EXPLANATORY NOTES

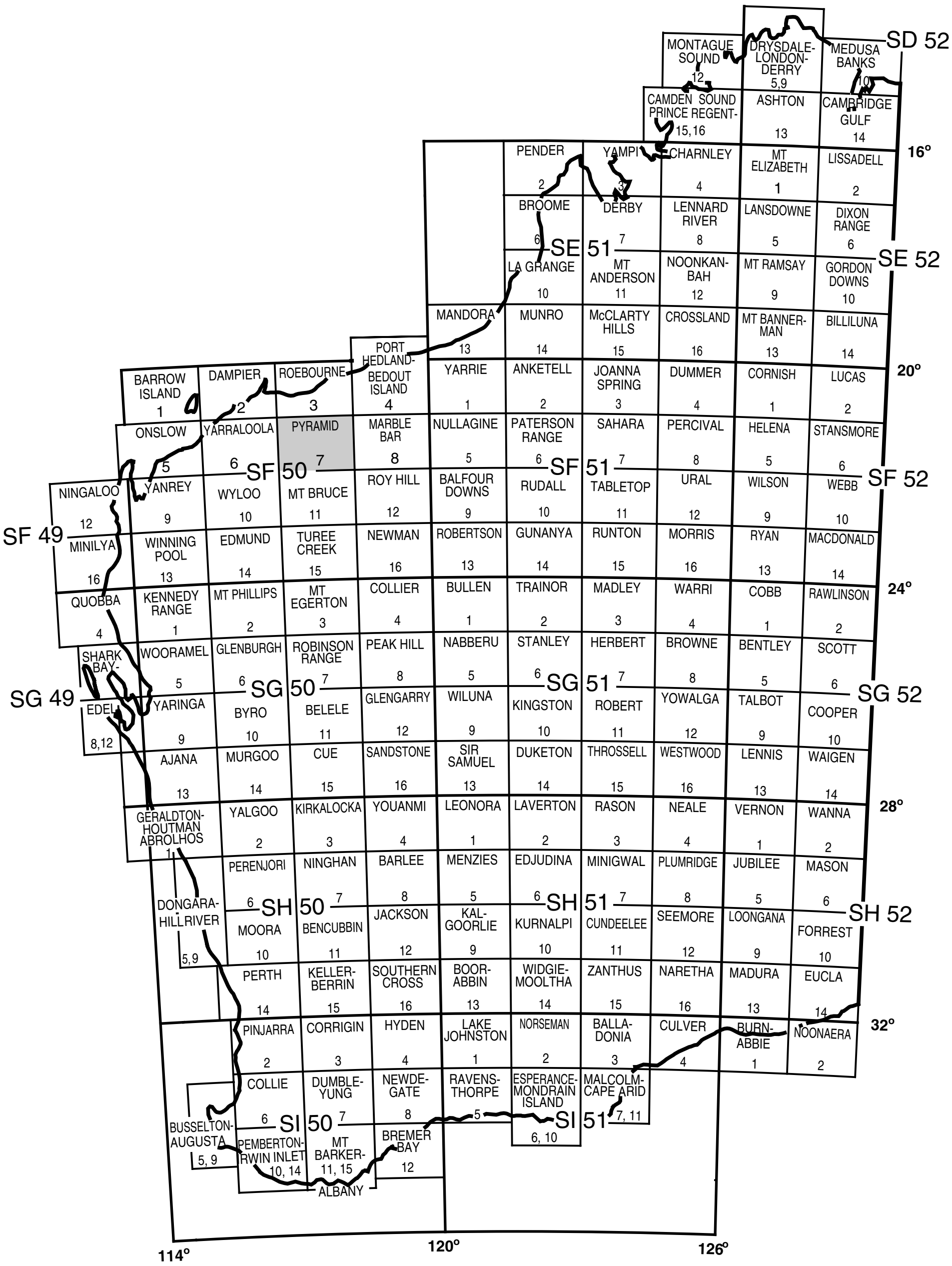
Department of
Industry and Resources

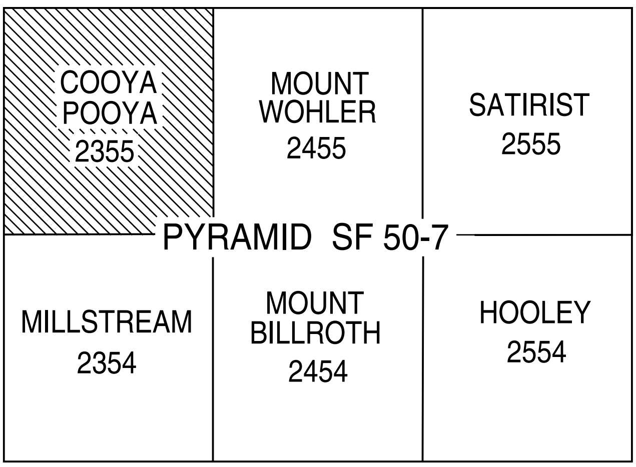
GEOLOGY OF THE COOYA POOYA 1:100 000 SHEET

by A. H. Hickman

1:100 000 GEOLOGICAL SERIES

Geological Survey of Western Australia





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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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by
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Cover photograph:
Convergent sandstone channels in felsic pyroclastic rocks of the Lyre Creek Member, 1.5 km southeast of Mount Montagu

Contents

Appendix

Figures

Tables

Geology of the Cooya Pooya 1:100 000 sheet

by

A. H. Hickman

Abstract

The Cooya Pooya 1:100 000 sheet is located in the northwestern part of the Pilbara Craton, and covers parts of the Mesoarchaean West Pilbara Granite–Greenstone Terrane (WPGGT) and Mallina Basin, and part of the Neoarchaean to Palaeoproterozoic Hamersley Basin. The WPGGT and Mallina Basin are separated by a fault zone, and both are unconformably overlain by the Hamersley Basin.

On Cooya Pooya, the WPGGT consists of the c. 3240–2930 Ma Cherratta Granitoid Complex and the c. 3130–3115 Ma Whundo Group. The dominantly basaltic, about 10 km-thick Whundo Group was deposited in a major northeasterly trending rift between older rocks of the WPGGT and the East Pilbara Granite–Greenstone Terrane. The contact between the Whundo Group and the Cherratta Granitoid Complex is partly tectonic (Maitland Shear Zone) and partly intrusive.

The first deformation event on Cooya Pooya was D_3 of the WPGGT, and involved c. 3015 Ma north–south thrusting of the Whundo Group onto older components of the Cherratta Granitoid Complex. D_4 involved northeasterly trending transpressional folding of the Whundo Group at 2945–2930 Ma. D_5 resulted in c. 2940–2930 Ma strike-slip faulting along the Maitland Shear Zone.

Only the lower part of the Mount Bruce Supergroup is preserved on Cooya Pooya. Deposition of the c. 2770–2630 Ma Fortescue Group was controlled by a northeasterly striking rift system. Initial basaltic volcanism (Mount Roe Basalt) was followed by clastic sedimentation and ultramafic to felsic volcanism (Hardey Formation) at c. 2760 Ma. This ultramafic to felsic volcanism was localized to Cooya Pooya, and adjacent areas, and could be related to reactivation of the WPGGT – Mallina Basin contact. A subsequent dominantly basaltic to andesitic magmatic event at 2750–2740 Ma resulted in eruption of the Kylena Formation and comagmatic intrusion of the Cooya Pooya Dolerite. Deformation and a period of erosion were followed by c. 2719 Ma deposition of the Tumbiana Formation, which is a succession of volcaniclastic rocks containing thin units of stromatolitic carbonate rocks. Subsequent basaltic to rhyolitic volcanism led to deposition of the Maddina Formation at c. 2717 Ma.

Known mineral occurrences on Cooya Pooya are limited to small subeconomic Ni–Cu deposits in the Whundo Group. However, northeastern Cooya Pooya could also contain concealed base metal, platinum group element, and gold mineralization.

KEYWORDS: Archaean, Pilbara Craton, West Pilbara Granite–Greenstone Terrane, Mallina Basin, Hamersley Basin, Whundo Group, Fortescue Group, deformation events, mineralization.

Introduction

The Cooya Pooya* 1:100 000 geological map sheet (SF 50-7, 2355), bounded by latitudes 21º00'S and 21º30'S, and longitudes 117º00'E and 117º30'E, is situated in the northwestern part of the Pilbara region (Fig. 1). It occupies the northwestern corner of the Pyramid 1:250 000 sheet.

The only permanent habitation on Cooya Pooya is Pyramid Homestead†, and access is poor across most of the area, particularly in the south. A graded gravel road links Highway 1 (north of the sheet area) to Millstream (south of Cooya Pooya), and good gravel roads (private) run along the Dampier – Tom Price and Robe River railways. In northern Cooya Pooya, access to 4WD vehicles is provided by a system of partly disused pastoral tracks.

* Capitalized names refer to standard 1:00 000 map sheets, unless otherwise indicated

† MGA coordinates of localities mentioned in the text are listed in the Appendix

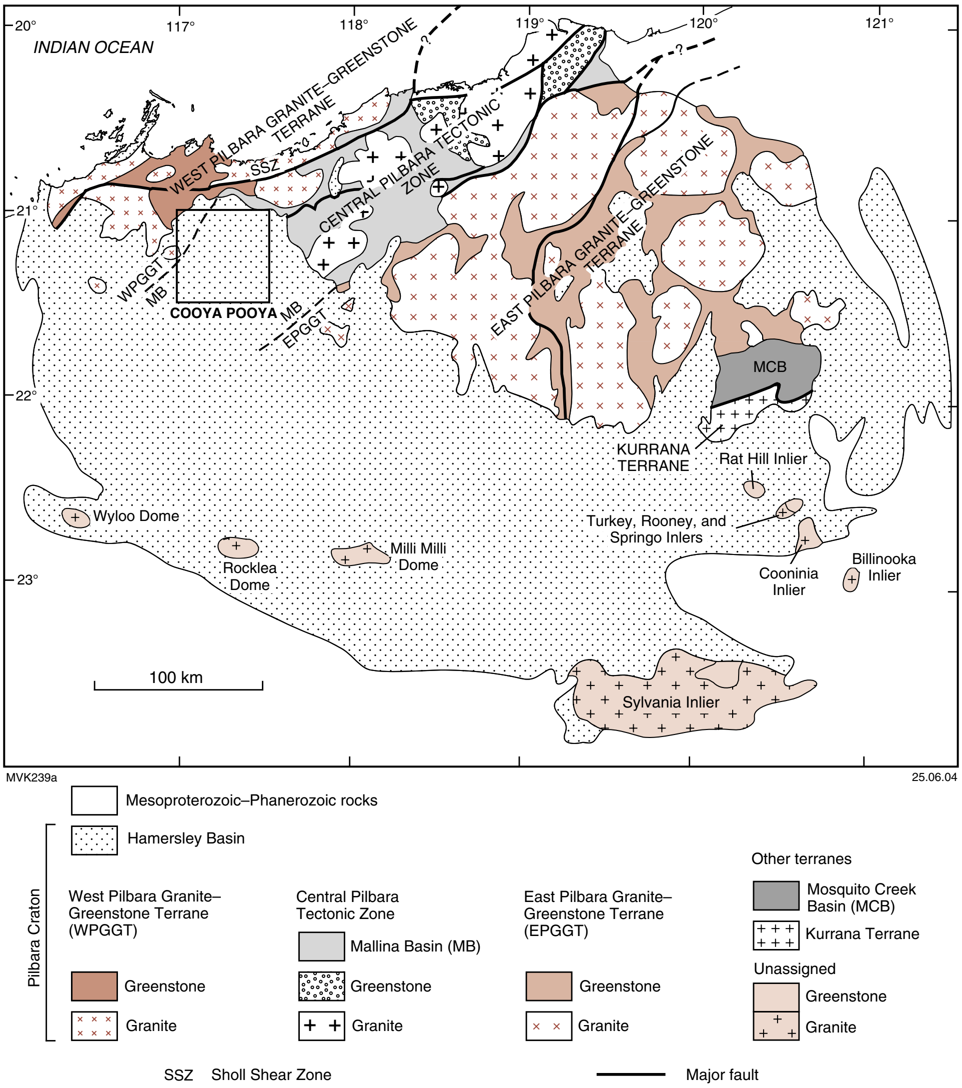

Figure 1. Regional geological setting of Cooya Pooya within the Pilbara Craton

Climate and vegetation

Cooya Pooya has a tropical, semi-desert climate with an average rainfall between 250 and 300 mm. Annual precipitation is extremely variable, being largely dependent on the passage of tropical cyclones through the area. Rainfall in excess of 100 mm during 24-hour periods is common, causing rivers to flow and eventually flood parts of the coastal plain. Outside the cyclone season, longer periods of low to moderate rainfall, commonly during May and June, are associated with southeasterly moving low-pressure systems or the trailing southern edges of strong equatorial systems. Daily maximum temperatures in summer are about 35–40°C. Daily maxima during winter months are typically about 25°C, with night temperatures of 10–15°C.

Cooya Pooya occupies part of the Fortescue Botanical District (Beard, 1975), in which flora is related to topography, soil types, and proximity to the coast. The valleys of the Harding and George rivers contain poorly drained sands, silt, and expansive silty clay (gilgai). Fine-grained soils support grasses such as *Eragrostis setifolia* and *Triodia wiseana* (buck spinifex), whereas colluvial slopes near hills also contain *Acacia pyrifolia* (kanji), and creeks and rivers are lined with eucalypts.

Formations of the Fortescue Group form rocky dissected plateau, and there are large areas without soil cover. The basaltic rocks of the area have given rise to hard alkaline soils and shallow loams. This country consists of sparse tree steppe with *Eucalyptus brevifolia* (snappy gum) and *Triodia wiseana*, and scattered shrubs such as *Acacia xiphophylla* (snakewood). Trees and shrubs are concentrated along the banks of creeks. Low hills and ridges, corresponding to outcrops of greenschist-facies metamorphosed volcanic and sedimentary rocks in northwestern Cooya Pooya, are dominated by spinifex and scattered shrubs.

Physiography

Figure 2 summarizes the major physiographic divisions of Cooya Pooya, and closely follows divisions previously

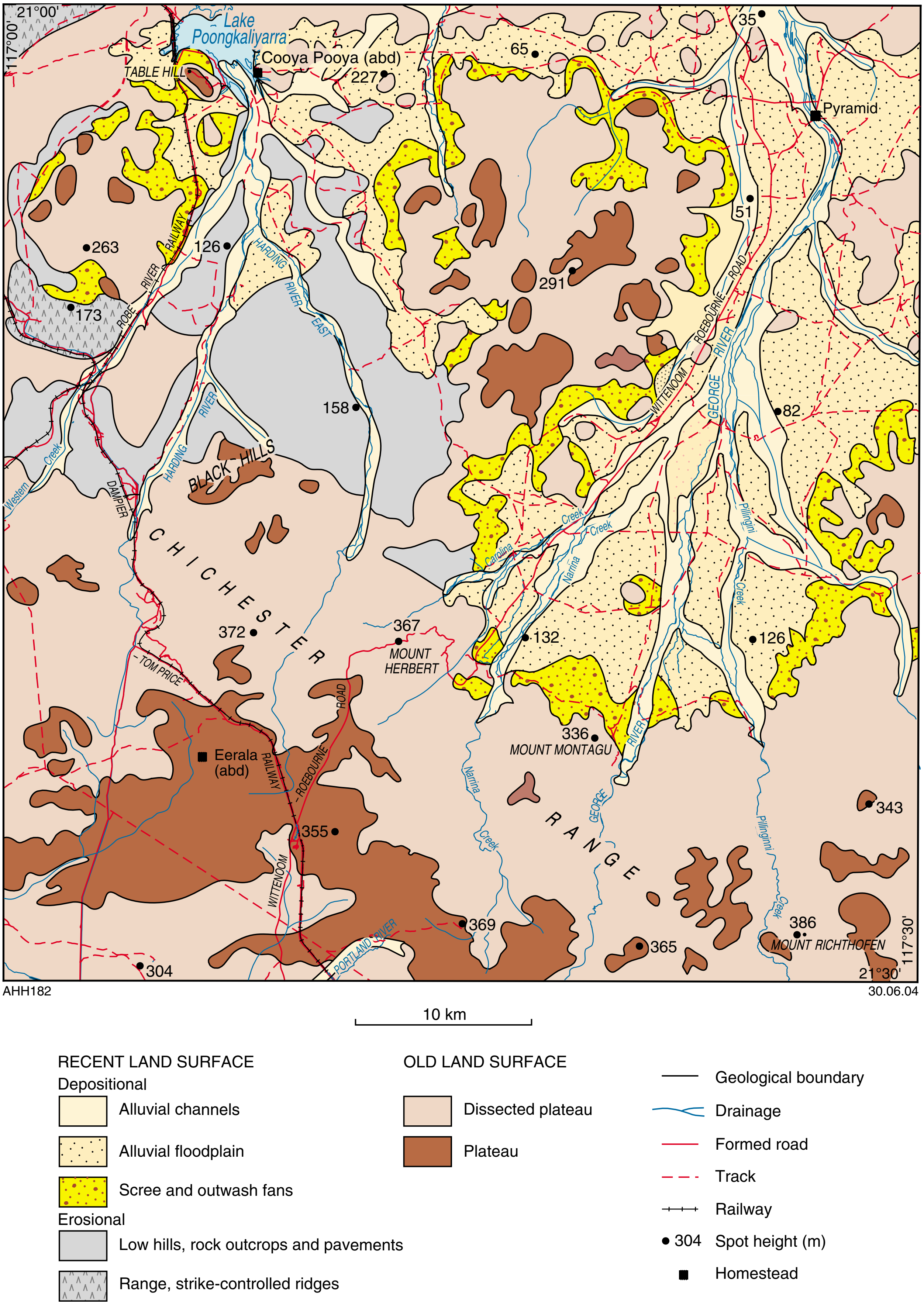

Figure 2. Physiography and access on Cooya Pooya

used by Hickman (1983). The present physiography of Cooya Pooya is mainly the product of erosional and depositional processes during the Cainozoic Era, but the Precambrian rocks were also deeply eroded during the Archaean.

The alluvial plain division (Fig. 2) forms gently sloping tracts of sand, silt, and clay deposited from rivers, creeks, and minor channels. The rivers and larger creeks occupy wide alluvial channels containing unconsolidated sand and pebble beds. The alluvial plain of the George River occupies about 20% of the sheet area, and is dominated by anastomosing channels with intervening flood plains. Scree and outwash fans fringe the northern foothills of the Chichester Range in southern Cooya Pooya, and two large areas of dissected plateau in the northern part of the sheet area (Fig. 2).

Erosional land surfaces are separated into two divisions (Fig. 2). The low hills division comprises areas of undulating low hills, including small inliers of Archaean granitoid rocks. The range division consists of strike-controlled ridges that are separated by narrow, locally steep sided valleys. In northwestern Cooya Pooya, the ranges are formed over steeply dipping greenstones, but moderately inclined units of the Fortescue Group also form this division in some areas. Remnants of an older (Late Cretaceous to Eocene) land surface, named the 'Hamersley Surface' by Campana et al. (1964), are preserved in the more elevated areas of Cooya Pooya, and are underlain by rocks relatively resistant to erosion, such as dolerite and basalt. Figure 3 shows an example of the dissected plateau division developed on Cooya Pooya Dolerite north of Lake Poongkaliyarra. Where the dissected plateau division is underlain by near-horizontal strata, the dissected plateau contains steep V-shaped valleys, gorges, nick-points, dendritic drainage patterns, and abrupt margins. Remnants of the Hamersley Surface are mainly preserved in southern Cooya Pooya (Fig. 2).

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Figure 3. Dissected plateau north of Lake Poongkaliyarra, viewed from Table Hill (MGA 510600E 7674200N). The plateau surface coincides with the tops of dark hills of Cooya Pooya Dolerite visible in the far distance

Previous investigations

Before 1960, all geological investigations of the northwest Pilbara were either reconnaissance or limited to local studies of mineral deposits. Consequently, knowledge of the regional geology of the region was extremely limited until the Geological Survey of Western Australia (GSWA) commenced a 1:250 000-scale geological mapping program in 1962. Hickman (1983) reviewed the principal pre-1976 investigations, and Ruddock (1999) provided a general summary of the mining and mineral exploration history of the west Pilbara. Hickman (2001) reviewed changing interpretations of the area's geology between 1962 and 1995. Most investigations have concentrated on mineralized areas of metamorphosed volcanic and sedimentary rocks (Archaean greenstones) north and west of Cooya Pooya, but there are recent regional studies of the Fortescue Group (Blake, 1993; Thorne and Trendall, 2001) that are more relevant to the sheet area.

Pilbara Supergroup

On Cooya pooya, outcrops of the Pilbara Supergroup are restricted to formations of the Whundo Group in the northwestern corner of sheet area (Fig. 4). Previous publications (Hickman, 1997, 2001, 2002; Sun and Hickman, 1998; Van Kranendonk et al., 2002) provide descriptions of the Whundo Group, and its relations to the Archaean granitoids of the area.

Fortescue Group

About 98% of the area of Cooya Pooya is occupied by outcrops or shallow subcrops of the Fortescue Group (Fig. 4; Table 1). Hickman (1983) recognized eight formations in the Fortescue Group, with volcanic formations alternating with dominantly sedimentary formations. Three of the volcanic formations — the Mount Roe, Kylena, and Maddina Basalts — were described as being composed of basalt and andesite. The fourth volcanic unit, the Nymerina Basalt (now included within the lower part of the Maddina Basalt), was described as composed mainly of basalt, but including local units of tuff and rare rhyolite. Thorne and Tyler (1997a) found that separation of the Nymerina and Maddina Basalts is difficult over large areas where an intervening sedimentary formation, the Kuruna Siltstone (Hickman, 1983), is absent. Consequently, they redefined the Maddina Basalt to include all rocks previously separately assigned to the Nymerina Basalt, Kuruna Siltstone, and Maddina Basalt. Kojan and Hickman (1998) used airborne-gamma ray imagery, petrography, and whole-rock geochemical data to argue that two distinct mafic–felsic volcanic cycles are present within the redefined Maddina Basalt (Thorne and Tyler, 1997a). These cycles are interpreted to coincide with the previously recognized Nymerina and Maddina Basalts. Kojan and Hickman (1998) observed that regional airborne-gamma ray data across the west and east Pilbara indicate that andesite and dacite are widespread in the upper parts of the Kylena and Maddina Basalts, and therefore renamed these units as the Kylena and Maddina Formations. Thorne and Trendall (2001, p. 220) stated that, on a regional scale, most of the lavas of the Fortescue

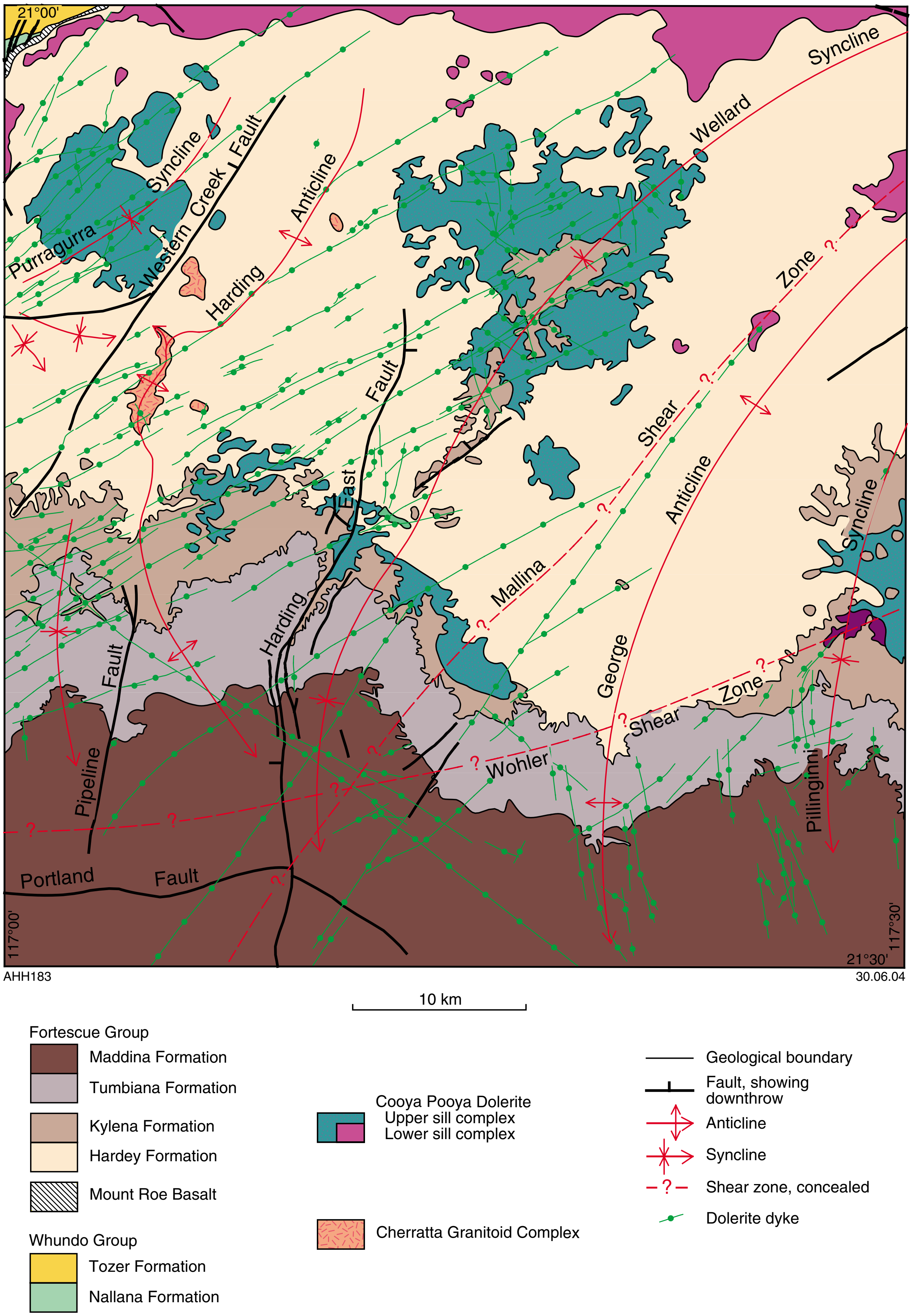

Figure 4. Stratigraphy and structural geology of Cooya Pooya

Table 1. Archaean lithostratigraphy of COOYA POOYA

Group	*Formation*	*Thickness (m)*	*Lithology and relationships*
Fortescue	Maddina Formation	700–1 100	Massive and amygdaloidal basalt, basaltic andesite, andesite, dacite, and rhyolite. Age 2717 ± 2 Ma
	Tumbiana Formation	200	Sandstone, siltstone, basaltic and andesitic tuff and tuffaceous units, and stromatolitic limestone and dolomite. Age 2719 ± 6 Ma
~ ~ ~ *local unconformity* ~ ~ ~			
	Kylena Formation	0–200	Massive and amygdaloidal basalt, basaltic andesite, andesite, dacite, and rhyolite; local high-Mg basalt
	Cooya Pooya Dolerite	0–150 (combined thickness of sills)	Dolerite sills, with local xenoliths of quartzite. Intrudes the Hardey Formation and lower Kylena Formation
	Hardey Formation	0–1 000	Sandstone, conglomerate, siltstone, shale, and ultramafic lava (Coolajacka Member) overlain by andesitic to dacitic tuff and agglomerate (Lyre Creek Member). Age c. 2760 Ma
~ ~ ~ *unconformity* ~ ~ ~			
	Mount Roe Basalt	0–200; possibly 500 in northeast (concealed)	Massive, vesicular, and glomeroporphyritic basalt. Age c. 2770 Ma
~ ~ ~ *regional unconformity* ~ ~ ~			
Bookingarra (concealed)	Kialrah Rhyolite	0–1 000	Feldspar-phyric, commonly flow-banded rhyolite. Maximum age c. 2975 Ma. Overlies or intrudes Louden Volcanics
	Mount Negri Volcanics	0–1 000	Variolitic and vesicular basalt
	Louden Volcanics	0–1 000	High-Mg basalt with pyroxene spinifex texture, and undivided massive and pillow basalt
	Rushall Slate	0–300	Laminated shale and siltstone, locally graphitic, and minor sandstone. Includes the Comstock Member, comprising high-Mg and vesicular basalt
	Cistern Formation	0–800	Clastic and volcaniclastic rocks, including wacke, sandstone, siltstone, and conglomerate. Age <2978 ± 5 Ma
~ ~ ~ *unconformity* ~ ~ ~			
Whim Creek (concealed)	Red Hill Volcanics	0–500	Felsic volcanic and volcaniclastic rocks, and dacite intrusions. Age c. 3009 Ma
	Warambie Basalt	0–500	Vesicular and amygdaloidal basalt, pyroclastic units, hyaloclastite, and local pillow basalt. Basal polymictic conglomerate and sandstone
~ ~ ~ *high-angle regional unconformity* ~ ~ ~			
Whundo	Woodbrook Formation (concealed)	1 000	Rhyolite tuff and agglomerate, and minor basalt and thin banded iron-formation. Age 3117 ± 3 Ma
	Bradley Basalt (concealed)	>4 000	Pillow basalt, massive basalt, and minor units of felsic tuff, tuffaceous sedimentary rocks, and chert. Age 3115 ± 5 Ma
	Tozer Formation	2 000	Calc-alkaline volcanic rocks, including felsic pyroclastic units. Minor chert and very thin banded iron-formation. Age c. 3120 Ma
	Nallana Formation	200	Dominantly basalt. Age 3125 ± 4 Ma. Base of formation intruded by 3130 Ma granitoids and truncated by Maitland Shear Zone
~ ~ ~ *tectonic contact along Maitland Shear Zone* ~ ~ ~			

Group are basaltic andesite rather than basalt, and acknowledged the evidence of Kojan and Hickman (1998) from PINDERI HILLS that andesite, dacite, and rhyolite form parts of the Kylena and Maddina Formations.

Felsic volcanic rocks have also been mapped at other stratigraphic levels of the Fortescue Group. In the west Pilbara, Kriewaldt and Ryan (1967) mapped felsic volcanic rocks of the 'Lyre Creek Agglomerate Member' of the 'Cliff Springs Formation' between the Mount Roe Basalt and the Kylena Formation. The Cliff Springs Formation was later correlated with the Hardey Formation (Hickman, 1983). The Kylena and Maddina Formations are separated by the Tumbiana Formation (Table 1), which, being dominated by well-bedded sedimentary and volcaniclastic rocks, is an exceptionally good stratigraphic marker unit. At the top of the Fortescue Group, within the dominantly sedimentary Jeerinah Formation (not preserved on COOYA POOYA), Kriewaldt and Ryan (1967) discovered a felsic volcanic unit, the 'Nallanaring Volcanic Member', which was subsequently dated at 2684 ± 6 Ma (Arndt et al., 1991).

National Geoscience Mapping Accord

The National Geoscience Mapping Accord (NGMA) Pilbara project, between GSWA and the Australian Geological Survey Organisation (AGSO, now Geoscience Australia), commenced in 1995. In that inaugural year, GSWA mapped DAMPIER and SHERLOCK, supported by data from NGMA aeromagnetic and radiometric surveys of the west Pilbara. Other west Pilbara 1:100 000-scale sheets were mapped between 1996 and 1999.

Geological mapping of COOYA POOYA was undertaken during 1999 using 1:25 000-scale colour aerial photography flown during 1998. The mapping was assisted by field interpretation of multispectral Landsat Thematic Mapper images provided by AGSO. Preliminary images generated from high-resolution magnetic and gamma-ray spectrometric data obtained in 1995 (part of the NGMA program) were also used during map compilation. These data were subsequently published by GSWA (Geological Survey of Western Australia, 1995a,b).

Geological mapping of the Kylena and Maddina Formations over extensive inaccessible areas of southern COOYA POOYA was achieved by widely spaced helicopter traverses, following a preliminary geological interpretation of Landsat and radiometric images.

Regional geological setting

COOYA POOYA is located in the northwestern part of the Pilbara Craton, where the northwestern part of the Hamersley Basin unconformably overlies the contact between the West Pilbara Granite–Greenstone Terrane (WPGGT) and the Mallina Basin (Figs 1 and 3). Outcrops of the WPGGT are restricted to a small area of greenstones in the northwestern corner of COOYA POOYA, and small inliers of granitic rocks in the northwestern part of the sheet area. The Mallina Basin is concealed on COOYA POOYA (Figs 4 and 5; see diagrammatic section on the map).

As discussed below, there is strong geological and geophysical evidence that the Fortescue Group of northeastern COOYA POOYA conceals a greenstone belt linking the Whim Creek greenstone belt of SHERLOCK and ROEBOURNE with the Sholl greenstone belt of ROEBOURNE, DAMPIER, and PINDERI HILLS. These concealed greenstones are interpreted to include thick sections of the Bookingarra, Whim Creek, and Whundo Groups (Fig. 5; Table 1). Although dominantly basaltic, elsewhere these groups include economically important felsic volcanic and sedimentary formations on PINDERI HILLS, with the c. 3120 Ma volcanic-hosted massive sulfide (VHMS) Cu–Zn mineral deposits in the Tozer Formation of the Whundo Group, and SHERLOCK, with the c. 2960 Ma VHMS Cu–Pb–Zn mineral deposits in the Rushall Slate and Cistern Formation of the Bookingarra Group. Two linear magnetic anomalies in northeastern COOYA POOYA could indicate concealed mafic–ultramafic intrusions similar to the Munni Munni Intrusion of PINDERI HILLS.

Lithostratigraphy and geological history

The lithostratigraphy of COOYA POOYA is summarized in Table 1, and its evolution is outlined within the context of the area's geological history in Table 2. The greenstones in northwestern COOYA POOYA (Fig. 4) form a small part of the c. 3130–3115 Ma Whundo Group, which was probably deposited in a rift setting (Hickman, 2004b). Northeastern COOYA POOYA is also interpreted to be underlain by the Whundo Group (Fig. 5), but probably at depths exceeding 1 km. The original stratigraphic base of the Whundo Group is not exposed, but Sm–Nd isotopic data (Sun and Hickman, 1998) indicate that the succession is not underlain by crust older than c. 3240 Ma. The group is in faulted contact with the Cherratta Granitoid Complex on PINDERI HILLS, and this major structure, the Maitland Shear Zone, is interpreted to extend eastwards beneath northwestern COOYA POOYA (Fig. 5). The Cherratta Granitoid Complex was largely emplaced during two thermotectonic events (Hickman, 2004b). The older of these, a tonalite–granodiorite suite contemporaneous with the Whundo Group, contains isotopic evidence of pre-existing c. 3170–3150 Ma felsic crust, probably formed during a pre-Whundo Group phase of rifting between the WPGGT and the East Pilbara Granite–Greenstone Terrane (Hickman, 2001). Granitic intrusions of this age have been dated on the opposite, southeastern margin of the zone of rifting (Nelson, 2000). Much of the Cherratta Granitoid Complex is composed of c. 3006–2982 Ma granitic intrusions that also dominate the other granitoid complexes of the west Pilbara, and are probably related to arc volcanism of the c. 3000 Ma Whim Creek Group (not exposed on COOYA POOYA).

The Fortescue Group of the Mount Bruce Supergroup is a continental succession of volcanic and sedimentary rocks that unconformably overlies the Whundo Group, the Cherratta Granitoid Complex, and the Mallina Basin. Deposition of the Fortescue Group commenced at c. 2770 Ma (Arndt et al., 1991; Nelson et al., 1999). The regional extent and angularity of this unconformity attest to major erosion of the WPGGT and Mallina Basin between 2940 and 2770 Ma. On COOYA POOYA, volcanic formations of the Fortescue Group include basalt, basaltic

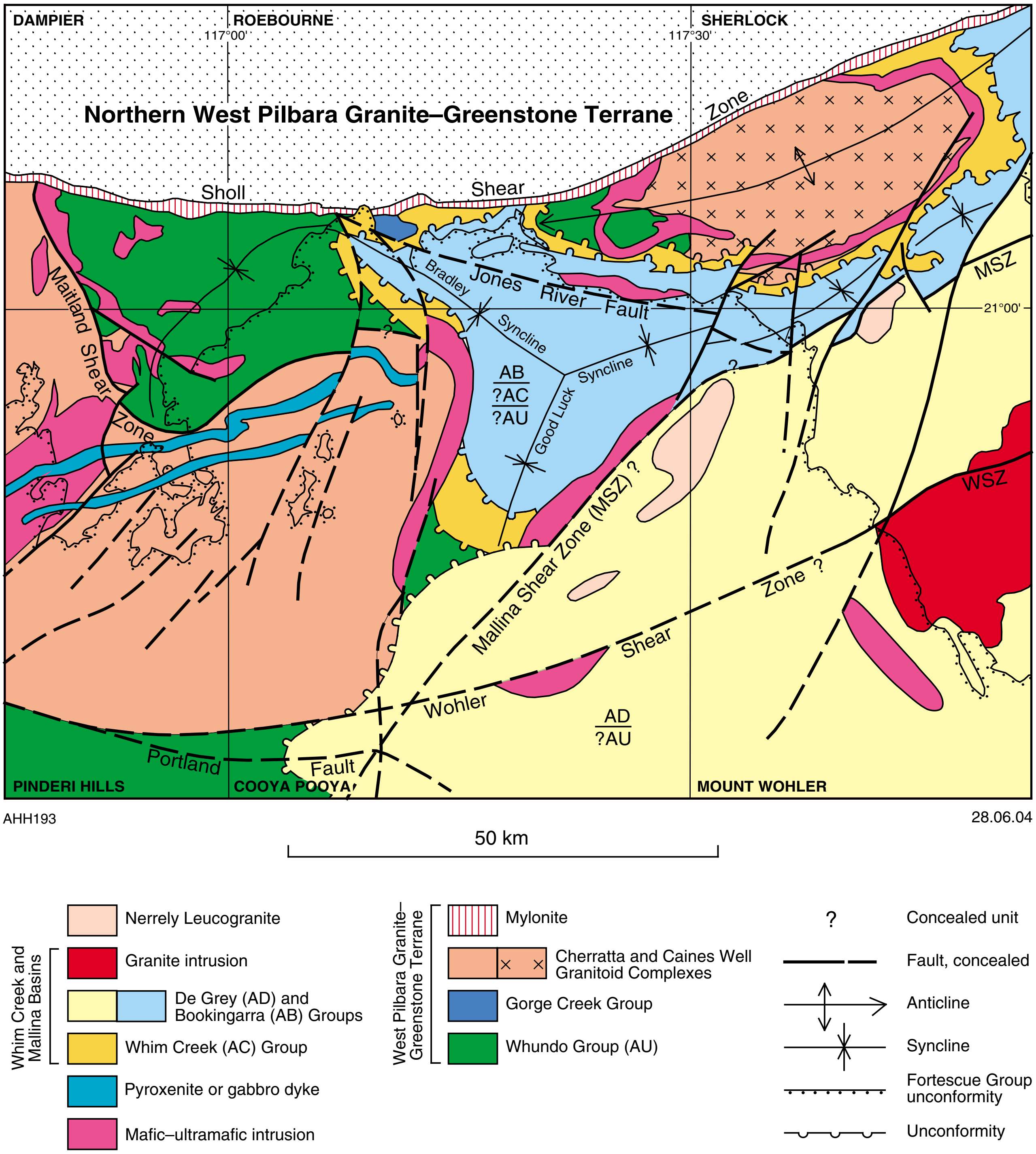

Figure 5. Pre-Fortescue Group geology of Cooya Pooya and adjacent areas, based on outcrop geology of the WPGGT, and Mallina and Whim Creek Basins, and geophysical interpretation of data (Figs 6 and 7) from areas covered by the Fortescue Group. Note that the northeastern part of Cooya Pooya is interpreted to be underlain by a greenstone syncline containing dominantly basaltic units of the Bookingarra, Whim Creek, and Whundo Groups. This area coincides with a strong positive gravity anomaly in Figure 7

Table 2. Summary of the geological history of Cooya Pooya, with reference to adjacent areas

Age (Ma)	*Geological event*
3130–3090	Deposition of the Whundo Group (c. 3130–3115 Ma); intrusion of c. 3130–3090 Ma granitoids in the Cherratta Granitoid Complex
3015	D_3: North–south thrusting of Whundo Group onto the Cherratta Granitoid Complex
3010–2990	Extensive intrusion of granitoids throughout the WPGGT, including the Cherratta Granitoid Complex, and volcanism of the Whim Creek Group (not exposed on Cooya Pooya); possibly related to a northeasterly trending volcanic arc
2970–2950	Deposition of the Bookingarra and De Grey Groups (Mallina Basin, not exposed on Cooya Pooya)
2945–2930	D_4: Transpressional, northeasterly trending tight to open folding of the Whundo Group
2940–2930	D_5: Westerly to northwesterly striking strike-slip faulting along the Maitland Shear Zone
2920–2770	Erosion
2770–2720	D_{10}(early): North-northeasterly trending rifting of the WPGGT, and deposition of the Mount Roe Basalt and Hardey Formation (2770–2760 Ma); intrusion of dolerite and pyroxenite dykes. Deposition of the Kylena Formation (post-2750 Ma), accompanied by intrusion of the Cooya Pooya Dolerite. Open folding about northeasterly trending axes
2720–2700	Erosion, followed by deposition of the Tumbiana and Maddina Formations. Continuation of D_{10} open folding about northeasterly trending axes
1830–1780	D_{11}: Capricorn Orogeny D_2. Open folding of the upper Fortescue Group about northwesterly trending axes. Movement on the Portland Fault. Intrusion of west-northwesterly trending dolerite dykes
755	Intrusion of east-northeasterly trending dolerite dykes (Mundine Well Suite)
545–65	Palaeozoic and Mesozoic erosion
55–present	Uplift and dissection of plateau surface, deposition of Cainozoic units

komatiite, basaltic andesite, andesite, dacite, and minor rhyolite, mainly as lava flows, but locally including basaltic to rhyolitic pyroclastic rocks. Sedimentary rocks dominate the Hardey and Tumbiana Formations of the Fortescue Group.

Blake (1993) and Nelson et al. (1999) described the volcanic rocks of the Fortescue Group as flood basalts. Thorne and Trendall (2001, p. 220) described the Mount Roe Basalt, and the Kylena and the Maddina Formations of the northern Pilbara as principally composed of subaerial to shallow marine mafic lavas similar to those of Phanerozoic flood basalt provinces. Thorne and Trendall (2001) agreed with Blake (1993) in explaining the felsic volcanic rocks of the Hardey Formation in the northeast and northwest Pilbara as being related to major north-northeasterly trending faults. They argued against the Fortescue Group being a plume-related continental flood basalt province, partly on the basis of its lithological diversity and partly on the duration of deposition (about 140 million years). However, Arndt et al. (2001) attributed Fortescue Group volcanism to melting of the lithosphere above three successive mantle plumes.

Thorne and Trendall (2001) concluded that the Hamersley Basin formed by lithospheric stretching, and evolved from rift-related volcanism and sedimentation to deposition on a subsiding, passive continental margin. The tectonic model preferred by Thorne and Trendall (2001) involved protracted north–south or north-northeast–south-southwest crustal extension related to a major rift along the present-day southern Pilbara margin. In this model, north-northeasterly trending rifts in the northern Pilbara are interpreted to have formed at a high angle to the principal east-southeasterly trending rift of the southern Pilbara, probably analogous to a failed rift arm.

Geochronology

Precise U–Pb zircon SHRIMP geochronology from Cooya Pooya and adjacent areas is summarized in Table 3, and age data within the lithostratigraphy are provided in Table 1. The U–Pb data, which indicate crystallization ages of granitoids or volcanic rocks, are used in the map legend, and are referred to throughout these Notes.

Structure

The Whundo Group contains structures that formed before the Hamersley Basin. Information from more extensive outcrops on Pinderi Hills (Hickman and Kojan, 2003) and Roebourne (Hickman, 2002) indicates that structures of three pre-Hamersley Basin deformation events are present in northwestern Cooya Pooya. Within the tectonic history of the entire WPGGT, as reviewed by Van Kranendonk et al. (2002) and Hickman (2004b), these structures are assigned to the D_3, D_4, and D_5 events. D_3 included c. 3015 Ma north–south thrusting of the Whundo Group onto c. 3115 Ma parts of the Cherratta Granitoid Complex (Hickman and Kojan, 2003); D_4 involved c. 2945–2930 Ma transpressional, northeasterly trending, tight to open folding; and D_5 was expressed as c. 2940–2930 Ma strike-slip faulting along the Maitland Shear Zone. Figure 5 interprets aeromagnetic data from northeastern Cooya Pooya (Fig. 6) to indicate that a concealed greenstone syncline links the D_4 Bradley Syncline of Pinderi Hills,

Table 3. SHRIMP U–Pb zircon geochronology data for Cooya Pooya and adjacent parts of Pinderi Hills

Age (Ma)	*Lithology, stratigraphic unit*	*Location (MGA)* *Easting*	*Northing*	*Sample*	*Reference*
3130 ± 4	Tonalite, Cherratta Granitoid Complex	49250	766400	142835	Nelson (1999)
3114 ± 5	Granodiorite, Cherratta Granitoid Complex	48949	766567	JS33	Smith et al. (1998)
3068 ± 6	Tonalite, Cherratta Granitoid Complex	48646	766175	142661	Nelson (1998)
3013 ± 4	Monzogranite, Cherratta Granitoid Complex	49193	766728	JS35	Smith et al. (1998)
3006 ± 12	Monzogranite, Cherratta Granitoid Complex	51919	766499	168932	Nelson (2001)
2990 ± 3	Granodiorite, Cherratta Granitoid Complex	47895	766455	142657	Nelson (1999)
2988 ± 4	Granodiorite, Cherratta Granitoid Complex	48610	766835	142438	Nelson (1999)
2988 ± 7	Monzogranite, Cherratta Granitoid Complex	48646	766175	168934	Nelson (2001)
2925 ± 16	Pegmatite, Munni Munni Intrusion	48456	766508	103227	Arndt et al. (1991)
2924 ± 5	Microgranite, Munni Munni Intrusion	48545	766475	142436	Nelson (1998)
2719 ± 6	Tuffaceous siltstone, Tumbiana Formation	50687	763551	168934	Nelson (2001)
2717 ± 2	Dacite, Maddina Formation	47540	762410	144993	Nelson (1998)
2715 ± 6	Tuffaceous siltstone, Tumbiana Formation	52114	764145	94775	Arndt et al. (1991)

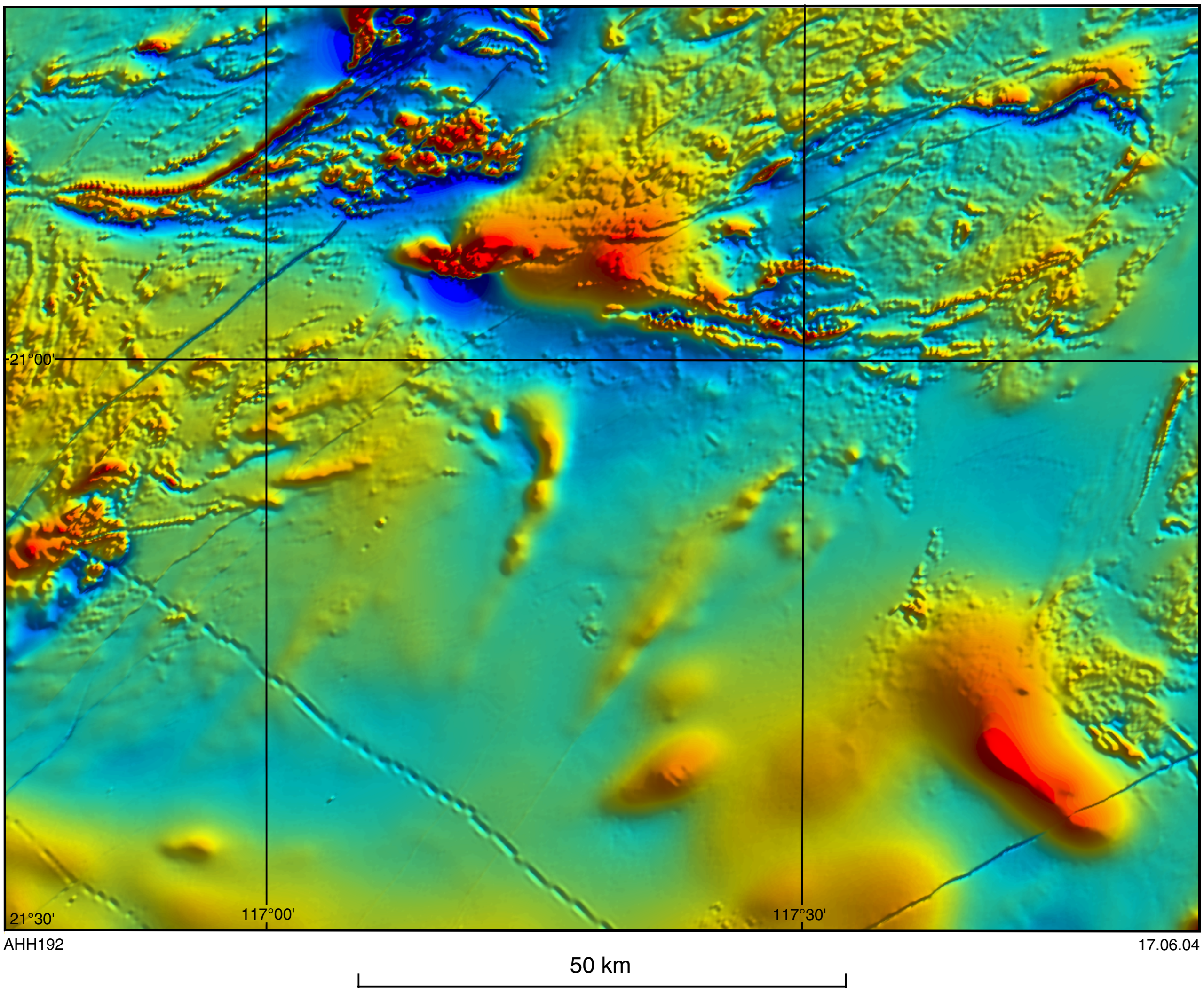

Figure 6. Total magnetic intensity image of Cooya Pooya and adjacent areas (area covered by Fig. 5). Data from Geological Survey of Western Australia (1995b)

DAMPIER, and ROEBOURNE with the D_3 (Mallina Basin structural scheme: Smithies, 1998a,b) Good Luck Syncline on SHERLOCK. Bouguer gravity anomalies suggest another syncline (D_4 in the WPGGT structural scheme) trending south or south-southwest, approximately underlying the D_{10} (see below) Wellard Syncline (Fig. 4).

The lower part of the Hamersley Basin succession on COOYA POOYA was deformed by structures related to c. 2770–2720 Ma northeasterly trending rifting and open folding (D_{10} as defined by Hickman and Kojan, 2003). Mapping of COOYA POOYA led to recognition of an angular unconformity directly beneath the c. 2719 Ma Tumbiana Formation. However, northeasterly trending open folding (late D_{10}) resumed after deposition of the Tumbiana and c. 2717 Ma Maddina Formations, suggesting that this unconformity is a local feature. The Portland Fault, in southwestern COOYA POOYA, is interpreted to have formed at c. 1830–1780 Ma, related to the Capricorn Orogeny in the Capricorn Orogen to the south of the Pilbara Craton, and overlies an earlier fault formed during D_{10} rifting (Hickman and Kojan, 2003).

Archaean geology

Archaean rocks exposed on COOYA POOYA form parts of the WPGGT and Hamersley Basin (Fig. 1).

West Pilbara Granite–Greenstone Terrane

The WPGGT comprises an Archaean supracrustal succession of metamorphosed volcanic, sedimentary, and intrusive rocks (generally referred to as ‘greenstones’) that has been intruded by major granitoid complexes (Fig. 1). The greenstone succession on COOYA POOYA was assigned to the Whundo Group by Hickman (1997) but, to preserve continuity with previously published maps (DAMPIER, ROEBOURNE, and PINDERI HILLS), the greenstones of the Whundo Group on COOYA POOYA were mapped lithologically rather than stratigraphically. No age relationships are implied by the vertical arrangement of units bracketed as ‘Pilbara Supergroup, no stratigraphic subdivision’ in the map legend. Granitic rocks of the Cherratta Granitoid Complex are described separately.

Pilbara Supergroup (no stratigraphic subdivision)

Ultramafic rock (Au)

Undivided metamorphosed ultramafic rock (*Au*) forms a narrow outcrop between two units of grey and white banded chert (*Acw*) in northwestern COOYA POOYA. The ultramafic rock is schistose and extensively altered (carbonated and silicified), and its protolith is uncertain.

Mafic volcanic rocks (Ab, Aba)

Undivided basaltic rock (*Ab*) forms about half of the small area of greenstones in northwestern COOYA POOYA. The unit includes massive and pillowed basalt metamorphosed to greenschist facies. Vesicles in the pillows are filled with quartz, carbonate minerals, or chlorite. Flow tops are generally difficult to recognize except where there are interflow sedimentary rocks or where flow-top breccias are silicified and epidotized. Most basalt is a fine-grained assemblage of amphibole (actinolite, tremolite, or hornblende), quartz (largely secondary), albite, epidote, chlorite, and minor sericite, sphene, clinozoisite, carbonate minerals, and unidentified opaque minerals. The basaltic rock (*Ab*) on COOYA POOYA is mainly assigned to the Tozer Formation of the Whundo Group, but the stratigraphically lowest basalt (adjacent to the Mount Roe Basalt; *AFr*) is part of the Nallana Formation (Hickman, 1997).

Foliated amphibolite-facies metabasalt (*Aba*) does not outcrop within the map sheet area, but is interpreted to underlie much of northwestern COOYA POOYA as shown on the diagrammatic section. Data from outcrops on ROEBOURNE and PINDERI HILLS indicate that the amphibolite is composed of a randomly oriented assemblage of secondary amphibole and altered plagioclase, with minor chlorite, quartz, calcite, sphene, phlogopite, rutile, and opaques.

Felsic tuff (Aft)

On COOYA POOYA, metamorphosed felsic tuff (*Aft*) is intercalated with undivided basaltic rock (*Ab*), and ranges in composition from andesite to rhyolite. The felsic tuff is lithostratigraphically assigned to the Tozer Formation of the Whundo Group (Hickman, 1997), which includes calc-alkaline volcanic assemblages. In thin section, it consists of devitrified felsic glass, with abundant chlorite, minor quartz and feldspar, and accessory leucoxene, titanite, zircon, carbonate, and sericite.

Grey and white banded chert (Acw)

Two units of grey and white banded chert (*Acw*) outcrop in northwestern COOYA POOYA, and could be silicified interflow fine-grained clastic sedimentary rocks rather than primary chemical sedimentary deposits. Layers of grey and white chert alternate at 5 to 20 mm intervals.

Quartz–feldspar porphyry (Apf)

Quartz–feldspar porphyry (*Apf*), of rhyolitic or dacitic composition, forms a single small intrusion in the northwestern corner of COOYA POOYA. The porphyry forms similar small intrusions on southwestern ROEBOURNE, where Hickman (2002) described the rock as consisting of plagioclase, quartz, and K-feldspar, with minor chlorite, and rare epidote, carbonate, sericite, and zircon.

Granitoid rocks

Cherratta Granitoid Complex (AgC, AgCm)

The small inliers of the Cherratta Granitoid Complex in northwestern COOYA POOYA are composed of syenogranite and monzogranite (*AgCm*), locally including biotite monzogranite, granodiorite, and late-stage microgranite veins and sheets. Undivided syenogranite to tonalite (*AgC*) is shown on the diagrammatic section, but does not outcrop on COOYA POOYA. Elsewhere, particularly adjacent to the Maitland Shear Zone on PINDERI HILLS, the undivided syenogranite to tonalite (*AgC*) includes granitic gneiss with mafic xenoliths.

Granitic samples from two of the four inliers on COOYA POOYA were dated by the SHRIMP U–Pb zircon method (Nelson, 2001). A sample of biotite monzogranite collected 3 km west-northwest of Waloo Waloo Pool (GSWA 168934) has been dated at 2988 ± 7 Ma, interpreted as the maximum age of igneous crystallization, and porphyritic granodiorite collected from a small inlier 1 km northwest of Mardeburra Pool (GSWA 168932) was dated at 3006 ± 12 Ma, interpreted to be the age of igneous crystallization. Neither sample had simple zircon populations, with the oldest xenocrystic zircons indicating partial inheritance from 3279–3266 Ma rocks. The monzogranite near Waloo Waloo Pool is locally porphyritic and compositionally banded, but is not visibly foliated. In thin section, it consists of similar amounts of plagioclase and microcline (30–35% each by volume), about 25% quartz, minor biotite (about 5%), and sparse muscovite. Accessory minerals include magnetite, leucoxene, apatite, epidote, carbonate, prehnite, and zircon. Plagioclase is partly saussuritized, and biotite is chloritized. The monzogranite locally contains thin veins of leucogranite, and it is possible that 2988 ± 7 Ma is the age of these late veins rather than the crystallization age of the monzogranite; in this less favoured interpretation, a 3050 ± 8 Ma zircon population would date the crystallization age of monzogranite (Nelson, 2001). The biotite granodiorite of the Mardeburra Pool inlier is foliated, and weakly compositionally banded. In thin section, the rock is composed of plagioclase (50% by volume), quartz, microcline, and K-feldspar phenocrysts. Biotite (about 5% by volume) has been altered to chlorite or smectite. Epidotization of the granitic rocks is locally common directly beneath the unconformity of the overlying Hardey Formation.

About 3 km west-northwest of Petrov Well, the most northwesterly of the four inliers includes a 1 km^2 outcrop containing angular blocks of granitic rock and pegmatite within a biotite granite. The age and origin of this unit are uncertain: it could be an intrusion breccia at the contact of separate granitic bodies, an explosion breccia (possibly adjacent to a concealed vent of the Lyre Creek Member, Hardey Formation), or a tectonically brecciated granite close to the Western Creek Fault (Fig. 4).

Mafic and ultramafic intrusive rocks (no stratigraphic subdivision)

Metamorphosed gabbro, dolerite, and pyroxenite (Ao, Aod, Aol, Aux)

Metadolerite (*Aod*) and metamorphosed leucogabbro (*Aol*) outcrop on northwestern COOYA POOYA, but aeromagnetic data indicate that metagabbro (*Ao*) and metapyroxenite (*Aux*) form dykes concealed beneath the Fortescue Group (see diagrammatic section on map). Metamorphosed dolerite (*Aod*) occupies a single sill within the volcanic rocks of the Whundo Group, whereas metamorphosed leucogabbro (*Aol*) on COOYA POOYA is merely the most easterly exposure of a large dyke or stock. This intrusion is related to a large west-northwesterly trending composite dyke (also contains metagabbro), up to 1 km wide, on PINDERI HILLS. This dyke post-dates the c. 2925 Ma mafic–ultramafic Maitland and Radio Hill intrusions, but is unconformably overlain by the Fortescue Group.

Metagabbro (*Ao*) and metapyroxenite (*Aux*) are components of major westerly trending dykes that intrude the c. 2925 Ma Munni Munni Intrusion, and are unconformably overlain by the c. 2760 Ma Hardey Formation. In outcrop, these rocks are massive and jointed at 0.5–2 m intervals. In thin section, metagabbro (*Ao*) is typically a hypidiomorphic assemblage of saussuritized plagioclase, pyroxene (variably replaced by actinolite and chlorite), and hornblende, with accessory sphene and carbonate, and quartz. Metapyroxenite (*Aux*) is dominated by pyroxene, variably replaced by actinolite or tremolite, serpentine, chlorite, epidote, and minor carbonate, with minor plagioclase that is partly replaced by sericite, epidote, carbonate, and clinozoisite.

Structure of the West Pilbara Granite–Greenstone Terrane

Outside COOYA POOYA, the structural history of the WPGGT has been reviewed in terms of seven deformation events (Van Kranendonk et al., 2002; Hickman, 2004b). Only sections of the WPGGT are exposed on COOYA POOYA, and the structural geology of these is relatively simple. The metamorphosed volcanic and sedimentary rocks in the northwestern part of the sheet area dip northwesterly at about 60°, and are right-way-up. This succession lies on the southeastern limb of the Bradley Syncline (Hickman, 2001), a major northeasterly plunging fold that formed at c. 2945–2930 Ma during the fourth deformation event (D_4) of the WPGGT (Van Kranendonk et al., 2002). D_1 and D_2 events pre-date the Whundo Group, and are therefore absent from the sheet area. D_3 thrusting (c. 3015 Ma) and D_5 strike-slip faulting (c. 2940–2930 Ma), exposed south of Whundo on PINDERI HILLS (Hickman and Kojan, 2003), are interpreted to be concealed beneath the Fortescue Group in northwestern COOYA POOYA (Fig. 5; see diagrammatic section on map), but structures of these events are absent from outcrops of the Whundo Group on the sheet area. Of the four Cherratta Granitoid Complex inliers on COOYA POOYA, only the one near Mardeburra Pool exposes moderately foliated granitic rock. The foliation in the biotite granodiorite of the Mardeburra Pool inlier is inclined 65° towards the north-northeast, an orientation that on PINDERI HILLS (Hickman and Kojan, 2003) would be consistent with it being either S_3 (thrust-related) or S_5 (strike-slip). However, because the interpreted age of S_3 is c. 3015 Ma (Van Kranendonk et al., 2002), and the granodiorite at Mardeburra Pool was dated at 3006 ± 12 Ma (Nelson, 2001), the foliation is more probably S_5 (D_5 at c. 2940–2930 Ma). This interpretation implies that the Mardeburra Pool inlier could expose granitic rocks relatively close to the concealed Maitland Shear Zone because strike-slip foliations related to this structure on PINDERI HILLS are restricted to rocks within a

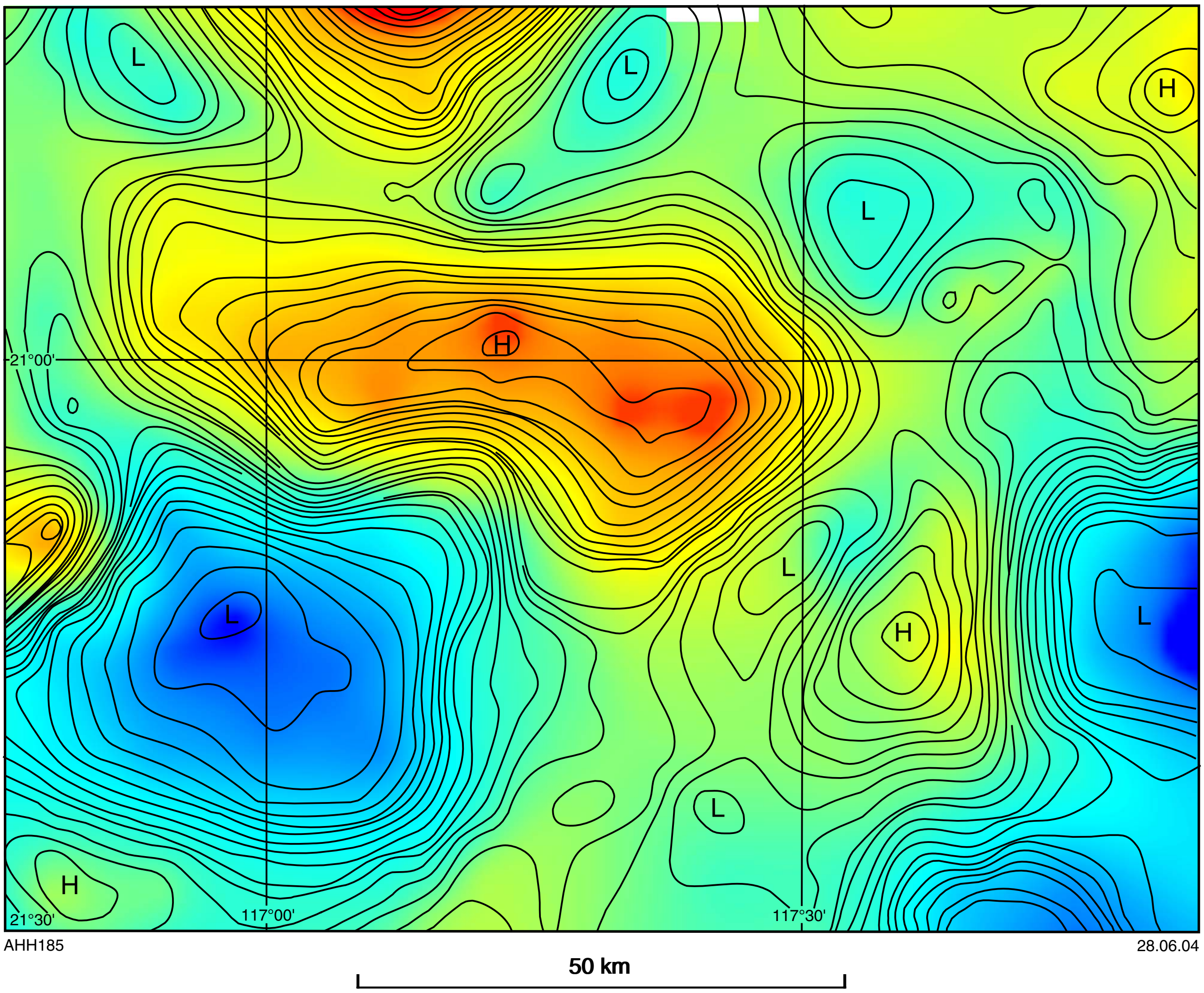

Figure 7. Bouguer gravity anomaly plot for Cooya Pooya and adjacent areas (area covered by Fig. 5). Contour interval is 20 μm/s². Data from Blewett et al. (2000), and reproduced with permission of Geoscience Australia

few kilometres of the fault. Zircon age data from the granodiorite are consistent with its proximity to the Maitland Shear Zone because the rock contains a large zircon population dated at 3127 ± 8 Ma (Nelson, 2001). This is the approximate age of the Whundo Group and its related granitoids, which on Pinderi Hills are tectonically interleaved along the shear zone. In contrast, the Waloo Waloo Pool monzogranite contains no xenocrystic zircons of this age.

The Fortescue Group on Cooya Pooya conceals the contact between the WPGGT and the Mallina Basin. The contact is interpreted from regional gravity data (Fig. 7) to trend northeast across the centre of the sheet area (Fig. 5), and was probably initially controlled by a fault, or zone of faults (southeast-side-down), formed during rifting of the Mallina Basin at c. 2970–2955 Ma (Van Kranendonk et al., 2002). The diagrammatic section on the map shows the contact as intrusive between the Cherratta Granitoid Complex and metasedimentary rocks of the De Grey Group. Late components of the Cherratta Granitoid Complex, like granitic intrusions of the Mallina Basin, include c. 2950–2935 Ma intrusions.

Metamorphism of the West Pilbara Granite–Greenstone Terrane

Greenstone xenoliths within the Cherratta Granitoid Complex and greenstones of the Whundo Group just north of the Maitland Shear Zone have been metamorphosed to amphibolite facies, but most of the Whundo Group has been metamorphosed to greenschist facies. Granitoids of the Cherratta Granitoid Complex show evidence of retrogression from amphibolite facies.

Mallina Basin

The Mallina Basin is a rift-controlled, dominantly clastic sedimentary basin that overlies the contact between the WPGGT and the East Pilbara Granite–Greenstone Terrane (Smithies, 1997; Smithies et al., 2001; Van Kranendonk et al., 2002). East of Cooya Pooya, the Mallina Basin is about 70 km wide and extends for about 200 km to the northeast. Gravity data (Blewett et al., 2000) indicate that the basin continues southwestwards, beneath the Fortescue

Group of MOUNT WOHLER, COOYA POOYA, and MILLSTREAM, beyond which a low-density ridge suggests it is faulted against, or intruded by, granitic rocks. The c. 2970–2930 Ma clastic succession that fills the basin is assigned to the De Grey Group.

De Grey Group (*AD*)

The De Grey Group is a succession of metamorphosed sandstone, conglomerate, siltstone, shale, and wacke (*AD*). This succession does not outcrop on COOYA POOYA, but is interpreted to underlie the Fortescue Group in the southeastern part of the sheet area (Fig. 5; see diagrammatic section on map). The contact between the De Grey Group and WPGGT on COOYA POOYA could be faulted or intrusive (see **Structure of the West Pilbara Granite–Greenstone Terrane**).

Hamersley Basin

The Hamersley Basin is a Neoarchaean to early Palaeoproterozoic tectonic unit that unconformably overlies the WPGGT and all other terranes of the Pilbara Craton. The lithostratigraphy of the Hamersley Basin consists of three groups that together constitute the Mount Bruce Supergroup. Only the oldest group of this succession, the Fortescue Group, is preserved on COOYA POOYA, and this group is entirely Archaean in age. Thorne and Trendall (2001) described four Fortescue Group sub-basins within the Hamersley Basin and, using this scheme, COOYA POOYA is located in the centre of the northwest Pilbara sub-basin.

Fortescue Group

The Fortescue Group is a succession of volcanic and sedimentary rocks, up to 6.5 km thick, that covers about 40 000 km^2 of the Pilbara Craton (Thorne and Trendall, 2001), and ranges in age from c. 2770 to 2630 Ma (Arndt et al., 1991; Nelson et al., 1992, 1999; Wingate, 1999; Thorne and Trendall, 2001). On COOYA POOYA, all rocks in the Fortescue Group are metamorphosed to prehnite–pumpellyite facies (Smith et al., 1982). The contact between the Fortescue Group and the WPGGT is an angular unconformity (see diagrammatic section on map).

The Fortescue Group on COOYA POOYA comprises a mixed assemblage of mafic to felsic volcanic and sedimentary rocks, and is subdivided into the Mount Roe Basalt and the Hardey, Kylena, Tumbiana, and Maddina Formations. The volcanic rocks of the Mount Roe Basalt and Hardey Formation in the lower part of the Fortescue Group are bimodal (Arndt et al., 1991), whereas volcanic rocks within the Kylena, Tumbiana, and Maddina Formations represent four phases of mafic to felsic volcanism, and exhibit mixed calc-alkaline and tholeiitic affinities (Kojan and Hickman, 1998).

Blake (1993), and Thorne and Trendall (2001) discussed the regional stratigraphy and tectonic evolution of the Fortescue Group. An important feature is the extent to which regional faults controlled the locations of depositional basins. Blake (1993) emphasized this by pointing out that deposition of the lower part of the Fortescue Group took place in several north-northeasterly trending rifts formed by west-northwest–east-southeast extension. Some of the faults were pre-Fortescue Group structures that were reactivated at c. 2770 Ma. In the west Pilbara, GSWA mapping has provided additional evidence in support of fault-controlled deposition for the Mount Roe Basalt and the Hardey Formation (Hickman, 2002; Hickman and Kojan, 2003).

Arndt et al. (2001) attributed Fortescue Group volcanism to melting of the lithosphere above three successive mantle plumes. However, Thorne and Trendall (2001) argued against the Fortescue Group being a plume-related continental flood-basalt province, partly on the basis of its lithological diversity and partly on the duration of deposition (about 140 million years).

Mount Roe Basalt (AFr)

On COOYA POOYA, the Mount Roe Basalt is restricted to an outcrop of massive, vesicular, and glomeroporphyritic basalt (*AFr*) that unconformably overlies the Whundo Group in the northwestern corner of the sheet area. In thin section, vesicular basalt typically contains rare, squat subhedral phenocrysts of plagioclase and clinopyroxene, and vesicles filled by quartz and calcite, in a groundmass rich in plagioclase laths, with interstitial chlorite and epidote (after mafic phases and glass). The glomeroporphyritic rocks differ from the vesicular variety only in that they contain abundant clots of plagioclase, up to 2 cm in size. Both the vesicular and glomeroporphyritic basalt show local development of pillows. Some outcrops of basalt show extensive brecciation and development of hyaloclastite that, together with the presence of pillowed basalt, indicate deposition in a subaerial to shallow marine environment.

Hardey Formation (AFh, AFhc, AFhs, AFhft, AFhy, AFhyr, AFhj)

The Hardey Formation (*AFh*) conformably or disconformably overlies the Mount Roe Basalt in the northwestern corner of COOYA POOYA, and unconformably overlies granitic rocks of the WPGGT in the central western part of the sheet area; it forms about 40% of Archaean outcrop and subcrop on COOYA POOYA (Fig. 4). This formation is present in all Fortescue Group sub-basins of the Hamersley Basin, although its thickness and composition vary considerably (Thorne and Trendall, 2001). Geochronological data from several areas outside COOYA POOYA indicate that the formation was deposited at c. 2760 Ma (Arndt et al., 1991).

On COOYA POOYA, the Hardey Formation comprises three distinct lithofacies: sandstone, conglomerate, siltstone and shale (*AFh, AFhc, AFhs*), with minor tuff (*AFhft*) in the lower part of the formation; ultramafic lava (*AFhj*) of the Coolajacka Member in the middle of the formation; and felsic lava and volcaniclastic rocks (*AFhy, AFhyr*) of the Lyre Creek Member in the upper part of the formation. A major transgressive sill and dyke system, the Cooya Pooya Dolerite (*AFdc*), intrudes the Hardey

Formation, and also locally intrudes the lower part of the overlying dominantly basaltic, Kylena Formation (see diagrammatic section on map).

The lower part of the Hardey Formation on Cooya Pooya consists of two associations. The first is composed of undivided clastic sedimentary and volcaniclastic rocks dominated by poorly to moderately sorted, medium- to coarse-grained sandstone, but locally including conglomerate, siltstone, shale, tuff, and tuffaceous sedimentary units (*AFh*). The second comprises sandstone intercalated with siltstone, minor beds of shale and conglomerate, and rare tuff (*AFhs*). These two associations are laterally equivalent, the former being ascribed to a proximal fluvial and alluvial fan facies, derived mainly from erosion of the Cherratta Granitoid Complex, and the latter, interpreted as a finer grained deltaic facies, being developed farther southeastwards and eastwards. Cross-bedding is locally preserved in both units, and Thorne and Trendall (2001) recorded southeasterly and southerly directed palaeocurrents in this part of the northwest Pilbara sub-basin. Hickman and Kojan (2003) interpreted a syndepositional, northeasterly trending normal fault (downthrow to the southeast) on the eastern side of the Munni Munni Intrusion (Pinderi Hills), with a southeasterly deepening depositional basin on Cooya Pooya and eastern Pinderi Hills. Palaeocurrent data (from cross-bedding, ripple marks, and trough structures) recorded during the mapping of Cooya Pooya are consistent with this interpretation.

On Cooya Pooya, units of conglomerate within the Hardey Formation are typically less than 5 m thick, and were not mapped separately. An exception is present about 12 km south-southeast of Pyramid Homestead, between the McShay and Stewart Wells, where there are widespread beds of matrix-supported polymictic conglomerate (*AFhc*). The conglomerate contains rounded and subrounded pebbles of vein quartz, quartzite, and chert, up to 5 cm in diameter, within a coarse-grained sandstone matrix.

Undivided sandstone, conglomerate, siltstone, shale, and tuffaceous facies (*AFh*) of western Cooya Pooya contain several mappable outcrops of felsic tuff (*AFhft*). Outcrops along, and to the north of, the Dampier – Tom Price Railway, west of Western Creek, consist of a massive dacitic pyroclastic rock, in which fragments interpreted as felsic lava, to 1 cm in diameter, are clast-supported within a felsic tuff matrix. Because this section of the Hardey Formation is tightly folded, the felsic tuff (*AFhft*) could belong to the adjacent overlying Lyre Creek Member rather than being a separate unit within the sandstone.

The Lyre Creek Member ('Lyre Creek Agglomerate Member', Williams, 1968; renamed by Thorne and Trendall, 2001) outcrops extensively between Western Creek and Carolina Creek in central Cooya Pooya, but is also exposed in the northern foothills of the Chichester Range, southwest of Lake Poongkaliyarra, and east of Pinnacle Mount. As defined by Thorne and Trendall (2001, p. 236), the member comprises bedded and massive tuff, crystal tuff, agglomerate, quartzitic tuff, and some calcareous beds. Figure 8 shows an outcrop of the Lyre Creek Member on the northern slopes of Table Hill, with reworked volcaniclastic breccia containing rounded boulders and pebbles of dacitic volcanic rocks, and intercalated sandstone (*AFhy*).


AHH186 29.04.04

Figure 8. Reworked volcaniclastic breccia of the Lyre Creek Member, northern face of Table Hill (MGA 510600E 7674200N). Partly rounded boulders and pebbles of dacitic volcanic rocks are set in a poorly sorted dacitic tuffaceous matrix. Scale card is 10 cm long

Arndt et al. (1991) unsuccessfully attempted to date the depositional age of the Lyre Creek Member, obtaining inherited zircons dated as c. 3240–2940 Ma. These zircon grains were probably inherited from the underlying WPGGT and Mallina Basin. The age of the Lyre Creek Member is assumed to be similar to that of felsic volcanic members of the Hardey Formation in the northeast Pilbara sub-basin, where the Bamboo Creek and Koongaling Volcanic Members have been dated at c. 2760 Ma (Pidgeon, 1984; Arndt et al., 1991).

Based on lateral thickness variations between Preston and Mount Wohler, the eruptive centre of the Lyre Creek Member is interpreted to have been central Cooya Pooya. This area overlies a pre-Fortescue Group, northeasterly striking zone of faulting that forms the contact between the Mallina Basin and the WPGGT. Examples of early Fortescue Group deformation (D_{10}) reactivating pre-Fortescue faults have been recorded elsewhere in the west Pilbara (Hickman and Kojan, 2003; Hickman and Strong, 2003). On Mount Wohler, intrusion of the c. 2765 Ma Nerrely Leucogranite (Nelson, 1997; Smithies, 1998b; Smithies and Hickman, 2003) could have been a consequence of such reactivation, and a larger granitic intrusion is interpreted to underlie the Fortescue Group in northeastern and central Cooya Pooya (Blewett et al., 2000). The Lyre Creek Member could be the volcanic component of this c. 2760 Ma, fault-related felsic magmatism.

Thorne and Trendall (2001) described the Lyre Creek Member as consisting mainly of lenticular-bedded lapilli tuffs and breccias, with erosional contacts between beds. They also noted accretionary lapilli tuff, planar-stratified tuff, and tuff with graded bedding, but no evidence of welded tuffs. They interpreted this volcanic facies as a mixture of primary pyroclastic deposits and reworked

AHH187 29.04.04

Figure 9. Convergent sandstone channels in felsic pyroclastic rocks of the Lyre Creek Member, 1.5 km southeast of Mount Montagu (MGA 534750E 7635250N). Hammer is 32.5 cm long

volcanic debris. Thin, lenticular beds of sandstone or conglomerate are locally interstratified with the pyroclastic deposits, and indicate local reworking in fluviatile channels. Excellent examples of convergent sandstone channels are exposed 1.5 km southeast of Mount Montagu (Fig. 9). The orientations of these channels indicate local palaeocurrent directions to the east and northeast.

The composition of the Lyre Creek Member is dominantly andesitic to dacitic, but mapping of Cooya Pooya revealed a single outcrop of rhyolite and rhyolitic tuff (*AFhyr*) about 1.5 km north of Mount Montagu, where the member is unconformably overlain by the Tumbiana Formation.

The status of the Coolajacka Member (*AFhj*) as a member of the Hardey Formation was first published on Pinderi Hills (Kojan and Hickman, 2000). The member is composed entirely of fine-grained, silicified, and pyroxene-rich ultramafic rock, with talc–chlorite pseudomorphs after orthopyroxene and olivine. The anomalous silica content of the rock, and the local presence of quartzite fragments or quartz grains, are attributed to contamination from sandstone of the Hardey Formation. Chemical analyses have confirmed the ultramafic compositions of these rocks, with up to 20.52% MgO (Wallace and Hoatson, 1990). Wallace and Hoatson (1990), and Thorne and Trendall (2001) interpreted these ultramafic rocks as being part of the Cooya Pooya Dolerite, but Kojan and Hickman (2000) interpreted the member as being extrusive, and part of the Hardey Formation. Thorne and Trendall (2001) suggested that ultramafic rocks in the Cooya Pooya Dolerite were indicative of a genetic relationship with komatiitic volcanic rocks of the Pyradie Formation in the south Pilbara sub-basin. However, this relationship is no longer supported for reasons given below.

The Pyradie Formation is stratigraphically equivalent to the Tumbiana Formation (Hickman, 1983; Thorne and Trendall, 2001), and mapping of Cooya Pooya and Pinderi Hills has confirmed that the Tumbiana Formation of the northwest Pilbara sub-basin contains no ultramafic rocks.

AHH188 29.04.04

Figure 10. Table Hill (MGA 510600E 7674200N) viewed from a quarry on the Robe River Railway (just north of Cooya Pooya), showing the upper sill of the Cooya Pooya Dolerite (top of hill) overlying volcaniclastic rocks of the Lyre Creek Member. Dark rubbly outcrops and low hills in the middle distance are composed of the lower sill of the Cooya Pooya Dolerite. Also shown are Lake Poongkaliyarra (centre left) and the Robe River Railway (centre)

Moreover, near Mount Montagu, the Tumbiana Formation unconformably overlies the Kylena Formation, which locally contains sills of the Cooya Pooya Dolerite.

On Cooya Pooya, dolerite sills of the Cooya Pooya Dolerite intrude the Fortescue Group at two stratigraphic levels: above the Lyre Creek Member (Fig. 10), with transgressive offshoot sills penetrating the overlying Kylena Formation; and below the Lyre Creek Member (Fig. 11), where dolerite sills and dykes intrude both the lower sandstone lithofacies of the Hardey Formation and the fine-grained ultramafic rock of the Coolajacka Member. Field observations and the outcrop pattern in three areas of the map (northeast of Lake Poongkaliyarra, and 5 km north and 7 km southeast of Pyramid

AHH189 29.04.04

Figure 11. Lake Poongkaliyarra from Table Hill (MGA 510600E 7674200N), with typical black hilly outcrops of the lower sill of the Cooya Pooya Dolerite beyond

Homestead) show that the lower dolerite sill–dyke complex post-dated the Coolajacka Member. The Coolajacka Member is no longer interpreted as an early ultramafic phase of the lower Cooya Pooya Dolerite for two reasons. Firstly, rounded clasts of fine-grained ultramafic rock are present in the basal part of Lyre Creek Member 1.2 km east of Dunn Well, indicating that the Coolajacka Member pre-dates the Lyre Creek Member. Secondly, the lower and upper dolerite sills of the Cooya Pooya Dolerite are lithologically similar, and the upper sill has the same compositional range as the Kylena Formation it intrudes (see **Kylena Formation**). Thus, evidence available from mapping of COOYA POOYA indicates that both the lower and upper sills of the Cooya Pooya Dolerite are comagmatic with the Kylena Formation, and the Coolajacka Member stratigraphically underlies the Lyre Creek Member. The extremely fine grain size of the ultramafic rocks in the Coolajacka Member, and the presence of fine spinifex texture, suggest rapid cooling in ultramafic flows.

AHH190 29.04.04

Figure 12. Unconformity between moderately dipping basaltic flows of the Kylena Formation (centre right) and almost horizontal beds of the Tumbiana Formation (upper part of hill), 4 km southeast of Python Pool (MGA 524750E 7640900N)

Kylena Formation (AFk, AFkbm, AFkf)

Thorne and Trendall (2001) provided a comprehensive regional description of the Kylena Formation, including its volcanic facies and petrography. On COOYA POOYA, most outcrops of the formation are located in rugged terrain in dissected plateau country on the northern slopes of the Chichester Range. Access is limited to two roads and two tracks, and, consequently, most parts of the formation were mapped using interpretation of aerial photography and gamma-ray spectrometric images, with ground control provided by widely spaced helicopter traverses. On the adjacent sheet, PINDERI HILLS, Kojan and Hickman (1998) used petrology and geochemical traverses to show that gamma-ray spectrometric data provided a powerful tool in mapping compositional variations in the well-exposed volcanic formations of the Fortescue Group. Their work confirmed that these formations, previously thought to be almost entirely basaltic, do include flows ranging from basaltic komatiite to rhyolite.

The Kylena Formation is absent from the stratigraphy between Narrina Creek and Pillinginni Creek, with the result that the Tumbiana Formation rests directly on the Hardey Formation. The absence of the Kylena Formation between the Tumbiana and Hardey Formations is unique to this area of the Pilbara, and results from local folding and erosion of the Kylena Formation prior to deposition of the Tumbiana Formation. The angular unconformity between the two formations is visible 4 km southeast of Python Pool, where flows of komatiitic basalt of the Kylena Formation (*AFkbm*) dip 30° to the south-southwest beneath volcaniclastic sandstone of the Tumbiana Formation (*AFtsv*) that dips 5° to the south (Fig. 12). On a larger scale, the unconformity coincides with the culmination of the D_{10} George Anticline (Fig. 4), which visibly deforms the Hardey and Kylena Formations, but has limited effect on the Tumbiana and Maddina Formations. As for the Kylena Formation, the Cooya Pooya Dolerite is also absent across the southwestern closure of the George Anticline, but it is present in the Hardey and Kylena Formations in the northeastern closure of the fold, northeast of McShay Well. The mineralogy of the Kylena Formation in the Python Pool area is very similar to that of the adjacent Cooya Pooya Dolerite, with the consequence that mapping boundaries between the dolerite and thick flows of massive basalt is locally difficult. This supports other evidence (both units pre-date the Tumbiana Formation) that the Cooya Pooya Dolerite and Kylena Formation of COOYA POOYA are comagmatic.

On COOYA POOYA, the Kylena Formation is composed mainly of fine-grained massive and amygdaloidal basalt and basaltic andesite, with minor dacite (*AFk*). High-Mg basalt, or basaltic komatiite (*AFkbm*), forms the lower part of the formation in central COOYA POOYA. Good exposures of basaltic komatiite are available around Python Pool, and 4 km southeast of the pool where thick flows of massive basalt contain acicular and platy clinopyroxene crystals, up to 10 cm long in a groundmass of altered pyroxene and plagioclase, and variable amounts of quartz. Thorne and Trendall (2001) described the lower part of the Kylena Formation in this area as a cumulate zone, and also noted the presence of coarse-grained flows with equant to bladed plagioclase and clinopyroxene within graphic intergrowths of plagioclase and quartz.

A mixed assemblage of andesite and dacite, with minor rhyolite and dolerite (*AFkf*), forms the upper part of the formation south of Western Creek. This dominantly felsic unit is clearly identified on regional gamma-ray spectrometric images by virtue of elevated concentrations of potassium, uranium, and thorium. On PINDERI HILLS, Hickman and Kojan (2003) recorded spherulitic textures in some of the felsic volcanic rocks of this unit. Kojan and Hickman (1998) analysed samples collected just west of COOYA POOYA (Robe River Railway traverse) to demonstrate compositions ranging from tholeiitic dacite to tholeiitic rhyolite.

Cooya Pooya Dolerite (AFdc, AFhq)

The Cooya Pooya Dolerite (*AFdc*) is an lenticular intrusive complex, consisting of laccoliths, sills, and dykes, that intrudes two main stratigraphic levels: the lower part of the Hardey Formation, beneath the Lyre Creek Member; and the contact between the Hardey and Kylena Formations. Although restricted to the northwest Pilbara sub-basin, the Cooya Pooya Dolerite is nevertheless of regional extent, extending from Armstrong Creek on PINDERI HILLS to the western part of MOUNT WOHLER, a distance of 130 km. At the lower stratigraphic level, the Cooya Pooya Dolerite varies in vertical thickness up to 100 m, and forms sills and small laccoliths. Networks of dolerite dykes transgress the stratigraphy and locally fragment the Coolajacka Member. The dykes have no dominant orientation, but outcrop in a polygonal pattern visible at map scale, suggesting either intrusion along pre-existing joints in the ultramafic lavas, or forceful injection above laccoliths. On northeastern PINDERI HILLS, one of the lower laccoliths of the Cooya Pooya Dolerite is underlain by a large feeder dyke that trends north for 6 km through the Whundo Group east of North Whundo, but farther north changes to trend northeast. Although no major feeder dykes for the upper sills of the Cooya Pooya Dolerite have been identified, northern COOYA POOYA contains numerous dolerite plugs that penetrate the Lyre Creek Member (e.g. 4 km east of Darling Peak, and 5 km southwest of Lake Poongkaliyarra). The upper sill of the Cooya Pooya Dolerite has an average thickness of about 50 m, and it ranges from being locally absent to 100 m thick.

The lower and upper sills are separated by the Lyre Creek Member of the Hardey Formation, which interestingly has the same regional extent as the Cooya Pooya Dolerite. For reasons given above, the Cooya Pooya Dolerite is now interpreted as an intrusive equivalent of the Kylena Formation. The Kylena Formation extends throughout the northern half of the Hamersley Basin, but nowhere else it is underlain and intruded by a comagmatic sill complex. Elsewhere, the Kylena Formation was erupted through northeasterly trending fractures that are now preserved as dolerite dykes. The present interpretation is that emplacement of the Cooya Pooya Dolerite intrusions was largely controlled by the local presence of the Lyre Creek Member, the massive beds of which formed a barrier to upward intrusion of basaltic magma. This would explain the laccolithic sill complex beneath the Lyre Creek Member, and local fragmentation of the Coolajacka Member, which directly underlies the Lyre Creek Member.

The Kylena Formation is anomalously thin where it is underlain by the Cooya Pooya Dolerite. West of the Cooya Pooya Dolerite, on western PINDERI HILLS (Hickman and Kojan, 2003), the formation is 300 to 520 m thick, and to the east, on southern MOUNT WOHLER and northern MOUNT BILLROTH, it is at least 225 m thick (Thorne and Trendall, 2001). In contrast, the average thickness of the Kylena Formation on COOYA POOYA is only about 100 m, consistent with local trapping of basaltic magma within a subvolcanic intrusion, the Cooya Pooya Dolerite.

The Cooya Pooya Dolerite outcrops as black hills, ridges, or large areas of dissected plateau fringed by cliffs, or in high mesas as at Table Hill, south of Lake Poongkaliyarra (Fig. 8). These outcrops are typically fringed by steep, bouldery scree slopes without vegetation. The dolerite is massive, and generally jointed at 0.5 to 3 m intervals (Fig. 13). In thin section, the rock is a fine- to medium-grained plagioclase-rich and biotite-bearing dolerite, with local olivine–orthopyroxene–clinopyroxene–plagioclase cumulate. The lower intrusive complex of the Cooya Pooya Dolerite contains ubiquitous inclusions of contact metamorphosed quartzite derived from the lower part of the Hardey Formation (*AFhq*). Some of these large xenoliths of quartzite are over 100 m wide (e.g. 1.5 km northeast of Nimingarra Well).

AHH191 29.04.04

Figure 13. Jointed outcrops of the upper sill of the Cooya Pooya Dolerite on Table Hill (MGA 510600E 7674200N), with low hills of Cooya Pooya Dolerite (upper sill) in the middle distance

Tumbiana Formation (AFtc, AFtsl, AFtss, AFtsv, AFtt)

The Tumbiana Formation outcrops along the northern slopes of the Chichester Range, and is a distinctive formation in the field and on aerial photographs due to closely interbedded sandstone, siltstone, basaltic to andesitic tuff, and stromatolitic limestone and dolomite. Thorne and Trendall (2001) provided a detailed description of the sedimentary and volcanic facies that make up the formation, and interpreted these to include coastal and nearshore shelf sediments (sandstone, siltstone, and carbonate rocks), offshore shelf sediments (black argillite), and subaerial basalt and tuff.

On COOYA POOYA, the Tumbiana Formation is about 200 m thick. The base of the formation is a unit of volcaniclastic sandstone and siltstone with minor tuff and carbonate rocks (*AFtsv*). This unit reaches a maximum thickness of about 70 m in western COOYA POOYA but becomes thinner eastwards, and stratigraphically wedges out near the boundary with MOUNT WOHLER. As noted above, this basal part of the Tumbiana Formation unconformably overlies folded flows of the Kylena Formation 4 km southeast of Python Pool. Exposures on Narrina Creek (MGA 526400E 7636750N) show a basal siltstone overlying leached amygdaloidal basalt of the Kylena Formation. The 70 m-thick unit of siltstone and sandstone contains intercalations of accretionary lapilli-bearing tuff and beds of massive, tuffaceous, and lithic sandstone. Tuff beds are locally very fine grained, with shale layers displaying ripple marks. Southeast of Mount

Montagu, where the George River cuts the basal contact of the Tumbiana Formation, the underlying rock is andesitic to dacitic tuff of the Lyre Creek Member. Here, the basal unit of the Tumbiana Formation is a massive, but jointed 10–15 m-thick unit of sandstone. This is overlain by a 15 m-thick unit of well-bedded sandstone and siltstone.

Dark grey, siliceous, stromatolitic dolomite and limestone beds within carbonate-rich tuff, mudstone, and siltstone (*AFtc*) conformably overlie the basal sandstone and siltstone (*AFtsv*) in western COOYA POOYA. Eastwards, this lithological association is too thin to be mapped separately at 1:100 000 scale until it thickens close to the boundary with MOUNT WOHLER. The stromatolitic unit is correlated with the Meentheena Member of the east Pilbara (Awramik and Buchheim, 2001), although that member contains more carbonate rocks. Stromatolitic beds constitute only a minor part of the succession but, where exposed, as at Mount Herbert, they typically form small but prominent dark brown to black escarpments between recessive fine-grained tuffs or tuffaceous volcaniclastic rocks. Awramik and Buchheim (2001) interpreted the Meentheena Member as a lacustrine deposit.

The central part of the formation is composed of a prominently outcropping sandstone–siltstone unit (*AFtss*) that is locally both underlain and overlain by tuff and tuffaceous siltstone, commonly with accretionary lapilli (*AFtt*). The sandstone–siltstone unit (*AFtss*) is a distinctive stratigraphic marker that extends across COOYA POOYA, and westwards onto PINDERI HILLS. It typically forms low escarpments or caps mesas, as at Mount Herbert. The uppermost unit of the Tumbiana Formation on COOYA POOYA is a very arenaceous unit of siltstone and tuff (*AFtsl*) that forms extensive pavement-like surfaces on almost horizontal dip slopes. The siltstone and tuff (*AFtsl*) are conformably overlain by the Maddina Formation.

Maddina Formation (AFm, AFmbi, AFmfi)

On COOYA POOYA, the top of the Chichester Range is underlain by locally horizontal, but regionally south-dipping, basalt and basaltic andesitic flows of the Maddina Formation (*AFm*). Exposure is poor in most areas, with large, poorly drained areas of colluvial material separating isolated low hills and low ridges of volcanic rock. Most exposures of the Maddina Formation on the top of the range lie directly beneath the Hamersley Surface, with the result that silicification, lateritization, and leaching are widespread. The stratigraphic top of the formation is not exposed on COOYA POOYA, but Thorne and Trendall (2001) recorded thicknesses up to 1100 m in other areas. On PINDERI HILLS, Kojan and Hickman (1998) estimated the thickness of the formation to be 740 m.

Kojan and Hickman (1998) described the Maddina Formation as a succession of volcanic rocks ranging in composition from high-Mg basalt to rhyolite, although high-Mg basalt was not identified on COOYA POOYA. Its compositional range is similar to that of the Kylena Formation but, in contrast to the single mafic to felsic cycle of that formation, two such cycles are developed in the Maddina Formation (Kojan and Hickman, 1998).

On ROY HILL, MacLeod and de la Hunty (1966) subdivided the succession currently assigned to the Maddina Formation into three members of the ‘Mount Jope Volcanics’ (name no longer used), and Hickman (1983) redefined these as formations, from bottom to top: the ‘Nymerina Basalt’, the ‘Kuruna Siltstone’, and the ‘Maddina Basalt’. Thorne and Tyler (1997a) redefined the Maddina Basalt to include all rocks previously assigned to the Kuruna Siltstone and the Nymerina Basalt. The name Nymerina Basalt then ceased to be applied. However, recognition of the two volcanic cycles on PINDERI HILLS (Kojan and Hickman, 1998) indicates that more detailed regional mapping of the upper Fortescue Group, including the application of data from remote sensing techniques such as airborne gamma-ray spectrometry, could again require division of the Maddina Formation into two volcanic formations, even where the ‘Kuruna Siltstone’ (currently Kuruna Member) is absent. On COOYA POOYA, this separation would be at the boundary between felsic (*AFmfi*) and dominantly mafic (*AFm*) units at Mount Richthofen, and westwards along the valley of the Portland River. The U–Pb zircon date of 2717 ± 2 Ma (Nelson, 1998, p. 133–135) for the Maddina Formation was from a dacite at the top of the lower cycle at Booloomba Pool on PINDERI HILLS. The upper cycle has not been dated, but Arndt et al. (1991) dated the overlying Jeerinah Formation, 75 km west of COOYA POOYA, at 2684 ± 6 Ma.

Much of the Maddina Formation on COOYA POOYA is composed of massive flows of non-vesicular basalt, with subordinate vesicular and amygdaloidal basalt, and minor andesite, dacite, and rhyolite (*AFm*). Where field observations, petrography, geochemistry, and gamma-ray spectrometric data indicate andesitic to dacitic volcanic units, these are shown on the map. Basaltic andesite with minor basalt and andesite (*AFmbi*) forms thick sequences of flows in the central part of the lower cycle and the lower part of the upper cycle. The petrography and whole-rock geochemistry of both basalt and basaltic andesite, and associated metasomatized and altered variants, are very similar to those of corresponding rocks mapped and sampled from the Kylena Formation. Vesicles and amygdales, together with carbonate alteration, are less prevalent than in the Kylena Formation, where sericite alteration is more abundant (Radke, 1997).

Andesite and dacite (*AFmfi*) comprise the uppermost unit of the lower cycles of the Maddina Formation on COOYA POOYA. The dacite is a massive pale grey rock comprising mainly potash feldspar and plagioclase, and locally has granophyric and tridymitic devitrification textures (Radke, 1997).

Dolerite (AF(d))

A large dolerite unit (coded *AF(d)* on the map) within outcrops of the Hardey Formation 5 km southeast of the abandoned Cooya Pooya Homestead could be unconformably overlain by the Hardey Formation, rather than being a later intrusive dyke. Aeromagnetic data suggest the dolerite is part of an east-northeasterly trending intrusion related to pre-Fortescue Group pyroxenite–gabbro dykes on PINDERI HILLS (Fig. 5).

Structure of the Hamersley Basin

The structural geology of the Hamersley Basin on COOYA POOYA includes open folds, faults, and dykes of various orientations. Some of these structures are probably superimposed on underlying rift structures that were active during deposition of the Mount Roe Basalt and Hardey Formation (Blake, 1993). On DAMPIER (Hickman, 2001), the earliest structures preserved in the Fortescue Group were assigned to D_{10}, with an age range of 2770–2750 Ma. However, most structures on COOYA POOYA deform all exposed levels of the Fortescue Group and, therefore, their minimum ages are unknown.

Deformation events

D_{10} (c. 2770–2700 Ma)

Blake (1993) recognized a period of crustal extension oriented west-northwest–east-southeast during deposition of the Mount Roe Basalt and the overlying Hardey Formation. The resulting structures were northeasterly trending normal faults and mafic dykes. Extrusion of flood basalts (Mount Roe Basalt) was followed by the development of extensional intracratonic sedimentary basins (Hardey Formation). Concealed, pre-Hardey Formation ultramafic–mafic dykes in northwestern COOYA POOYA could be related to extrusion of the Mount Roe Basalt, but these dykes have an easterly trend, which is inconsistent with the extension described by Blake (1993). It is possible that these major easterly trending dykes are only slightly younger than the major mafic–ultramafic intrusions.

The northeasterly trending George Anticline, which deforms the Kylena Formation but pre-dates the Tumbiana Formation, is one example of a D_{10} structure on COOYA POOYA; it results in an angular unconformity between these formations. East of Western Creek, the Harding Anticline (Fig. 4), with culminations and depressions along its axis, strikes northeast. Near Waloo Waloo Pool, this anticline has been sufficiently eroded to expose the Cherratta Granitoid Complex within its core. Easterly trending anticlines and synclines west of Western Creek are assigned to early D_{10} because folds of the same orientation pre-date the Tumbiana Formation 4 km southeast of Python Pool.

D_{11} (1830–1780 Ma)

Deformation along the Portland Fault post-dates the D_{10} folds, and was assigned to D_{11} by Hickman and Kojan (2003), who considered the fault to be of similar age to northwesterly trending open folding of the Fortescue and Hamersley Groups south and southwest of COOYA POOYA. D_{11} folds are interpreted to belong to the 1830–1780 Ma Capricorn Orogeny (Occhipinti et al., 2001), based on a similar trend to structures of this generation in the Hamersley Range (Thorne and Tyler, 1997b).

Archaean–Proterozoic intrusions

Dolerite and gabbro dykes (d)

Massive, medium- to coarse-grained dolerite and gabbro (*d*), of uncertain and varying ages, form dykes across most of COOYA POOYA. Most dykes strike northeast, but northwesterly and northerly striking dykes are also present. Northwesterly to northerly trending dolerite dykes are correlated with D_5 dykes in the MOUNT BRUCE 1:250 000 sheet area, which were interpreted by Blight et al. (1996) to be younger than 1840 Ma. Dolerite dykes trending east-northeasterly on COOYA POOYA are correlated with the Mundine Well Suite of Hickman and Lipple (1975), which Wingate and Giddings (2000) dated at 755 Ma.

Cainozoic rocks

Cockbain and Hocking (1990) recorded several stages of climatic evolution for the Cainozoic, and these were accompanied by fluctuations in sea level. In the west Pilbara, the older Cainozoic deposits are associated with previous palaeosurfaces such as the Hamersley Surface (Campana et al., 1964), and the Peawah, Millstream, and Yule Surfaces (Kriewaldt and Ryan, 1967). The age of the Hamersley Surface is imprecisely defined, and this surface probably developed following separation of Australia from Gondwana, and reached maturity between the Late Cretaceous and Palaeocene (Cockbain and Hocking, 1990). Dissection of the Hamersley Surface related to marine regressions resulted in Miocene to early Pleistocene land surfaces, with extensive valley-fill deposits such as partly consolidated colluvium (*Czc*) and alluvial calcrete (*Czak*).

Eocene to Early Pleistocene

Clastic and chemical sedimentary deposits (Czag, Czak, Czwb, Czc, Czcb, Czcd, Czrf, Czrk)

Eocene to early Pleistocene clastic and chemical deposits have been eroded by the present drainage system. Dissected deposits of Cainozoic alluvial gravel deposits (*Czag)* are exposed in beds up to 5 m thick in the banks of larger drainages such as the Harding River and its tributaries north of Black Hills. Alluvial calcrete (*Czak*) is distributed along drainages, particularly where these contain alluvium derived from mafic or ultramafic units. Dissected colluvium (*Czc*) is locally divided into colluvium with a gilgai surface (*Czcb*) overlying basaltic units on the plateau of the Chichester Range, and colluvium derived from dolerite and basalt (*Czcd*). The colluvium with a gilgai surface (*Czcb*) forms large, flat expanses of clay soil on high, poorly drained areas of the Hamersley Surface (see **Physiography**), and includes residual material derived from the chemical weathering of adjacent basalt, particularly above the Maddina Formation. The colluvium derived from dolerite and basalt (*Czcd*) fringes almost all cliffs containing the Cooya Pooya

Dolerite, but is also developed at the foot of scree slopes beneath outcrops of the Kylena Formation. Dissected sheetwash deposits, with gilgai surface in areas of expansive clay (*Czwb*), are exposed along Harding River East about 6 km west-northwest of Hicks Gap.

On southern Cooya Pooya, outcrops of residual ferricrete and ferruginous duricrust (*Czrf*) form some of the higher parts of the Chichester Range, and are remnants of the Hamersley Surface (see **Physiography**). The distinction between residual calcrete (*Czrk*) and alluvial calcrete (*Czak*) can be difficult, particularly in areas mapped by photointerpretation. Calcrete deposits that are interpreted to be mainly residual overlie poorly drained basaltic rocks of the Chichester Range, particularly in low-lying areas.

Recent deposits

Alluvial, colluvial, eluvial, and eolian deposits (Qaa, Qab, Qao, Qw, Qwb, Qws, Qc, Qcb)

Present-day drainage systems contain alluvial clay, silt, and sand in channels on floodplains, and sand and gravel in rivers and creeks (*Qaa*). Alluvial clay, silt, and sand form overbank deposits on floodplains (*Qao*), and locally include brown soil and expansive clay, or gilgai (*Qab*) where the floodplain deposits include a substantial amount of clastic material derived from mafic or ultramafic sources. Such areas are generally impassible by vehicle in wet weather, and in dry weather the surface of the ground is broken by expansion crevices and depressions known as 'crabholes'.

Sheetwash, including sand, silt, and clay (*Qw*), is deposited on distal outwash fans and includes some gilgai (*Qwb*). Quartzofeldspathic sand (*Qws*) locally forms sheetwash adjacent to outcrops of sandstone or felsic volcanic rocks of the Hardey Formation. Colluvial sand, silt, and gravel (*Qc*) form scree slopes and proximal outwash fans around many of the hills on Cooya Pooya. Whereas colluvial fans commonly exhibit a well-defined radial drainage system of small gullies that originate from adjacent hills, the lower slopes (typically 0–5°) of the sheetwash fans do not have well-developed discrete drainage lines. The composition of colluvial units depends on the lithology of source rocks in the adjacent hills. Colluvial clay, silt, and rock fragments with a gilgai surface (*Qcb*), locally derived from weathering of the Cooya Pooya Dolerite, occupy a poorly drained area about 15 km southwest of Lake Poongkaliyarra.

Economic geology

The distribution of metallic mineral deposits in the west Pilbara is summarized by Ruddock (1999). No mining, other than for road metal, has been undertaken on Cooya Pooya, and mineral occurrences are limited to small Ni–Cu and Cu–Pb prospects in greenstones of the Whundo Group in the northwestern part of the sheet area. During the mapping of Cooya Pooya, a new platinum-group element (PGE) occurrence was identified by geochemistry (see below) and accumulations of magnesite were discovered 6 km southeast of Pyramid Homestead. The magnesite was not analysed.

The present interpretation of the pre-Fortescue Group geology of Cooya Pooya (Fig. 5) indicates that the sheet area has the potential to host concealed VHMS base metal deposits of types previously mined from the Whundo Group at Whundo (Pinderi Hills), and the Bookingarra Group at Whim Creek (Sherlock). Being higher in the stratigraphy, mineralization within the Bookingarra Group is more likely to be preserved at mineable depths, particularly where the Mount Roe Basalt is thin or absent, as in the northeastern corner of Cooya Pooya.

Figure 5 interprets two linear magnetic anomalies in northeastern Cooya pooya (Fig. 6) as concealed mafic–ultramafic intrusions. If this interpretation is correct, these intrusions could be prospective for PGE or Ni–Cu mineralization. There is PGE mineralization in the Munni Munni Intrusion on Pinderi Hills, and Ni–Cu deposits are associated with mafic–ultramafic intrusions at Radio Hill and Mount Sholl (Dampier), and Sherlock Bay (Sherlock). Just east of Cooya Pooya, PGE, Ni–Cu, and accompanying gold mineralization are also associated with c. 2950 Ma mafic–ultramafic sills and high-Mg diorite (sanukitoid) intrusions in the Mallina Basin on Mount Wohler and Satirist (De Grey Mining Limited, 2002; Hickman, 2004a), and similar mineralization could therefore underlie northeastern Cooya Pooya.

Gold

Mapping of Cooya Pooya and interpretation of available geophysical data (Blewett et al., 2000) combine to suggest that central and northeastern Cooya Pooya has exploration potential for concealed gold mineralization. This area is interpreted to be underlain by the contact between the WPGGT and the Mallina Basin, delineated on Figure 5 as an extension of the Mallina Shear Zone. The Mallina Shear Zone is an important control on gold mineralization on Yule.

Huston et al. (2002) interpreted some gold deposits of the Mallina Basin as c. 2765 Ma epithermal deposits related to intrusion of the c. 2765 Nerrely Leucogranite (previously incorrectly named the Opaline Well Granite) and felsic volcanism (Lyre Creek Member of the Hardey Formation). Blewett et al. (2000) used geophysical data to interpret a concealed granitic intrusion of unspecified age in northeastern Cooya Pooya. Figure 5 suggests that this, and an interpreted smaller intrusion to the southwest, are the same age as the Nerrely Leucogranite. The presence of gold-related granitic intrusions in the concealed De Grey Group of northeastern Cooya Pooya raises the possibility of concealed epithermal gold mineralization. Support for gold mineralization that is either epithermal or shear zone hosted beneath the Fortescue Group is provided by gold mineralization (interpreted to be placer gold) intersected in the Hardey Formation on southeastern Pinderi Hills (CRA Exploration Pty Ltd, 1987).

Nickel–copper, PGE, and gold

Several small nickel and copper occurrences, including the Sullam and Cunig prospects, are hosted by the Whundo Group in northwestern COOYA POOYA. At the Sullam prospect, metabasalt near a gabbro contact contains pyrite, bravoite, violarite, and millerite (Ruddock, 1999). Surface outcrops of gossan are associated with colloform textures in chert, suggesting that the mineralization is epithermal. At the nearby Cunig prospect, Ni–Cu mineralization occupies a shear zone in metabasalt close to a gabbro contact, and two samples of gossan collected during mapping of COOYA POOYA contained very high levels of palladium, platinum, and gold. One sample (GSWA 144280) contained 4400 ppb palladium, 980 ppb platinum, and 1.25 g/t gold, in addition to anomalous nickel (720 ppm), chromium (2750 ppm), and copper (2900 ppm). This discovery increases the prospectivity of northwestern COOYA POOYA for gabbro-hosted Ni–Cu–PGE–Au mineralization, as associated with sanukitoid intrusions in the Mallina Basin (Hickman, 2004a). Felsic volcanic rocks of the Maddina Formation are considered to be prospective for base metal mineralization, but mineral occurrences are unknown within this unit on COOYA POOYA.

Road building and construction materials

Road building and construction materials include river gravels, colluvium, and weathered rock, which are available throughout the area.

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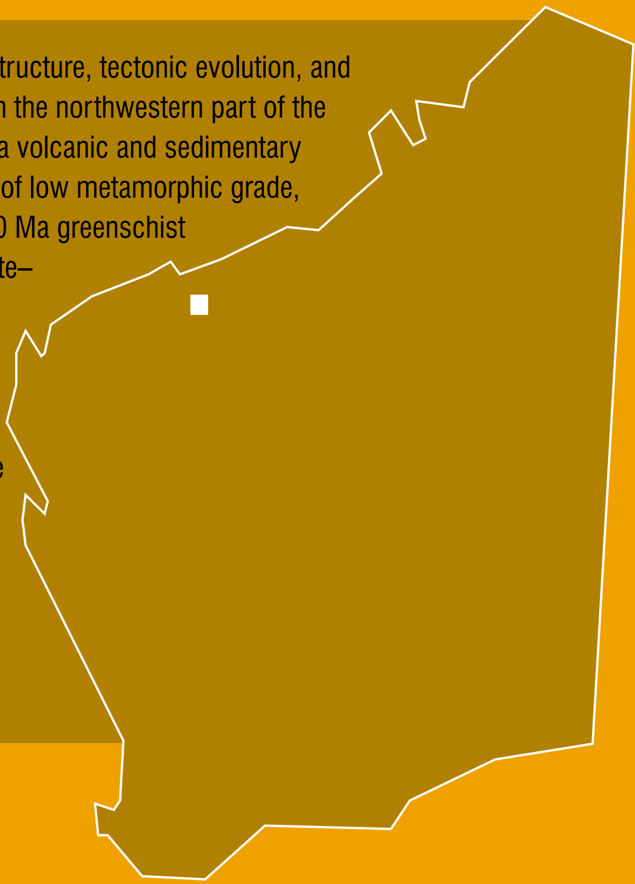
Appendix

Gazetteer of localities on COOYA POOYA

Locality	*MGA coordinates*	
	Easting	*Northing*
Black Hills	513000	7652500
Cooya Pooya Homestead	514500	7674150
Cunig prospect	500950	7677700
Darling Peak	522150	7673600
Dunn Well	506400	7675600
Hicks Gap	526300	7652600
Lake Poongkaliyarra	512000	7676000
McShay Well	547100	7660100
Mardeburra Pool	519500	7664100
Mount Herbert	522500	7641800
Mount Montagu	533600	7636200
Mount Richthofen	545050	7625100
Mount Sholl (on DAMPIER)	491600	7684700
Nimingarra Well	546400	7676150
North Whundo prospect (on DAMPIER)	495500	7678150
Petrov Well	513600	7662000
Pinnacle Mount	522750	7672700
Pyramid Homestead	546100	7671550
Python Pool	524750	7640900
Radio Hill (on DAMPIER)	486430	7679570
Sherlock Bay (on DAMPIER)	557400	7698450
Stewart Well	551100	7661450
Sullam prospect	501600	7676275
Table Hill	510600	7674200
Waloo Waloo Pool	509750	7653200
Whim Creek (on SHERLOCK)	586738	7694955
Whundo mine (on PINDERI HILLS)	492460	7669100

These Explanatory Notes describe the stratigraphy, structure, tectonic evolution, and mineralization of the COOYA POOYA 1:100 000 sheet in the northwestern part of the Archaean Pilbara Craton. In this area, 2770–2717 Ma volcanic and sedimentary rocks of the Fortescue Group, almost horizontal and of low metamorphic grade, unconformably overlie folded and faulted 3240–2930 Ma greenschist to amphibolite facies rocks of the West Pilbara Granite–Greenstone Terrane (volcanic rocks of the c. 3130–3115 Ma Whundo Group and 3240–2930 Ma granitic rocks of the Cherratta Granitoid Complex) and greenschist facies rocks of the 3010–2930 Ma Mallina Basin (volcanic and sedimentary rocks of the Whim Creek, Buckingarra, and De Grey Groups). The area has potential for gold, platinum group elements, base metals,and manganese, but no mining has been recorded.



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HICKMAN

Geology of the Cooya Pooya 1:100 000 sheet

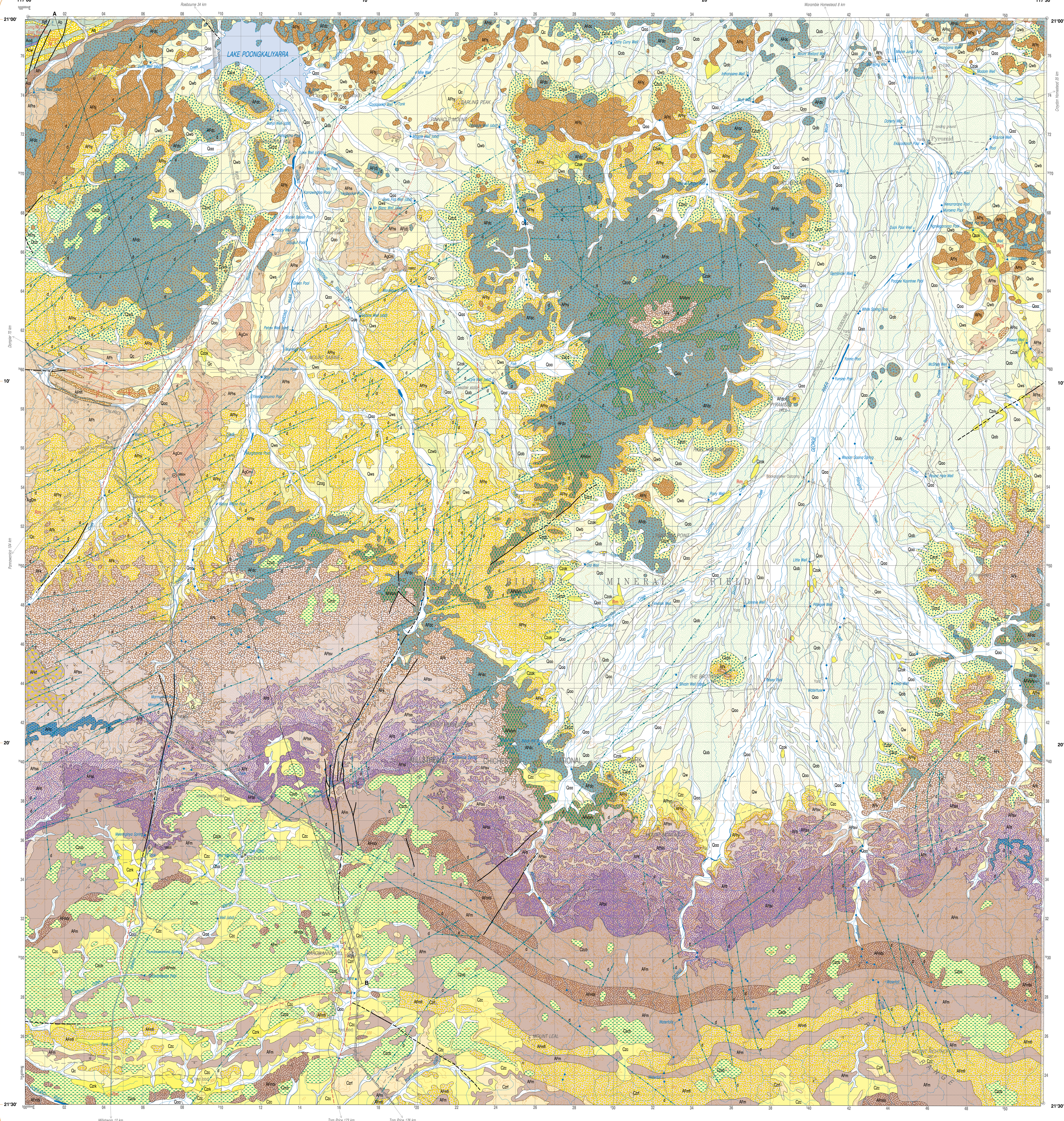
EXPLANATORY NOTES

AUSTRALIA 1 : 100 000 GEOLOGICAL SERIES

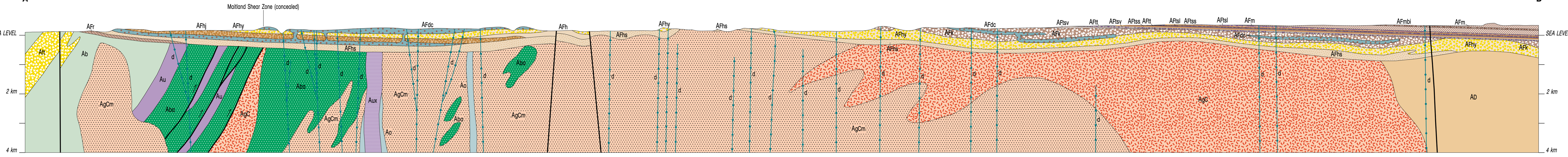
COOYA POOYA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET 2355



DIAGRAMMATIC SECTION



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qaa Alluvial sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains
Qab Alluvial sand, silt, and clay in floodplains, with gilgai surface in areas of expansive clay
Qao Alluvial sand, silt, and clay in floodplains
Qw Sheetwash sand, silt, and clay in distal outwash fans
Qwb Sheetwash sand, silt, and clay in distal outwash fans, with gilgai surface in areas of expansive clay
Qws Sheetwash quartzofeldspathic sand
Qc Colluvium — sand, silt, and gravel in outwash fans and scree slopes
Qcb Colluvial clay, silt, and rock fragments derived from mafic rock, with gilgai surface in areas of expansive clay

Czag Alluvial gravel deposits, dissected by recent drainage
Czak Alluvial calcrete; includes massive, nodular, and cavernous limestone; variably silicified
Czwb Sheetwash deposits, with gilgai surface in areas of expansive clay; dissected by recent drainage
Czc Colluvium, dissected by recent drainage
Czcb Colluvium, dissected by recent drainage, with gilgai surface in areas of expansive clay
Czcd Colluvium, derived from dolerite or basalt, dissected by recent drainage
Czrf Residual ferricrete; includes ferruginous and pisolitic ironstone; dissected by recent drainage
Czrk Residual calcrete; includes massive, nodular, and cavernous limestone; variably silicified; dissected by recent drainage

d Dolerite and gabbro dykes; interpreted from aeromagnetic data where dashed

ARCHAEAN — PILBARA CRATON — HAMERSLEY BASIN — Mount Bruce Supergroup — Fortescue Group

AF(d) Dolerite

c. 2717 Ma[1]

AFm **MADDINA FORMATION:** massive, vesicular, and amygdaloidal basalt and basaltic andesite, with minor andesite, dacite, and rhyolite
AFmbi Basaltic andesite with minor basalt and andesite
AFmfi Andesite and dacite

c. 2719 Ma[2]

TUMBIANA FORMATION
AFtc **Meentheena Member:** dark grey, siliceous, stromatolitic dolomite and limestone, carbonate-rich tuffaceous sedimentary rock, mudstone, and siltstone
AFtsl Siltstone and tuff
AFtss Sandstone and siltstone
AFtsv Volcaniclastic sandstone with minor tuff and carbonate rock
AFtt Tuff and tuffaceous siltstone, commonly with accretionary lapilli; local intermediate coarse tuff and agglomerate

AFkf Andesite, dacite, minor basalt, rhyolite, and dolerite
AFk **KYLENA FORMATION:** massive or amygdaloidal basalt, basaltic andesite, and dacite; local high-Mg basalt and rhyolite
AFkbm High-Mg basalt

AFdc **COOYA POOYA DOLERITE:** fine- to medium-grained dolerite, pyroxene-rich and olivine-bearing dolerite; local xenoliths of quartzite
AFhq Quartzite, as rafts within **COOYA POOYA DOLERITE**

AFhy **Lyre Creek Member:** felsic tuff and agglomerate, and volcaniclastic sandstone and conglomerate with acid to intermediate rock clasts; local abundant accretionary lapilli
AFhyr Rhyolite and rhyolitic tuff
AFhj **Coolajacka Member:** fine-grained ultramafic lava; abundant quartz xenocrysts
AFhs Medium- to coarse-grained, poorly sorted sandstone, siltstone, and minor shale and conglomerate; local felsic tuff
AFhc Polymictic conglomerate
AFhft Felsic tuff

c. 2760 Ma[3]

AFh **HARDEY FORMATION:** sandstone, conglomerate, siltstone, shale, and tuff

c. 2770 Ma[3 4]

AFr **MOUNT ROE BASALT:** massive, vesicular, and glomeroporphyritic basalt

Pilbara Supergroup — De Grey Group

AD Undivided; sandstone, conglomerate, siltstone, shale, and wacke; metamorphosed (Section only)

Ao Gabbro and dolerite; metamorphosed
Aod Metadolerite
Aol Leucogabbro; metamorphosed
Aux Pyroxenite, metamorphosed (Section only)

c. 3000 Ma[2]

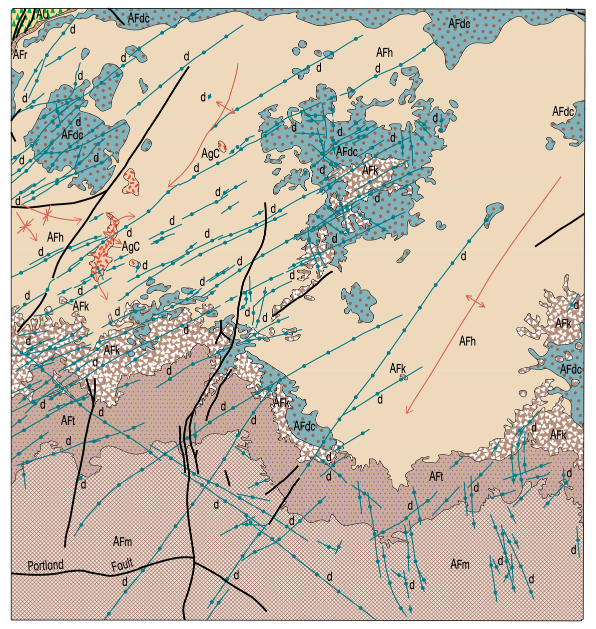
AgC **CHERRATTA GRANITOID COMPLEX:** syenogranite to tonalite; locally porphyritic and typically foliated; gneissic granitoid contains mafic xenoliths (Section only)
AgCm Syenogranite and monzogranite; locally biotite-rich, foliated

Pilbara Supergroup (no stratigraphic subdivision)

c. 3120 Ma[5 6 7 8]

Apf Quartz–feldspar porphyry, rhyolite, and dacite; chiefly intrusive; metamorphosed
Acw Chert, grey and white banded
Aft Felsic tuff; rhyolitic to andesitic composition; metamorphosed
Ab Basaltic rock, undivided; metamorphosed
Aba Amphibolite; after basaltic rock (Section only)
Au Ultramafic rock, undivided; metamorphosed

INTERPRETED BEDROCK GEOLOGY



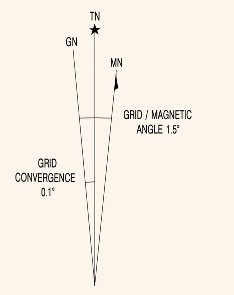
SCALE 1:500 000
0 5 10 15 20
Kilometres

Geological boundary
- exposed
Fault
- exposed
- concealed
- relative displacement
- concealed, interpreted from aeromagnetic data
Fold, showing axial trace and generalized plunge direction
- anticline, exposed, concealed
- syncline, exposed, concealed
Bedding, showing strike and dip
- inclined
- horizontal
- strike and dip estimated from aerial photography
  - 0–15°
  - 15–45°
Way-up indicator
- cross-bedding
Stromatolite fossil locality
Isotopic age determination site with identification number — 168932

Formed road
Track
Fence, generally with track
Railway
Powerline
Homestead — Pyramid
Locality — Cumberabbera
Building
Yard — Yard
Microwave repeater station
National park boundary
Breakaway
Contour line, 20 metre interval — 280

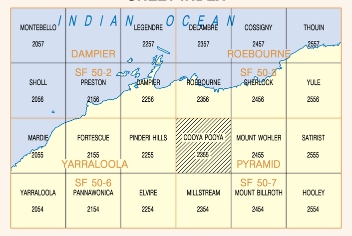
Watercourse with ephemeral pool or waterhole
Lake
Pool — Pool
Rockhole or waterhole — Rockhole, Waterhole
Waterfall — Waterfall
Spring — Spring
Pipeline — pipeline
Bore, well — Bore, Well
Windpump
Tank — Tank
Abandoned — (abd)

Quarry or pit
Prospect — Sullam
Mineral occurrence
Mineral and rock commodities
- Copper — Cu
- Lead — Pb
- Magnesite — Mgs
- Nickel — Ni
- Road material — Rm

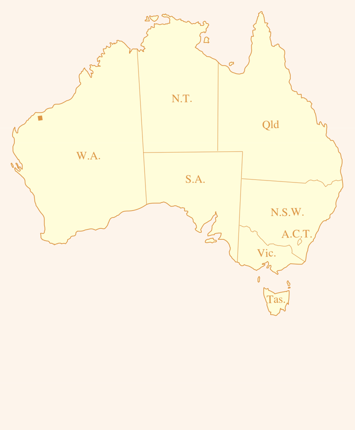


True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 2002 and moves easterly by about 0.1° in 2 years.

SHEET INDEX



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



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Geochronology by:
(1) D. R. Nelson, 1998, GSWA Record 1998/2, p. 133–135.
(2) D. R. Nelson, in prep., GSWA Record 2002/2.
(3) N. T. Arndt et al., 1991, Australian Journal of Earth Sciences, v. 38, p. 261–281.
(4) M. T. D. Wingate, 1999, Australian Journal of Earth Sciences, v. 46, p. 493–500.
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(7) D. R. Nelson, 1996, GSWA Record 1995/6, p. 156–167.
(8) J. B. Smith, 1997, University of Western Australia, PhD thesis.

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SCALE 1:100 000
1000 0 1 2 3 4 5 6 7 8 9 10
Metres Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Map Grid Australia Zone 50

The Map Grid Australia (MGA) is based on the Geocentric Datum of Australia 1994 (GDA94)
GDA94 positions are compatible within one metre of the datum WGS84 positions

Reference points to align maps based on the previous datum, AGD84, have been placed near the map corners

COOYA POOYA

SHEET 2355 **FIRST EDITION 2002**
Version 1 – June 2002