most of the area east of the Baramine Fault.

The latest movement on these major faults, which are commonly expressed at the surface by discontinuous, thick quartz dykes ('blows') dipping steeply eastwards, is east side up. Thus, rocks on the eastern sides are either stratigraphically lower, of higher metamorphic grade, or both, than rocks on the western sides. Although there is sufficient evidence that the stratified rocks within each slice belong to the Fortescue Group, and for lithological correlations between the slices, there are substantial differences in both thickness and lithology. For example, in the Warri Warri slice, the Warri Warri Member of the Hardey Formation is the lowest unit of the Fortescue Group present. Above this a continuous section to the top of the uppermost unit (Jeerinah Formation) is present. However, in the Newdegate slice, immediately to the east, the Koongaling Volcanic Member of the Hardey Formation is the lowermost unit of the Fortescue Group. Above this, a mixed sequence of volcanic and sedimentary rocks included in the Warri Warri Member (in spite of major differences from that member in the Warri Warri slice) extends to the northern margin of the sheet area. The Warri Warri and Newdegate slices appear to constitute a gently north-plunging antiform, although the east and west limbs of this structure exhibit some stratigraphic differences. In the Tanguin and Isabella slices, only the Koongaling Volcanic Member of the Hardey Formation is present on PEARANA.

Hardey Formation

There is strong regional geochronological and stratigraphic evidence for the rapid accumulation of very large thicknesses of sedimentary and volcanic rocks during the formation of the lower part of the Fortescue Group. A lithostratigraphic correlation between the Hardey Formation in the Fortescue Group west of PEARANA and the lower units (labelled Hardey Formation) of the Fortescue Group on PEARANA is discussed by Thorne and Trendall (in prep.). The name is applied to a wide variety of rock types in marginal or disconnected outcrop areas, even where exact lithostratigraphic correlation is open to some doubt, because it avoids the proliferation of new and locally restricted stratigraphic names. No certain correlation with any subdivisions of the Hardey Formation of the type area, or elsewhere in the main outcrop area of the group is implied. Most of the rocks included by Hickman (1978) in the 'Koongaling Volcanics' are incorporated here into the Hardey Formation, and the name Koongaling Volcanic Member is now restricted to the rhyolite, rhyodacite, and dacite component of the unit defined by Hickman (1978).

Koongaling Volcanic Member (AFhi)

The Koongaling Volcanic Member of the Hardey Formation, is the lowest stratigraphic unit of the Fortescue Group present in the Gregory Range Inlier. It outcrops in two areas on PEARANA, on either side of the Baramine Fault. West of the fault (around AMG 300900) southeast of Mount Gregory and close to the southern end of the Newdegate slice, a small area of mildly deformed rhyolite lies in the core of an anticline. The rhyolite is a massive, buff-coloured, and flinty rock with small K-feldspar phenocrysts in an aphanitic matrix. Undulating terraces 3–5 m high in the rugged hills of the outcrop area probably reflect a coarsely sheeted structure acquired by the thick viscous magma body during extrusion; the structure may be related to the ogives present in this unit on BRAESIDE. Arndt et al. (1991) reported a U–Pb zircon age of 2764 ± 8 Ma (Table 1) for the rhyolite. Outcrop east of the Baramine Fault extends northward from the Woodie Woodie – Nifty road to the northern edge of the sheet area. The rhyolite in this area is a tough, flinty, and dark-grey or brown porphyritic rock with no discernible original flows or flow structure, and K-feldspar phenocrysts up to 5 mm across. A vertical lineation and near-vertical penetrative foliation striking approximately north–south permeates the rock, and is easily visible in weathered exposures. Williams and Trendall (1998b) contains detailed petrographic descriptions of the Koongaling Volcanic Member. The base of the Koongaling Volcanic Member is not seen on PEARANA. However, field observations on BRAESIDE indicate that gradational and faulted contacts exist between the volcanic rocks and the granophyre of the Gregory Granitic Complex. The granophyre is consistently present where the local structure indicates the presence of the shallowest rocks of the Gregory Granitic Complex. On PEARANA, such an area of granophyre is centred about 9 km east of Woodie Woodie (AMG 270070). From outcrop width and structural evidence the thickness of the Koongaling Volcanic Member is estimated to be between 1 and 2 km.

Warri Warri Member (AFhw, AFhwt, AFhwh, AFhwo, AFhws, AFhwr, AFhwa, AFhp)

The Warri Warri Member of the Hardey Formation overlies the Koongaling Volcanic Member conformably in the southern part of the Newdegate slice. Here the lowest component of the Warri Warri Member, a tuffaceous sedimentary rock (mainly tuffaceous sandstone, *AFhwt*), dips consistently away from the northern and western rhyolite hills of the Koongaling Volcanic Member. The implied anticlinal structure extends westward across the Antiform Fault into the Warri Warri slice, and the consistent lithology and structure of this basal tuffaceous sandstone unit of the

Warri Warri Member provides compelling evidence for its lithostratigraphic equivalence in both the Warri Warri and Newdegate slices. The basal, tuffaceous sandstone is well exposed over a wide area of the headwaters of Warri Warri Creek (south of Mount Gregory around AMG 280860). It is typically a massive, green sandstone with subordinate siltstone in which bedding may not be conspicuous; however, close examination of apparently massive exposures commonly reveals Bouma sequences between 10 and 50 cm thick. Thin sections reveal a fine-grained matrix recrystallized to biotite and chlorite, and a uniformly fine-grained mixture of both quartz, feldspar, and lithic grains, many with a trachytic flow texture confirming their volcanic derivation, although such rocks do not outcrop locally. Associated pale-green siltstones are typically finely laminated. A bed of tuff at the top of the tuffaceous (*AFhwt*) unit has abundant accretionary lapilli, and is locally associated with black manganiferous shale; it is well exposed 3.3 km northwest of Mount Gregory (near AMG 258937).

Thin galena and galena-bearing quartz veins have been found in tuffaceous sandstone (*AFhwt*) in the headwaters of Warri Warri Creek. Unlike most of the widespread galena occurrences in the Kylena and Maddina Basalts on BRAESIDE, the lead mineralization on PEARANA does not appear to be related to major shear and fault zones. Two samples of galena, independently submitted by exploration companies, gave Pb t7/6 model ages of c. 2440 and 2460 Ma (Table 2), slightly younger than most of the BRAESIDE samples (Williams and Trendall, 1998b).

Intercalated within this tuffaceous volcaniclastic sandstone unit in the Warri Warri slice is an approximately 100 m thick stratiform body of massive felsic igneous rock (*AFhwf*). This outcrop defines a double northwestward plunging fold pattern in the anticline core; no evidence for intrusion or extrusion was found. Towards the top of the sandstone a quartz-phyric rhyolite sill (*AFhp*) forms a prominent east-facing scarp along its outcrop. The existence of isolated patches of the tuffaceous sandstone (*AFhwt*) above the sill confirms its intrusive nature. This is also suggested by both its lithological uniformity, and by a complete absence of any flow banding or other textural feature implying extrusion. However, a SHRIMP U–Pb zircon age of 2760 ± 10 Ma reported by Arndt et al. (1991) is within error of the age determined for the stratigraphically lower Koongaling Volcanic Member (*AFhi*; Table 1). Although the rhyolite sill differs from the rhyolite in the Koongaling Volcanic Member, having abundant quartz phenocrysts, both rocks probably belong to the same volcanic episode. This is supported by major and trace element chemistry (Appendix 2). The tuffaceous sandstone (*AFhwt*), the felsic igneous rock (*AFhwf*), and the rhyolitic porphyry sill (*AFhp*) have a total thickness of about 1 km in the Warri Warri slice. These units are conformably overlain either directly by the Kylena Basalt or locally by mixed mafic–felsic lava flows (*AFhwh*), which are included in the Warri Warri Member. Such mixed volcanic rocks are restricted in this slice to a small area centred 4 km west of Mount Gregory (AMG 250925). Although some of these rocks resemble the overlying Kylena Basalt, being fine-grained, greenish, well jointed, and massive, they have a paler colour and lack clearly stacked flows. They have a significant fine-grained quartz content, and K-feldspar phenocrysts with textural similarities to those of the Koongaling Volcanic Member and other rhyolite units of the Fortescue Group.

The lithology and thickness of the unit above the basal tuffaceous sandstone (*AFhwt*) in the Newdegate slice differs radically from the equivalent unit in the Warri Warri slice. The tuffaceous sandstone and shale pass upward into a thick-bedded oligomictic conglomerate unit (*AFhwo*; AMG 280925). The predominant oligomictic conglomerate of this unit consists of close-packed and well-rounded boulders of quartz porphyry in a matrix consisting of the same material (Trendall, 1991; fig. 6B). Although the largest boulders in the coarser conglomerate beds are up to a metre across, the larger boulders in most conglomerate beds have diameters of about 30 cm. The oligomictic conglomerate (*AFhwo*) also contains minor sandstone beds and rare tuff with accretionary lapilli. It is intruded by several thin, discontinuous, quartz-porphyry sills similar in appearance to the boulders in the conglomerate. The unit is gradational upwards into coarse cross-bedded quartz sandstone over a stratigraphic thickness of about 170 m. The transition is marked both by a gradual decrease in size and abundance of quartz-porphyry clasts, and an increase in quartz content.

Upward stratigraphic continuity exists between the epiclastic sandstone (*AFhws*), massive green tuff (*AFhwt*), mixed lava (*AFhwh*; similar to the adjacent Warri Warri slice), well-stratified, green, tuffaceous sandstone with accretionary lapilli (also mapped as *AFhwt*), and flow-banded to massive, locally spheroidal rhyolite (*AFhwr*) in the Newdegate slice north of the oligomictic conglomerate (*AFhwo*). The rhyolite (*AFhwr*) is capped by agglomerate with mixed angular volcanic clasts (*AFhwa*). Dolerite sills are present throughout the succession.

Although exposure is not continuous in the central part of the Newdegate slice, the consistent dip and strike suggests that the succession is continuous between the oligomictic conglomerate (*AFhwo*) and the base of the Kylena Basalt. If this is correct the Warri Warri Member has a total stratigraphic thickness of at least 4 km in the Newdegate slice, about four times thicker than in the Warri Warri slice. Correlation of these two disparate sequences is indicated by their common position below the Kylena Basalt, and by outcrops of tuff with accretionary lapilli 8.5 km north-northwest of Mount Gregory (AMG 265005) showing a very close resemblance to those in the Warri Warri slice (AMG 258937), 3.3 km northwest of Mount Gregory.

The Warri Warri and Tanguin Members (48 km to the north) have similar lithostratigraphic relationships to the Koongaling Volcanic Member. The possibility that these two members are the same unit displaced by the sinistral strike-slip Baramine Fault is discussed in detail by Williams and Trendall (1998b).

Table 2. Summary of lead-isotope data and ages from galena associated with the Warri Warri Member, Hardey Formation on PEARANA

			Pb-isotope ratios			*Model ages (Ma)*[b]			
Sample[a]	*Locality*	*Occurrence*	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	*t 7/6*	*t 6*	*t 8*	*Source*
51805	Headwaters of the Warri Warri Creek; AMG 298914	Galena vein in tuffaceous sedimentary rock, *AFhwt* (Warri Warri Member)	14.0723	14.8307	33.8939	2 440	2 500	2 420	D. R. Nelson (unpublished)
86211	Headwaters of the Warri Warri Creek; AMG 291878	Galena in quartz vein in tuffaceous sedimentary rock, *AFhwt* (Warri Warri Member)	13.986	14.782	33.761	2 460	2 530	2 470	I. R. Fletcher (unpublished)

NOTES: (a) Geological Survey of Western Australia sample number
(b) Pb–Pb model age calculated from Cumming and Richards (1975) method

Kylena Basalt (AFk)

The Kylena Basalt is present in both the Warri Warri and Newdegate slices. The first appearance of a thick sequence of stacked basaltic flows within the Fortescue Group is arbitrarily taken to be the base of the unit. In the Warri Warri slice, such basalts lie with apparent conformity on either the tuffaceous sedimentary rocks (*AFhwt*), or the mixed felsic and mafic lava (*AFhwh*) of the Warri Warri Member. This boundary is mostly concealed or complicated by the rhyolitic porphyry sill (*AFhp*) emplaced close to the top of the underlying tuffaceous sandstone unit (*AFhwt*). In the Newdegate slice, apparent conformity exists between the lowest stacked basalt flows and either the underlying rhyolite or agglomerate units of the Warri Warri Member. However, along strike lithological differences beneath the contact may define a minor unconformity.

Each basalt flow forms a uniformly rough and dissected terrain, which is clearly defined on aerial photographs as thin subparallel lines marking the flow-tops. The flows, up to 20 m-thick, have an average thickness of 15 m and individual flows may be traced continuously for many kilometres along strike. It is uncertain whether slight local angular discordances between packages of stacked flows result from pene-contemporaneous erosion or from minor faulting subparallel to their strike. In the Warri Warri slice, there are 30–40 flows in a 500 m-thick section of the Kylena Basalt. In the Newdegate slice, about 70 flows are present in the 1 km-thick Kylena Basalt on PEARANA. The upper part of this unit extends northwards onto BRAESIDE, where the total thickness of the Kylena Basalt of the Newdegate slice is at least 3 km.

Each successive flow of the Kylena Basalt consists of tough, massive, dark-green, and well-jointed aphanitic basaltic lava. The basalt flows are subaerial, with amygdales (commonly filled with quartz, chlorite, or carbonate) distributed throughout the flows (with the highest concentrations near the top of the flows). The more pervasively amygdaloidal parts of each flow (about a metre to a few metres in thickness) are commonly strongly bleached and silicified, dissected by quartz veins, and brecciated. The original pyroxene and labradorite of the primary basalt are almost entirely altered to a fine-grained felted mass of amphibole, set in a matrix of albite, quartz, and epidote.

The clearly defined basalt flows form, with the underlying Hardey Formation, a north-northwesterly gently plunging anticline, which is transected axially by the Antiform Fault. Flows in the Kylena Basalt of the Newdegate slice have low east-northeasterly dips, whereas those in the Warri Warri slice dip gently northward around the nose of the anticline and west-southwest on the western limb.

The penetrative axial cleavage, which is heterogeneously expressed within the underlying Warri Warri Member, is rarely developed in the highly competent stacked flows of the Kylena Basalt.

Tumbiana Formation (AFt)

The unit assigned to the Tumbiana Formation (*AFt*) on PEARANA is visible on aerial photographs as a pale band conformably sandwiched between the top of the Kylena Basalt and the base of the Maddina Basalt. It extends southward from the nose of the northerly plunging anticline of the Warri Warri slice, where outcrop is complicated by minor faults, then south-southeastward along the gently west-southwesterly dipping western side of the antiform. The discontinuity of the outcrop in this area is probably due to parallel faulting rather than discontinuity in the original stratigraphy. There is a steep, heterogeneously developed, axial-planar cleavage throughout the formation. Although exposure is generally poor, in many places the formation forms spectacular scenic outcrops (e.g. 8.5 km west of Mount Gregory; AMG 205915) where tuffaceous sedimentary rocks with steep north–south cleavage have weathered into stacks of thin vertical plates, similar in appearance to giant packs of playing cards.

The Tumbiana Formation on PEARANA resembles the Mingah Tuff Member, the lower of the two members in this formation on BRAESIDE. On PEARANA, the unit is composed of greyish green, tuffaceous siltstone and minor amounts of fine-grained sandstone with a few thin bands of agglomerate in the southern section of the outcrop. Beds, up to 10 cm thick, of closely packed accretionary lapilli (2–4 mm across) are abundant throughout the formation. The formation is estimated to be 100–150 m thick from dip and outcrop width.

Maddina Basalt (AFm, AFma)

The Maddina Basalt (*AFm*) outcrops between Depot Creek and Carawine Rock Hole along the western margin of the sheet area. Here the basalts have a shallow southeasterly dip and are conformably overlain by the Jeerinah Formation. The base of the Maddina Basalt is not exposed in this area.

The Maddina Basalt also occupies a narrow, northerly trending, westerly dipping belt between Binbianna Rock Hole in the south and the northern margin of PEARANA. In this area the basaltic lavas overlie the Tumbiana Formation with perfect conformity, although it is unclear why the upper carbonate rock member, present elsewhere in the Tumbiana Formation, is absent in this area.

The Maddina Basalt consists of a sequence of subaerial basalt flows similar to the Kylena Basalt. The flows are clearly defined on aerial photographs in rough and dissected terrain. Individual flows (up to 50 m thick) average 20 m in thickness and can be traced for many kilometres along strike. The flows consist of massive, dark-green, and well-jointed aphanitic basalt lava with amygdales containing quartz, carnelian (red to orange-red chalcedony), chlorite, or carbonate minerals concentrated in the upper parts. Basalts of the Maddina Basalt are petrographically indistinguishable from those of the Kylena Basalt; however, a distinctive porphyritic lava in the Maddina Basalt can be used to identify it in the field. This lava contains clusters of pale-green, euhedral feldspar phenocrysts up to 15 mm long, and is in the upper part of the Maddina Basalt toward the southern end of the Gregory Range Inlier. The original extent of this porphyritic lava is unknown.

The Maddina Basalt is approximately 1 km thick and is made up of about 50 flows distinguished by flow-tops. The penetrative axial-planar cleavage, which is locally conspicuous in the underlying Tumbiana Formation of the Gregory Range Inlier, is rarely detectable in the much more competent Maddina Basalt.

Shallow, northeast-dipping, pale yellow, bedded siltstone, and tuffaceous volcaniclastic siltstone (*AFma*), interlayered with basalt flows, lie 6 km west-northwest of Carawine Rock Hole on the western margin of PEARANA. Previous mapping assigned this unit to the Kuruna Siltstone (Hickman, 1978). The siltstone contains reworked accretionary lapilli and the base of the volcaniclastic siltstone (*AFma*) has been intruded by fine-grained dolerite.

Jeerinah Formation (AFj)

The Jeerinah Formation (*AFj*), previously called the Lewin Shale (Hickman, 1978), is composed predominantly of fine-grained clastic rocks with minor chert and carbonate units. It forms a number of discrete outcrops on PEARANA. In the Gregory Range Inlier, east of the Oakover River, the formation is exposed in three outcrops in the Warri Warri slice (Trendall, 1991). One outcrop lies in a small syncline 1 km southeast of Binbianna Rock Hole, and is bounded to the east by the Baramine Fault. This exposure, previously shown as felsic lava on NULLAGINE (1:250 000) consists of thin-bedded chert and fine-grained clastic rocks. The second outcrop lies in a smaller syncline 10.5 km west-southwest of Mount Gregory (AMG 190885). The third and largest exposure lies in a continuous narrow strip extending from about 11 km south of Woodie Woodie to the northern edge of PEARANA. The formation appears to conformably overlie the uppermost lavas of the Maddina Basalt.

The Jeerinah Formation in this narrow strip is poorly exposed. The white, buff, or pale-purple, thinly bedded shale and siltstone are mostly concealed by a thin pale soil, which forms a distinctive airphoto pattern. A characteristic feature of many outcrops is the presence of scattered chert debris derived from the abundant bands of laminated, pale chert within the epiclastic sedimentary rocks. Dolerite sills are locally present. In the north, an accretionary lapilli tuff is a minor component of the lower part of the formation. No complete section of the formation was found during mapping, but maximum thicknesses are estimated to range from about 200 m in southern PEARANA to about 250 m in the north.

West of the Oakover River, the Jeerinah Formation outcrops almost continuously from 8 km north of Skull Springs (AMG 932890) to 6.5 km southeast of Carawine Rock Hole (AMG 020064). The formation is capped by a ferruginous duricrust (*Czd*), which may represent completely weathered Marra Mamba Iron Formation of the Hamersley Group. A similar horizon patchily overlies the Jeerinah Formation east of Woodie Woodie. The western exposures of the Jeerinah Formation dip regularly to the southeast, and are up to 400 m thick. The formation consists of flaggy, white, buff, or reddish brown silicified shale, and mudstone overlying blue and grey, thin-bedded chert, with interbedded dark-grey dolomite, shale, and greenish tuffaceous sandstone. The base of the Jeerinah Formation (around AMG 005040) 6.5 km northwest of Wannawatha Pool is cut by a porphyritic metadolerite sill (*Ad*).

Hamersley Group

Carawine Dolomite (AHC)

The Carawine Dolomite (Noldart and Wyatt, 1962; Hickman, 1983) is the only unit from the Hamersley Group on PEARANA. Good exposures of Carawine Dolomite lie north of the Upper Carawine Pool, east and west of the Davis–Oakover river junction, around the Tarra Tarra pools on the Oakover River, and northeast of the Radio Hill manganese opencut mine. The Carawine Dolomite and Pinjian Chert Breccia form bold, typically rounded hills with topographic relief up to 150 m. The close association with the Pinjian Chert Breccia (discussed below) indicates that it probably underlies the broad north–south zone now occupied by the Oakover and Davis river valleys. An accurate total thickness is difficult to obtain due to erosion and subsequent infilling by the Pinjian Chert Breccia. However, the maximum thickness of the Carawine Dolomite is known to exceed 500 m, an assumption borne out by recent diamond drilling just south of the Pearana Rock Hole, where a 500 m thick sequence of dolomite was intersected (WAMEX Item 7844; Appendix 1).

Although the contact between the Carawine Dolomite and underlying Jeerinah Formation appears to be conformable (for example, northeast of the Radio Hill manganese opencut mine), the contact relationship described by Williams and Trendall (1998b) and the absence of the Marra Mamba Iron Formation indicate a disconformity, probably a depositional hiatus with erosion (Williams and Trendall, 1998b). The Carawine Dolomite is unconformably overlain by the Pinjian Chert Breccia, and both are unconformably overlain by the Mesoproterozoic Woblegun Formation of the Manganese Subgroup, the Neoproterozoic Waltha Woora Formation, and the Lower Permian Paterson Formation.

The Carawine Dolomite is variegated from grey and brown to dark orange (due to iron and manganese impurities), but is mainly a brown-weathering, grey, recrystallized dolomite containing only minor amounts of shale and blue, nodular chert intercalations. The dolomite averages around 20% MgO, and is commonly low in silica (Jahn and Simonson, 1995). The Carawine Dolomite is notable for the wide range of sedimentary structures indicative of dominantly shallow-water deposition. These include wave ripples, oncolitic flat-pebble conglomerate, oolites, reverse-graded pisolites, stromatolites, oncolites, dololaminites, and evaporitic crystal pseudomorphs after aragonite, gypsum, and halite (Simonson et al., 1993b; Simonson and Jarvis, 1993). There are small columnar and laterally linked hemispheroid stromatolites and uncommon oncolites 4 km northwest of Woodie Woodie, 2 km north-northeast and 7 km north-northwest of the Radio Hill opencut mine, 2 km north-northeast of Wannawatha Pool, and at several localities north of the Upper Carawine Pool.

The Carawine Dolomite and Pinjian Chert Breccia host a number of manganese deposits in the Woodie Woodie and Skull Springs areas. The distribution seems to indicate that the deposits are most numerous in the basal unit of the dolomite. This is borne out by analysis of dolomite from the deep diamond drill-hole at Pearana Rock Hole, where manganese concentration progressively increases downward over 500 m from 0.5 to 1% (WAMEX Item No. 7844, Appendix 1).

Recent detailed sedimentological studies support the hypothesis that the Carawine Dolomite is mainly a shallow-water, platformal deposit, although there is some evidence for localized deposition in deeper water at the base (Simonson et al., 1993b; Simonson and Jarvis, 1993; Jahn and Simonson, 1995). The problematic relationship between the Carawine Dolomite and the Wittenoom Formation (revised name, Simonson et al., 1993a) of the Hamersley Basin (deposited in deeper water) to the southwest has been discussed by Williams and Trendall (1998b).

Jahn and Simonson (1995) recently obtained a Pb–Pb isochron age of 2541 ± 32 Ma from Carawine Dolomite samples collected from PEARANA and BRAESIDE (Table 1). This is believed to be the minimum age for the dolomite, and may represent the time of regional diagenesis. It confirms a late Archaean age for the Carawine Dolomite.

Archaean–Proterozoic rocks

Sedimentary rocks

Pinjian Chert Breccia (ᴘcb)

The Pinjian Chert Breccia is extensively exposed in the Oakover and Davis river valleys (west and central PEARANA). The unit forms high rounded hills, exemplified by Mount Traine. There are similar rounded hills in the Skull Springs area, and around the Tarra Tarra pools and Pearana Rock Hole in central-southern PEARANA.

The breccia, which is locally crudely bedded, consists of randomly mixed angular fragments of chert and banded chert set in a siliceous matrix. In some places the breccia is enriched in iron- and manganese-oxides. The eclectic origin of the chert breccia is discussed in detail by Williams and Trendall (1998b)

The Pinjian Chert Breccia has a highly irregular, unconformable contact with the underlying Carawine Dolomite. This contact surface is interpreted as a palaeokarst topography (Hickman, 1978; Williams, 1989), with many palaeokarst features (such as fissures, caves, and dolines) in the Carawine Dolomite preserved by infill of the Pinjian Chert Breccia. A secondary karst topography, probably initiated in the early Cainozoic, and continuing up to the present time, has developed by dissolving many of the Carawine Dolomite remnants within or beneath the Pinjian Chert Breccia surface. This weathering event included deep chemical weathering with redistribution of manganese- and iron-oxides (see **Cainozoic rocks**), and produced a number of collapsed dolines now partly filled with soil and sand. Such dolines are at Mount Traine and in clusters about 7 km north of Pearana Rock Hole and 5 km north of Lower Tarra Tarra Pool. Small bedding-plane and joint-controlled caves are located in the cliffs around the Upper Carawine Pool.

The Pinjian Chert Breccia is unconformably overlain by the Mesoproterozoic Woblegun Formation, the Neoproterozoic Waltha Woora Formation, and the Lower Permian Paterson Formation.

Mafic and ultramafic rocks (*Adm, Aut, Ad, ᴘd*)

Several ages of mafic and ultramafic rocks are present in the Pilbara Craton on PEARANA. The oldest mafic rocks (*Adm*), restricted to the Gregory Granitic Complex, are found as rafts, xenoliths, and fragmented dykes. These metamorphic rocks range from granoblastic and decussate-textured amphibolite and garnet amphibolite to recrystallized metagabbro and metadolerite bodies with amphibolite rims. The metagabbro and metadolerite form large fragmented dyke-like bodies. The largest body of these mafic rocks *(Adm),* which intrudes the fine-grained microporphyritic granitoid rock (*ARp*) on the eastern side of the Gregory Granitic Complex, stretches from 2 km north of the Nifty copper-mine road to about 3 km north of Fletchers Find — a distance of over 30 km. Thin, north-northwesterly trending amphibolite and metadolerite dykes (*Adm*) have penetrated the metamorphosed syenogranite (*ARm*) west and northwest of Fletchers Find. These rocks have a polymetamorphic history — low-grade amphibolite facies partly retrogressed to greenschist facies — similar to the host granitoids.

Several small rafts of chlorite–tremolite–talc (–serpentine) schist and zoisite–talc–chlorite hornfels (*Aut*) are present in the microporphyritic rocks (*ARp*) 2 km south of the Nifty road on the eastern side of the Gregory Granitic Complex.

Sills of low-grade metadolerite (*Ad*) intrude the Warri Warri Member 14 km southeast of Woodie Woodie and 8 km north-northwest of Lookout Rocks, and the Jeerinah Formation 18 km south of Woodie Woodie. A plagioclase-phyric metadolerite sill intrudes the contact between the Maddina Basalt and Jeerinah Formation 18 km northwest of Wannawatha Pool. This sill is similar to one in the Jeerinah Formation on BRAESIDE.

Northerly trending dolerite dykes (*ᴘd*) intrude the Carawine Dolomite 7 km north of the Radio Hill Manganese Mine and 5 to 6 km north-northwest of Upper Carawine Pool.

Quartz veins (*q*, *qh*, *qm*, *go*)

Large, commonly massive or faintly banded crypto-crystalline, white quartz veins (*q*) occupy many of the major fault zones that intersect the Gregory Granitic Complex and Fortescue Group. Quartz breccia, commonly annealed with late silica, indicates repetitive movement along many of the faults. The fault zones may contain single, multiple parallel, or discontinuous, en echelon quartz veins. The Gregory Granitic Complex also contains quartz-filled tension gashes.

Weak base-metal mineralization has been recorded in quartz veins in the Gregory Granitic Complex (copper) and in tuffaceous sedimentary rocks (*AFhwt*) of the Warri Warri Member of the Hardey Formation (lead; see **Economic geology**). Unusual iron-rich quartz–hematite (martite) veins (*qh*) trend about 340° across the Gregory Granitic Complex from the Fletchers Find area to about 6 km east-southeast of Mount Gregory. These veins are described in detail in **Economic geology**.

The southern half of the Gregory Granitic Complex contains a number of quartz mylonite zones (*qm*), which range from less than a metre thick to prominent steep-sided ridges over 200 m thick. These zones consist of compact, chert-like rock, sometimes banded, and veined with late quartz. The margins grade into strongly deformed granitoid and gneissic host rocks. A prominent quartz mylonite zone (postulated to be a ductile fault zone) marks the contact between the metamorphosed medium- to coarse-grained syenogranite (*ARm*) and metamorphosed, fine-grained to microporphyritic granitoid rock (*ARd*) east of Fletchers Find.

Rubbly, gossanous quartz-veins (*go*), now limonite–goethite veined- and stained-quartz, lie amongst ironstone pebbles adjacent to the Nifty copper mine road 2.8 km west of the eastern boundary of PEARANA. This outcrop probably corresponds to the Vines Fault.

Structure

The structural geology of the Archaean rocks in PEARANA was only briefly described in earlier publications (Hickman 1978, 1983). Diverse structures and fabrics, including folds (e.g. the large Oakover Syncline), faults, the tectonic foliation in the Gregory Granitic Complex, and cleavage in the overlying Fortescue Group were all allocated to 'D_5' — a Proterozoic deformation episode in the Pilbara Craton — by Hickman (1983). Isotopic data at that time indicated that tectonism took place between 2200 and 1200 Ma. The present study, supported by recent U–Pb SHRIMP studies of zircons and combined with a recent reappraisal of the adjoining Paterson Orogen, has revealed a more complicated structural history (Arndt et al., 1991; Hickman et al., 1994; Bagas et al., 1995). Trendall (1991) showed that the Fortescue Group of the Gregory Range Inlier and the Gregory Granitic Complex are intersected by numerous north to north-northwesterly trending, subparallel, and in some cases, anastomosing, steep, easterly dipping faults (Fig. 5). Although the early investigations recognized these faults as steep reverse faults with older rocks east of the fault (Hickman, 1983; Trendall, 1991), new data from the present study indicate a more complicated movement history. These new data also indicate a previously unrecognized, irregular strike-slip component and reactivation of fault zones during the Proterozoic. This strike-slip component is only evident when displacement along the fault zones is viewed on a regional scale. Strike-slip displacement of faults in the Pilbara Craton on PEARANA is consistently sinistral. This displacement can be seen along the Antiform Fault (Fig. 4), where movement of the Tumbiana Formation indicates a sinistral displacement of 38 km. The Southwest Fault, which intersects the large Oakover Syncline, is also interpreted as a sinistral transpressional fault, with an apparent displacement of 20 km. These large displacements cannot be entirely explained by simple reverse faulting (i.e. east block up), since there is, in most cases, little obvious change in metamorphic grade across the fault zone. These apparent displacements are maximum values. Further examples are described in the BRAESIDE (Williams and Trendall, 1998b) and ISABELLA (Williams and Trendall, 1998a) Explanatory Notes. In contrast, the northerly trending Baramine Fault, west of Lookout Rocks, has a large vertical component. This fault separates granite gneiss and gneissic syenogranite (*ARm*) of the Gregory Granitic Complex from the Jeerinah Formation which lies at the top of the 6.5 km-thick Fortescue Group.

The fault zones are typically filled by quartz that forms discontinuous ridges or multiple quartz veins separated by sheared bedrock. These are particularly well developed along faults separating the Gregory Granitic Complex from the Fortescue Group. Although copper mineralization has been recorded in quartz-filled shear zones, 15 km southeast of Woodie Woodie (AMG 308004), lead and zinc mineralization — abundant in similar fault zones on BRAESIDE — is rarely present in fault zones on PEARANA. Prominent quartz mylonite zones, indicative of ductile faults in lower crustal levels, are abundant in the southern half of the Gregory Granitic Complex on PEARANA where the metamorphic grade reaches upper-amphibolite facies.

Faults are generally oblique or subparallel to the weak axial-planar cleavage in the Fortescue Group and to the prominent metamorphic foliation of the Gregory Granitic Complex. The cleavage is best developed in the lower units of the Fortescue Group, particularly the Koongaling Volcanic and Warri Warri Members of the Hardey Formation and, to a lesser extent, in the Tumbiana Formation. Most units of the Warri Warri Member have a steeply dipping penetrative cleavage parallel to the axial surface of the anticline that is jointly defined by the Warri Warri and Newdegate slices. The cleavage intensity is variable, and appears to depend both on the rock's competency and its proximity to either the crest of the anticline or one of the major faults bounding the slices. Thus, the oligomictic conglomerate (*AFhwo*) of the Newdegate slice locally shows extreme flattening of the boulders where it abuts the eastern side of the Antiform Fault 1.5 km west of Mount Gregory (AMG 274924). However, in exposures in the hills 2 km east-southeast of this point the cleavage is barely detectable. In other units the cleavage is axial planar to northwesterly and north-northwesterly plunging folds that tend to die out upwards in the Fortescue Group succession as the fold profiles become more open. This fold orientation predates the sinistral transpressional component of the larger faults. The Antiform Fault has sheared out a large north-northwesterly plunging anticline in the northern half of PEARANA. Cleavage appears to be absent from the Fortescue and Hamersley Group rocks in the western half of PEARANA.

The metamorphic foliation in the Gregory Granitic Complex has a more northerly strike than the cleavage in the Fortescue Group, and has been refolded about northerly plunging folds 8 km north-northeast of Lookout Rocks. Although the relationship between the cleavage in the Fortescue Group rocks and the metamorphic foliation in the Gregory Granitic Complex is not entirely clear, they probably represent the coeval expression of the regional deformation at different crustal levels juxtaposed by later faulting (Hickman 1983).

Although movement along the major faults post-dates the main folding event, the overall movement sense and asymmetry of the folds indicates a common stress field. Further discussion on the origin of the large faults can be found in Williams and Trendall (1998b).

Proterozoic rocks

A succession of faulted and folded sedimentary rocks, sandwiched between the Neoproterozoic Tarcunyah Group and Archaean Carawine Dolomite (and associated Pinjian Chert Breccia) around Brownrigg Hill, is correlated with units of the Mesoproterozoic Manganese Subgroup (c. 1300 Ma) of the Bangemall Basin.

Proterozoic sedimentary and metasedimentary rocks also unconformably overlie the Gregory Granitic Complex along the eastern and southern margins of PEARANA, and the Hamersley Basin succession in the central-north area, west and northwest of Woodie Woodie, and in small, scattered outliers in the north-western and central-southern parts of the sheet. Most of these rocks belong to the younger Tarcunyah Group. The older Throssell Group, a component of the Yeneena Supergroup (Bagas et al., 1995; Williams and Bagas, in prep.), is confined to the northeastern corner of BRAESIDE. The Tarcunyah Group has been assigned to the Officer Basin (Perincek, 1996) and the Throssell Group to the Yeneena Basin (Williams and Bagas, in prep.). Both groups are deformed and lie within the Paterson Orogen (Williams and Myers, 1990), which lies to the east of the Pilbara Craton. An overview of the Paterson Orogen is presented by Williams and Trendall (1998a). Although recent work supports a Neoproterozoic age for the Tarcunyah Group (c. 800 Ma), the precise age of the older Throssell Group is enigmatic, but there is evidence it straddles the boundary between the Mesoproterozoic and Neoproterozoic erathems (c. 1000 Ma; Bagas et al., 1995). The Neoproterozoic Waltha Woora Formation, a correlate of lower units in the Tarcunyah Group, occupies a faulted basin in the central-northern part of PEARANA.

Bangemall Basin

Manganese Subgroup

Sedimentary rocks belonging to the Manganese Subgroup of the Bangemall Basin (Muhling and Brakel, 1985; Williams, 1989) extend into the south-central parts of PEARANA. These exposures, identified as Woblegun Formation, represent the northeasternmost extent of the Manganese Subgroup (a correlate of the Collier Subgroup), the younger siliciclastic succession of the Bangemall Group (Williams, 1990a).

Woblegun Formation (ⱣMw, ⱣMwd, ⱣMwa)

The Woblegun Formation is a mixture of patchily exposed black, red, cream, and white shale, mudstone, and chert, interbedded locally with grey to red-brown, fine- to coarse-grained sandstone and less common conglomerate. Cream to grey chert beds, 8.5 km east-northeast of Brownrigg Hill, contain voids whose shape indicates they may be after gypsum. A stratiform, sedimentary-hosted barite unit, 7.5 km east of Brownrigg Hill and 20 m beneath the Tarcunyah Group unconformity, consists of well-crystallized, tabular or prismatic barite crystals oriented at about right-angles to the bedding. Faint colour bands can be traced across the crystals suggesting primary growth precipitation. The barite is interbedded with thin beds of silicified brown and purple dolomite, shale, and mudstone. Thick lenses of purple to brown, fine-grained dolomite and oolitic dolomite lie northwest of this locality.

A thick unit of dark-purple to grey stromatolitic dolomite (*ⱣMwd*), 3 km north of Brownrigg Hill, unconformably overlies, and is faulted against, the Pinjian Chert Breccia. The dolomite is characterized by large, parallel, columnar stromatolites up to 2 m high, and domical stromatolites passing upwards to numerous small columns (2–3 cm diameter) of silicified stromatolites. Although this unit is included in the Woblegun Formation on PEARANA, it may correlate to the overlying Stag Arrow Formation, which contains similar large columnar stromatolites in dolomite, near Enacheddong Water Hole on BALFOUR DOWNS (1:250 000).

Brown-red to grey, fine- to coarse-grained sandstone, pebbly sandstone, and pebble conglomerate (*ⱣMwa*) fills depressions in the Pinjian Chert Breccia 7.5 km north of Carawine Rock Hole, 5.5 and 6.5 km north of Pearana Rock Hole, and 5 km northwest of Brownrigg Hill. These units have been included in the Woblegun Formation. However, they also resemble parts of the basal Coondoon Formation in the Davis River, Ant Hill, and Sunday Hills regions of BALFOUR DOWNS (1:250 000), hence this correlation is tentative. The Woblegun Formation was deposited under placid, shallow, near-shore marine or lagoonal conditions, which were periodically interrupted by influxes of coarse, clastic material.

Davis Dolerite (Ᵽdd)

A sill less than 30 m thick of Davis Dolerite (*Ᵽdd*) (Williams, 1989) has intruded the blue-black shales of the Woblegun Formation at Brownrigg Hill. This fine-grained dolerite has a high titano-magnetite content, which gives it a distinctive black-speckled weathered surface, and a strong magnetic signature.

Structure

The Woblegun Formation is openly folded with moderate dips on PEARANA. The formation lacks the penetrative cleavage found in similar rocks further south along Gregory Creek on BALFOUR DOWNS (1:250 000). Here, the Woblegun Formation is isoclinally folded with moderately plunging northerly trending axes. The formation is intersected by north-northwesterly trending transpressional faults. The folding and fault activity may be related to the Miles (D_4) and Paterson (D_6) orogenies of the Paterson Orogen (Bagas et al., 1995).

Yeneena Supergroup

The Throssel Group is the only unit of the Yeneena Supergroup of the Yeneena Basin (Williams and Trendall, 1998a,b; Williams and Bagas, in prep.) on PEARANA. It is restricted to the northeastern corner and field data show that it is separated from the younger Tarcunyah Group to the west by the north-northwesterly trending Vines Fault.

Throssell Group (ⱣT)

Units of the Throssell Group are largely sand covered, and most data have been obtained from shallow exploration drillholes. These show that only the Broadhurst Formation (Williams et al., 1976) is present beneath the sand cover on PEARANA. The lower Coolbro Sandstone, widespread in the Throssell Ranges to the south-southeast, is not exposed on PEARANA.

Broadhurst Formation (ⱣTb, ⱣTbs, ⱣTbf)

The Broadhurst Formation (Williams et al., 1976) is very poorly exposed and is restricted to a few scattered, low rises between sand dunes. The most widespread unit, intersected in drillholes, is white weathering, black to grey carbonaceous shale and siltstone (*ⱣTbs*). Some of this shale and siltstone contains fine-scale banding and graded bedding indicative of deposition from turbidity currents. Both cubic pyrite and fine-grained disseminated pyrite are present in the black shale. Red-brown feldspathic sandstone and wacke (*ⱣTbf*) lie in low rubbly outcrops. These units are interbedded with red-brown micaceous and calcareous siltstone, and resemble a succession located further north near the Rainbow Prospect on BRAESIDE. All rocks in the Broadhurst Formation exhibit a strong penetrative foliation.

The Broadhurst Formation is a shallow-marine deposit probably formed under euxinic conditions (Williams and Bagas, in prep.).

Other sedimentary rocks

Tarcunyah Group (ⱣU)

The Tarcunyah Group rests unconformably on the Pilbara Craton and Bangemall Basin in the west, and is bounded to the east by the north-northwesterly trending Vines Fault. The dextral transpressional Vines Fault juxtaposes the older Throssell Group against the Tarcunyah Group. The basal Googhenama Formation of theTarcunyah Group is well exposed throughout PEARANA. In contrast, the conformably overlying Waroongunyah Formation, Brownrigg Sandstone, and Yandanunyah Formation are poorly exposed in the eastern zone, although the Waroongunyah Formation and Brownrigg Sandstone are reasonably exposed in low hills along the southern margin of PEARANA east of Brownrigg Hill.

The Tarcunyah Group has recently been included in the Officer Basin (Perincek, 1996).

Googhenama Formation (ⱣUg)

The Googhenama Formation (Williams, 1990b), previously mapped as Bocrabee Sandstone (Hickman, 1978), is a mixed sandstone and conglomerate succession up to 500 m thick. The formation unconformably overlies the northerly trending Gregory Granitic Complex along its eastern margin, and the Woblegun Formation around Brownrigg Hill on the southern margin of PEARANA.

The Googhenama Formation forms an abrupt, almost continuous, north-northwesterly trending, 50 km-long strike ridge close to the eastern margin of PEARANA. The formation was deposited on a mature, undulating surface of weathered granitoid rocks, and basal conglomerates contain locally derived granitic or gneissic clasts. These clasts are absent from conglomerates higher in the succession. The number of conglomerate beds in the formation and the size of clasts increase southward across PEARANA. The conglomerates tend to be polymictic and poorly sorted low in the formation, and oligomictic (quartz pebble) and well sorted higher in the formation. Northern (pebble and cobble) conglomerates are mostly matrix supported, whereas southern (large-cobble to boulder) conglomerates are typically clast supported. Nine kilometres northeast of Lookout Rocks, boulder- and cobble-conglomerate beds, up to 30 m thick, extend for several kilometres. Clasts, up to 50 cm across, are mature and comprise coloured and banded chert, quartzite, sandstone, white vein quartz, red jasper, and rare quartz-pebble conglomerate. Some conglomerate beds fine upward to coarse-grained sandstone and pebbly sandstone, and are commonly planar or trough cross-bedded. Palaeocurrent data, derived from cross-beds, indicate flow southeastward and northeastward away from the Pilbara Craton. Rocks of the Pilbara Craton and Bangemall Basin appear to have been a provenance for the Tarcunyah Group in this region.

The conglomerate beds occupy channels, incised either within the granitoid basement rocks or pene-contemporaneously within the formation. Single-pebble horizons, current striations, and abundant cross-bedding indicate a fluvial environment, and may imply deposition in a braided stream.

Iron-rich, deep-purple to very dark red, fine- to coarse-grained sandstone, and hematitic siltstone beds are distributed throughout the formation. These are consistently overlain in the higher parts of the formation by cream to white, fine- to medium-grained sandstone, and orthoquartzite. Minor quartz-pebble conglomerate beds lie in the upper part of the formation.

In earlier mapping, Hickman (1978) assigned all the scattered shale, siltstone, and sandstone outcrops overlying the Googhenama Formation to the now superseded Wandy Wandy Shale. Recent mapping, however, has found that the succession defined on BALFOUR DOWNS (1:250 000) can be followed northward onto PEARANA. These units have now been formally reassigned to the units described in Figure 6.

Waroongunyah Formation (ĿUw)

The Waroongunyah Formation (Williams, 1989), conformably overlying the Googhenama Formation, is best exposed 8.5 km east of Brownrigg Hill where it is at least 300 m thick. Here, red-brown, brown, and yellow calcareous siltstone, and fine- to medium-grained sandstone are interbedded and overlain by pink and brown fine-grained dolomite. A few halite casts, up to 4 mm in size, have been found in red, thin-bedded, fine-grained sandstone. Some thin-bedded sandstones also show graded bedding.

A poorly exposed, red-brown micaceous siltstone and fine-grained sandstone lying beneath the Brownrigg Sandstone along the eastern margin of PEARANA have been assigned to the Waroongunyah Formation.

Brownrigg Sandstone (ĿUr)

Flaggy to thick-bedded, fine- to coarse-grained, grey, cream, brown, and reddish sandstone, and cream to white orthoquartzite that form a discontinuous low ridge about 2 km east of and parallel to the Googhenama Formation (eastern margin of PEARANA) have been assigned to the Brownrigg Sandstone (*ĿUr*). Further outcrops of pale-brown, medium-grained sandstone overlie the Waroongunyah Formation 9 km east of Brownrigg Hill. The formation is estimated to be at least 400 m thick. Thin beds of quartz-pebble conglomerate, granule sandstone, and intraclastic sandstone reflect higher energy conditions, whereas quiet, shallow-water conditions are indicated by small-scale symmetrical ripple marks. Cross-beds are small and uncommon. Hence, the Brownrigg Sandstone was probably deposited in a shallow-water marine shelf environment. Brown spotting on weathered surfaces of some sandstones may be after pyrite.

Yandanunyah Formation (ĿUy)

Some poorly exposed, silicified, grey and brown, interbedded shale, siltstone, and fine-grained sandstone immediately west of the Vines Fault, and north of the Nifty copper-mine road, are assigned to the Yandanunyah Formation of Williams (1989). The formation is estimated to be at least 450 m thick and shows increasing evidence of shearing with decreasing distance from the Vines Fault.

Waltha Woora Formation (ĿUa, ĿUas)

The Waltha Woora Formation (Hickman, 1978) occupies a faulted and partly fault-controlled basin west of the Gregory Range, in the central-northern part of PEARANA. The exposures lie along the eastern side of the Oakover River valley, with one small outlier 10 km west of the Woodie Woodie mining centre on the western side of the Oakover River. The formation unconformably overlies the Maddina Basalt, Jeerinah Formation, Carawine Dolomite, and the Pinjian Chert Breccia and, in turn, is unconformably overlain by the Lower Permian Paterson Formation.

The previous correlation of the Waltha Woora Formation with the Bangemall Group (Hickman, 1978) is now known to be incorrect (Williams and Trendall, 1998b). Recent studies of stromatolite taxa indicate it can be correlated with the nearby Waroongunyah Formation (Grey, 1978, 1984) on BALFOUR DOWNS (1:250 000), which is now part of the Tarcunyah Group.

The Waltha Woora Formation consists of a basal, irregularly developed clastic succession (*ĿUas*) overlapped by a mixed carbonate-clastic succession (*ĿUa*). The formation is estimated at 250–300 m thick; however, this is considered a minimum thickness as the formation is eroded.

In some areas the basal clastic succession occupies well-defined channels eroded into the underlying Carawine Dolomite, Pinjian Chert Breccia, and Fortescue Group rocks. One such sinuous channel can be traced for over 8 km, from 3 km west of Woodie Woodie to north of Muddauthera Creek where it is overlain by the carbonate-clastic succession. This channel, incised in Carawine Dolomite and Pinjian Chert Breccia, contains pebbly, coarse-grained sandstone at the base, overlain by cream, brown, purplish brown to red-brown, medium- to coarse-grained sandstone. Chert clasts in this basal sandstone are eroded from the adjacent Pinjian Chert Breccia. Trough cross-beds indicate a northward-directed palaeocurrent. A second channel, 2 km east of the abandoned Radio Hill manganese opencut mine, trends northwestward from the Maddina Basalt, across the Jeerinah Formation, onto the Carawine Dolomite and Pinjian Chert Breccia, where it again passes beneath the overlying carbonate-clastic succession (*ĿUa*). The basal sandstone in this channel contains scattered pebbles and cobbles of Maddina Basalt. Overlying medium- to coarse-grained, purplish brown sandstone contains feldspar, zircon, and tourmaline grains, indicating granitoid provenance. The source lay to the southeast, as cross-beds indicate a northwesterly palaeocurrent.

Where the carbonate-clastic succession overlaps the basal channel sandstones, locally derived clasts of Carawine Dolomite and Pinjian Chert Breccia are contained within the fine-grained carbonate-rich basal units. In some areas these basal units are manganiferous. The carbonate-clastic succession is a rapid alternation of pink, maroon, red, violet, buff, cream, and grey dolomite, doloarenite, shale, siltstone, and fine- to medium-grained sandstone. Sandstones have variable carbonate content. Stromatolite bioherms are located about 15 m above the base of the succession, ranging from small hemispherical bodies to large bioherms up to 10 m thick. Several horizons of stromatolites are exposed along Muddauthera Creek. Cauliflower chert, a siliceous replacement of anhydrite, and scattered halite casts have also been recorded in this succession.

The Waltha Woora Formation is characterized by a prevailing pink to maroon-red colour similar to that of redbeds. This, coupled with evaporites, points to arid conditions during deposition, similar to that expressed by the Googhenama and Waroongunyah Formations of the Tarcunyah Group.

Mafic intrusive rocks (*Ed*)

Although mafic intrusions are abundant in the Paterson Orogen (Hickman and Clarke, 1994), the only mafic intrusive rock in the orogen on PEARANA is a thin, undeformed, northerly trending dolerite dyke (*Ed*) in the Googhenama Formation, 1.5 km south of the Nifty copper-mine road.

Structure

The Paterson Orogen is a northwesterly trending belt of Palaeoproterozoic to Neoproterozoic sedimentary, metamorphic, and igneous rocks that show a variety of deformation and metamorphic episodes indicative of a complex tectonic history (Williams and Myers, 1990). At least six deformation episodes have been recognized within the Paterson Orogen (Hickman and Clarke, 1994; Hickman et al., 1994; Bagas et al., 1995; Bagas and Smithies, in prep.). The relationship of these events to the eastern margin of the Pilbara Craton has been discussed in some detail by Williams and Trendall (1998b).

Structural data are very limited on PEARANA. The Broadhurst Formation of the Throssell Group is cut by a northeasterly dipping penetrative cleavage (S_4, Miles Orogeny, Bagas et al., 1995) in the northeastern corner of PEARANA. There is also evidence of moderate to tight southeast-plunging folds (F_4) in this area. The northwest trending axes of these folds are truncated by the north-northwest trending Vines Fault (D_6, Paterson Orogeny, Bagas et al., 1995).

The Tarcunyah Group is separated from the Throssell Group by the dextral transpressional Vines Fault. The Tarcunyah Group is largely a planar, moderately easterly dipping succession although some open north-northwesterly trending folds are evident in the upper part of the succession and are assigned to the D_6 event (Paterson Orogeny). These are approximately parallel to the trend of the Vines Fault. There is no sign of tectonic activation of the moderately easterly dipping unconformable contact with the underlying Gregory Granitic Complex. Northeast, east, and southeast trending vertical faults intersect the unconformity. The unconformity with the underlying pre-folded Woblegun Formation around Brownrigg Hill is flat lying, and only large open folds are evident in the overlying Tarcunyah Group.

The Waltha Woora Formation, which lies to the west of the Gregory Ranges, is interpreted to have been deposited in a partly fault-controlled basin. The basin probably developed in the closing stages of the Miles Orogeny (D_4). Faulting was reactivated during the later Paterson Orogeny (D_6).

Palaeozoic rocks

Canning Basin

Lower Permian sedimentary rocks occupy narrow palaeoglacial valleys transecting PEARANA from north to south. The valleys are nearly parallel to and a little east of the present-day Oakover River. The valleys are connected to the Wallal Embayment of the Canning Basin (Hocking et al., 1994; Fig. 3) to the north. The Permian succession belongs to the fluvioglacial Paterson Formation.

Paterson Formation (Pa)

The Paterson Formation (*Pa*) is the sole Permian stratigraphic unit on PEARANA. It is at least 140 m thick near Twin Peaks north of the PEARANA boundary (Williams and Trendall, 1998b), but is probably less than 30 m thick east of Brownrigg Hill (southern boundary of the sheet area).

Northwest of Woodie Woodie the palaeoglacial valley, which contains the Paterson Formation, is about 11 km wide, and bifurcates due west of Woodie Woodie into narrow (1–1.5 km wide) U-shaped valleys. The eastern branch peters out about 11 km south of the Mike mine, whereas the western branch extends 42 km across PEARANA to a point 2 km east of Brownrigg Hill. From here it can be traced a further 30 km south-southeast across BALFOUR DOWNS (1:250 000).

The Paterson Formation is not well exposed and is normally covered by eluvial boulder beds in a silty clay (*Qt*). The basal unit is a diamictite carrying scattered pebbles and boulders up to 1 m in diameter. The weathered diamictite is exposed in several recently worked manganese opencuts at Cracker, Lox, and Bell. It unconformably overlies the Pinjian Chert Breccia and Carawine Dolomite. Shallow-dipping (2–3°) sandstone, siltstone, and thin conglomerate lenses are exposed along Brumby Creek.

Glaciated pavements and roche moutonnées are well developed in the palaeoglacial valley, west and northwest of Pearana Rock Hole. Highly polished surfaces on the Pinjian Chert Breccia exhibit chatter marks and glacial grooves indicating northward ice movement.

In the northern half of PEARANA the Paterson Formation varies from a tillite at the base of the formation to fluvioglacial outwash deposits derived from a southward retreating glacier.

The Paterson Formation is part of the Palaeozoic depositional Sequence Pz5 (Middleton, 1990), and was emplaced during the Artinskian Stage of the Lower Permian (Towner and Gibson, 1983).

Cainozoic rocks

Superficial Cainozoic deposits cover 51% of PEARANA. They range from older, consolidated, lacustrine–fluvial deposits and lateritic residual deposits, to recent unconsolidated alluvial, colluvial, eluvial, eolian, and lacustrine deposits.

A distinctive ferruginous duricrust (*Czd*) caps the Jeerinah Formation west of the Davis River, and in several small areas east and south of Woodie Woodie. This unit is part of the 'Hamersley Surface' (Campana et al., 1964), and on BALFOUR DOWNS (1:250 000) it overlies the Marra Mamba Iron Formation. Although the Marra Mamba Iron Formation is not preserved on PEARANA, the distribution of the duricrust (*Czd*), the product of its extreme weathering, suggests that the formation may have extended as far north as latitude 21°37'S.

Laterite (*Czl*) has formed in the headwaters of the Wootha Wootha and Pearana creeks adjacent to exposures of the Maddina Basalt. The widespread ironstone pebble lag deposits (*Qp*) in the eastern half of PEARANA are indicators of laterite or ferruginous duricrust surfaces at shallow depth (Williams and Trendall, 1998b). The laterite consists of nodular, pisolitic, and massive varieties.

In the Oakover River valley the laterite is overlain by consolidated colluvium (*Czc*) and by the lower unit of the Oakover Formation (*Czoc*).

Siliceous duricrust, including silcrete and secondary chert breccia (*Czz*), in the southwestern part of PEARANA overlies the Pinjian Chert Breccia (*Ꝑcb*). The duricrust is locally derived from the breccia by deep weathering and secondary silicification. This dominantly chemical weathering process also produced the supergene manganese oxide deposits in the Woodie Woodie region. Such supergene deposits have overprinted primary Proterozoic manganese deposits.

Recently, these supergene K-bearing manganese oxides (mainly cryptomelane–hollandite) at Woodie Woodie have been dated using K–Ar and ^{40}Ar–^{39}Ar techniques. Initial results show that corrected K–Ar dates cover a range of ages from the Middle to Late Miocene (Dammer et al., 1993). Dating (using ^{40}Ar–^{39}Ar techniques) of cryptomelane–hollandite from Woodie Woodie indicates a late Oligocene age (Dammer et al., 1994).

Consolidated colluvium (*Czc*) outcrops are restricted to the Oakover River valley. These deposits consist of consolidated and cemented silt and sand through to coarse riverine gravels. The deposits are best exposed along the banks of the Oakover River and major tributaries. Although the unit appears to post-date the laterite surface (Williams and Trendall, 1998b), it seems to intertongue both the lower unit of the Oakover Formation (*Czoc*) and the secondary chert breccia (*Czz*) adjacent to Pinjan Chert Breccia exposures. The colluvium (*Czc*) unit probably formed during periods of active erosion between periods of quiescence and deep weathering, represented by the lower unit of the Oakover Formation (*Czoc*) and the siliceous duricrust (*Czz*).

The Oakover Formation (*Czoc* and *Czos*), first defined by Noldart and Wyatt (1962), is confined to the Oakover River valley, but the formation's distribution is not completely coincident with the course of the present Oakover River. Rather, the formation occupies an older palaeovalley of the Oakover River, which interweaves with the present course of the river.

The Oakover Formation has been divided into two units: a cliff-forming, grey-white to bluish white, translucent, vuggy, opaline, and chalcedonic silica with lesser amounts of calcareous sandstone (*Czos*); and a lower, more widespread, unit containing blue, grey, and fawn limestone beds and calcareous sandstone (*Czoc*). Both units can be traced across PEARANA. The siliceous (*Czos*) unit varies between 3 and 10 m thick, whereas the lower carbonate unit (*Czoc*) is at least 30 m thick. A brief historical review of the Oakover Formation is given in Williams and Trendall (1998b).

The Oakover Formation is considered to be a lacustrine deposit (Towner and Gibson, 1983), and represents a stable-environment stillstand with little or no concurrent erosion sometime during the Miocene–Holocene period (Cockbain, 1978).

Calcrete (*Czk*) on PEARANA is restricted to palaeodrainage lines in the Great Sandy Desert region east of the Gregory Range. The calcrete, originally precipitated in the valley alluvium, now forms low mounds, rises, and hummocky surfaces in interdunal areas. These linear deposits reveal a north-northeasterly trending palaeodrainage system that flowed towards the Percival Palaeoriver (Williams and Trendall, 1998b). The time relationship between the Oakover Formation and 'valley calcrete' (Butt et al., 1977) or 'groundwater calcrete' (Mann and Horwitz, 1979) is unclear.

The calcrete consists of pisolitic, nodular, and laminar carbonate containing scattered bedrock fragments. Incipient surface silicification is locally present. The calcrete formed during arid regimes periodically between the Pliocene and Pleistocene (Hocking and Cockbain, 1990). Consequently, the formation of the calcrete may have overlapped, in time, deposition of the upper part of the Oakover Formation.

Unconsolidated clay, silt, sand, and gravel (*Qa*) are present in the well-defined drainage systems in the western two-thirds of PEARANA. The Oakover and Davis rivers contain sand, silt, and gravel in banks and pointbars up to 4 m high in the main channels, and deposits of clay and silt on the adjacent floodplains. East of the Gregory Range the short, easterly flowing streams contain mainly silt and sand.

Lacustrine silt and clay deposits (*Ql*), and mixed claypan and dune deposits (*Qd*), are sparsely scattered along the broad calcrete palaeodrainages of the Great Sandy Desert area. The claypan and dune deposits (*Qd*) consist of numerous small pans separated by low (commonly less than 2 m) sand and silt barriers. An example lies east of Tooncoonoragee Pool on the floodplain adjacent to the Oakover River.

The eastern third of PEARANA is covered by red eolian sand in dunes (*Qs*), and interdunal and lag-pebble sandplain (*Qp*). The longitudinal (seif) dunes and net dunes are concentrated east of the strike ridge, which marks the unconformity between the Tarcunyah Group and the Gregory Granitic Complex. West of this ridge the red eolian sand (*Qs*) is restricted to widely spaced longitudinal dunes separated by wide corridors of red sand carrying a veneer of scattered pebbles of ironstone and quartz, and fragments of weathered rock. This eolian lag deposit commonly indicates shallow bedrock.

Scree and mixed colluvial deposits (*Qc*) lie along the eastern and western margins of the Gregory Range adjacent to fresh bedrock. Partly ferruginized silt, sand, and gravel with a clay hardpan (*Qe*) locally overlies older Cainozoic units (*Czc* and *Czz*). This mixed eluvial and colluvial unit is located northeast of Mount Traine, just west of the Mike mine, and 5 km east-southeast of Pearana Rock Hole. Eluvial swelling-clay deposits (*Qb*), known as gilgai or crabhole, are sparsely scattered through the Oakover River valley. These clay deposits fill depressions between low outcrops of the lower carbonate unit of the Oakover Formation (*Czoc*). Swelling clays with scattered boulders of Maddina Basalt, 8 km northwest of Lookout Rocks, are included in this unit.

Another distinctive eluvial deposit, overlying and derived from the fluvioglacial Paterson Formation, consists of scattered pebbles, cobbles, and boulders embedded in, and overlying, clay-silt and silty-sand (*Qt*).

Economic geology

During the first half of this century PEARANA was unsuccessfully explored by prospectors for base and precious metals (lead, zinc, copper, and silver). This contrasts with BRAESIDE where mineral exploration was successful in locating economic mineralization (Williams and Trendall, 1998b). However, around 1950 high-grade manganese ore (>45% Mn) was discovered in the Woodie Woodie area. The first production of manganese ore in 1953 was followed by a manganese pegging rush, which peaked around 1956–1958 (de la Hunty, 1963). Small-scale production continued from several centres on PEARANA until 1972, when mining difficulties and problems competing against large tonnages generated from the major Groote Eylandt deposit in the Northern Territory led to the closure of operations.

Despite this setback, interest in the manganese potential of the area remained high due to the high grade and good quality of the known deposits. Investigations continued over the next 18 years resulting in new discoveries, which upgraded and increased the known reserves. In 1990, openpit mining recommenced in the Woodie Woodie area, operated mainly by the Pilbara Manganese Venture (managed by Portman Mining). Initial production began at the Radio Hill mine, 7 km north of Woodie Woodie, and the Lox mine, 6.5 km to the south. Manganese was later produced at the large Cracker mine, 3 km northwest of Woodie Woodie, and the Green Snake mine just south of the old Bell mine. In 1994, Valiant Consolidated commenced production from the Mike mine, 12 km south of Woodie Woodie. In 1996, Portman Mining sold all its mining operations and infrastructure to Valiant Consolidated (Wilkinson, 1994), and in October 1997 Valiant Consolidated ceased production.

The discoveries of gold at Telfer in 1971 and high-grade copper mineralization at Nifty in 1983 also had a positive effect on exploration activity in the region. Exploration companies have employed modern geophysical (ground and aerial magnetic and gravity surveys, and TEM surveys), and geochemical (soil, stream, and lag sampling) techniques in the area, particularly in the sand-covered Paterson Orogen in northeast PEARANA. Anomalous areas have been investigated using shallow RC and RAB drilling, followed by deeper diamond drilling.

Manganese

The genesis, distribution, and history of development of the manganese deposits on PEARANA have been widely discussed in a number of publications (Owen, 1953; Casey and Wells, 1956; de la Hunty, 1963, 1965; Hickman, 1978, 1983; Fetherston, 1990; Ostwald, 1992, 1993). Available exploration company data submitted since 1952 are obtainable from the WAMEX open-file system, as listed in Appendix 1.

Specific production figures from individual mines on PEARANA are difficult to trace, particularly the early production years when companies combined the tonnages from several pits or, in some cases, from areas outside PEARANA.

Production from the Woodie Woodie area between 1989 and 1996 amounted to 1 387 153 t of manganese ore grading 48.2% manganese. The newly discovered Mike mine, 12 km south of Woodie Woodie, produced 303 371 t of manganese ore grading 51.3% manganese between 1994 and December 1996. Published resources include 2 500 kt of ore grading 46% manganese from the Woodie Woodie area, and a further 995 kt grading 41.5% manganese from the Mike mine (Wilkinson, 1994).

An unknown amount of manganese ore was also produced from the Skull Springs area, 33 km southwest

Table 3. Partial analyses of crystalline barite, goethite, and quartz-ironstone (hematite–martite) samples from PEARANA

GSWA sample no. *AMG coordinate*	*91554* *261671*	*91687A* *402766*	*91587B* *402766*	*91587C* *402766*	*91587D* *402766*
			Percentage		
SiO_2	16	–	–	–	–
TiO_2	0.4	–	–	–	–
Al_2O_3	2	–	–	–	–
Fe_2O_3	1.5	–	–	–	–
MnO	<0.1	–	–	–	–
MgO	0.5	–	–	–	–
CaO	0.2	–	–	–	–
Na_2O	0.5	–	–	–	–
P_2O_5	<0.1	–	–	–	–
$SO_2^{(a)}$	30	–	–	–	–
$BaO^{(a)}$	54	–	–	–	–
Total	**104.3**	**–**	**–**	**–**	**–**
			Parts per million		
As	–	18	<4	<4	<4
Ba	–	66	53	54	68
$Ce^{(b)}$	200	52	51	56	46
Cr	30	<4	<4	13	<4
Cu	150	4	<4	<4	11
Ga	<10	–	–	–	–
$La^{(b)}$	–	<6	<6	<6	<6
$Li^{(b)}$	–	<6	<6	<6	<6
Mo	–	<6	<6	<6	<6
Nb	15	<6	<7	<7	<7
Ni	–	60	4	10	8
Pb	30	9	7	8	10
Rb	10	<2	<2	<2	<2
$Sc^{(b)}$	–	3	6	7	8
Sn	<10	<4	10	9	9
Sr	2 500	3	<2	<2	<2
Th	20	<2	<2	<2	<2
U	<10	2	<2	<2	5
V	700	37	215	239	208
Y	10	3	<2	<2	4
Zn	40	6	12	8	15
Zr	170	11	12	11	17

NOTES: Analyses by Mineral Science Laboratory, Chemistry Centre (WA); analysis by x-ray fluorescence spectrometry unless otherwise indicated
(a) calculated
(b) analysis by inductively coupled plasma-emission spectrometry

91554: crystalline barite; 91687A: goethite cap; 91587B: quartz–hematite (martite); 91587C: quartz–hematite (martite); 91587D: quartz–hematite (martite)

of Woodie Woodie, and from a small mine 7.5 km northwest of the Upper Carawine Pool.

Undeveloped manganese prospects lie in the Pearana Rock Hole area, southeast of Mount Traine, 13 km north of Skull Springs, and in the Wootha Wootha Creek area southeast of Pearana Rock Hole. In all these localities the manganese mineralization is closely associated with the Carawine Dolomite and the overlying Pinjian Chert Breccia. The distribution of the manganese deposits on PEARANA is preferentially located in the lower part of the Carawine Dolomite. The high manganese background (up to 2.9% MnO) of the Carawine Dolomite (de la Hunty, 1963; Jahn and Simonson, 1995) make it a prime candidate for the original source of the manganese in the Woodie Woodie area. The manganese mineralization in the Woodie Woodie area lies in a narrow zone, 3 km wide and 30 km long, stretching from the Whodowe and Radio Hill mines in the north to unnamed mines 22 km south of Woodie Woodie. This zone includes the newly discovered Mike mine. Manganese concentration initially took place during early weathering associated with the formation of a palaeokarst surface in the Carawine Dolomite during the Palaeoproterozoic.

The orebodies are largely supergene caps on, or cavity (cave) and fissure fills within, the Pinjian Chert Breccia and Carawine Dolomite. Some large tabular orebodies are capped by the Waltha Woora Formation, or by thick clay deposits (deep-weathered Permian diamictite). The supergene enrichment is attributed to Tertiary weathering, an event recently dated by ^{40}Ar–^{39}Ar techniques. Growth bands from densely layered cryptomelane ($K(Mn^{+4}, Mn^{+2})_8O_{16}$) collected from the Woodie Woodie mine yielded a late Oligocene age (Dammer et al., 1994). More detailed discussions on the genesis of the manganese deposits can be found in Ostwald (1992, 1993).

Coarsely bladed pyrolusite (MnO_2) and finely banded or colloform cryptomelane constitute the main supergene minerals in the Woodie Woodie area. The deposits have very high Mn/Fe ratios. The first Australian discovery of jiangshuiite ($MgMnO_7.3H_2O$) was found at the Radio Hill mine during this study.

Base metals

Base metals are rare on PEARANA in contrast to the numerous prospects on BRAESIDE. In the headwaters of Warri Warri Creek, tuffaceous sedimentary rocks (*AFhwt*) contain galena and galena-bearing quartz veins. These veins are not directly related to faults. The galena samples, collected from two localities, yielded Pb t7/6 model ages of c. 2440 and 2460 Ma (Table 2). These ages are slightly younger than lead ages obtained from the Kylena and Maddina Basalts on BRAESIDE (Williams and Trendall, 1998b).

Copper mineralization (malachite) has recently been found by prospectors in a large quartz vein (AMG 308004) occupying a splay of the Camel Hump Fault.

Barite

During this study an unusual, sedimentary rock-hosted, stratiform barite deposit was discovered in the southern headwaters of Wootha Wootha Creek, 7.5 km east of Brownrigg Hill (AMG 261671). The bedded barite lies in folded Woblegun Formation of the Manganese Subgroup, close to the unconformity with the younger Googhenama Formation of the Tarcunyah Group.

The barite forms a single bed, 3–9 cm thick, traceable intermittently over 350 m. It consists of well-crystallized tabular or prismatic barite oriented at about right-angles to the bedding. The tabular crystals are intermixed with interlocking half-rosettes, which grow upward from the base of the bed. The barite is grey to bluish grey when broken, and has a pearly, pale reddish brown weathered surface. Colour bands, parallel to bedding, can be traced across the crystal faces.

Thin- to thick-bedded, brown and purple dolomite, silicified dolomite, shale, and mudstone host the barite bed. It is capped by a 1–2 cm-thick layer of limonite–goethite ironstone. Analysis of the barite indicates low base-metal (lead, zinc, and copper) content (Table 3) with quartz sand apparently the only impurity.

Genesis of the bedded barite deposit is uncertain, but the host Woblegun Formation is a clastic and carbonate, shallow-marine shelf or near-shore deposit. The presence of gypsum casts in chert beds is evidence of evaporative minerals in the rocks nearby. The syngenetic barite probably resulted from initial concentration in a marine setting followed by further concentration and crystallization during diagenesis (Clark et al., 1990).

Gold

A gold-bearing quartz vein is reported from Fletchers Find (AMG 421711; WAMEX Item 3547; Appendix 1), but apart from some shallow costeans in scree on the side of a large hill of mylonitized quartz–hematite veins in weathered syenogranite, no other prospecting activity was found in the area.

Iron

Several unusual, north-northwesterly trending, quartz–hematite (martite) veins (*qh*), up to 6 m wide, cut syenogranite (*ARm*) and a large metasedimentary rock pendant (*Alqm*) in southeastern PEARANA (AMG 402766), 6 km north-northwest of Fletchers Find. The quartz veins carry scattered black, non-magnetic martite crystals (Fe_2O_3) and large botryoidal hematite masses, with secondary caps of goethite–limonite. Four samples, analysed for trace elements, showed no anomalies of economic significance (Table 3).

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Appendix 1

WAMEX open-file company exploration reports for PEARANA

WAMEX Item no. [(a)]	*Duration*	*Title*	*Company*
5734	1952–1981	Woodie Woodie manganese exploration	Northern Minerals Syndicate
1840	1966–1973	Nullagine and Balfour Downs iron-manganese exploration	Goldsworthy Mining
			Sentinel Mining Company
6348	1974–1979	Woodie Woodie manganese exploration	Broken Hill Pty Company
			Dampier Mining Company
4549	1974–1984	Woodie Woodie manganese exploration	Longreach Manganese
			Mount Sydney Manganese
			Mount Sydney Manganese Syndicate
3250	1977–1977	Gregory Range uranium exploration	Mid-East Minerals
6882	1979–1992	Nifty copper–lead–zinc exploration	Western Mining Corporation
4148	1982–1985	Woodie Woodie manganese exploration	Preussag Australia
3234	1983–1986	Rudall River copper–lead–zinc exploration	Esso Exploration Australia
2721	1984–1984	Balfour Downs copper–lead–zinc exploration	Hancock and Wright Prospecting
3547	1986–1987	Fletchers gold exploration	Mr P. R. Fletcher, prospector
7475	1986–1994	Bee Hill manganese–diamond exploration	Pennant Resources
			Portman Mining
			Stockdale Prospecting
			Valiant Consolidated
3743	1988–1988	Braeside gold–platinum exploration	Newmont Australia
6032	1989–1991	Skull Spring manganese exploration	Portman Mining
6093	1989–1992	East Pilbara manganese diamond exploration	Pennant Resources
			Portman Mining
7297	1989–1993	Woodie Woodie manganese exploration	Portman Mining
5851	1990–1991	Carawine gold–base metal exploration	MIM Exploration
8138	1990–1995	Wandanya manganese exploration	Valiant Consolidated
8642	1991–1996	Wandanya manganese – base-metals – gold – uranium	ACM Exploration
			Normandy Exploration Poseidon
			Poseidon Exploration
			Valiant Consolidated
6658	1992–1992	Gregory Range gold – base-metals exploration	Newcrest Mining
7569	1992–1993	Fence 4 base-metals exploration	CRA Exploration
7415	1992–1994	Bocrabee base-metal exploration	CRA Exploration
7842	1992–1994	Skull Springs manganese exploration	Valiant Consolidated
8343	1992–1994	Bocrabee base-metals exploration	CRA Exploration
8118	1992–1995	Mount Sydney manganese exploration	Valiant Exploration
8744	1992–1996	Mount Sydney Manganese exploration	Valiant Consolidated
8846	1992–1996	Skull Springs Managanese exploration	Portman Mining
7046	1993–1993	Skull Springs manganese exploration	Valiant Consolidated
7844	1993–1994	Gregory Range gold–copper exploration	Normandy Exploration
7845	1993–1994	Paterson Range base-metals exploration	Fodina Minerals
8854	1993–1996	Carawine Crossing Manganese exploration	Valiant Consolidated
8965	1993–1996	Depot Creek Manganese exploration	Valiant Consolidated
8770	1994–1996	North Woodie Woodie Creek manganese exploration	Valiant Consolidated
9040	1995–1997	Mount Traine – Stockyard Creek Manganese exploration	Valiant consolidated

NOTE: (a) Information available from Geological Survey of Western Australia library

Appendix 2

Major- and trace-element analyses of selected samples from the Koongaling Volcanic Member and Gregory Granitic Complex

	Koongaling Volcanic Member		*Gregory Granitic Complex*												
GSWA sample[a]	*94759*[b]	*94760*[b]	*118923*	*118922*	*116254*	*116267*	*114077*	*118921*	*114010*	*116255*	*118920*	*118925*	*116269*	*114l022*	*118924*
AMG coordinate	*276897*	*248901*	*262070*	*364099*	*360118*	*365936*	*346707*	*299158*	*306956*	*338113*	*297175*	*339730*	*336775*	*317949*	*313074*
Rock unit	*AFhi*	*AFhp*	*ARy*	*ARp*	*ARp*	*ARm*	*ARm*	*ARm*	*ARm*	*ARm*	*ARm*	*ARm*	*ARm*	*ARr*	*ARr*
								Percent							
SiO_2	74.8	78.8	73.2	72.3	73.2	73.1	70.9	71.3	74.2	74.3	76.70	76.80	81.8	70.1	70.20
TiO_2	0.41	0.25	0.28	0.40	0.39	0.46	0.63	0.43	0.31	0.39	0.20	0.24	0.40	0.62	0.54
Al_2O_3	11.00	11.20	11.90	12.30	12.2	12.1	12.5	12.30	11.8	12.2	10.9	10.90	6.92	12.6	12.9
Fe_2O_3	1.75	1.50	2.85	1.75	1.95	2.16	1.46	2.68	1.65	1.87	1.57	1.22	3.40	1.70	1.97
FeO	2.30	0.91	0.31	1.48	1.34	0.91	2.75	1.76	1.63	0.93	0.60	0.99	0.20	2.95	2.22
MnO	0.08	0.04	0.06	0.02	<0.05	<0.05	0.07	0.08	0.06	<0.05	0.03	0.03	<0.05	0.07	0.06
MgO	0.67	0.15	0.18	0.27	0.29	0.25	0.45	0.29	0.17	0.25	0.12	0.15	0.07	0.45	0.48
CaO	0.13	0.06	0.87	0.86	0.76	0.88	1.89	1.59	0.79	0.83	0.42	0.67	0.06	1.73	1.55
Na_2O	0.08	1.41	4.60	3.92	3.73	3.15	3.59	3.50	3.65	3.63	3.50	3.08	0.27	3.40	3.72
K_2O	7.07	4.40	5.25	5.39	5.54	5.80	4.36	4.90	5.30	5.54	5.09	4.93	5.84	5.11	5.13
P_2O_5	0.11	0.02	0.05	0.08	0.08	0.10	0.16	0.11	0.05	0.07	0.02	0.02	0.06	0.19	0.15
CO_2	–	–	<0.10	<0.10	0.30	<0.1	<0.1	<0.10	<0.1	<0.1	<0.10	0.26	<0.1	<0.1	<0.10
S	–	–	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
H_2O^+[c]	–	–	0.19	0.39	0.23	0.39	0.62	0.31	0.27	1.61	0.22	0.54	0.20	0.60	0.61
H_2O^-[c]	–	–	0.09	0.06	<0.1	<0.1	0.11	0.04	<0.1	<0.1	0.09	0.06	<0.1	0.15	0.02
O=S[d]	–	–	–	–	<0.01	<0.01	<0.01	–	<0.01	<0.01	–	–	<0.01	<0.01	–
Rest[e]	–	–	–	–	0.29	0.29	0.32	–	0.26	0.28	–	–	0.21	0.34	–
Total	**99.1**	**98.7**	**99.9**	**99.2**	**100.2**	**99.3**	**99.5**	**99.3**	**99.9**	**101.6**	**99.5**	**99.9**	**99.2**	**99.7**	**99.7**
								Parts per million							
Ag[f]	–	–	<2	<2	1	<1	<1	<2	<1	1	<2	<2	3	1	<2
As	–	–	<4	<4	<4	<4	4	<4	<4	<4	<4	<4	<4	<4	<4
Ba	–	–	1 030	1 010	933	970	1 476	1 100	792	864	379	859	864	1 152	1 190
Bi	–	–	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Cd	–	–	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Ce	–	–	REE	REE	236	245	175	REE	190	252	REE	REE	111	252	REE
Co	59	55	6	5	–	–	–	9	–	–	4	5	–	–	9
Cr	<4	<4	<5	<5	17	4	6	<5	<4	<4	5	5	19	4	10
Cu	<4	<4	5	8	8	9	11	4	10	9	<4	<4	6	15	9
Ga	–	–	18	16	17	16	17	18	18	16	18	15	6	18	18
Ge	–	–	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
La	–	–	REE	REE	124	137	91	REE	100	148	REE	REE	68	135	REE
Mo[g]	–	–	<2	2	<2	3	<2	5	6	<2	<2	2	<2	4	2
Nb	30	23	REE	REE	47	51	21	REE	34	49	REE	REE	27	38	REE
Ni	12	17	4	3	24	13	14	4	17	16	3	3	17	34	7

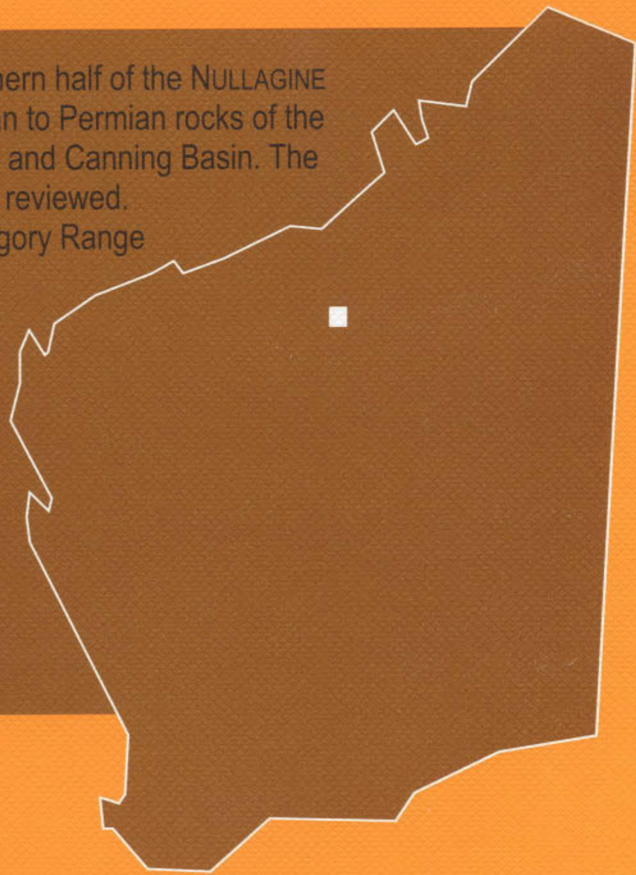
Pb	–	–	21	15	10	38	30	41	39	41	33	36	13	40	26
Rb	267	161	223	188	209	243	115	208	198	262	229	167	182	211	184
Sb	–	–	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sc(h)	5	3	REE	REE	–	–	–	REE	–	–	REE	REE	–	–	REE
Sn	–	–	9	10	8	11	<4	7	4	8	7	6	<4	4	5
Sr	15	41	26	17	18	31	154	50	24	26	13	47	20	59	62
Ta	–	–	REE	REE	<5	<5	<5	REE	<5	<5	REE	REE	<5	<5	REE
Te	–	–	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Th	23	21	REE	REE	31	31	12	REE	24	33	REE	REE	27	35	REE
U	5	5	REE	REE	7	7	3	REE	5	6	REE	REE	2	5	REE
V	9	3	4	3	3	12	31	8	4	4	<3	<3	14	25	20
W	–	–	8	9	–	–	–	7	–	–	7	7	–	–	8
Y	80	55	REE	REE	85	80	57	REE	82	86	REE	REE	74	84	REE
Zn	53	67	84	22	20	49	20	110	94	52	76	57	7	98	73
Zr	632	345	666	674	633	498	432	672	546	477	339	344	324	595	600
Rb/Sr	17.8	3.9	8.6	11.1	11.6	7.8	0.7	4.2	8.3	10.1	17.6	3.6	9.1	3.6	3.0
La	110	109	94.9	98.6	–	–	–	75.8	–	–	125	106	–	–	61.9
Ce	210	210	180	184	–	–	–	144	–	–	199	207	–	–	118
Pr	–	–	18.9	18.7	–	–	–	15.8	–	–	23.8	21.8	–	–	13.1
Nd	90.1	84.9	72.2	69.9	–	–	–	62.6	–	–	92.8	84	–	–	50.7
Sm	17.7	14.4	10.8	13.2	–	–	–	10.8	–	–	16.8	12.6	–	–	9.6
Eu	2.50	1.26	1.6	1.4	–	–	–	1.9	–	–	0.8	1	–	–	1.9
Gd	15.2	11.4	12.8	10.8	–	–	–	10.9	–	–	14.6	11.6	–	–	9.1
Tb	–	–	2.5	2.2	–	–	–	2.2	–	–	2.7	2.1	–	–	1.9
Dy	14.4	10.9	13.5	11.3	–	–	–	11.1	–	–	14.2	10.6	–	–	9.5
Ho	3.19	2.20	2.7	2.3	–	–	–	2.4	–	–	3.1	2.2	–	–	2.1
Er	9.71	6.63	7.9	7	–	–	–	6.8	–	–	8.8	6.1	–	–	5.8
Tm	–	–	1.4	1.2	–	–	–	1.2	–	–	1.5	1	–	–	1
Yb	10.2	6.42	10.1	9.1	–	–	–	8.6	–	–	10.9	7.6	–	–	7.7
Lu	1.57	0.96	1.4	1.3	–	–	–	1.2	–	–	1.5	1.1	–	–	1
Hf	–	–	14.3	14.4	–	–	–	16.2	–	–	10.6	9.2	–	–	4.5
Nb	–	–	38.4	49.6	–	–	–	35	–	–	32.5	25.8	–	–	32.1
Sc	–	–	2	4	–	–	–	4	–	–	2	2	–	–	5
Ta	–	–	3.5	5.3	–	–	–	3.8	–	–	2.5	1.5	–	–	3.3
Th	–	–	24.3	24.5	–	–	–	19.4	–	–	2.86	19.9	–	–	14.6
U	–	–	3.4	4.4	–	–	–	4.3	–	–	3.6	3.4	–	–	3.3
Y	–	–	98.3	77.9	–	–	–	80.8	–	–	111	74.3	–	–	68.8

NOTES: Analysis by Mineral Science Laboratory, Chemistry Centre, Department of Minerals and Energy (WA); analysis by x-ray fluorescence spectrometry unless otherwise indicated
REE: analysis in separate rare-earth element column below; analysed by inductively coupled plasma mass spectrometry (ICP-MS)

(a) Geological Survey of Western Australia sample number
(b) Nelson et al. (1992)
(c) Analysis by classical chemistry methods
(d) Calculated
(e) Sum of trace elements expressed as oxides
(f) Analysis by flame atomic absorption
(g) Analysis by electrochemical atomic absorption
(h) Analysis by inductively coupled plasma-emission spectrometry (ICP-ES)

94759: metamorphosed rhyolite
94760: metamorphosed rhyolite porphyry
118923: metamorphosed porphyry granophyre
118922: porphyritic microgneiss
116254: porphyritic microgneiss
116267: alkali granite gneiss
114077: monzogranite gneiss
118921: alkali granite gneiss
114019: syenogranite gneiss
116255: metamorphosed syenogranite
118920: leuco-alkali granite gneiss
118925: alkali granite gneiss
116269: brecciated alkali granite
114022: syenogranite augen gneiss
118924: alkali granite augen gneiss

The PEARANA 1:100 000 map sheet covers the northern half of the NULLAGINE 1:250 000 sheet. These notes describe the Archaean to Permian rocks of the Pilbara Craton, Bangemall Basin, Paterson Orogen, and Canning Basin. The structural geology of Archaean rocks on PEARANA is reviewed. Reassessment of the Fortescue Group and the Gregory Range Granitic Complex, after detailed field observations, has revealed a possible correlation between the Complex and the Koongaling Volcanic Member. Important manganese mineralization is hosted in the Pinjian Chert Breccia, with previous mining activity in the Woodie Woodie area. Minor copper and barite mineralization is also present.



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

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

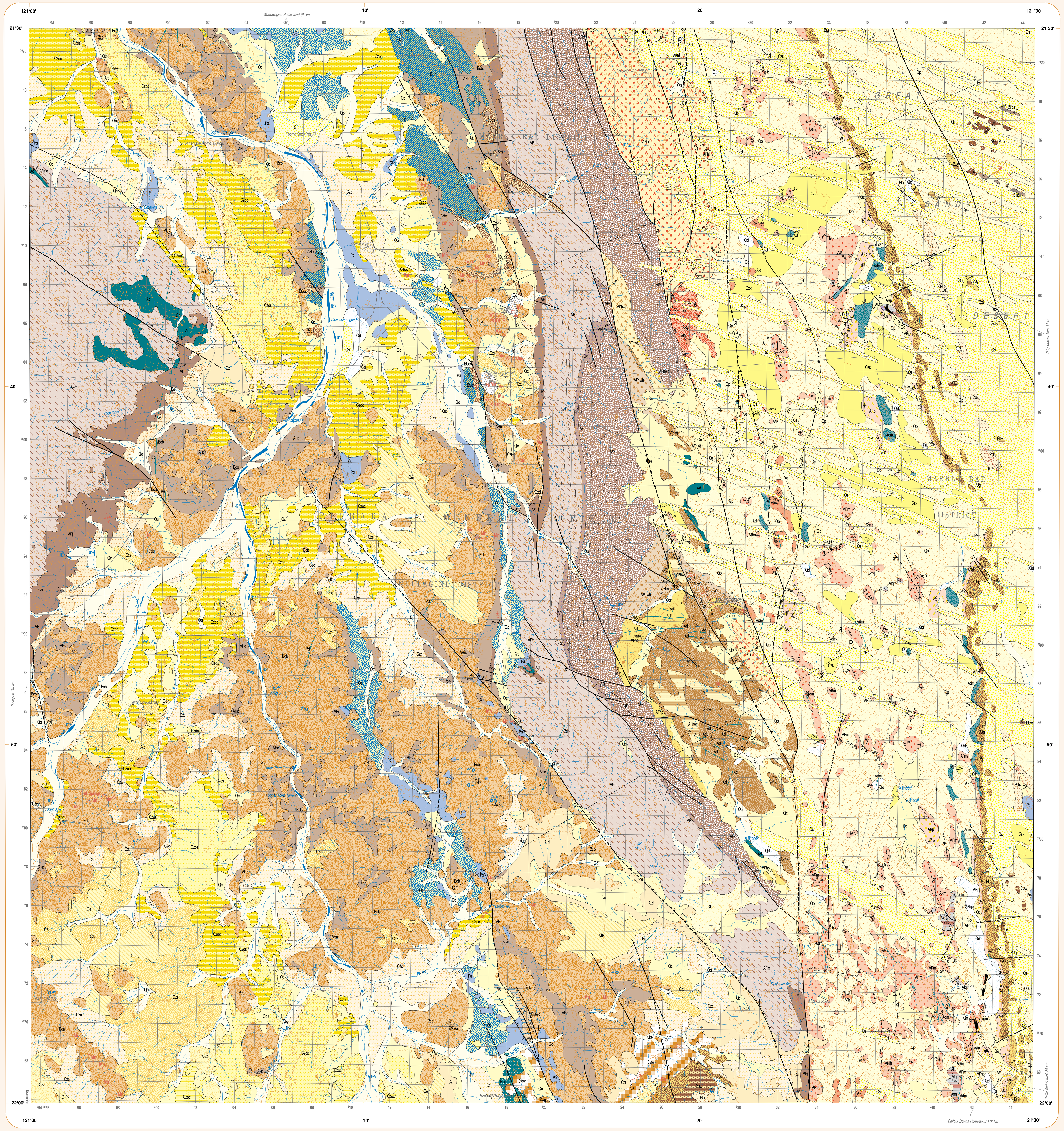
WILLIAMS, TRENDALL

Geology of the Pearana 1:100 000 sheet

EXPLANATORY NOTES

PEARANA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qa Alluvium—unconsolidated clay, silt, sand, and gravel; in drainage channels and on adjacent floodplains
Ql Lacustrine deposits—clay, silt, and silty sand; playa (saline) and claypan (freshwater) deposits
Qd Mixed lacustrine and eolian deposits—clay, silt, and sand; vegetated swamps, numerous small claypans with fringing lunette dunes
Qs Eolian deposit—sand; in sheets and longitudinal (seif) and chain dunes
Qp Lag and eolian deposits—ironstone pebble, rock fragment, or quartz pebble veneer with eolian sand; in sheets and between dunes; overlies shallow bedrock
Qc Colluvium—quartz pebble and rock fragment veneer on sand; adjacent to or on shallow bedrock; scree deposits
Qe Colluvium and eluvium—clay hardpan, partly ferruginized silt, sand, and gravel derived from and overlying Czc and Czz
Qb Eluvium—swelling clay soil (gilgai); characterized by crabhole
Qt Eluvium—scattered boulders, cobbles, and pebbles on clay, silt, and sand; lag deposit derived from fluvioglacial PATERSON FORMATION

Czos **OAKOVER FORMATION**, upper unit; vuggy, white to grey opaline silica; silicified carbonate; minor calcareous sandstone
Czoc **OAKOVER FORMATION**, lower unit; blue, grey and fawn limestone, calcareous sandstone
Czk Calcrete—massive, nodular and vuggy limestone; some surface silicification in palaeodrainages
Czc Colluvium—consolidated silt, sand, gravel, boulder beds, and fluvial deposits; dissected by present-day drainage
Czz Silcrete and siliceous duricrust; secondary chert breccia
Czl Lateritic deposits—massive and pisolitic laterite, and ferruginous duricrust
Czd Ferruginous duricrust; overlying and restricted to top of JEERINAH FORMATION

PALAEOZOIC — PERMIAN — CANNING BASIN

Pa **PATERSON FORMATION:** fine- to coarse-grained sandstone, siltstone, and mudstone (all with dropstones); diamictite, fluvioglacial deposits

q Quartz vein and pod; various ages
go Gossanous quartz vein

Pd Dolerite dyke and sill

PROTEROZOIC — PATERSON OROGEN

Tarcunyah Group (c. 800 Ma)

PUy **YANDANUNYAH FORMATION:** siltstone, shale, and fine-grained sandstone
PUr **BROWNRIGG SANDSTONE:** fine- to coarse-grained sandstone and orthoquartzite; pyrite nodules
PUw **WAROONGUNYAH FORMATION:** shale, siltstone, sandstone, and dolomite
PUg **GOOGHENAMA FORMATION:** medium- to coarse-grained sandstone and pebble to boulder conglomerate
PUa **WALTHA WOORA FORMATION:** dolomite, stromatolitic dolomite, siltstone, shale, and sandstone
PUas Medium- to coarse-grained sandstone; pebbly sandstone and conglomerate

Yeneena Supergroup — Throssell Group (> 900 Ma) — Yeneena Basin

PTb **BROADHURST FORMATION:** shale, carbonaceous shale, siltstone, wacke, sandstone, and dolomite (section only)
PTbs Carbonaceous shale, shale, siltstone, and fine-grained sandstone
PTbf Fine- to medium-grained feldspathic sandstone and wacke
PTc **COOLBRO SANDSTONE:** quartz sandstone, quartz wacke, siltstone, and shale (section only)

Pdd **DAVIS DOLERITE:** fine- to medium-grained dolerite; in sills; prominent magnetite

Bangemall Group — Manganese Subgroup — BANGEMALL BASIN

PMw **WOBLEGUN FORMATION:** shale and siltstone, interbedded with fine-grained sandstone
PMwa Medium- to coarse-grained sandstone, and pebbly sandstone; thin beds of conglomerate and siltstone
PMwd Grey-brown dolomite and stromatolitic dolomite

Pcb **PINJIAN CHERT BRECCIA:** chert breccia, poorly bedded chert; overlies CARAWINE DOLOMITE

ARCHAEAN — Mount Bruce Supergroup — Hamersley Basin — PILBARA CRATON

Hamersley Group (> 2500 Ma)

AHc **CARAWINE DOLOMITE:** massive to well-bedded, recrystallized, dolomite and stromatolitic dolomite; minor chert

Ad Fine- to coarse-grained dolerite; in dykes and sills; weakly metamorphosed

Fortescue Group (c. 2687 Ma; c. 2757-2764 Ma)

AFj **JEERINAH FORMATION:** shale, chert, ferruginous chert, mudstone, fine-grained sandstone, and dolomite
AFm **MADDINA BASALT:** basalt and andesitic basalt with silicified flow tops; abundant quartz-chlorite amygdales
AFma Well stratified, tuffaceous sedimentary rock; common accretionary lapilli
AFt **TUMBIANA FORMATION:** tuff, pisolitic tuff, mudstone, and lithic sandstone
AFk **KYLENA BASALT:** basalt and basaltic andesite; flows

HARDEY FORMATION
AFhw **Warri Warri Member:** mixed felsic and mafic lavas, and tuffaceous and epiclastic sedimentary rocks (section only)
AFhwh Mixed felsic and mafic lavas
AFhwr Rhyolite
AFhwt Tuffaceous sedimentary rock
AFhwa Felsic agglomerate
AFhwf Stratiform felsic volcanic rock
AFhwo Oligomictic conglomerate; felsic clasts
AFhws Epiclastic sedimentary rock; mainly sandstone
AFhp Rhyolite porphyry sill; brecciated rhyolite dyke, sanidine-bearing felsic dyke
AFhi **Koongaling Volcanic Member:** porphyritic and fine-grained felsic lavas; dacite, rhyodacite, and rhyolite

GREGORY GRANITIC COMPLEX
qm Quartz mylonite zone
qh Quartz-hematite (martite) vein
ARp Even, fine-grained to microporphyritic granitoid rock; probably derived from high-grade metamorphism of rhyolitic volcanic rocks (possibly related to Koongaling Volcanic Member)
ARr Metamorphosed porphyritic to seriate syenogranite, rapakivi texture; sheared, foliated, and gneissic
ARy Granophyre, gneissic granophyre, granophyric gneiss
ARm Metamorphosed medium- to coarse-grained syenogranite; sheared, foliated, and gneissic

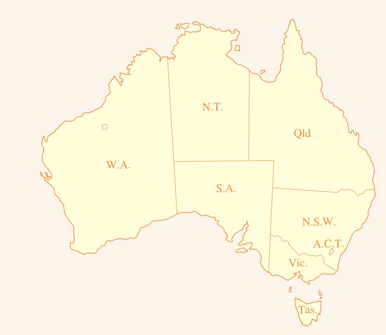
Alqm Schistose metasedimentary rock; quartz-muscovite-biotite-sillimanite(-cordierite) assemblages; metamorphosed quartz pebble conglomerate
Adm Metamorphosed dolerite and gabbro, and amphibolite
Aut Ultramafic intrusive rock, talc-chlorite-tremolite-serpentine assemblages

Rafts restricted to GREGORY GRANITIC COMPLEX

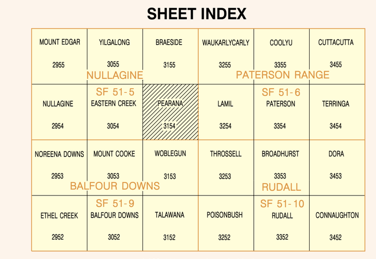
Geological boundary
- exposed
Fault
- exposed
- concealed
- concealed, position uncertain
- thrust or reverse, concealed
- strike-slip, showing relative horizontal movement
Fold, showing trend and plunge direction
- anticline, concealed
- syncline, concealed
Minor fold, showing trend and plunge direction
- minor anticline
- minor syncline
- asymmetric
Bedding, showing strike and dip
- inclined
- vertical
Glacial striae, direction of ice movement
Direction of movement of sediment-bearing current, from cross-bedding
Metamorphic foliation, showing strike and dip
- inclined
- vertical
Cleavage, showing strike and dip
- Paterson Orogen
  - vertical
- Pre-Paterson Orogen
  - inclined
  - vertical
Mineral lineation, showing trend and plunge direction
Stromatolite locality
Isotopic age determination site with identification number — 94670
Airphoto lineament
- flow-top trend and ogive structure

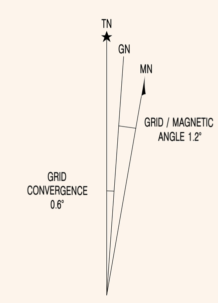
Formed road
Track
Building, mining camp
Yard — Yd
Sand dune
Contour line, 20 metre interval — 260
Watercourse, ephemeral
Pool, waterhole — P, WH
Bore — B
Well — W
Spring — S
Rockhole — RH
Sinkhole — SH
Abandoned — (abd)
Position doubtful — (PD)

Mineral field district boundary
Mining locality — WOODIE WOODIE
Opencut; abandoned — Bell
Quarry
Prospect
Mining area, made ground
Beneficiation plant
Mineral exploration drillhole, showing subsurface data — AHc 500m
Mineral occurrence
- Barite (bedded unit) — Ba
- Copper — Cu
- Gold — Au
- Gypsum — Gp
- Iron (martite) — Fe
- Lead — Pb
- Manganese — Mn
- Road materials — Rm



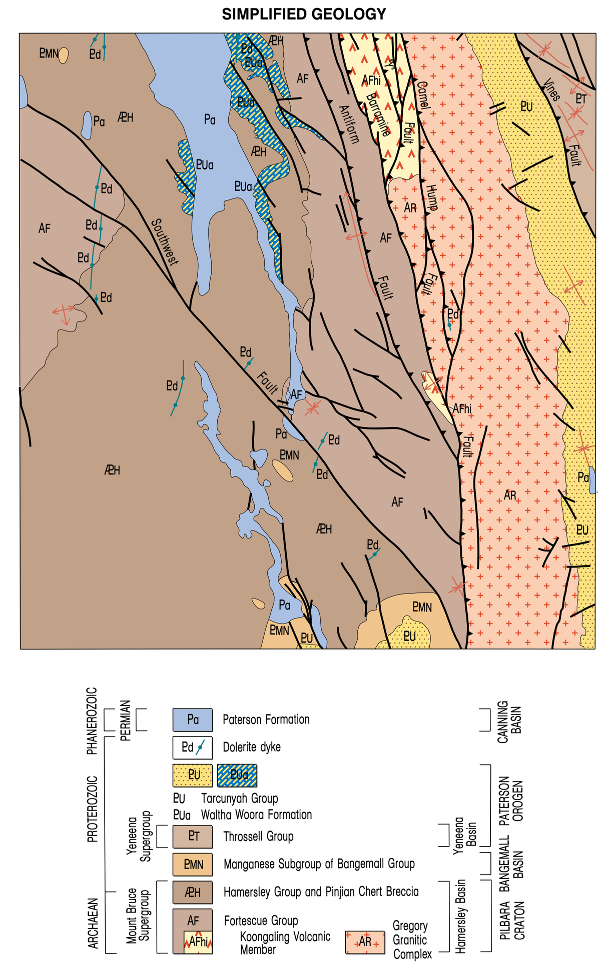
SHEET INDEX





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 9 years.

SIMPLIFIED GEOLOGY



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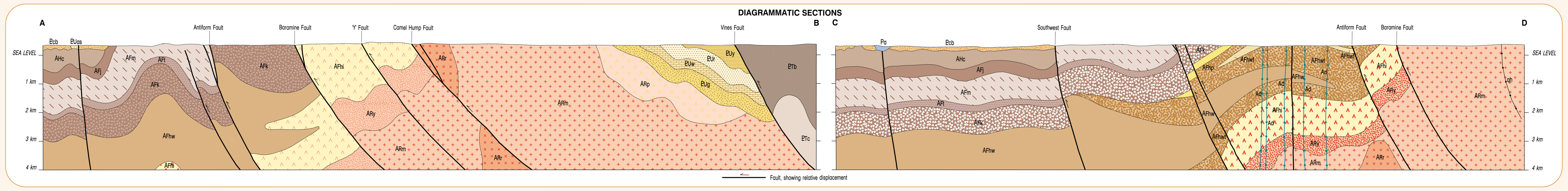
K.R. PERRY, DIRECTOR GENERAL

PIETRO GUJ
DIRECTOR, GEOLOGICAL SURVEY
OF WESTERN AUSTRALIA

SCALE 1:100 000

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

DIAGRAMMATIC SECTIONS



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PEARANA
SHEET 3154 FIRST EDITION 1996