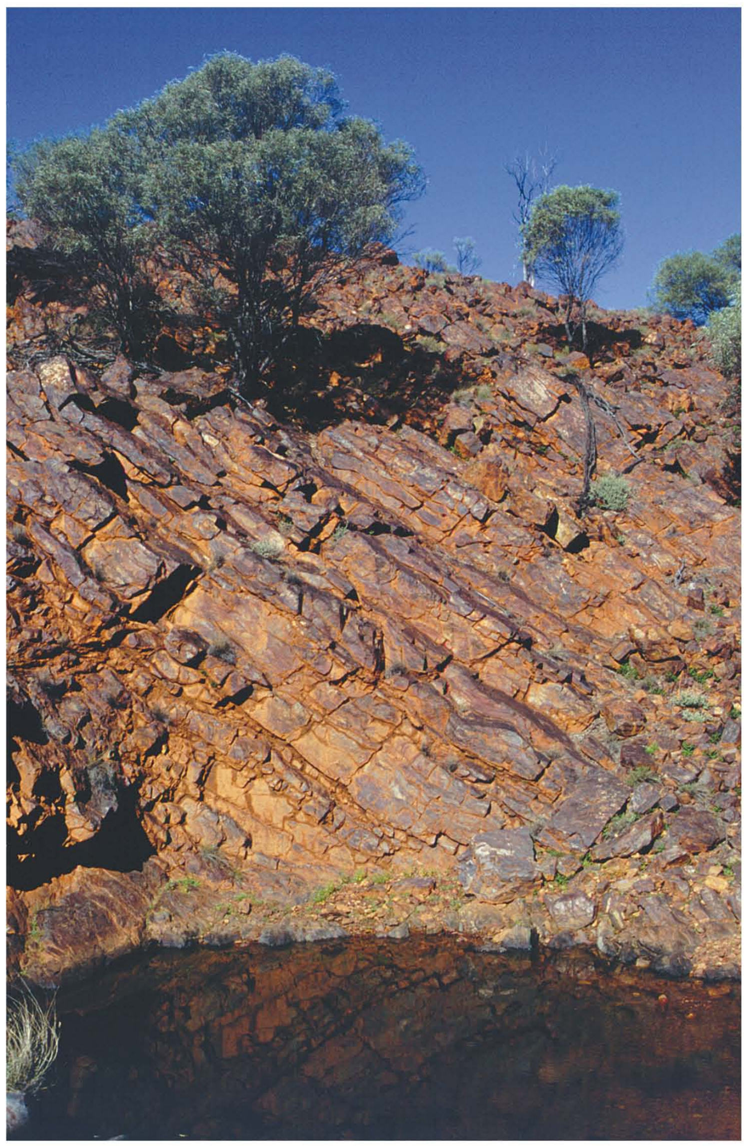
EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE EARAHEEDY 1:100 000 SHEET

By R. M. Hocking, N. G. Adamides, F. Pirajno, and J. A. Jones

1:100 000 GEOLOGICAL SERIES



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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Perth 2001

Copy editor: M. Apthorpe

REFERENCE
The recommended reference for this publication is:
HOCKING, R. M., ADAMIDES, N. G., PIRAJNO, F., and JONES, J. A., 2001, Geology of the Earaheedy 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 33p.

National Library of Australia Card Number and ISBN 0 7307 5687 4

ISSN 1321–229X

Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid of Australia (MGA) coordinates, Zone 51. All locations are quoted to the nearest 100 m.

Printed by Optima Press, Perth, Western Australia

Copies available from:
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Cover photograph:
Interbedded granular iron-formation and ferruginous shale of the Frere Formation, in river section 4.8 km south-southeast of Nunegnoo Pool (MGA 399200E 7173500N).

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Geology of the Earaheedy 1:100 000 sheet

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Abstract

The EARAHEEDY 1:100 000 sheet is located entirely within the Palaeoproterozoic Earaheedy Basin, which contains clastic and chemical sedimentary rocks of the Earaheedy Group. The group was probably deposited between about 1800 and 1770 Ma (although it could be as old as 2000 Ma), and was deformed at about 1760 Ma. The Earaheedy Group on EARAHEEDY includes, from the base upwards in conformable succession, the Yelma, Frere, Chiall, and Wongawol Formations. The lower two units are part of the Tooloo Subgroup, and the upper two are part of the Miningarra Subgroup. The Yelma Formation is composed of quartz sandstone and siltstone. The Frere Formation is predominantly granular iron-formation, with lesser ferruginous siltstone. Both are shallow-water deposits. On EARAHEEDY, both formations are present only in the Stanley Fold Belt, an east-northeasterly trending zone of deformation near the northern margin of the exposed portion of the Earaheedy Basin. The Chiall Formation includes the former Wandiwarra Formation and Princess Ranges Quartzite, both of which are now reduced to member status, and the Karri Karri Member. The Karri Karri Member, at the base of the Chiall Formation, is dominated by laminated siltstone that was deposited below wave base, with local lenses of storm-derived quartz sandstone. The Chiall Formation is a siliciclastic succession of thin-bedded quartz sandstone and siltstone, with thicker, texturally mature sandstone intervals higher in the formation. The latter are the same lithofacies as the Princess Ranges Member, but may be at a different stratigraphic level on EARAHEEDY from that of the type area of the member. The Wongawol Formation is a succession of thin-bedded, feldspathic and glauconitic fine-grained sandstone and siltstone that was deposited in very shallow, intermittently emergent, coastal conditions. Carbonate beds are present at higher levels, and the formation grades upwards into the Kulele Limestone on sheets further to the east. A gently folded sequence of probable Proterozoic age, the Sydney Heads Pass Conglomerate, is exposed at Sydney Heads Pass. The fluvial to fluvioglacial Paterson Formation (Permian) unconformably overlies the Earaheedy Group in the southwestern part of the sheet.

The rocks of the Earaheedy Group on EARAHEEDY form a broad south-verging asymmetric syncline, with a steep northern limb and a shallow plunge to the east-southeast. The structure in the southern part of the sheet is relatively simple, with gentle mesoscale folding in the core of the syncline. Along the northern limb of the syncline on northern EARAHEEDY, the rocks are strongly deformed in the Stanley Fold Belt, within which there is local isoclinal folding and thrusting.

Known mineralization on EARAHEEDY is minor. There are bands of manganiferous ironstone along faults, and thin beds of synsedimentary ironstone within the Wongawol Formation, and locally within the Karri Karri Member. These manganese-rich rocks are also anomalous in lead, copper, zinc, cobalt, and barium. These anomalous concentrations are interpreted as indicating the local development of exhalative vents within the basin, and suggest that there is potential for the development of base metal deposits in suitable rock types.

KEYWORDS: Earaheedy Basin, Palaeoproterozoic, iron formation, stratigraphy, regional geology, Stanley Fold Belt

Introduction

Location and access

The EARAHEEDY* 1:100 000 map sheet (SG 51-6, 3246) covers the southwestern part of the STANLEY 1:250 000 map sheet, from latitude 25°30' to 26°00'S and longitude 121°30' to 122°00'E (Fig. 1), and lies entirely within the Earaheedy Basin. The area is located approximately 170 km northeast of Wiluna† (population 260; 1996 census), 330 km east-northeast of Meekatharra (population 1270), and 260 km north-northeast of Leinster (population 1440). Access is via the unsealed Gunbarrel Highway,

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

† Coordinates of localities mentioned in text are shown in Appendix 1.

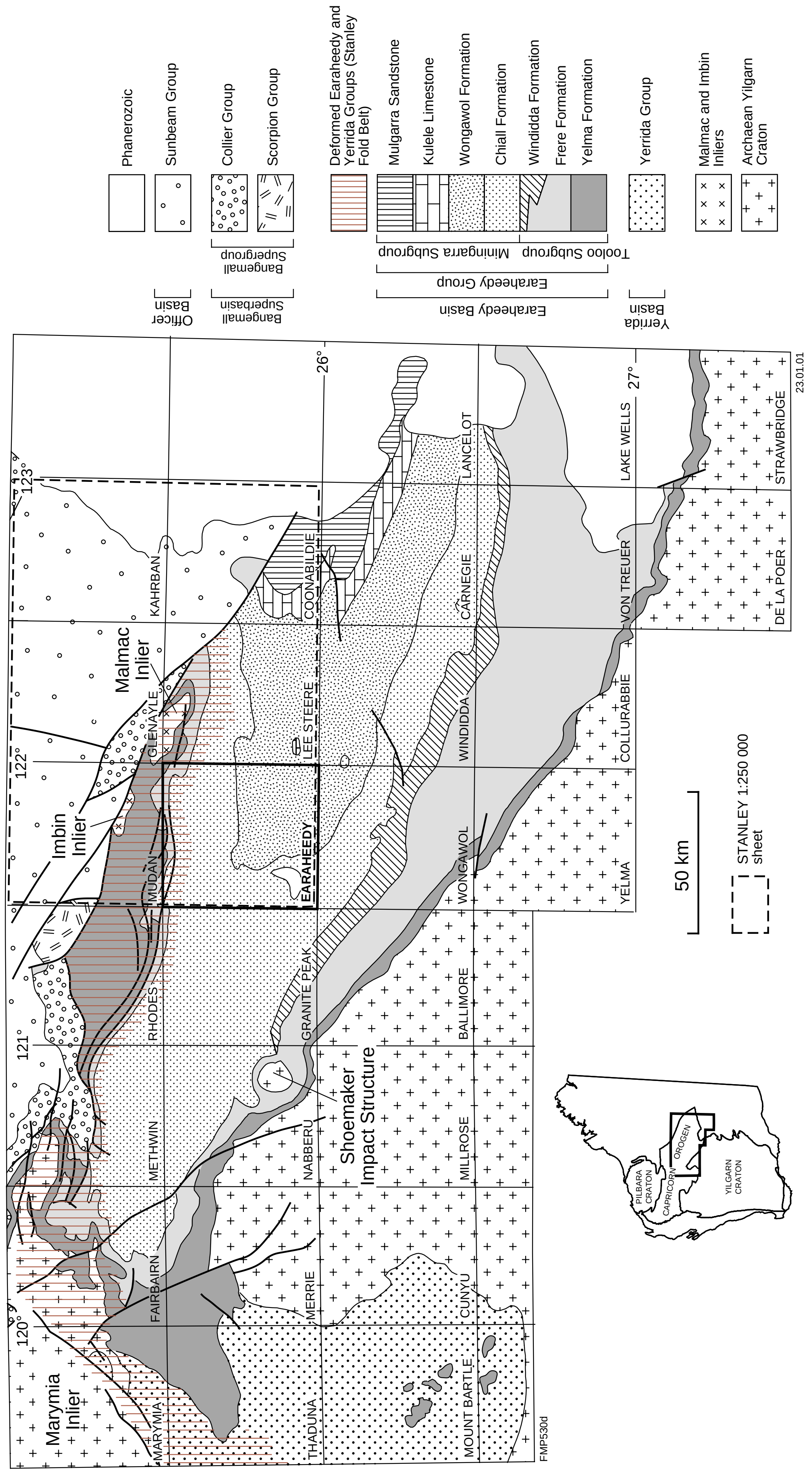

Figure 1. Simplified geology of the Earaheedy Basin and location of EARAHEEDY

which passes through the extreme southeastern corner of the sheet, and via the Wiluna–Glenayle road, along which Earaheedy Homestead is located (Fig. 2). These roads are closed for brief periods following heavy rain. Access to most of the map sheet is by four-wheel drive vehicle only, on station tracks which are in variable condition. Earaheedy is the only station within the map area, and was resumed by the Department of Conservation and Land Management in 2000 for restoration to its native, undeveloped state. Granite Peak, Wongawol, and Glenayle Homesteads (all occupied throughout the year) are adjacent to the area.

Climate and vegetation

The climate of the area is arid with long, hot summers and mild winters. Mean daily maximum temperatures range from 39°C in January* (46°C highest recorded temperature) to 20°C in July, and mean daily minima from 24°C in January to 5.3°C in July (lowest recorded temperature 3.6°C). Annual rainfall is unreliable and within the range 200–240 mm, and is related to both summer cyclones and winter depressions. Potential evaporation is between 2400 and 3000 mm.

EARAHEEDY is within the eastern extension of the Gascoyne Region of the Eremaean Botanical Province (Beard, 1990), and encompasses the western part of the Carnegie Salient system of lakes. These remnants of palaeodrainage continue eastwards to link with a main palaeodrainage through Lake Burnside. The Gascoyne Region is mulga dominated. Typical vegetation, apart from mulga (*Acacia aneura*), includes *A. quadrimarginea* and *A. grasbyi*. A large range of *Cassia* and *Eremophila* species provide the typical undershrubs, and there is abundant growth of various annuals (e.g. *Clianthus formosus*, *Goodenia maideniana*, *Ptilotus exaltatus*, *Trachymene glaucifolia*) in season. Red river gums (*Eucalyptus camaldulensis*) line major creeks, and sandplain areas are covered by spinifex (*Triodia* sp.) and scattered mallee (*Eucalyptus* sp.).

In the Carnegie Salient, salt flats and surrounding areas are covered by low mulga woodland, with samphire communities (*Arthrocnemum* sp.) in the lowest, most saline sections of the lakes. A *Frankinea atriplex* community is typical of higher elevations around the lakes and *Acacia* scrub covers sandhills.

Physiography

Five main physiographic divisions are present on EARAHEEDY (Fig. 3):

- erosional uplands with surrounding scree slopes in the north and west;
- an elevated sandplain fringed by breakaways in the southwest;
- intermediate areas of sheetwash deposition;
- active alluvial channels; and
- the lake system which occupies the central eastern and southeastern part of the sheet area.

To the north, the landscape is controlled by the erosional characteristics of the Yelma and Frere Formations. The silicified quartz sandstones and iron formations in these two units form resistant ridges that rise several tens of metres above the surrounding topography. Intervening valleys are occupied by recessive siltstones and shales. Breakaways several metres high and with scree-covered tops are typical of the shaly units of the Chiall Formation, and also of the fluvial sandstones of the Permian Paterson Formation, in the southwestern part of the sheet. Abundant kaolinitic material in the Paterson Formation gives a characteristic blue response on standard (bands 7, 4, and 1) false-colour LANDSAT images.

Extensive sheetwash flats and low-gradient slopes, characteristic of the intermediate zone between erosional uplands and saline lake systems, extend from and between breakaways. On Figure 3, well-defined alluvial systems and more diffuse sheetwash areas have been differentiated within the zone. Sandstone ridges of the Chiall Formation occur through this region, as rounded hills and linear ridges with scree-covered slopes, and these are shown as outcrop ridges on Figure 3. Thin-bedded sandstones and siltstones occupy the flat ground between or adjacent to ridges, and commonly control the drainage.

The Wongawol Formation in the centre is typified by hematite-stained rounded hills with no fresh rock (Fig. 4), and by subdued topography in the southeast with low, rounded hills, some fresh rock, and local carbonate bands. The different physiographic expression is presumably the result of deeper erosion and a more saline setting adjacent to the major lake system in the southeast, which has etched down to reasonably fresh rock. Some playas are floored by an etched surface of Wongawol Formation, with only a veneer of lacustrine deposits.

A substantial inactive sandplain is present in the southwestern part of the area (Fig. 3). The sand locally forms dunes up to 10 m high and up to 2 km in length. The sand is assumed to be residual in origin, but has undergone extensive eolian reworking. It mostly overlies the Permian Paterson Formation and may be largely derived from it. Further sandplain areas in the northern part of the sheet appear to be remnants of an originally more extensive area in front of the ridges of the Frere and Yelma Formations. Pell et al. (1999) suggested that for Australian sandsheets, the source of much of the sand is from underlying or nearby quartzose rocks, and the restriction of sandplain areas on EARAHEEDY to areas with underlying sandy rock types supports this suggestion.

Most drainage on EARAHEEDY flows southwards or eastwards into the saline lake area in the central to eastern part of the sheet. This lake area is a tributary of the northward-flowing Disappointment Palaeoriver east of the area, which was active during the Cretaceous to ?Miocene (van de Graaff et al., 1977).

Previous investigations

The EARAHEEDY area was traversed by the explorers John Forrest, in 1874, and L. A. Wells, in 1896–97, but the first geological reconnaissance was by H. W. B. Talbot (1920,

* Climate figures from Bureau of Meteorology website, for Earaheedy Homestead 1946–1996.

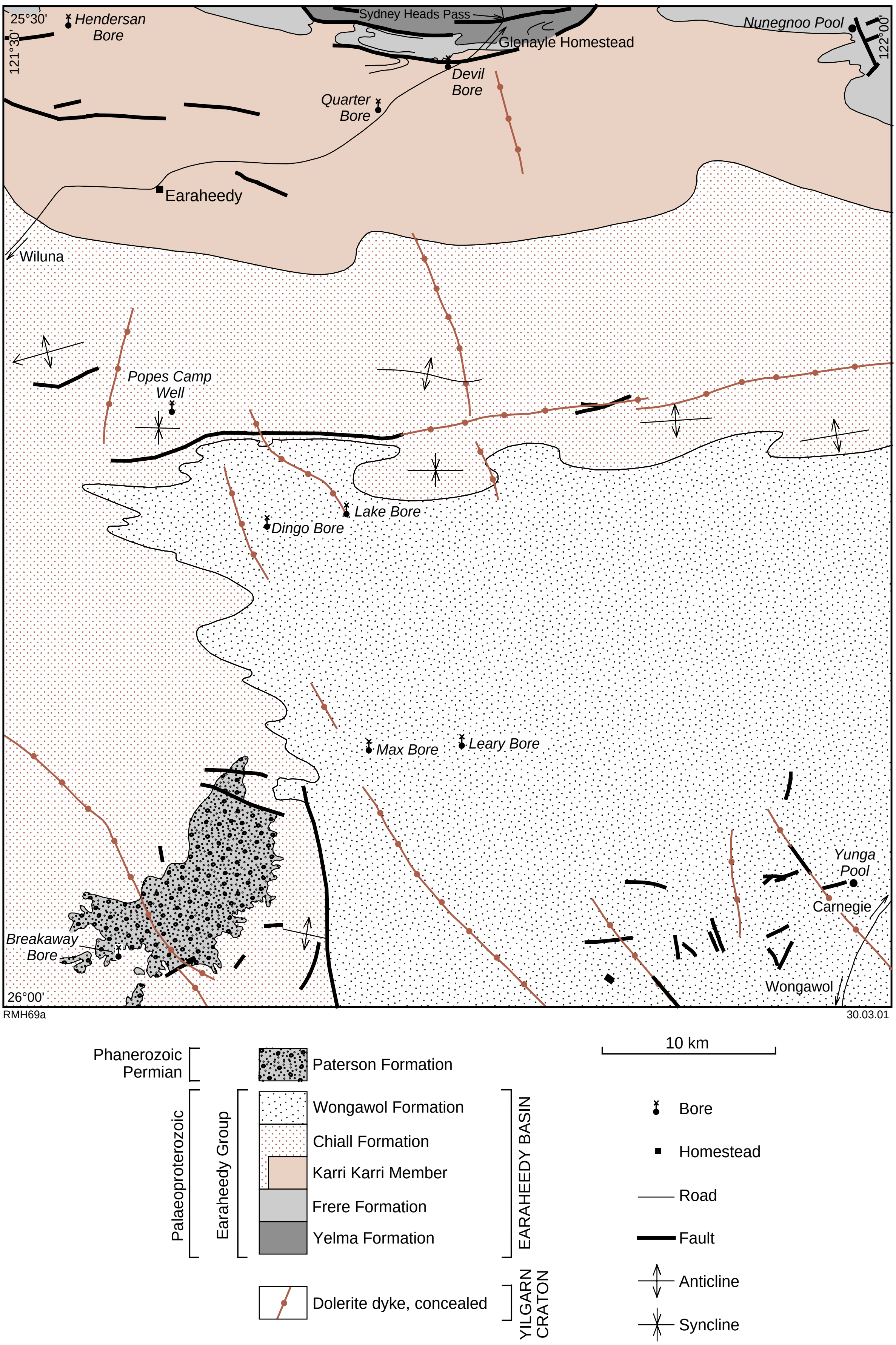

Figure 2. Simplified bedrock geology of EARAHEEDY, roads, and localities mentioned in text

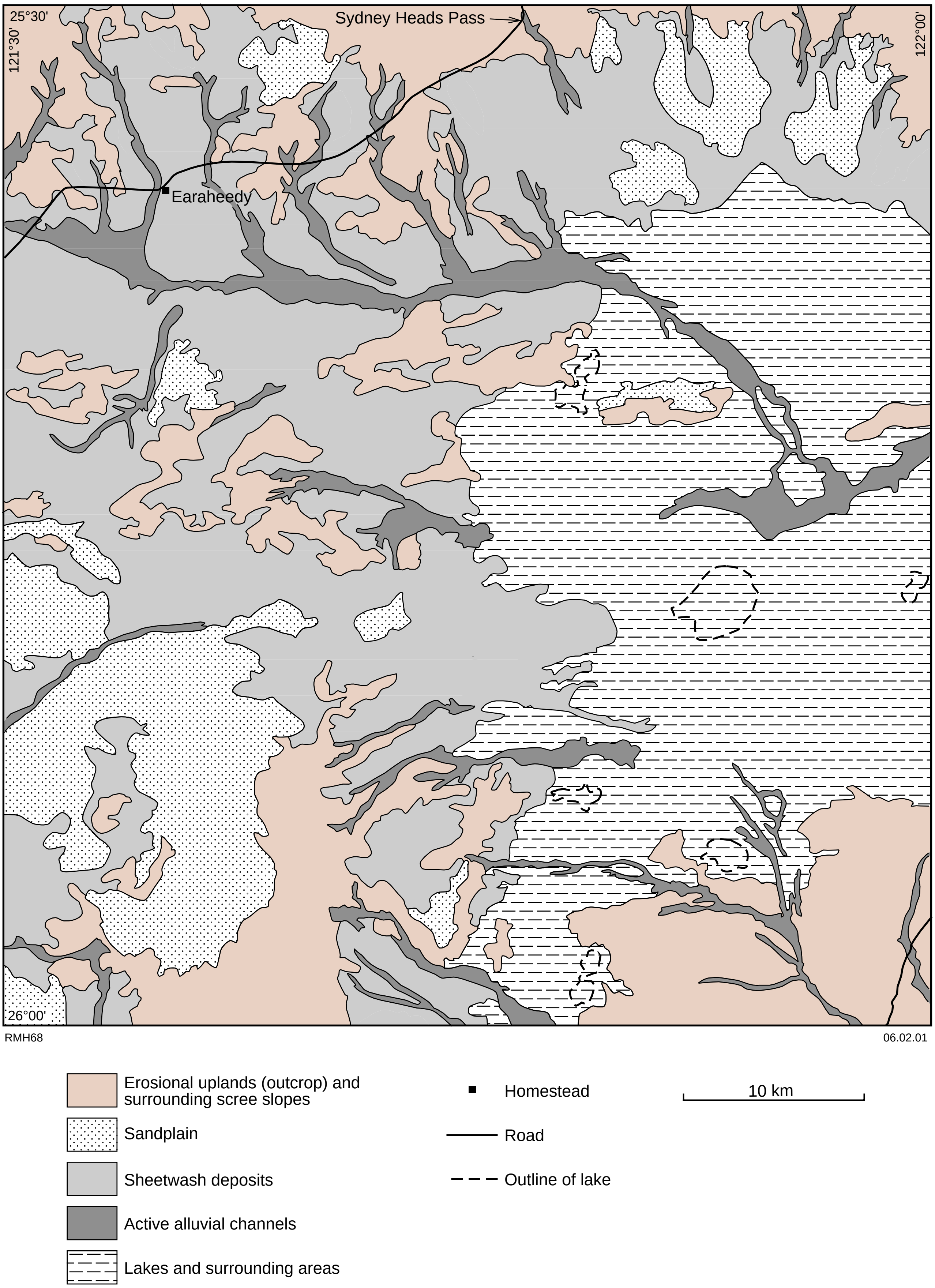

Figure 3. Landform-elements map of Earaheedy

Figure 4. Typical exposures of soft siltstone, in this case Wongawol Formation, beneath hardened caprock, with sandy sheetflood areas between mesas and plateaux, 7.6 km southwest of Leary Bore

1928) who accompanied A. W. Canning during the establishment of the Canning Stock Route in 1908.

In the 1970s, the disparate nature of the Earaheedy, Padbury, Bryah, and Yerrida Basins had not been recognized (Bunting et al., 1977; Hall and Goode, 1978; Gee, 1987), and the name 'Nabberu Basin' was used to group all these rocks, with a simple subdivision into the Earaheedy Sub-basin and Group in the east, and the Glengarry Sub-basin and Group in the west (Hall et al., 1977; Bunting et al., 1977; Bunting, 1986). Hall and Goode (1975, 1978) thus included the EARAHEEDY area in descriptions of the regional geology of the 'Nabberu Basin'. The STANLEY 1:250 000 sheet (of which EARAHEEDY is a part) was mapped in 1975 and 1976 as part of the systematic geological mapping of Western Australia by GSWA (Geological Survey of Western Australia; Commander et al., 1982). Bunting (1986) presented an integrated view of the Earaheedy Basin (referred to as the eastern part of the 'Nabberu Basin'), including detailed examination of the iron formations, and the stromatolite biostratigraphy (Grey, 1986). Gee (1990) presented a summary of the geology of the Earaheedy Basin as part of a review of the 'Nabberu Basin', and clearly foresaw the dismemberment of the latter as a geological unit. Pirajno et al. (1996) and Occhipinti et al. (1997) set out the present subdivision, preparatory to final reports on the Yerrida (Pirajno and Adamides, 2000a), and Bryah and Padbury Basins (Pirajno et al., 1998, 2000). Sanders and Harley (1971) described the hydrogeology of the region surrounding EARAHEEDY. Morris et al. (2000) discussed the regolith geochemistry of STANLEY at length, and presented a thematic regolith map.

Regional geological setting

EARAHEEDY covers the central portion of the presently exposed Earaheedy Basin (Fig. 1), which lies at the eastern end of the Capricorn Orogen. The Capricorn Orogen reflects a series of collisional events during the Palaeoproterozoic that culminated in the amalgamation of the Archaean Pilbara and Yilgarn Cratons, between c. 2200 Ma and c. 1780 Ma (Table 1). The orogen includes several Palaeoproterozoic sedimentary basins, the deformed margins of the Yilgarn and Pilbara Cratons, and the plutonic and high-grade metamorphic rocks of the Gascoyne Complex (Tyler and Thorne, 1990; Occhipinti et al., 1998).

The Earaheedy Basin is filled by the rocks of the Earaheedy Group, and onlaps various units of the Capricorn Orogen to the west, and the Yilgarn Craton to the south (Fig. 1). It is overlain by the Collier Group of the Bangemall Superbasin to the north, and by the Centralian Superbasin (Officer and Gunbarrel Basins) to the east and northeast. The present margins do not reflect the original extent of the basin; the basin axis lies further to the northeast beneath the Bangemall Superbasin and Officer Basin, and scattered outliers of probable Earaheedy Group extend for more than 100 km south and southwest across the Yilgarn Craton and older Palaeoproterozoic basins (Adamides, 1998; Dawes and Pirajno, 1998; Pirajno and Occhipinti, 1998). Magnetic and gravity images indicate that the basin is floored by the Yilgarn Craton south of the Stanley Fold Belt. Granitic and greenstone basement is exposed 5 to 15 km northeast of EARAHEEDY in the Malmac and Imbin Inliers (Pirajno and Hocking, in prep.a), immediately north of the Stanley Fold Belt (Fig. 1). Rhyodacite from the Imbin Inlier returned a tentative U–Pb SHRIMP* age of 1990 ± 7 Ma (D. Nelson, 2000, pers. comm.), very similar to the ages of granitic rocks of the Gascoyne Complex in the northwestern corner of the Yilgarn Craton.

The Stanley Fold Belt (Bunting et al., 1982; Commander et al., 1982) is a west-northwesterly trending zone of deformation along the northern margin of the exposed Earaheedy Basin (Jones et al., 2000a; Pirajno et al., 2000). The fold belt is 15–30 km wide and has a well-defined southern edge of tectonized Frere Formation. Within the fold belt, rocks of the Earaheedy Group have been tightly folded and cleaved, and wide mylonite zones are present (Pirajno and Hocking, in prep.b). These deformed rocks were previously thought to be an older succession, the Troy Creek Beds (Commander et al., 1982; Bunting et al., 1982; Bunting, 1986; Troy Creek Schist of Hocking and Jones, 1999), but they are now recognized as dynamically metamorphosed Earaheedy Group (Pirajno and Hocking, in prep.a,b; Jones and Hocking, in prep.). Deformation (the degree of shearing and cleavage, and tightness of folding) increases progressively northwards into the fold belt, and is most intense along the northern margin of EARAHEEDY. The few exposures of Earaheedy Group rocks north of the fold belt are stratigraphically low in the Earaheedy Basin successsion and undeformed, even where close to the northern margin of the belt. This suggests that the Stanley Fold Belt is a narrow zone deformed in part by strike-slip movement, rather than just by large-scale southwards-directed folding and thrusting. Given the presence of Archaean basement south of the fold belt (Jones, in prep.) and the Palaeoproterozoic age of the Imbin Inlier on the northern margin of the fold belt, the Stanley Fold Belt can reasonably be interpreted as marking the suture between the northern edge of the Yilgarn Craton and younger Palaeoproterozoic basement rocks related to, or part of, the Gascoyne Complex. In the latter case, 350 to 500 km of dextral transcurrent movement along the suture is inferred.

North of the Stanley Fold Belt on MUDAN (Fig. 1), the Earaheedy Basin is faulted against rocks previously thought to be part of the Bangemall Superbasin (the 'Kahrban Subgroup'; Muhling and Brakel, 1985; Williams, 1995). Detailed mapping, and comparison with unequivocal Sunbeam Group north of Kahrban Creek on MUDAN, indicates that these rocks are the basal unit of the Neoproterozoic Sunbeam Group of the northwestern Officer Basin (Hocking et al., 2000). To the northwest of EARAHEEDY on RHODES, probable correlatives of the Edmund Group (lower Bangemall Superbasin, younger than about 1640 Ma (Martin et al., 1999; Nelson, 1997) are present in the Scorpion Group (Hocking et al., 2000). The Scorpion Group fills a deep graben immediately north of the Stanley Fold Belt (Fig. 1).

* All ages given in this publication are from sensitive high-resolution ion microprobe (SHRIMP) U–Pb zircon geochronology, unless stated otherwise.

Proterozoic geology

Mafic dykes (*Pdy*)

On EARAHEEDY, linear magnetic anomalies, mostly negatively polarized, trend in a north to northwesterly direction, with one exception (Fig. 2). These anomalies are interpreted as dykes of unknown age. Because they are not visible at the surface on EARAHEEDY it is assumed that they cut through Archaean basement, but do not intrude the sedimentary package of the Earaheedy Group. It is also assumed, but not proven, that these dykes are of Proterozoic age. Some anomalies are represented at the surface by faults or airphoto lineaments. The northwesterly lineaments parallel a series of dykes which, elsewhere, intrude the Bangemall Supergroup and are overlain unconformably by the Paterson Formation (Commander et al., 1982). The single easterly lineament may correspond to part of the post-cratonization dyke suite of Hallberg (1987).

Earaheedy Group

Age of the Earaheedy Basin

The age of the Earaheedy Basin is poorly constrained. The basal unit of the Earaheedy Group unconformably overlies the Yerrida Group (Table 1), on PEAK HILL and GLENGARRY 1:250 000 sheets to the west (see inside cover for locations). The age of the basal units of the Yerrida Group is estimated at around 2200 Ma on the basis of Pb–Pb isochron data from stromatolitic carbonate of the Bubble Well Member (Woodhead and Hergt, 1997). The Earaheedy Group has not been affected by either the Glenburgh (2.0 Ga) or Capricorn (1800 Ma) Orogenies (Occhipinti et al., 1998, 1999a, 1999b; Tyler et al., 1998), and so most likely post-dates them. Although the Earaheedy Basin is located east of the main focus of these orogenies, and may simply have been unaffected, it is conceivable that conglomerates at the base of the Earaheedy Group, on the northwestern side of the presently preserved basin, may be related to faulting during the later stages of the Capricorn Orogeny.

The Earaheedy Group predates the Scorpion Group (Pirajno and Hocking, in prep.b), which is probably the same age as the lower Edmund Group further to the west (Hocking et al., in prep.). Correlation of the Edmund and Scorpion Groups is based on broad similarities in stromatolite form, rather than unequivocal biostratigraphic or chronostratigraphic data. Deposition of the Edmund Group began slightly later than 1650 Ma based on U–Pb SHRIMP dating of an intercalated rhyolite at the base of the group (maximum age 1638 ± 14 Ma; Nelson, 1995).

The Earaheedy Basin was deformed within the Stanley Fold Belt prior to deposition of the Collier Group, which overlies it further to the west on NABBERU 1:250 000 sheet. The Collier Group post-dates both the deposition and

Table 1. Summary of the geological history of the Earaheedy Basin and adjoining areas

Age (Ma)	*To west*	*Earaheedy Basin*	*To east and north*
Archaean	Yilgarn Craton	Northern Yilgarn Craton (basement to the Earaheedy Group, south of Stanley Fold Belt)	
c. 2200	Deposition of Yerrida Group, on Yilgarn Craton		
c. 2000–1800	Deposition of Bryah and Padbury Groups		Deposition of metasedimentary rocks, Rudall Complex, Paterson Orogen
2000	**Glenburgh Orogeny** Convergence of Yilgarn Craton and Glenburgh Terrane		
c. 1990		Felsic volcanic basement to Earaheedy Group, northern Stanley Fold Belt, in Imbin Inlier (U–Pb SHRIMP age)	
1830–1780	**Capricorn Orogeny** Convergence of Yilgarn and Pilbara Cratons		
	Deformation of Yerrida Group along Goodin Fault		
?1800–1770		Deposition of Earaheedy Group	
1790–1760		Deformation of Earaheedy Group, formation of Stanley Fold Belt	**Yapungku Orogeny**, 2nd phase (D_2), Paterson Orogen
1640–1465[a]	Deposition of Edmund Group	?Deposition of Scorpion Group, syndepositional normal movement on Salvation Fault	
		Folding and erosion	
1211[b]–1070[a]		Deposition of Collier Group	
		?Deposition of Sydney Heads Pass Conglomerate, perhaps in hinterland to Collier Group depositional basin	
1250–900			Deposition of Throssell Group, Paterson Orogen
c. 1130–800			**Miles Orogeny**, Paterson Orogen. Folding and regional deformation due to southwesterly directed compression
1070[a]–750	**Edmundian Orogeny** Deformation of Bangemall Supergroup		
<1050			Deposition of Lamil Group, Paterson Orogen

Table 1. (continued)

Age (Ma)	*To west*	*Earaheedy Basin*	*To east and north*
820–c. 800			Deposition of Sunbeam Group (base Supersequence 1, Centralian Superbasin) in northwestern Officer Basin
?600			Intrusion of Sunbeam Group by dolerite sills
c. 550			**Paterson Orogeny**, Paterson Orogen Folding and thrusting from north-northeast in Paterson Orogen. Correlates with Petermann Ranges Orogeny in Musgrave Complex and southern Officer Basin
?480			Intrusion of cross-cutting dolerite dykes, through Sunbeam Group and dolerite sills
Middle Carboniferous – Early Permian		Continental-scale glaciation of Gondwana, followed by glacigene deposition (Paterson Formation)	
Late Mesozoic		Development of palaeodrainage system across Western Australian interior, after some periods of ferruginous and siliceous duricrust development	
Late Eocene – Miocene		Waning of interior palaeodrainage system, last significant flow probably late Miocene	
24 000–15 000 yrs BP		Last major dune activity, formation and mobilization of major dunefields across Western Australia, during arid glacial maximum	

NOTES: (a) M. Wingate, 2000, written communication; cited in Martin and Thorne (2001)
(b) P. Cawood and A. Nemchin, 2000, written communication; cited in Martin and Thorne (2001)

deformation of the Edmund Group, but is older than the Edmundian Orogeny, which began at about 1020 Ma (see Table 1).

Structures of the Stanley Fold Belt (Gee, 1979, 1990) extend along the northern margin of EARAHEEDY. These are generally parallel to the structural grain of the Paterson Orogen, and may have developed during the second phase of the Yapungku Orogeny (Paterson Orogen, 1790 to 1760 Ma; Bagas and Smithies, 1998), which marks the initial collision of the North Australian and West Australian cratons (Myers et al., 1996). If the lack of imprint by the Capricorn Orogeny is accepted as indicating that the basin post-dates the orogeny, then the rocks in the Earaheedy Basin were deposited between the Capricorn and Yapungku Orogenies, between about 1770 and 1800 Ma (see Table 1). This age range is slightly older than that indicated by isotopic data from within the Earaheedy Group. Glauconites from the Yelma Formation (at the base of the Earaheedy Group) on DUKETON 1:250 000 sheet give minimum K–Ar ages around 1700 Ma and minimum Rb–Sr ages between 1590 and 1710 Ma (Preiss et al., 1975). Horwitz (1975) reported a K–Ar age of 1688 ± 72 Ma from glauconite in sandstone of the Wandiwarra Member (near the middle of the group). However, K–Ar isotopic dating is subject to resetting and this may have happened to glauconite from rocks of the Earaheedy Group. A major dynamic and thermal event in the region was the meteorite impact that formed the Shoemaker Impact Structure, for which a whole rock Rb–Sr date of 1630 Ma was determined (Pirajno and Glikson, 1998). Richards and Gee (1985) reported a lead isotope age of 1700 Ma from galena within stromatolitic dolomite of the upper Yelma Formation. Nelson (1997) obtained a U–Pb SHRIMP age of 1785 ± 11 Ma on detrital zircons from the Mount Leake Formation (PEAK HILL 1:250 000), which may correlate with the basal Yelma Formation but is geographically isolated from the remainder of the group.

Stromatolite biostratigraphy does not provide a precise determination of age. Grey (1995) commented on the lack of correlation between the taxa of the Earaheedy Group and taxa of presumably similar age (1800–1500 Ma) from the McArthur Basin (Northern Territory), and highlighted the similarities between two of the Earaheedy Group taxa (*Asperia digitata* and *Pilbaria deverella*) and taxa in older (1890–1840 Ma) successions such as the Duck Creek Dolomite of the Wyloo Group. On the basis of this evidence, Grey suggested that the age of the Earaheedy Group may lie between 1900 and 1800 Ma. It is difficult to reconcile this age with the lack of deformation that can be attributed to the Capricorn Orogeny, except by noting that the basin lies largely to the east of the focus of the orogeny. Conversely, an age greater than 1800 Ma allows a longer time frame for deposition prior to the Yapungku Orogeny, if this event was the cause of the Stanley Fold Belt.

Stratigraphic nomenclature

The stratigraphic terminology of the Earaheedy Group was initially formalized by Hall et al. (1977) and modified slightly by Bunting (1986). Further modifications have been made as a result of the current 1:100 000-scale mapping. A provisional revised lithostratigraphic framework has been established by Jones et al. (2000a,b) and defined by Hocking et al. (2000). The group is subdivided into the Tooloo (lower) and Miningarra (upper) Subgroups (Fig. 5). A disconformity was thought to separate the two but this is now interpreted as a submarine hardground (Jones et al., 2000a,b). The Tooloo Subgroup includes the Yelma, Frere, and Windidda Formations, and has an estimated aggregate thickness of about 2700 m (Bunting, 1986). The Miningarra Subgroup includes the Chiall Formation, Wongawol Formation, Kulele Limestone, and Mulgarra Sandstone. Its thickness is estimated to be at least 2500 m (Bunting, 1986). As a result of the current mapping program, the Wandiwarra Formation and Princess Ranges Quartzite of earlier workers are now downgraded to member status and included in the Chiall Formation (Jones et al., 2000b; Hocking et al., 2000). At the base of the Chiall Formation, the silty lower portion of the former Wandiwarra Formation is recognized as a separate member, the Karri Karri Member. This was mistakenly thought to be part of the Windidda Formation by Hocking and Jones (1999), Pirajno et al. (1999), Pirajno (1999), and Jones et al. (2000a). The realization that the Windidda is a correlative of the upper Frere Formation rather than the successor unit to the Frere Formation (Pirajno and Jones, in prep.) prompted the revised correlation of the Karri Karri Member.

The stratigraphic sequence on EARAHEEDY encompasses the succession from the Yelma to the Wongawol Formations (Table 2), and the younger Sydney Heads Pass Conglomerate (?Proterozoic) and Permian Paterson Formation. The Kulele Limestone and Mulgarra Sandstone are found east of EARAHEEDY (Fig. 1).

Yelma Formation (*ꝒEy, ꝒEya, ꝒEys*)

The Yelma Formation (Hall et al., 1977; Table 2; *ꝒEy*) is exposed across northern EARAHEEDY around Sydney Heads Pass, where it consists of a series of steeply dipping, folded, and commonly sheared, silicified (quartz-cemented) sandstone ridges (*ꝒEya*) interbedded with siltstone (*ꝒEys*). The upper contact with the Frere Formation is defined by the base of the stratigraphically lowest significant iron formation or chert bed (Bunting, 1986). A stromatolitic dolomite, the Sweetwaters Well Member, is present at the top of the formation west of EARAHEEDY. Estimates of thickness are uncertain because of structural repetition and shearing. Across the basin the formation shows wide variations in thickness, from a few metres in the southeast to about 1500 m in the northwest (Bunting, 1986), although some of this may be due to structural repetition. Based on grain size, sorting, and bedding, the Yelma Formation appears to be a coastal to nearshore deposit, possibly with some fluvial intercalations.

The sandstone units are silica cemented and variably ferruginous, and locally show fine spotting after carbonate. Beds range from 20 cm to 1 m in thickness. Sandstone units are mostly parallel bedded, with lesser trough cross-stratification. The sandstone is generally well sorted,

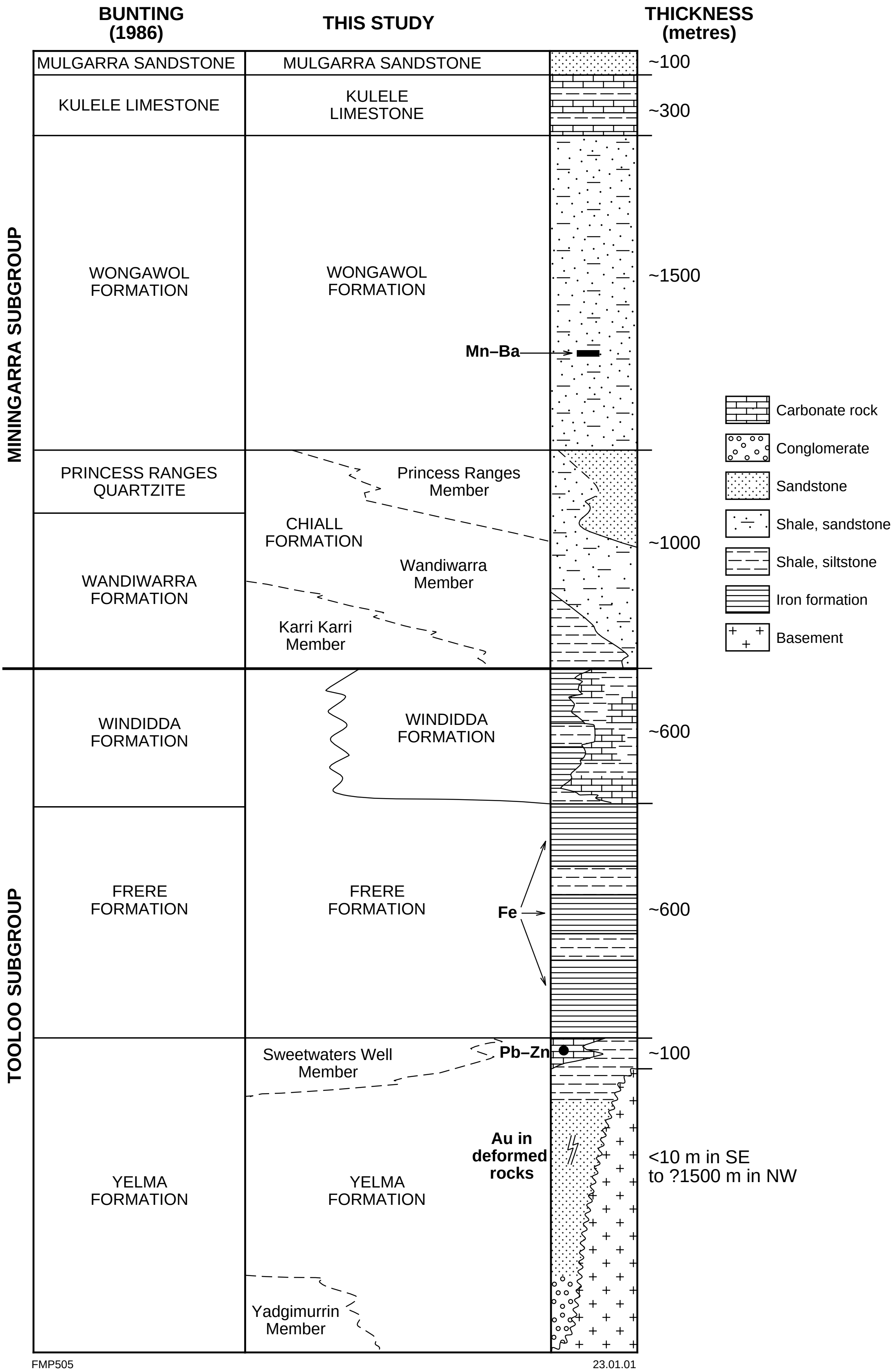

Figure 5. Stratigraphic column for Earaheedy Group, showing simplified rock types, thickness, and potential sites for mineralization

Table 2. Stratigraphic sequence on EARAHEEDY

Age	*Basin/Group*		*Formation*	*Lithology*	*Approximate thickness (m)*	*Depositional environment*
Late Carboniferous – Early Permian	**GUNBARREL** and **CANNING BASINS**		**Paterson Formation**	Coarse-grained lithic wacke, polymictic boulder lag and conglomerate, siltstone	100	Fluvial, fluvioglacial, ?glaciolacustrine
?Neoproterozoic or Mesoproterozoic			**Sydney Heads Pass Conglomerate**	Cobble to small boulder conglomerate, lesser siltstone and coarse-grained sandstone	30	Fluvial
Palaeoproterozoic	**EARAHEEDY BASIN Earaheedy Group**	**Miningarra Subgroup**	**Wongawol Formation**	Siltstone, very fine-grained sandstone, limestone, calcareous sandstone and siltstone, shale	?<1 500	Coastal, intermittent emergence
			Chiall Formation: Princess Ranges Member	Quartz sandstone, generally silicified and in continuous beds, interbedded siltstone and shale	?500	Nearshore to coastal
			Chiall Formation: Wandiwarra Member	Thin-bedded sandstone and interbedded shale	?500	Shallow marine
			Chiall Formation: Karri Karri Member	Laminated siltstone and shale with minor sandstone lenses	500–1 000	Below wave base, uncommon interbedded storm-derived sandstones
		Tooloo Subgroup	**Frere Formation**	Granular and banded iron-formation, shale, chert, minor carbonate	1 500	Shallow marine (inner shelf) to coastal
			Yelma Formation	Quartz sandstone, siltstone, minor chert and conglomerate	<1 000	Shallow marine, locally fluvial near base. Transgressive

and ranges from fine grained (dominant) to very coarse grained. Glauconite is widespread as mechanically deposited grains, and is locally replaced by quartz (Fig. 6a) which is optically continuous with the surrounding silica cement. Secondary ferruginization is indicated by euhedral magnetite crystals preferentially replacing the matrix of the rock and detrital grains (Fig. 6b). Granules and pebbles are predominantly chert, locally ferruginous, with subordinate quartz and quartzite. Elliptical ferruginous chert or massive iron oxide grains are widespread and are probably allochems transported and deposited with the detrital grains. The interbedded siltstones are composed of quartz with interstitial kaolinitic clays and widespread mica. Rounded tourmaline, pleochroic from blue-green to greenish and brown, and prismatic crystals of zircon are the main accessory minerals.

A 300 m-thick section of typical Yelma Formation is exposed 6.6 km east-northeast of Devil Bore (MGA 380500E 7177600N). It consists of approximately 50 m of creamy-grey, silica-cemented quartz sandstone with minor shale, overlain by 10 m of thinly bedded siltstone and sandstone, then by about 120 m of variably ferruginous quartz sandstone. The ferruginous sandstone is overlain by approximately 120 m of siltstone.

Frere Formation (*ɎEf*, *ɎEfg*, *ɎEfs*, *ɎEfa*, *ɎEft*)

The Frere Formation (Hall et al., 1977; Table 2) is a succession dominated by granular iron-formation, but also containing significant shale and siltstone intervals with minor sandstone. It extends throughout and characterizes the Earaheedy Basin. The lower and upper contacts of the formation are placed at the first and last thick beds of iron formation or chert (Bunting, 1986). On EARAHEEDY, the Frere Formation is found in tectonized outcrops in the northern and northeastern part of the sheet (Figs 7a and b), and commonly contains angular parasitic folds. Several facies can be recognized.

On EARAHEEDY granular iron-formation (*ɎEfg*) is interbedded with shale and siltstone, which are locally iron-rich (Fig. 8). Granular iron-formation beds are composed of sand-sized hematite, jasper, and chert peloids, in a cherty, jasperoidal, or chalcedonic quartz cement. Peloids occasionally have shrinkage cracks that could be due either to subaerial dessication or synaeresis cracking or, in places, to compaction while still plastic. Angular intraclasts of chert or jasper, ranging from sand- to cobble-sized, are common in places. Individual granular iron-formation beds are generally 5–50 cm in thickness and are commonly lenticular. Cross-bedding is locally discernible, and there are apparent clay drapes on foresets, now intensely ferruginized. The beds vary from highly ferruginous to dark-grey chert. Hematite is the dominant oxide, but magnetite is present as euhedral crystals that crosscut peloid boundaries, suggesting post-depositional iron crystallization in less oxidising conditions. Primary magnetite is also present and forms distinct layers. Magnetic susceptibility varies from less than 100×10^{-5} SI in the chert-rich bands to more than $10\,000 \times 10^{-5}$ SI in magnetite-rich shale bands. Granular iron-formation is well exposed in a stream section 4.8 km south-southeast of Nunegnoo Pool (MGA 399200E 7173500N; cover photo) on the eastern edge of the sheet.

Detailed studies of the granular iron-formations of the Earaheedy Group (Hall and Goode, 1978; Goode et al., 1983; Bunting, 1986) indicate textural similarities with iron formations of the Lake Superior region of North America (Gross, 1972; Kimberley, 1989; Morey, 1983). Peloidal textures, orthochemical and allochemical cements, iron-rich chlorite, and the presence of accessory minerals such as minnesotaite and stilpnomelane, are common in both areas. These features have been interpreted as the result of chemical deposition followed by limited reworking of the sediment whilst still plastic (Beukes and Klein, 1990, 1992). Microfossils from the Frere Formation were described by Walter et al. (1976) and re-evaluated by Tobin (1990). Tobin recognized eight distinct microbial assemblages, which are similar to those in the Gunflint Iron Formation and the Duck Creek Dolomite. He considered that the assemblages were transported, except for some stromatolitic and oncolitic forms, and followed Goode et al. (1983) in interpreting the water depth during deposition of the Frere Formation as above storm wave base, but still deeper than about 50 m.

Siltstone and shale (*ɎEfs*) are interbedded with iron formation at all scales, and locally contain thin dolomite bands (Fig. 9). They are similar to siltstone and shale in the Karri Karri Member of the Chiall Formation (see below), and without stratigraphic control, the two may be indistinguishable. They are interpreted as quiet, sub-wavebase deposits. Sandstone that may be Frere Formation, based on its stratigraphic relationships, is mapped locally as *ɎEfa*.

Laminar iron-formation (*ɎEft*), composed of meso- and micro-banded iron-formation with alternating ferruginous and siliceous layers (Fig. 7a,b), resembles banded iron-formation but is interpreted as having a tectonic origin due to tight folding and shearing (see **Structure and metamorphism**). The laminar iron-formation is composed of commonly massive mesobands of chert 2–5 cm thick, alternating with microbanded iron oxides of similar thickness with millimetre-size alternations of cherty microcrystalline quartz and iron oxides.

Laminar iron-formation is well exposed 2.3 km north of Quarter Bore (MGA 370600E 7175600N), as horizons within a shaly succession. Chert bands are mostly continuous, but are locally disrupted into lenses. An outcrop of laminar iron-formation, approximately 25 m thick, is exposed 2.5 km northeast of Devil Bore (MGA 376400E 7176900N). It is composed of alternating light (siliceous) and dark (ferruginous) bands 10–25 cm thick, with lenticular cherty layers. The sequence is folded in a series of tight synclines and anticlines with sheared common limbs. Locally, bedding-parallel quartz veins are present, and are disrupted by small-scale faults (Fig. 7b). Further east, 4 km east-northeast of Devil Bore (MGA 377900E 7176800N), a measured section approximately 11 m thick (Fig. 8) highlights the main features of this unit, in particular the semicontinuous

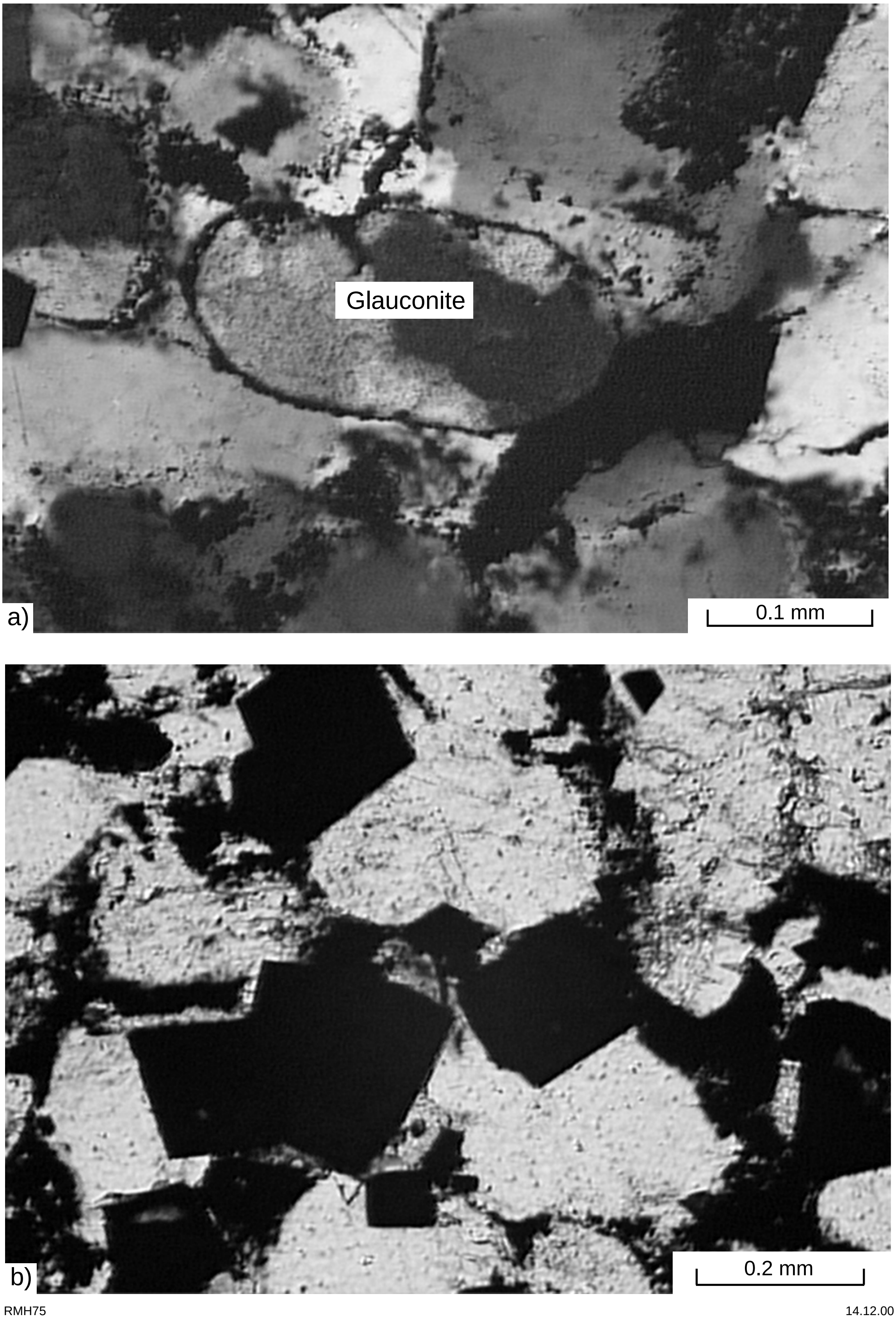

Figure 6. Petrographic features of sandstone of the Yelma Formation
a) Glauconite grain surrounded by quartz. GSWA 152725, cross-polarized light
b) Euhedral magnetite replacing the matrix and detrital grains of quartz sandstone. GSWA 152719, plane-polarized light

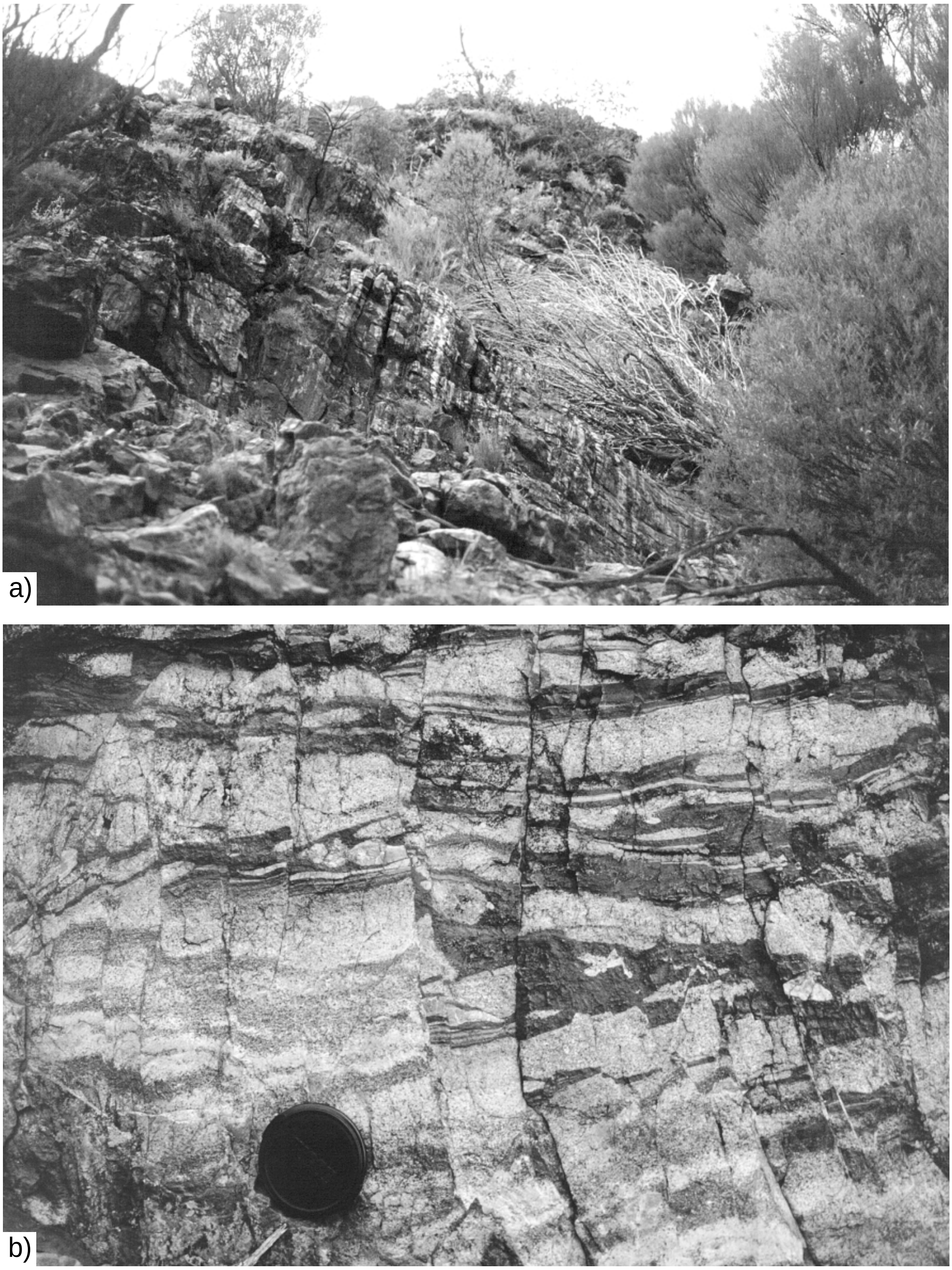

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Figure 7. Laminar iron-formation within Frere Formation
a) Outcrop of laminar iron-formation, deformed in Stanley Fold Belt (*PEft*), 1.8 km southwest of Sydney Heads Pass
b) Close-up view of laminar iron-formation, showing small-scale faulting, 1.8 km southwest of Sydney Heads Pass. The lens cap is 5.5 cm in diameter

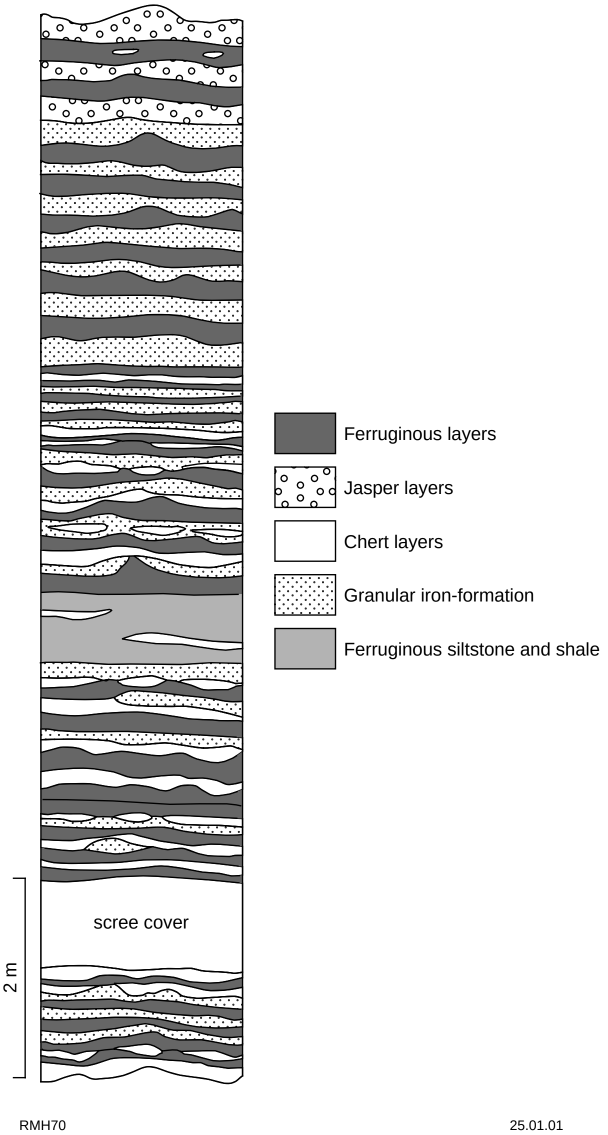

Figure 8. Measured section of Frere Formation 1.8 km south-southeast of Sydney Heads Pass. Ferruginous layers may be secondary enrichment of iron oxides, and some of the undulations are probably primary ripple stratification

nature of the layers and the alternations between the various rock types.

Chiall Formation (*ꝒEc, ꝒEca*)

The Chiall Formation (Hocking and Jones, 1999; defined by Hocking et al., 2000; Table 2) consists of siltstone and shale with lesser sandstone intercalations, and is subdivided into the Karri Karri, Wandiwarra, and Princess Ranges Members. The Wandiwarra and Princess Ranges Members were relegated to member status within a single formation following recognition that they were part of a single depositional package (Hocking et al., 2000). Essentially, the Karri Karri Member at the base of the formation is a shaly interval distal from its source; the Wandiwarra Member contains lithic wacke and quartz wacke that is texturally and compositionally somewhat immature; and the Princess Ranges Member is characterized by quartz sandstone. The Karri Karri Member can be differentiated relatively easily, but it cannot be determined whether the rocks previously mapped as 'Princess Ranges Quartzite' on EARAHEEDY are at the same stratigraphic level as those in the type section in the Princess Ranges to the south on WONGAWOL (Jones, in prep.), or instead are a facies equivalent at a higher or lower stratigraphic level. Therefore, a relatively simple two-fold division is made on EARAHEEDY. Undivided Chiall Formation (*ꝒEc*) consists mostly of siltstone and shale with lesser fine- to medium-grained sandstone, which dominates the Chiall Formation above the Karri Karri Member. Prominent sandstone ridges extend across central EARAHEEDY, and are mapped simply as sandstone-dominated intervals (*ꝒEca*), where they were previously mapped as both 'Wandiwarra Formation' and 'Princess Ranges Quartzite' by Commander et al. (1982). All are silicified, but are of variable textural and compositional maturity. They are present mostly higher in the Chiall Formation, but cannot be assigned confidently to the formally named Princess Ranges Member.

The lower Chiall Formation is typified by interbedded thin-bedded sandstone and siltstone (*ꝒEc*). The siltstones are purple-grey to red, locally quartz-rich, micaceous, and commonly show millimetre-scale parallel or wavy laminations and small-scale scour truncations. Glauconite is commonly present, as elliptical detrital peloids, and is in places partly or totally replaced by iron oxides. Detrital white mica is locally abundant, and subrounded to rounded tourmaline and zircon are common accessory minerals. Symmetrical, asymmetrical, and interference ripples, trough and planar cross-bedding, planar bedding, and hummocky cross-stratification have been recognized. Large, broadly symmetrical ripple marks, with wavelengths of 40 cm and heights of 6 cm are exposed next to the track 1.6 km west-northwest of Breakaway Bore (MGA 354600E 7126200N), and large-scale cross-bedding is present 3.6 km southeast of Breakaway Bore (MGA 359600E 7124700N). Groove marks and scours are present on the underside of some beds, and bedding is locally contorted (Fig. 10). Current lineations on thin sandstone units indicate mainly north-northwestwards trending palaeocurrents. Together, the structures and lithology suggest marine shelf deposition marginally below wave base, with scattered sand shoals and intermittent storm deposits. Mass-flow events were probably associated with storms, although some may have been earthquake-triggered.

Intervals mapped as *ꝒEca* are typically silica-cemented, cross-bedded quartz sandstone in mesofolded anticlinal ridges, separated by zones either of no exposure or of interbedded siltstone and shale. These relationships can be seen in the steeply dipping outcrops around Popes Camp Well, where sandstone ridges are well defined and can be easily traced on aerial photographs, whereas siltstones are recessive, with exposures restricted to low breakaways. In the southwestern corner of the sheet, gentle dips and outcrop-scale folding mask the continuity of the sandstone units and result in a more uniform photogeological response. Texturally and compositionally,

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Figure 9. Parallel-laminated siltstone, Frere Formation, 3.2 km north-northeast of Quarter Bore. Lens cap is 5.5 cm in diameter

the sandstones are similar to the thinner intercalations grouped with undivided Chiall Formation. White mica is an abundant component, and rounded tourmaline is the most common accessory detrital mineral. Glauconite is widespread, as rounded peloids of similar size to the clastic grains (Fig. 11). Some glauconite grains show plastic deformation at the contacts with more rigid grains (Fig. 12). In impure quartz sandstones, the quartz is generally subangular to subrounded, associated with glauconite, and enclosed in a clay matrix. Symmetrical megaripples with wavelengths of 55 cm and a height of 7 cm are present about 10.6 km east-northeast of Breakaway Bore (MGA 366800E 7127100N). Mud-chip intraclasts (Fig. 13), contorted bedding (Fig. 14), and erosional truncations are common. Siltstones interbedded with the sandstones are wavy bedded (Fig. 14), parallel-bedded, and low-angle cross-laminated, and locally enclose thin lenses of quartz sandstone. Current lineations and cross-beds indicate northwestwards and north-eastwards palaeocurrents (Fig. 15), although data are sparse.

Karri Karri Member (PEck, PEcka, PEckt)

The contact of the Karri Karri Member (Hocking and Jones, 1999; defined by Hocking et al., 2000) with the underlying Frere Formation is placed at the top of the last major unit of granular iron-formation or chert (Bunting, 1986). The upper boundary is placed at the onset of significant sandy deposition. On EARAHEEDY, the member is estimated to be at least 1 km thick based on dips and structure contours, although much of this thickness may be due to structural repetition.

The Karri Karri Member on EARAHEEDY is a gently to tightly folded succession dominated by parallel-laminated, reddish to red-brown and purple ‘pin-stripe’ siltstone and

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Figure 10. Contorted bedding from syndepositional slumping in Chiall Formation sandstone bed, 1.2 km east-southeast of Breakaway Bore. Lens cap is 5.5 cm in diameter

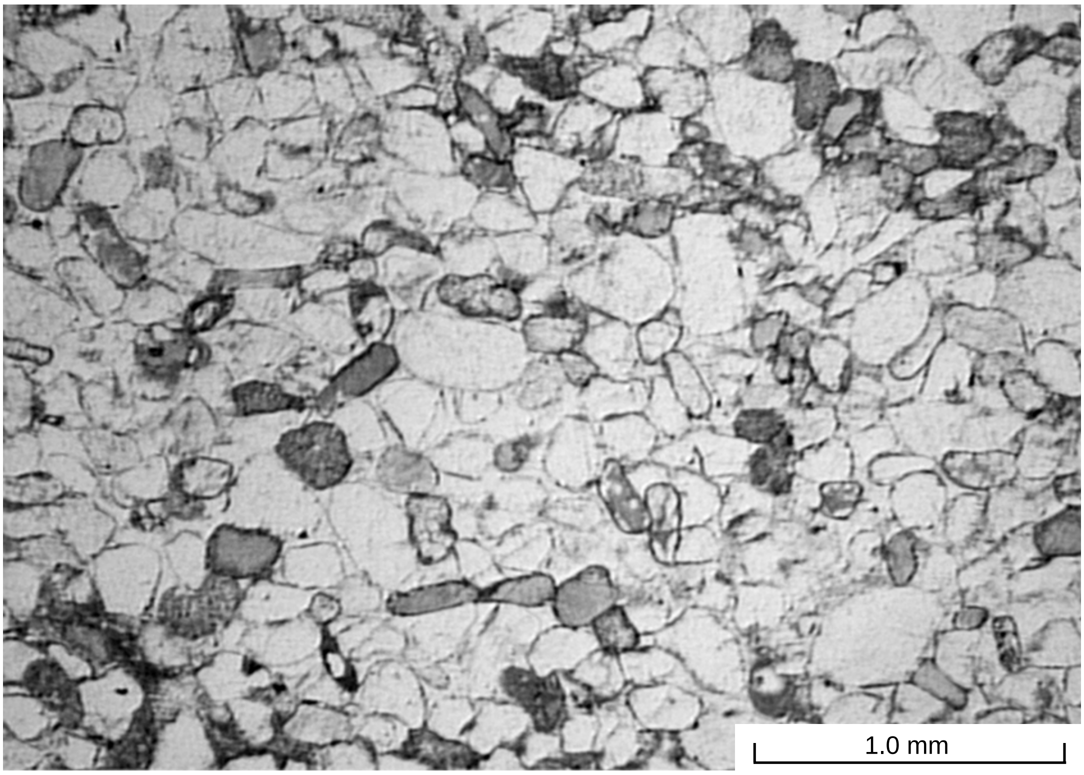

Figure 11. Association of rounded quartz (white) and glauconite (grey) in quartz sandstone of upper Chiall Formation. GSWA 152757, plane-polarized light

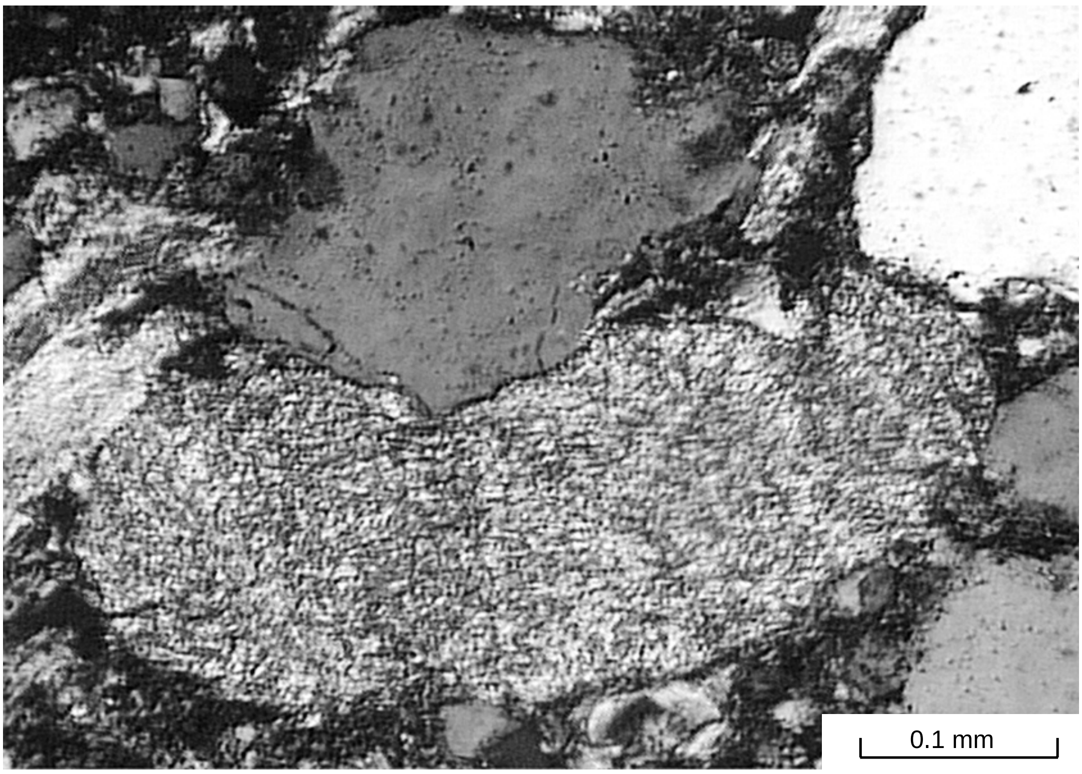

Figure 12. Plastic deformation of glauconite peloid (dark grey, mottled) at the contact with quartz (dark grey). Upper Chiall Formation, GSWA 152758, cross-polarized light

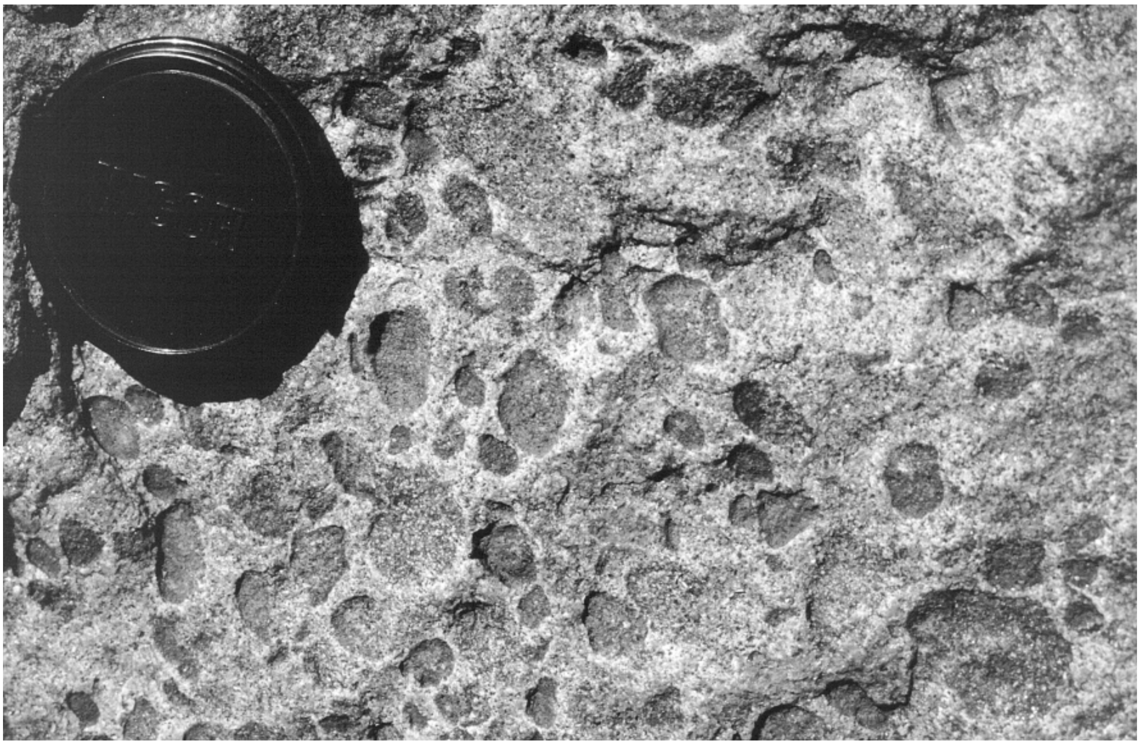

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Figure 13. Mud-chip moulds in quartz sandstone of upper Chiall Formation, 7.5 km south-southwest of Max Bore. Lens cap is 5.5 cm in diameter

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Figure 14. Low amplitude broad ripples over slumped bedding, possibly pillow structures, in upper Chiall Formation 11.3 km east-northeast of Breakaway Bore. Match is 45 mm in length

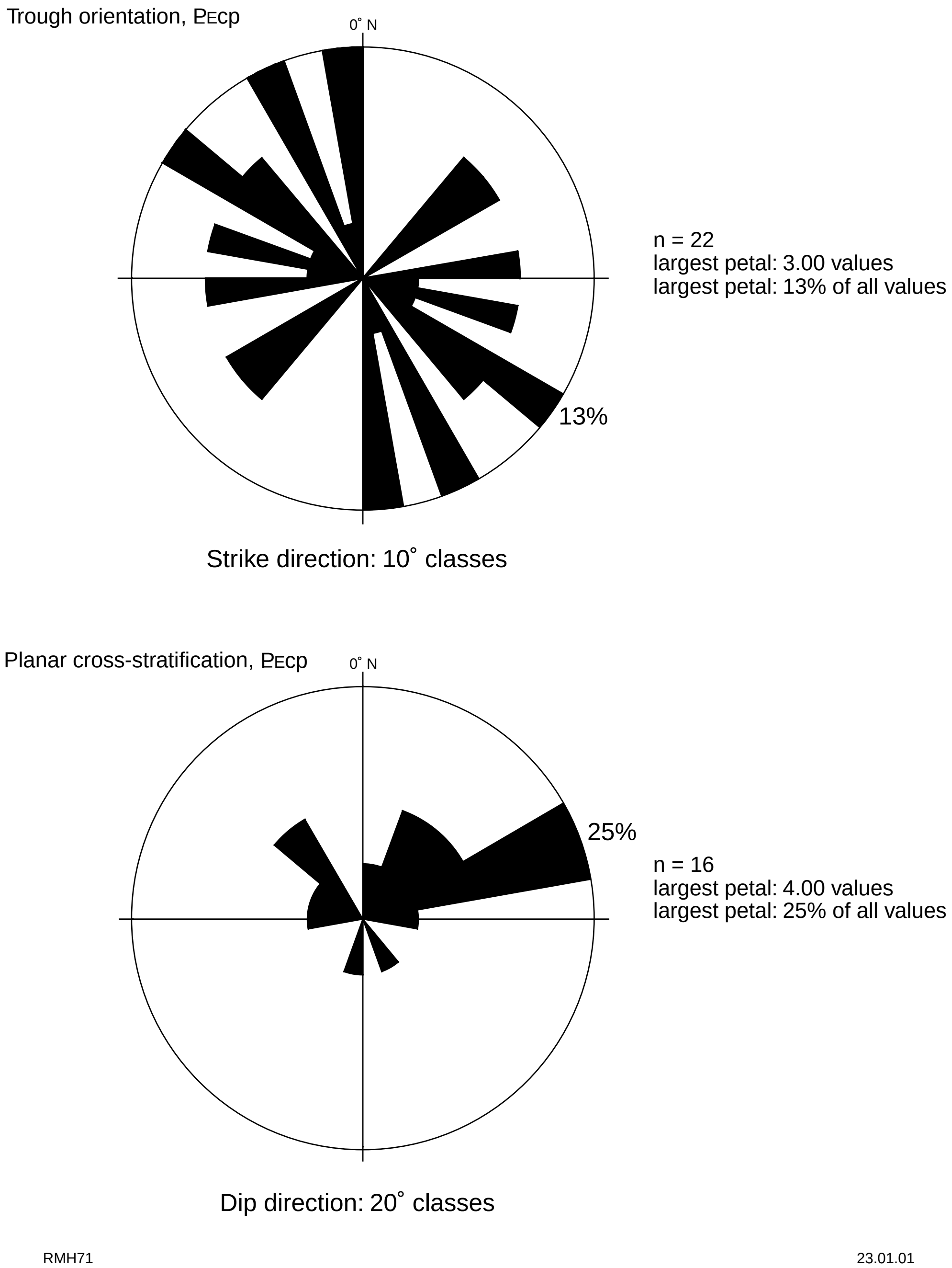

Figure 15. Palaeocurrent orientations in the upper Chiall Formation. Cross-bed orientations, sense of direction uncertain (top), and foreset dips of planar cross-bedding (bottom)

shale (*ꝒEck*). In outcrop, the siltstones are identical to the siltstones interbedded with iron formation of the Frere Formation. Small-scale contorted stratification, due to slumping, is present but uncommon, as are ripples and isolated small, low-angle cross-beds. Fresh material from drillholes commonly contains abundant green biotite, replaced in part by chlorite. Some laminae are carbonaceous, suggesting that the siltstones may have contained organic material. This inference is also supported by geochemical data on synsedimentary ironstones, discussed below in **Economic geology**.

Fine-grained micaceous sandstone (*ꝒEcka*) is present as lenses within the siltstone, and thin carbonate bands are locally present (e.g. 3.5 km south-southwest of the Henderson Bore, MGA 351800E 7174600N). Sandstone beds individually are up to one metre thick, but are mostly about 60 cm, and occur in lenses as much as 20 m in thickness. These contain minimal shaly material. Because of their position on the southern margin of the Stanley Fold Belt, exposures of the member are commonly tightly folded, cleaved, sheared, and locally intruded by quartz veins and veins containing abundant iron and manganese oxides. A separate unit (*ꝒEckt*) recognizes the Stanley Fold Belt structural overprint.

The siltstone and shale facies that dominates the Karri Karri Member is a low energy, sub-wavebase deposit. The regular, dominantly parallel lamination indicates generally stable conditions, with minor bottom-current activity forming scattered ripples and small-scale, low-angle cross-bedding. Slope failures and destabilizing shocks (such as from earthquakes) may have generated the small-scale contortions seen in some exposures. Grading, claystone intraclasts, sandstone beds with locally scoured, massive bases and parallel-laminated and rippled tops, and the association with thinly laminated siltstone, together suggest a mass-flow origin for the sandstone intervals.

Wongawol Formation (*ꝒEo*)

The Wongawol Formation (Hall et al., 1977; Table 2) is a monotonous succession of thin-bedded siltstone, feldspathic sandstone, and shale, with discontinuous scattered carbonate horizons and intraclastic breccias, particularly at higher levels (Sholl Creek Member of Hall et al., 1977, and Bunting, 1986). The lower contact with the Chiall Formation is placed at the top of the uppermost mature quartz sandstone. The upper contact with the Kulele Limestone is present to the south and east of EARAHEEDY. It is gradational, and placed where limestone becomes the dominant lithology (Bunting, 1986). Thickness estimates are complicated by shallow dips, mesoscale folding and local faulting, but the formation may be up to 1500 m thick.

Sandstone in the Wongawol Formation is fine to very fine grained, and locally glauconitic, with bands composed of subangular to subrounded glauconite peloids which are locally replaced by, or partly enclose, rhombs of brown ?ankeritic carbonate. Greenish-grey chloritic sandstone beds with chert intraclasts are locally interbedded with the siltstones. The lower Wongawol Formation on central EARAHEEDY, between Lake and Dingo Bores, is dominated by siltstone and is similar to the underlying siltstone facies of the Chiall Formation.

Carbonate bands increase in abundance higher in the formation. They are commonly 2–3 m thick, parallel- to wavy-laminated, and consist of thinner beds around 10–30 cm thick interbedded with fine-grained sandstone. The carbonate bands are composed of carbonate crystals around 0.15 mm in diameter, associated with clastic quartz, white mica, and minor green biotite. Veins of clear carbonate cut the rock, and are associated with euhedral ?ankerite. Peloidal horizons associated with the carbonates contain peloids of carbonate, glauconite, recrystallized chert, ferruginous chert, and iron oxides, in a fine-grained matrix that originally may have been carbonate. Chert beds, peloids of chert and ferruginous chert, and intraclasts of chert suggest brecciation and reworking of chemically precipitated sediments prior to lithification, and a similar depositional setting to that of the granular iron-formation in the Frere Formation, which contains similar intraclastic breccias. Thin beds of intraclastic breccia, largely derived from adjacent cherty layers, are present 2.3 km south of Max Bore (MGA 369900E 7135700N).

The Wongawol Formation contains abundant primary sedimentary structures indicative of a very shallow, intermittently emergent, coastal setting. These include swash marks, ripple washouts, wrinkle marks, mud-chip breccias, ball-and-pillow structures at sandstone–siltstone interfaces, abundant primary current lineation, and varied short-wavelength ripples (including straight, sinusoidal, interference, and parasitic forms). Typical ripple wavelength is 3–6 cm with a height around 0.2 – 0.5 cm. Supercritically climbing (in-phase) ripple marks (Fig. 16) indicate periods of high sediment supply. Irregular contorted bedding (Fig. 17) due to shock-loading of semi-consolidated sediment is widespread, and locally can be followed for several hundred metres.

Structure and metamorphism

The Stanley Fold Belt, along the northern margin of EARAHEEDY, is a zone of folding and sinistral strike-slip deformation that occurred as a result of compression from the northeast (Table 1). The rocks in the area between the Stanley Fold Belt and the presently exposed southern margin of the Earaheedy Basin form the southern limb of a broad south-verging, shallow east-southeasterly plunging asymmetric syncline (Fig. 1). The Stanley Fold Belt is the upthrust, steep to overturned northern limb of the syncline. The deformation was focused on a pre-existing zone of weakness, probably a west-northwesterly trending deep crustal suture between the Yilgarn Craton and younger crustal rocks to the north. The intensity of deformation in the Stanley Fold Belt decreases progressively southwards. Areas near the core of the regional syncline are characterized by crumpling of beds, and the development of widespread easterly trending mesoscale folding.

On EARAHEEDY, the structural patterns vary from strong folding in the north along the southern margin of the

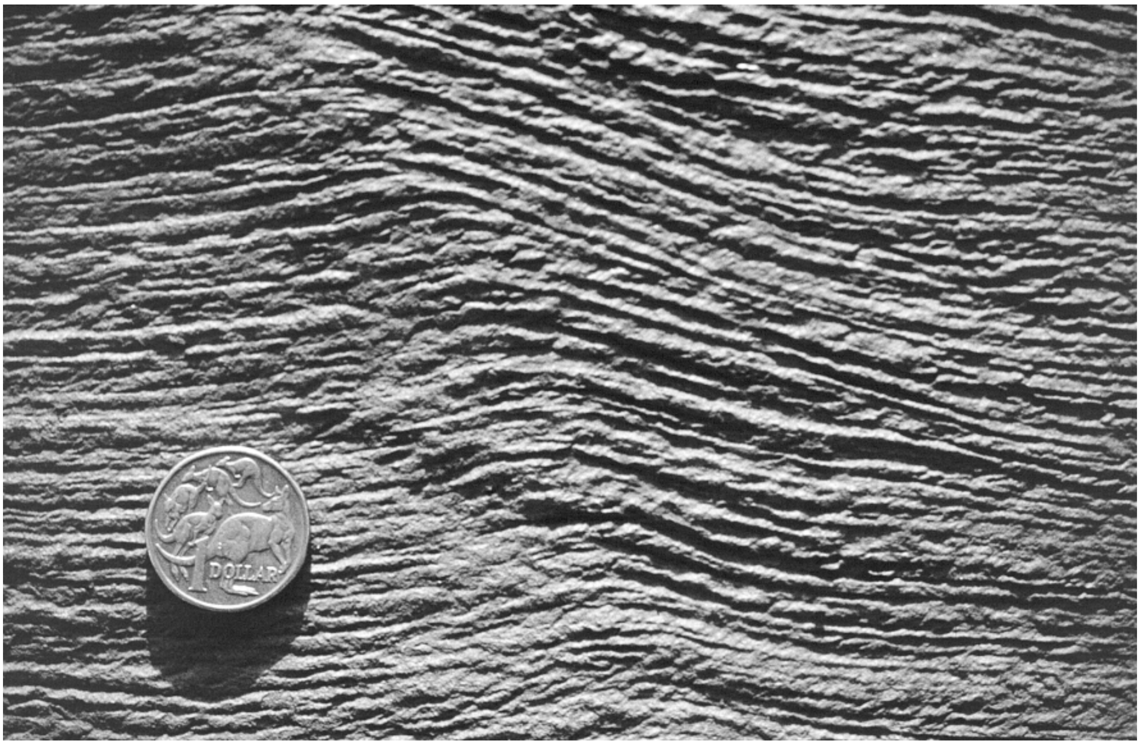

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Figure 16. Supercritically climbing ripples, indicating abundant sediment supply, in fine-grained sandstone of the Wongawol Formation, 13.4 km southwest of Yunga Pool. Coin is 24 mm in diameter

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Figure 17. Contorted bedding in fine-grained micaceous and feldspathic sandstone of the Wongawal Formation. Locality 6.2 km southwest of Yunga Pool. The lens cap is 5.5 cm in diameter

Stanley Fold Belt, with shearing of fold limbs, vertical and locally overturned beds, and development of pervasive axial-plane cleavage, to relatively weak deformation in most of the southern part of the sheet. In this area, gentle open folding is picked out by beds of fine-grained sandstone and, at higher stratigraphic levels, carbonate.

The strong deformation in the Stanley Fold Belt is typically shown by the Z-style vergence of folds in more competent units of the Yelma and Frere Formations, at Sydney Heads Pass. In this area, the folds are associated with development of a penetrative axial-plane cleavage, with bedding-cleavage intersection lineations showing a gentle (20°) westerly plunge. The effect of possible cross-folding is indicated by the presence of locally opposing dips, and fold limbs are sheared by easterly trending strike-slip faults. About 3 km north-northeast of Devil Bore (MGA 375400E 7178400N) a sequence of inter-bedded cleaved siltstone and sandstone is strongly deformed, with steep dips, and tight to isoclinal folding (Fig. 18a). The folding shows a gentle easterly plunge and is associated with low-angle reverse faulting. Quartz veins follow the bedding, and are deformed in conformity with the enclosing rocks.

Porphyroblastic magnetite crystals are present in deformed granular iron-formation, with fibrous quartz crystals locally developed in pressure shadow areas (Fig. 18b). Tight folding and shearing has produced laminar iron-formation in intervals of the Frere Formation with strong competency contrasts. The laminar structure (Fig. 18c) results from the redistribution of secondary iron oxides (hematite and goethite) along microshears that alternate with more competent cherty bands.

In central EARAHEEDY, mesoscale folding produces crumpled rocks, with easterly trending axes, and with fold hinges and bedding-intersection lineations plunging gently towards the east or west. These mesoscale folds have wavelengths of several metres to several tens of metres and are highlighted by the sandstone beds in the Chiall Formation.

Apart from the easterly trending faults in the Stanley Fold Belt, significant fault directions are east-northeasterly and northwesterly, with a major east–west fault above a dyke (based on magnetic expression) through the centre of the sheet. The northwesterly trending faults have a strong magnetic expression.

Depositional setting and basin evolution

Pirajno et al. (2000) and Jones et al. (2000a,b) presented a model for the geodynamic evolution of the Earaheedy Basin. The model takes into account the influx of iron during the deposition of the Frere Formation, the allochemical nature of the jasperoidal and iron oxide clasts, the coastal to shallow-marine environment for the Earaheedy Group, and the lack of evidence for contemporaneous volcanism, deformation, or major tectonism.

The exposed Earaheedy Group is characterized throughout by deposition in a northwards-deepening, shallow-marine to coastal environment, with a shoreline to the south and southeast. The rocks exposed on EARAHEEDY are dominantly inner-shelf deposits, with the exception of parts of the Yelma Formation, which may be fluvial to coastal sediments; sandstones in the upper Chiall Formation, which may be shoreface to foreshore deposits; and the bulk of the Wongawol Formation, which is dominated by an intermittently emergent coastal facies. The lack of major change in bathymetry in the Earaheedy Group suggests no abrupt hinterland uplift or substantial basin subsidence. This indicates that tectonism within the Earaheedy Basin was limited to passive subsidence, and suggests that the Earaheedy Basin was part of a passive continental margin along the northeastern edge of the Yilgarn Craton. The exposed part of the Earaheedy Group represents the southern coastal to nearshore portion of the continental margin, where deposition occurred in response to subsidence, sediment loading, and compaction. Deposition was strongly influenced by water chemistry, sediment supply, and minor sea-level fluctuations. The latter are thought to have been both eustatic and tectonic. Short-term eustatic changes in a greenhouse climate (greenhouse because there are no pronounced shifts in interpreted bathymetry: Read et al., 1995) are thought to have produced metre-scale cyclicity in carbonates. Longer term tectonism is believed to have been responsible for increases in sand deposition, due to either hinterland rejuvenation or basin subsidence. There are scattered indications of saline lagoonal environments, as in an arid climate, during deposition of the group (although generally not on EARAHEEDY). These indications occur specifically in the Sweetwaters Well Member; in cherts in the Frere Formation; and in carbonates in the Windidda Formation, Wongawol Formation, and Kulele Limestone. The persistent low-energy conditions in a nearshore and coastal setting may have been due to an arid climate with low runoff and sediment influx.

The northwards-deepening model, proposed by Pirajno et al. (2000) and Jones et al. (2000a,b), is consistent with the hypothesis that granular iron-formation is the shallow-water facies equivalent of deeper water banded iron-formations (Goode et al., 1983; Beukes and Klein, 1990, 1992; Isley, 1995). The ultimate source of the iron and manganese, and perhaps of other metals (Pb, Zn), is interpreted to have been from a mid-ocean ridge which was probably located well to the north of the presently exposed margin, and east of the Pilbara Craton. The approach of the North Australian craton towards the West Australian craton probably caused this spreading centre to become inactive. The collision of the cratons at about 1760 Ma (Tyler, 2000; Bagas and Smithies, 1997) is the most probable cause of deformation of the Earaheedy Basin and the formation of the Stanley Fold Belt.

Unassigned ?Proterozoic

Sydney Heads Pass Conglomerate (*Ꝑr*)

Outcrops of the Sydney Heads Pass Conglomerate (*Ꝑr*) are confined to a small area around Sydney Heads Pass (MGA 377400E 7178500N), where up to 20 m of conglomerate is exposed in a cliff face (Fig. 19). The

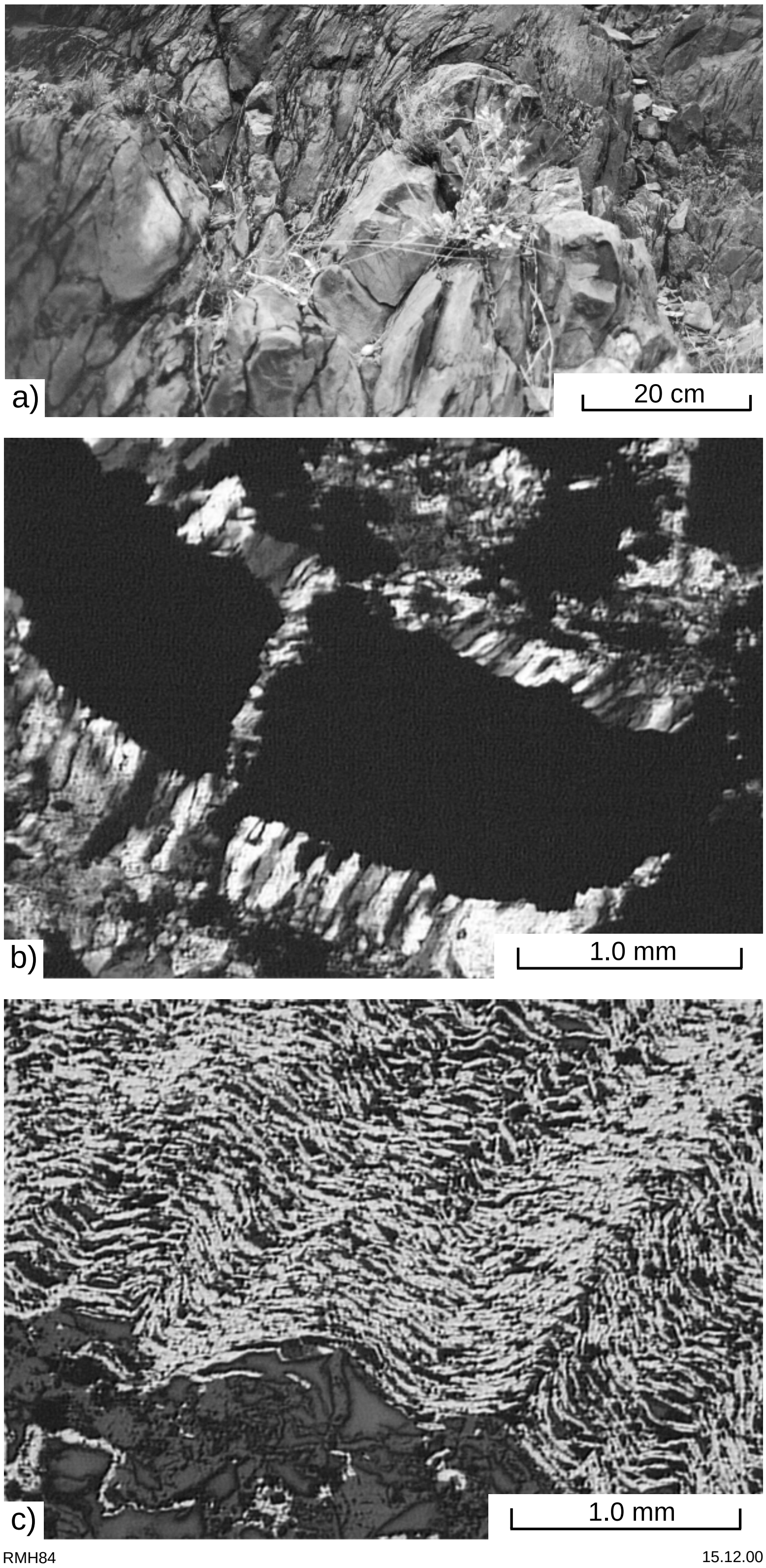

Figure 18. Structural features of rock types of the Earaheedy Group
a) Isoclinal folding of interbedded siltstone and sandstone, Yelma Formation, 2 km west of Sydney Heads Pass
b) Deformed granular iron-formation with porphyroblastic magnetite crystals and fibrous quartz crystals in pressure shadow areas. Frere Formation, GSWA 152723, cross-polarized light
c) Crenulation of ferruginous layers in laminar iron-formation, Frere Formation. GSWA 152722, reflected light

sequence dips at about 20° towards the southeast, and overlies steeply dipping Yelma Formation with marked angular unconformity. The unit comprises alternations of cobble to boulder and granule to pebble conglomerate with local lenses of highly ferruginous sandstone (Fig. 20). The conglomerate is clast supported, with rounded cobbles up to 15–20 cm in diameter, in a sandy matrix. Clasts include ferruginous sandstone, probably derived from the Frere Formation, quartz, and chert. Scattered imbricated clasts suggest current flow from the south. Directly east of the pass, coarse conglomerate contains rounded cobbles more than 30 cm in diameter. The conglomerate fines upwards, and is increasingly interbedded with poorly sorted, flaggy sandstone and shale. The conglomerate is interpreted as a fluvial deposit, probably in an incised hinterland valley. At one level, a sandy pisolitic ironstone (Fig. 21), that clearly dips with the remainder of the conglomerate, is interpreted as a syndepositional ferricrete.

The stratigraphic position of the Sydney Heads Pass Conglomerate is uncertain. It post-dates deformation of the Earaheedy Group, but is itself moderately folded. It is therefore unlikely to be Phanerozoic or even Neoproterozoic (as the Neoproterozoic is virtually unfolded on MUDAN to the north), and may be a hinterland correlative of the older or younger parts of the Bangemall Supergroup, or an entirely distinct local deposit. Commander et al. (1982) suggested that it may be a remnant of a more extensive intermontane deposit, an ancient analogue of the Eocene Robe Pisolite of the Hamersley Basin.

Phanerozoic geology

Paterson Formation (*Pa*)

Unfossiliferous outcrops and lags of polymictic boulder conglomerate, sandstone, and claystone that appear to be glacially related are scattered throughout the eastern Earaheedy Basin (Bunting, 1986). They are assigned to the Paterson Formation (*Pa*), a unit originally defined for the Permian glacially related deposits of the southern Canning Basin (Talbot, 1920; Traves et al., 1956) and later extended to the Officer Basin by Lowry et al. (1972). The dip of bedding ranges from horizontal to less than 3° northwards. Such outcrops are found on southwestern EARAHEEDY, in breakaways above the Chiall Formation.

Where the actual rock rather than a boulder lag is preserved, it is generally silcreted, and is dominated by poorly sorted, matrix-rich, coarse-grained sandstone with common planar cross-bedding, and bands of poorly rounded quartz-pebble conglomerate. The sandstone contains erratic blocks up to 50 cm in diameter. These encompass a wide variety of rock types, including vein quartz, fuchsitic quartzite, granitoids, metamorphic rocks, jasper and chert, and fine- and medium-grained mafic and felsic rocks. Peloidal jasper, grey peloidal chert, and granular iron-formation from the Frere Formation were noted during mapping. Sandstone beds range from 40 cm to 100 cm in thickness, and are commonly tabular cross-bedded (Fig. 22), with no bottomsets. The orientation of planar cross-bedding suggests predominantly north-northeastward palaeocurrents, with a subordinate easterly

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Figure 19. General view of Sydney Heads Pass Conglomerate looking south, showing 10 m bluff of conglomerate interbedded with thick sandstone lenses

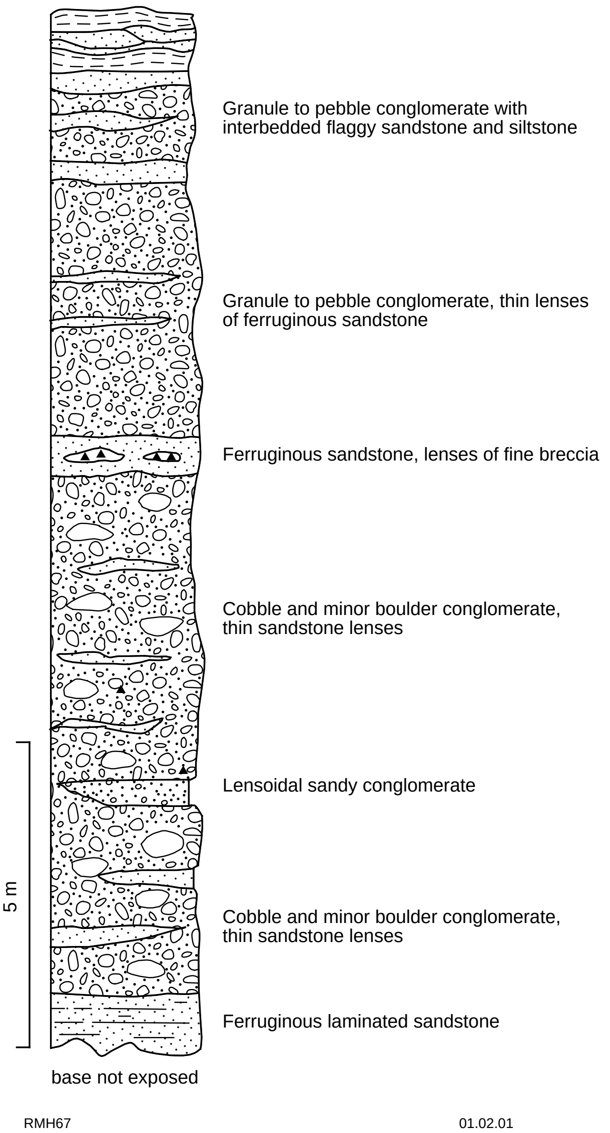

Figure 20. Measured section through the Sydney Heads Pass Conglomerate

component. The sandstone is interbedded with micaceous siltstone, and locally up to 20 m of siltstone underlies the sandstone, as in the area 2.2 km west-northwest of Breakaway Bore (MGA 354100E 7126300N). Siltstones are generally massive to locally flaser-bedded, suggesting quiet, shallow-water, probably lacustrine environments, across which meltwater-sourced bars prograded to deposit sandstone bodies. Regionally, exposures and lags such as those on STANLEY and KINGSTON 1:250 000 sheets are the feather-edge of the deposits resulting from the Gondwana-wide, continental-scale glaciation in the latest Carboniferous and Early Permian (Hocking and Preston, 1998).

An unconformable relationship with older rocks is evident regionally, but local relationships are sometimes complicated by the similarity in lithology and orientation of underlying units, especially when the lowermost Paterson Formation and the underlying Chiall Formation are both siltstone.

Regolith

EARAHEEDY depicts the regolith in terms of a new classification set out by Hocking et al. (2001). This scheme considers the regolith in terms of landscape components, each with a dominant process and regolith composition, and is derived from a regolith classification by Anand et al. (1993a,b). There is a basic division into residual (*R*), exposed (*X*), and depositional regimes, with the depositional regime further divided into colluvial (proximal slope, *C*), sheetwash (distal slope, *W*), alluvial (*A*), lacustrine (*L*), eolian (*E*), sandplain (mixed eolian-residual, or uncertain origin; *S*), coastal wave-dominated (*B*, for beach), coastal tide-dominated (*T*), and marine (*M*). Some of these are absent on EARAHEEDY. Absolute age designation is not an explicit part of the system, as the regolith is commonly very poorly dated, and could be as old as Permian in parts of Western Australia (Pillans, 1999). The relative age of units is indicated by their position in the map reference, and by a whole number (increasing with age) if more than one generation of a regolith type (alluvium, silcrete, etc.) is differentiated. Regolith composition is designated by a series of optional qualifiers; secondary codes are used to indicate composition, whereas tertiary codes can be used to indicate parent rock or cement type.

Areas of outcrop (shown as the individual rock units) are fringed by colluvium (*C*), a mixture of generally consolidated gravel, sand, silt, and rock fragments that generally occupies areas of high slope. Colluvium composed predominantly of angular quartz fragments (*Cq*) characterizes areas of quartz veining. Colluvium dominated by ferruginous rubble, and which has in places been itself ferruginized, is differentiated as *Cf*. Further from high areas, sheetflood and sheetflow processes produce non-channelized sheetwash deposits. On EARAHEEDY, two generations of sheetwash (*W1* and *W2*) are recognized. The younger generation (*W1*) is still active, grades into active alluvial channel systems (*A*) and lakes (*L*), and commonly shows a distinctive vegetation pattern on aerial photographs, called 'tiger bush' by Wakelin-King (1999), which contrasts with the smoother pattern of the colluvium and the alluvium (*A*). As with colluvium, ferruginous (*W1f*) and quartzose (*W1q*) variants are differentiated locally. The latter is composed primarily of angular vein quartz fragments, and is found adjacent to quartz blows and veins. The older generation (*W2*) is consolidated, locally dissected, and is gradational into colluvium (*C*). Both could be assigned to the Wiluna Hardpan of Bettenay and Churchward (1974). Alluvium (*A*) is recognized in areas dominated by channelized drainage, rather than sheetflow, including overbank areas. These are part erosional and part depositional, with sand and gravel the dominant deposits. The alluvial channels are commonly lined with calcrete (*Ak*), which forms by precipitation below the water table under conditions of low rainfall and high evaporation (Mann and Horwitz, 1979; Hocking and Cockbain, 1990). It commonly shows alteration to opaline silica. Claypans (A_p) are present in low-lying areas of sheetwash and alluvium where clay and silt settle from suspension after heavy rain.

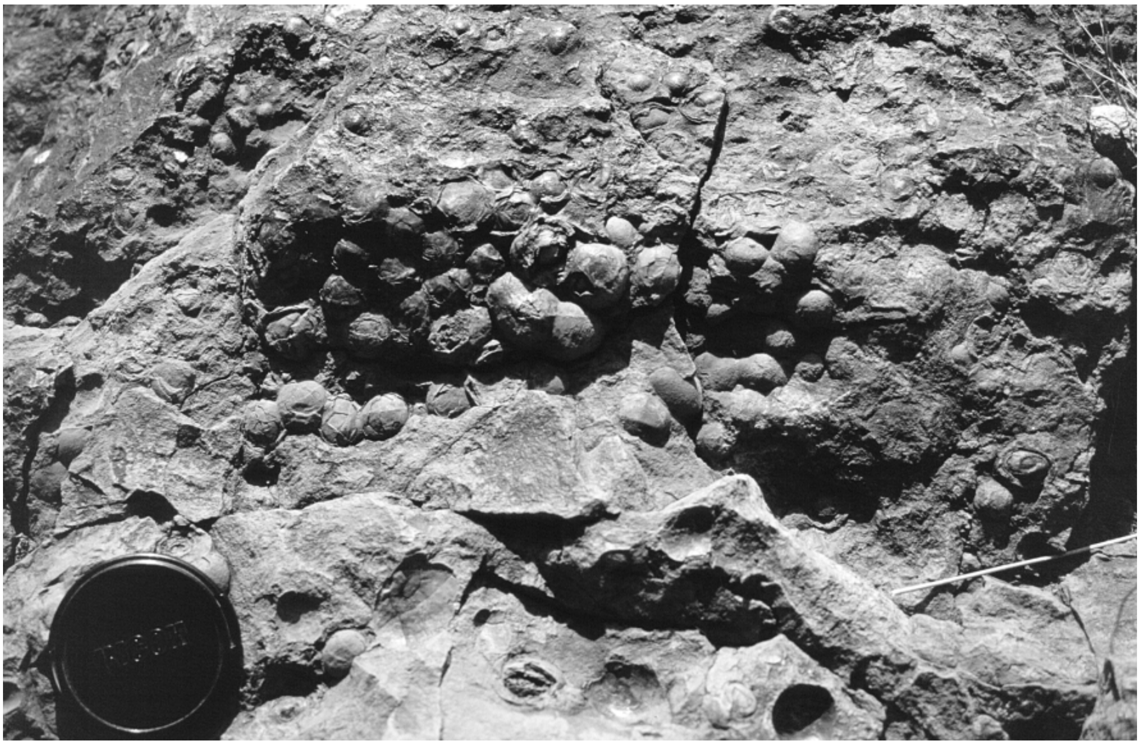

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Figure 21. Nodular ferricrete in Sydney Heads Pass Conglomerate, consisting of concentrically zoned ferruginous nodules in a ferruginous sandy matrix. This is probably a Proterozoic palaeosol. Lens cap is 5.5 cm in diameter

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Figure 22. Planar cross-bedding in fluvioglacial sandstone of the Permian Paterson Formation, one kilometre southeast of Breakaway Bore

Table 3. Summary of geochemical data relevant to EARAHEEDY

Sample no.	*Detection limit*	*Method*	*132416*	*160809*	*160810*	*152798*	*160804*	*160806*	*160814*
Eastings			*335000E*	*351600E*	*349600E*	*398500E*	*391900E*	*385800E*	*349800E*
Northings			*7117400N*	*7167700N*	*7169300N*	*7130600N*	*7124400N*	*7125500N*	*7171800N*
						Percentage			
Mn (wt%)	1	A/OES	7.8	39.0	19.5	3.00	3.00	9.40	12.5
Fe	0.01	A/OES	–	4.7	25.5	1.75	12.5	14.5	32
						Parts per million[(a)]			
Ag	0.1	A/MS	0.1	0.2	0.3	0.2	0.3	0.3	0.5
As	0.1	A/MS	12	31	10	76	9	9	32
Au (ppb)	1	FA*/MS	<1	3	<1	4	<	2	<1
Ba	0.1	A/MS	310	5 200	490	2 550	4 900	7 800	5 400
Bi	0.01	A/MS	0.15	0.14	0.28	0.03	7.8	10.4	0.27
Co	0.1	A/MS	72	265	140	3.8	23.5	45	620
Cr	2	A/OES	16	88	46	14	14	20	10
Cu	1	A/OES	116	1 400	98	46	340	320	98
Mo	0.1	A/MS	0.4	0.8	1.4	6.6	9.2	10.4	4.7
Ni	1	A/OES	15	82	60	13	13	23	145
Pb	2	A/MS	18	26	16	34	225	520	580
Pd (ppb)	1	FA*/MS	–	1	<	2	1	2	2
Pt (ppb)	1	FA*/MS	–	1	1	6	2	5	5
Sn	0.1	A/MS	0.7	0.8	1.4	0.3	1	1.2	1.2
Th	0.01	A/MS	–	3.4	6.6	35	6.6	9.8	5.4
U	0.1	A/MS	–	6	3.6	2.15	7.6	8.6	2.7
W	0.1	A/MS	0.8	5.6	3.6	0.5	6.8	4.2	0.8
Zn	1	A/OES	155	195	320	15	78	114	760

NOTES: A/MS: Multi-acid digest including hydrofluoric, nitric, perchloric, and hydrochloric acids. Analysed by inductively coupled plasma mass spectrometry
FA*/MS: Lead collection fire assay using new pots. Analysed by inductively coupled plasma mass spectrometry
A/OES: Multi-acid digest including hydrofluoric, nitric, perchloric, and hydrochloric acids. Analysed by inductively coupled plasma optical (atomic) emission spectrometry. All values are in parts per million (ppm), except for gold, platinum, palladium which are in parts per billion (ppb) and manganese given in weight per cent (wt%)
<: Sample was measured but was below detection level
–: Sample not analysed for element
(a) Unless otherwise indicated
Location shows MGA coordinates, all from zone 51

Ferruginous duricrust (*Rf*), composed of nodular, pisolitic or massive ferricrete is only present in limited areas on EARAHEEDY, particularly overlying iron-rich rock types of the Frere Formation. The laterite breaks down into finer ferruginous material (*Cf*), composed of ferruginized rubble mixed with pisoliths. Reworking of this material on floodplains results in the formation of ferruginous sheetwash (*W1f*). Silcrete, the siliceous equivalent of the ferricrete, is composed of angular quartz grains in a hard siliceous cement, and is confined to the Permian outcrops in the southwestern part of the sheet. Ironstone (*Ri*), in places manganiferous, is typically associated with quartz veining and is structurally controlled, commonly following cleavage directions and fractures.

An extensive sandplain (*S*), locally derived and largely residual, but with some eolian reworking, overlies rocks of the Permian Paterson Formation in southwestern EARAHEEDY. Smaller sandplains are scattered across the northern part of the sheet.

The playa lake system which occupies most of the eastern part of the sheet is characterized by a complex system of sediments. Most lakes contain saline silt, mud, and sand deposits (*L*), but some are merely etched rock surfaces, with subcropping rock visible on Landsat and aerial photographs (L_x). Fringing the lakes are sand dunes (L_d) composed of fine-grained red-brown quartz sand and silt, mixed with ironstone grains that are polished by wind action. The deposits build gentle mounds and linear dunes a few metres high that are vegetated mainly by mulga. Dune and playa terrain (L_m) constitutes much of the lacustrine system, and consists of a complex interfingering of saline playas, low dunes, and sand mounds. Lake calcrete (*Lk*) is only present in limited areas on EARAHEEDY. The calcrete is distinctly different in genesis to alluvial calcrete, and is particularly developed in the inner parts of the lake system. Formation of this calcrete is linked to evaporite processes, and the deposit is commonly gradational lakewards into the gypsite facies (Arakel and McConchie, 1982). Lake areas are commonly characterized by a distinct vegetation, with samphire communities being prominent.

Economic geology

Iron and manganese oxides

The average iron content of fresh or unaltered granular iron-formation is about 20 wt% (Pirajno and Adamides, 2000b). Given its extent, the Frere Formation represents a substantial iron resource. Further oxidation, during weathering processes or hydrothermal activity along faults, may enhance the iron content to values of up to 60 wt% (Pirajno and Adamides, 2000b). The economic potential of the Frere Formation is likely to be highest in the Stanley Fold Belt, parts of which outcrop on EARAHEEDY. In the fold belt, hydrothermal activity along fault zones combined with weathering may have produced zones of secondary iron enrichment.

In addition to the granular iron-formation, iron and manganese oxide mineralization is present on EARAHEEDY as structurally controlled hydrothermal veins, containing quartz and iron–manganese oxides, within shales of the lower Chiall Formation; and as thin beds associated with the sandstones and siltstones of the Wongawol Formation (Pirajno and Adamides, 2000b). Samples were collected from both the veins and the stratiform oxides and were analysed for trace elements. Results and analytical details are presented in Table 3.

The hydrothermal veins are possibly related to supergene processes and are widespread, as bodies of massive quartz-ironstone. These bodies have a maximum width of 8 m and a strike length of up to 80 m, with reported grades of up to 27% Mn, and 2.3% Fe (Bunting, 1986). They are structurally controlled and tend to follow the dominant cleavage fabric of the host rocks. One sample (GSWA 160809) returned anomalous abundances in copper (1400 ppm), cobalt (265 ppm), and barium (5200 ppm) (Table 3).

The second type of iron–manganese oxide mineralization is in the form of 5–30 cm-thick beds. The host rocks are weakly feldspathic quartz sandstones containing clastic white mica, glauconite, and accessory amounts of zircon and tourmaline. They are locally associated with beds of banded siliceous ironstone (jasper), which suggests that the mineralizaton may be of chemical origin. Three samples (GSWA 160804, 160806, and 160814; Table 3) returned anomalous values for barium, cobalt, lead, and zinc.

The association of stratiform iron–manganese and glauconite-bearing sandstone suggests a genetic relationship. This relationship was investigated by Ostwald and Bolton (1992), who found that glauconite tends to form in deeper water, whereas precipitation of manganese oxides occurs along palaeoshorelines. In addition, glauconite enhances the manganese content of the water, because it removes iron from the system (Ostwald and Bolton, 1992; Pirajno and Adamides, 2000b).

Diamonds

The discovery in 1991 by Stockdale Prospecting and Great Central Mines of diamondiferous intrusions around the Marymia Inlier to the west of EARAHEEDY (Fig. 1) spurred exploration for diamonds in the region. One such project was initiated in 1992 and is still ongoing, with several reports relating to exploration on released ground available in the Western Australian mineral exploration (WAMEX) open-file system at the Department of Minerals and Energy. This exploration revealed the presence of chrome spinels in stream sediments, but limited drilling failed to reveal any kimberlitic rocks or the source of the spinels.

Regolith geochemistry

Regolith was sampled over EARAHEEDY at a density of one sample per 16 km², as part of the STANLEY 1:250 000 regolith geochemistry program (Morris et al., 2000). This survey revealed two areas in southeastern EARAHEEDY with anomalous abundances in manganese (MnO), and base metals in the south-central parts of STANLEY. The manganese anomalies are in the Wongawol Formation, and are probably related to stratiform oxide mineralization. Anomalous concentrations of molybdenum, gold, selenium, bismuth, and arsenic in regolith samples were detected in the northwestern corner of EARAHEEDY, in areas underlain by the deformed Karri Karri Member and Frere Formation. In this general area, there are numerous quartz veins, some of which contain anomalous abundances of manganese and other metals as detailed above.

Groundwater

Groundwater suitable for livestock on EARAHEEDY is mainly obtained from alluvial deposits along stream channels, and from locally developed alluvial calcrete. Limited groundwater may also be obtained from bores in weathered or fractured bedrock. Calcrete is up to 20 m thick along major drainage channels, and has been known for a long time as a very good aquifer (Talbot, 1920), yielding large quantities of water. In addition to wells and bores, there are numerous ephemeral pools, particularly in the southeastern part of the area, in rocks of the Wongawol Formation, which contain surface water for part of the year. Several large dams, each about 50 m in diameter, have been excavated in the Wongawol Formation and silty parts of the Chiall Formation, in the central and southeastern part of EARAHEEDY.

A regional survey of the hydrogeology of the region (Sanders and Harley, 1971) included the STANLEY 1:250 000 sheet. The survey outlined major alluvial deposits south of the Earaheedy Homestead, which are a continuation of an east-southeasterly trending drainage system. Reported salinities (from bores and wells) in the alluvial system varied from less than 1000 mg/L total dissolved solids (TDS) to 9000 mg/L TDS.

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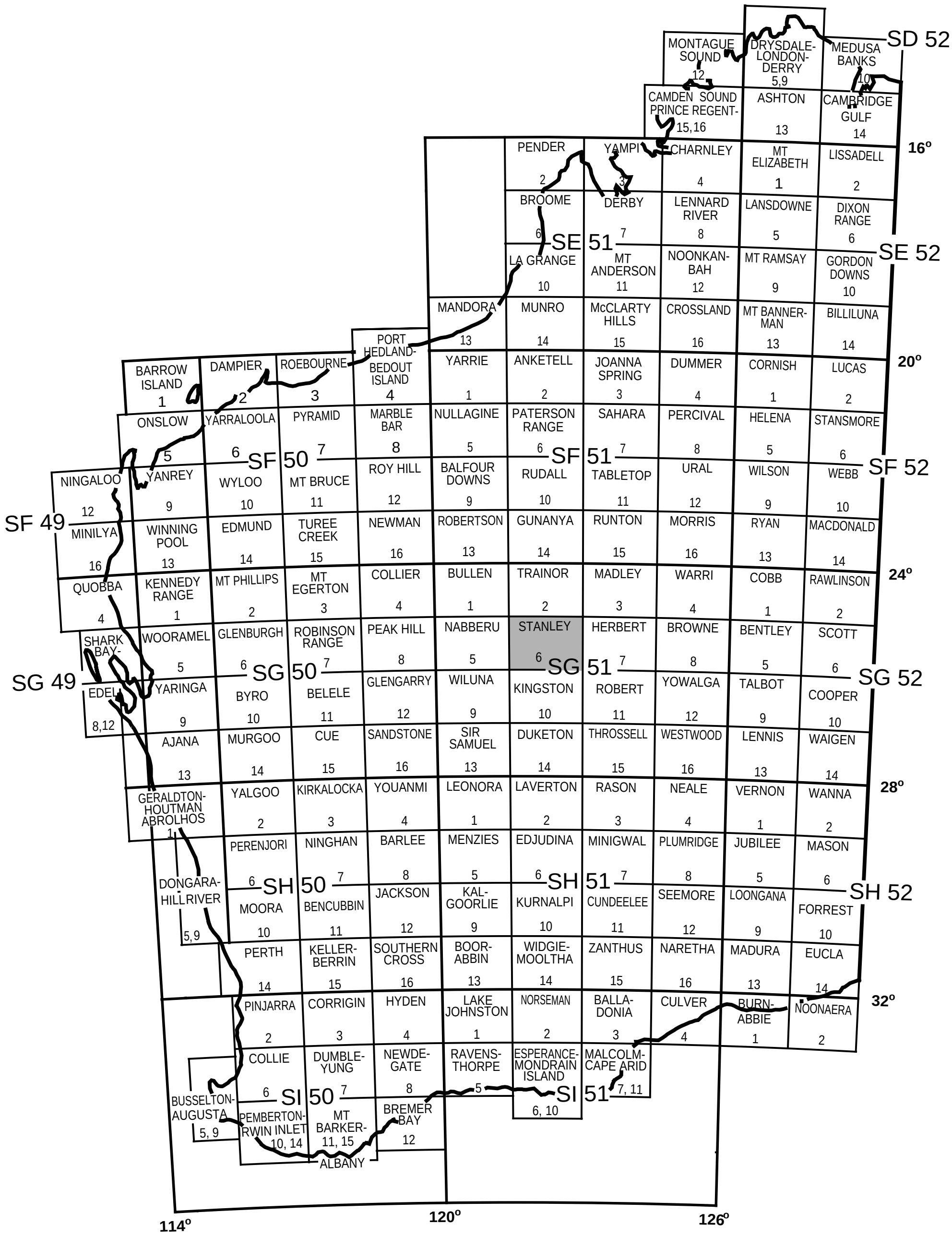
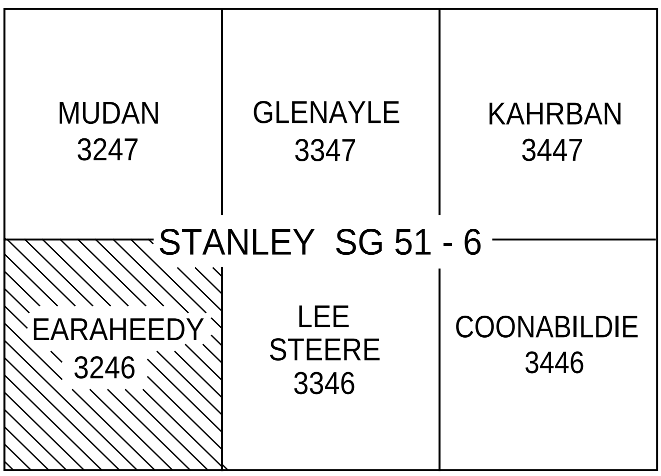
Appendix

Gazetteer of localities mentioned in text

Locality		*MGA coordinates*	
	Zone	*Eastings*	*Northings*
Breakaway Bore	51	356200	7126100
Canning Stock Route	51	236000	7132000
Carnegie Homestead	51	497400	7146600
Devil Bore	51	374300	7175600
Dingo Bore	51	364400	7150200
Earaheedy Homestead	51	358000	7168600
Glenayle Homestead	51	403600	7205200
Granite Peak Homestead	51	334600	7163200
Henderson Bore	51	352900	7178000
Lake Bore	51	368800	7151000
Lake Burnside	51	501000	7190000
Leary Bore	51	375800	7138100
Leinster	51	273200	6909300
Max Bore	51	370200	7137900
Meekatharra	50	649400	7057000
Nunegnoo Pool	51	397300	7178000
Popes Camp Well	51	351900	7156200
Princess Ranges	51	380000	7111000
Quarter Bore	51	370500	7173300
Sydney Heads Pass	51	377400	7178500
Wiluna	51	223500	7055500
Wongawol Homestead	51	394200	7110500
Yunga Pool	51	398000	7130800





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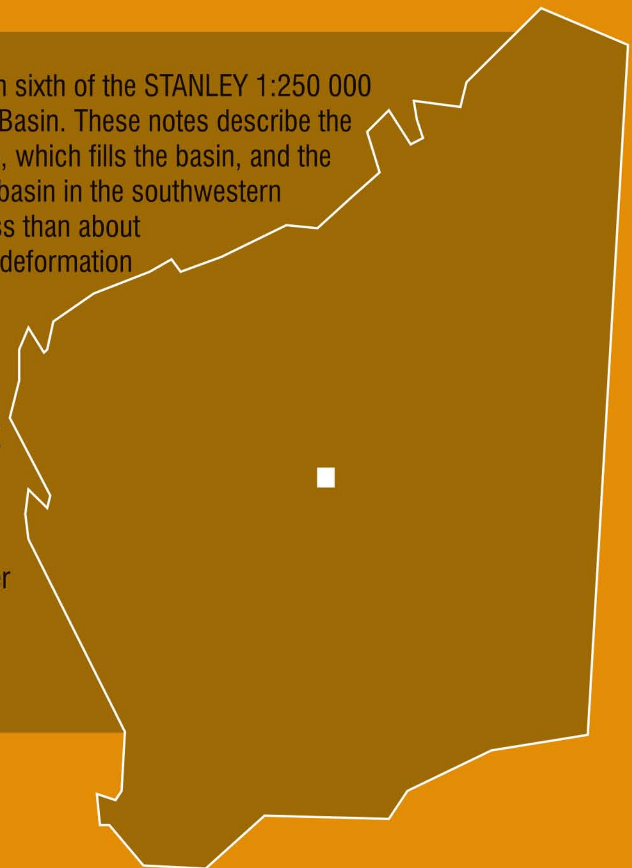
The EARAHEEDY 1:100 000 sheet covers the southwestern sixth of the STANLEY 1:250 000 sheet, and lies near the preserved centre of the Earaheedy Basin. These notes describe the shallow marine to coastal deposits of the Earaheedy Group, which fills the basin, and the glacigene Permian Paterson Formation, which overlies the basin in the southwestern part of the sheet. The rocks of the Earaheedy Group are less than about 1900 m.y. old, and were deformed at about 1760 Ma. The deformation was centred on the Stanley Fold Belt, which traverses the northern margin of EARAHEEDY. Known mineralization on EARAHEEDY is minor and consists of manganese and iron oxides, associated with quartz veins in deformed rocks of the Stanley Fold Belt in northwestern EARAHEEDY. The Frere Formation has potential for iron ore deposits, and there are bands of stratiform manganiferous ironstone in beds of the Wongawol Formation, which also contain anomalous lead, cobalt, copper, zinc, and barium. The latter suggest there is potential for base metal mineralization in suitable host rocks.



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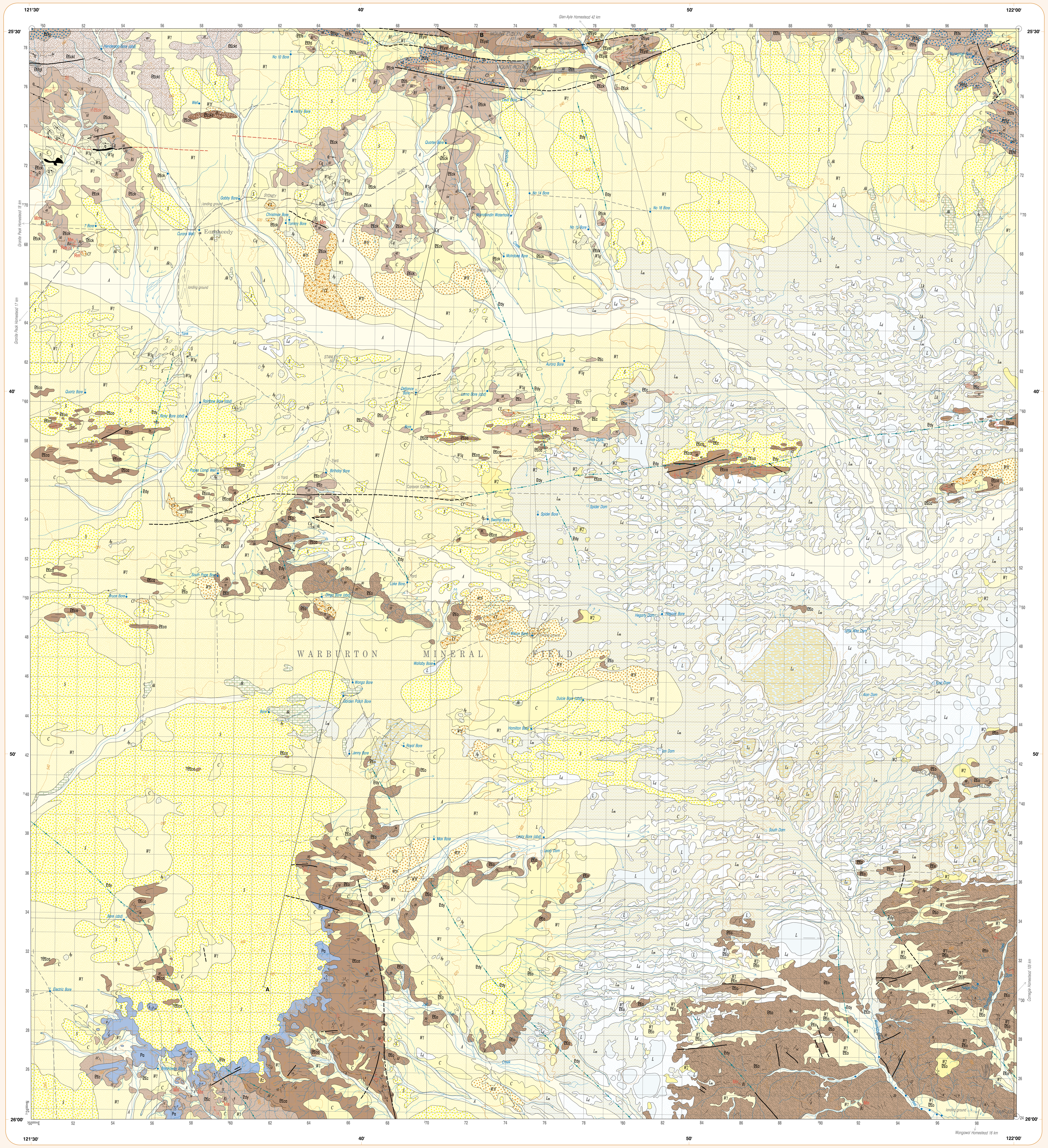
EARAHEEDY

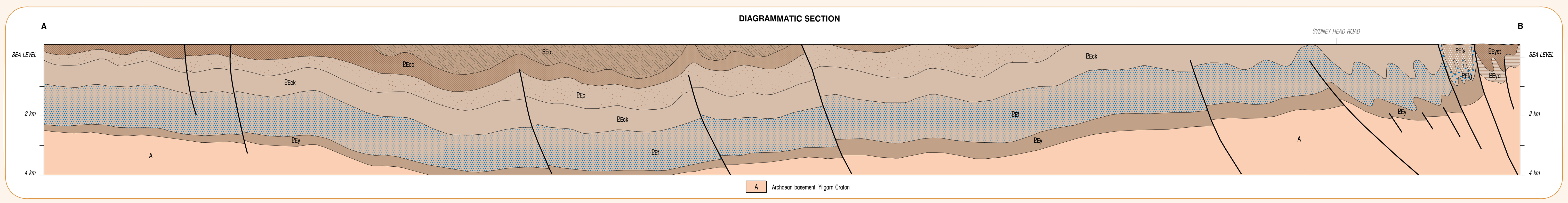
AUSTRALIA 1 : 100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET 3246



DIAGRAMMATIC SECTION



A — Archaean basement, Yilgarn Craton

Legend

QUATERNARY

Sheetwash units
- *W1* Ferruginous clay, silt, and sand as low gradient sheetwash areas
- *W1f* Ferruginous gravel in low-gradient sheetwash areas
- *W1q* Quartz rubble and debris adjacent to quartz veins in low-gradient sheetwash areas

Alluvial units
- *A* Gravel, sand, and silt in channels and floodplains
- *Ap* Clay and silt in claypans
- *Ak* Calcrete in alluvial systems

Lacustrine units
- *L* Saline silt, mud, and minor sand in playa lakes
- *Ld* Sand in dunes on and around playa lakes, in places gyspiferous
- *Lk* Calcrete and gypcrete deposits, in and around salt lakes
- *Lm* Gypsiferous and saline bedded and eolian deposits adjacent to salt lakes
- *Lx* Subcropping bedrock in lakes; variable to minimal exposure of rock beneath thin lacustrine deposits

Sandplain unit
- *S* Unconsolidated sand; minor silt and clay, with scattered low, vegetated dunes

Colluvium units
- *C* Gravel, rock fragments, sand, and silt, mostly proximal slope deposits
- *Cq* Quartz vein rubble and debris
- *Cf* Ferruginized rubble and colluvium; dominantly ferruginized pisolites and nodules, ferruginized rock, and ironstone rubble; degraded lateritic duricrust

Sheetwash unit
- *W2* Consolidated sheetwash deposits

Relict units
- *Rf* Ferruginous duricrust; nodular, pisolitic, and massive ferricrete (laterite) and associated debris
- *Ri* Ironstone; ferruginized rock, massive to rubbly; includes degraded ferruginous duricrust
- *Rz* Siliceous duricrust; nodular, pisolitic, and laminar silcrete and intensely silicified bedrock

PHANEROZOIC — CAINOZOIC — PALAEOZOIC

PERMIAN

- Pa **PATERSON FORMATION:** poorly sorted sandstone; minor conglomerate and siltstone

- q Quartz in massive bodies or veins

- Ꝑr **SYDNEY HEADS PASS CONGLOMERATE:** conglomerate, ferruginous sandstone, and siltstone; minor pisolitic ferricrete

PROTEROZOIC — PALAEOPROTEROZOIC

Stanley Fold Belt (?1760 Ma)

Earaheedy Group — Miningarra Subgroup — EARAHEEDY BASIN

- ꝐEo **WONGAWOL FORMATION:** undivided, very fine-grained sandstone, siltstone, and shale
- ꝐEc **CHIALL FORMATION:** sandstone and siltstone, coarsening-upwards; marine shelf to coastal
- ꝐEca Sandstone, variable textural and compositional maturity; stratigraphic position variable
- ꝐEckt Phyllite; restricted to the Stanley Fold Belt
- ꝐEck **Karri Karri Member:** shale, generally finely and evenly laminated, siltstone, and minor sandstone
- ꝐEcka Fine-grained sandstone and minor siltstone

Tooloo Subgroup

FRERE FORMATION
- ꝐEf Granular and laminar iron-formation, granular siliceous iron-formation, siltstone, shale, and chert; marine shelf to near shore
- ꝐEft Granular iron-formation, siltstone, and shale; deformed and metamorphosed in the Stanley Fold Belt
- ꝐEfgt Laminar granular iron-formation; deformed and metamorphosed in the Stanley Fold Belt
- ꝐEfg Granular iron-formation and granular siliceous iron-formation, in places peloidal; minor siltstone, shale, and chert
- ꝐEfs Siltstone and shale; minor iron-formation
- ꝐEfa Sandstone, locally with intercalated granular iron-formation; arenite to iron-formation transition

- ꝐEyst Phyllite and phyllitic shale; restricted to the Stanley Fold Belt
- ꝐEy **YELMA FORMATION:** sandstone and siltstone (Diagrammatic Section and Interpreted Bedrock Geology)
- ꝐEya Sandstone, coarse-grained and locally pebbly

YILGARN CRATON
- Ꝑdy Dolerite dyke, concealed; interpreted from aeromagnetic data

Symbols

Geological boundary — exposed; concealed

Fault — exposed, showing dip; concealed; concealed, interpreted from aeromagnetic data; horizontal relative displacement

Fold showing axial trace and generalized plunge direction — anticline, exposed; syncline, exposed, concealed; overturned anticline, exposed

Small-scale fold axial surface, showing strike and dip — inclined; fold axis

Small-scale fold axial surface, showing trend and plunge — anticline; syncline; Z-vergence; S-vergence; M-vergence; meso-scale folding

Bedding showing strike and dip — inclined; vertical; horizontal; overturned; bedding trend

Palaeocurrent, showing trend and sense of direction — from asymmetrical ripple marks; from cross bedding; from cross bedding, sense not known; from trough cross-bedding; from trough cross-bedding, sense not known; from current lineation, sense not known

Way-up indicator — sedimentary structure; cross bedding

Cleavage, showing strike and dip — inclined; vertical

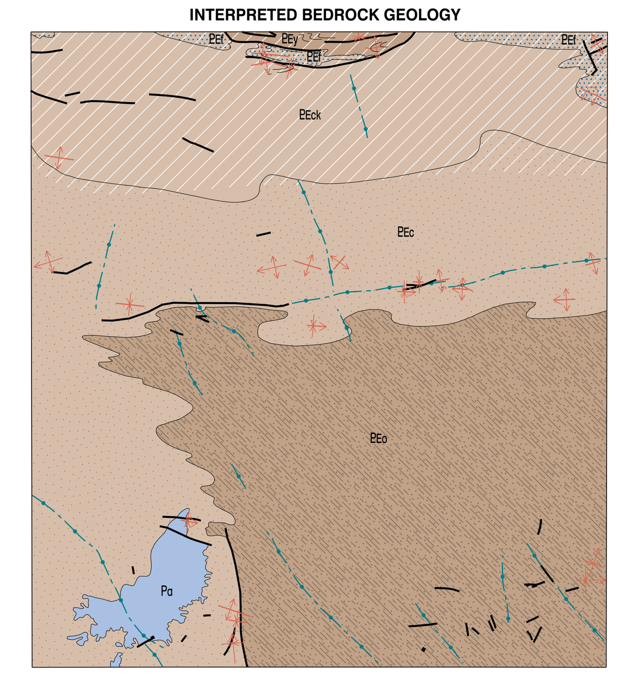
Air-photo lineament — structural trend, unspecified

Formed road; Track; Fence, generally with track; Homestead (Earaheedy); Yard; Horizontal control, minor; Breakaway; Sand dune; Contour line, 20 m interval

Watercourse with ephemeral pool, rockhole or waterhole; Bore, well; Dam; Abandoned

Quarry or open pit; Mineral exploration drillhole showing subsurface data; Mineral occurrence — Manganese (Mn); Road materials (Rm)

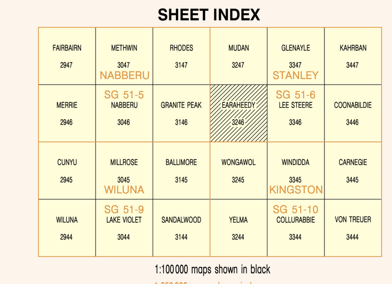
INTERPRETED BEDROCK GEOLOGY



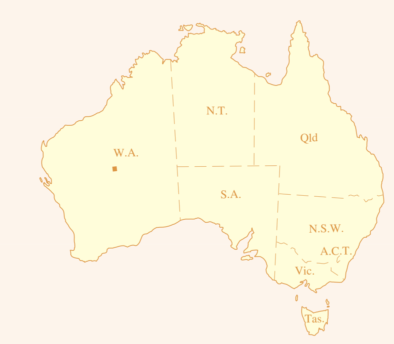
- Pa Paterson Formation
- Overprint indicates deformed and metamorphosed in Stanley Fold Belt
- ꝐEo Wongawol Formation
- ꝐEc Chiall Formation
- ꝐEck Karri Karri Member
- ꝐEf Frere Formation
- ꝐEy Yelma Formation
- Ꝑdy Dolerite dyke, concealed

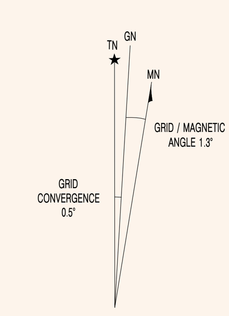
Earaheedy Group — EARAHEEDY BASIN — YILGARN CRATON

SHEET INDEX



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





True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 2000 and moves easterly by about 0.1° in 5 years

Geology by N. G. Adamides 1998; F. Pirajno, R. M. Hocking, and J. A. Jones 1999

Edited by D. Ferdinando and G. Loan

Cartography by E. Green, A. Francois, and B. Williams

Topography from the Department of Land Administration Sheet SG 51-6, 3246, with modifications from geological field survey

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ADAMIDES, N. G., PIRAJNO, F., HOCKING, R. M., and JONES, J. A., 2000, Earaheedy, W.A. Sheet 3246 Western Australia Geological Survey, 1:100 000 Geological Series

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SCALE 1:100 000

1000 Metres 0 1 2 3 4 5 6 7 8 9 10 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 51

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

EARAHEEDY

SHEET 3246 FIRST EDITION 2000