EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE FAIRBAIRN 1:100 000 SHEET

by N. G. Adamides, F. Pirajno, and R. M. Hocking

1:100 000 GEOLOGICAL SERIES

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DEPARTMENT OF MINERALS AND ENERGY

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Cover photograph:
Well-bedded sequence of granular iron-formation, 5 km northeast of Illyee Pool (AMG 359077)

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Abstract

The FAIRBAIRN 1:100 000 sheet occupies the northwestern edge of the Palaeoproterozoic Earaheedy Basin. It includes Archaean granite and greenstone rocks of the Marymia Inlier, and Proterozoic sedimentary rocks of the Earaheedy Group and Collier Group. The base of the Earaheedy Group is defined by sandstone, or, along the northern margin of the map, by shale. Three formations of the Earaheedy Group are exposed on FAIRBAIRN. The lowest formation in the group, the Yelma Formation, consists of sandstone, siltstone and minor conglomerate and dolomite. The overlying Frere Formation consists of ferruginous siltstone and shale, and granular iron-formation. Above this, the Chiall Formation is a coarsening-upwards sequence from laminated siltstones (Karri Karri Member), to interbedded sandstone and siltstone (Wandiwarra Member). The unconformity between the Earaheedy Group and the overlying Collier Group (Bangemall Supergroup) is poorly exposed. The Wonyulgunna Sandstone is the only Collier Group unit present. It is represented by medium grained sandstone with minor interbeds of conglomerate. Two major northwesterly trending structures, the Merrie Range and Lockeridge Faults, pass through the southwestern and southeastern corners of FAIRBAIRN. Archaean rocks are deformed in the Stanley Fold Belt, a zone of deformation that also affects the northern margin of the exposed Earaheedy Basin. On FAIRBAIRN the Stanley Fold Belt is indicated by locally pervasive penetrative fabrics, mylonites, zones of brecciation, and quartz veining in granitic rocks. In most areas, Earaheedy Group rocks are gently folded; however locally there is evidence of intense deformation and isoclinal folding. The Bangemall Supergroup rocks are only mildly deformed along zones of brittle fracturing. The Frere Formation has potential for iron ore deposits, particularly in areas of secondary enrichment, whereas carbonate rocks of the Yelma Formation (Sweetwaters Well Member) may host Mississippi Valley-type base metal deposits.

KEYWORDS: Archaean, Proterozoic, Earaheedy Basin, Earaheedy Group, Collier Group, Bangemall Supergroup, granular iron-formation, Marymia Inlier, base metal mineralization.

Introduction

The FAIRBAIRN* 1:100 000 map sheet (SG 51-5, 2947) is located in the northwestern corner of the NABBERU 1:250 000 sheet, approximately 850 km northeast of Perth, Western Australia. It extends from 25°00' to 25°30'S and from 120°00' to 120°30'E. The sheet contains part of the northernmost extension of the Archaean Yilgarn Craton, the northwestern part of the Palaeoproterozoic Earaheedy Basin, and includes, along its northern edge, exposures of the Middle Proterozoic Bangemall Supergroup (Fig. 1). FAIRBAIRN provides information on the nature of the contacts of the Earaheedy Group with the Archaean Marymia Inlier and the Bangemall Supergroup. It also contains extensive outcrops of granular iron-formation (Frere Formation), which are potentially important as future iron ore resources.

The area was geologically mapped during the 1997 field season as part of a re-evaluation of the Earaheedy Basin. Field work was carried out using colour aerial photographs at a scale of 1:25 000, available from the Western Australia Department of Land Administration (DOLA), with the aid of global positioning systems (GPS) for the determination of Australian Map Grid (AMG) coordinates. All coordinates are on the AGD 84 datum, which corresponds closely to the Geodetic Datum of Australia (GDA).

The publication of the FAIRBAIRN map preceded the writing of these Explanatory Notes by over a year. During this interval, further mapping on adjacent sheets resulted

* Capitalized names refer to standard 1:100 000 map sheets unless otherwise stated.

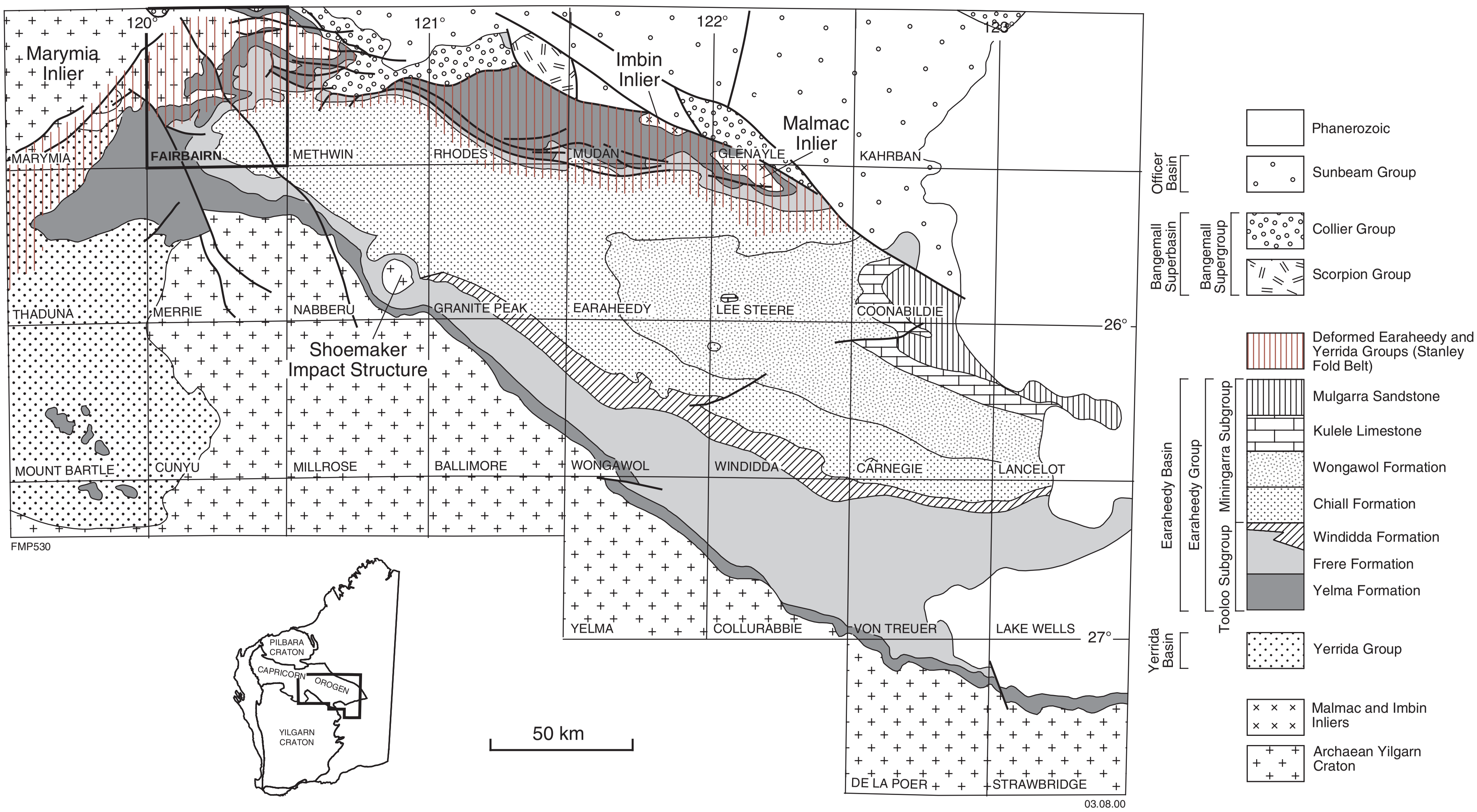

Figure 1. Simplified geology of the Earaheedy Basin and location of FAIRBAIRN

in changes to the stratigraphic nomenclature which are detailed in these Notes, but which do not appear on the map.

Location and access

FAIRBAIRN is located on the southwestern edge of the Little Sandy Desert. The nearest towns are Wiluna, 150 km to the south, and Meekatharra, 230 km to the southwest. Access from these towns is along unsealed roads to stations in the area. The Meekatharra–Wiluna road (180 km) is well maintained and open throughout the year, with the exception of brief intervals following heavy rain. From Wiluna, an equally well-maintained road extends to Neds Creek Homestead, approximately 140 km to the north-northwest. Access from Neds Creek is via station track through Simpson Well. Alternative access to the northern part of the map is through Marymia Homestead. Other routes are along the vermin-proof fence, and through a track which branches off the main Wiluna–Neds Creek road at the latitude of Cunyu Woolshed on MERRIE. Access along these secondary tracks requires four-wheel drive vehicles, and streams and salt lakes may be impassable during wet periods.

New Marymia (AMG 978273*), located along the vermin-proof fence in the northwestern corner of the sheet, is the only homestead within the map area. Other nearby homesteads are Neds Creek Homestead (on MARYMIA), and Cunyu Homestead (on MERRIE), and all three homesteads are occupied throughout the year.

Climate and vegetation

The climate of the area is semi-arid to arid with long, hot summers and mild winters. Mean daily maximum summer temperatures are between 35°C and 40°C† and minimum temperatures between 20°C and 23°C. In winter, average maximum temperatures are around 20°C and minimum temperatures 6°C, with frosts common on clear nights. Mean annual rainfall is about 200 mm and is unreliable, related to both summer cyclones and winter depressions. Potential annual evaporation may average between 2400 and 3000 mm.

FAIRBAIRN is located within the Eremaean Province of Beard (1990), and contains parts of both the Gascoyne and the Little Sandy Desert Regions of this province. The Gascoyne Region (Ashburton Botanical District) is dominated by mulga (*Acacia aneura*), often with snakewood (*Acacia xiphophylla*) and other species of acacia. Associated with these are smaller shrubs of the *Eremophila* and *Cassia* families. The main river channels are commonly lined with tall eucalypts (*Eucalyptus camaldulensis*). Perennial shrubs include *Ptilotus rotundifolius*, a prominent member of the mulla mulla family. In good seasons, small annuals, such as the billybuttons (*Gnephosis brevifolia*), bloom in abundance.

The Little Sandy Desert region occupies part of north-eastern FAIRBAIRN. It consists of sandy plains with linear dunes, with sandstone ridges of the Collier Group rising above the plains. The principal plant cover is spinifex (*Plectrachne schinzii* and *Triodia basedowii*) with scattered acacias and mallee. The hills are generally bare, with *Acacia aneura* and *Grevillea* sp. being the most common shrubs, and *Eremophila* sp. forming the usual understorey.

Physiography

Morris et al. (1997) described the regolith of the NABBERU 1:250 000 sheet, based on a division into relict, erosional and depositional regimes. Their mapping corresponds closely with the physiographic map of FAIRBAIRN (Fig. 2), in which erosional regimes are amalgamated with relict (lateritic) regimes, and sandplains are separated as a distinct facies of the depositional regime.

In the north, an extensive sandplain marks the southwestern edge of the Little Sandy Desert (Fig. 2). Sand dunes several metres high and averaging 4–6 km in length are present, with the average distance between dunes being 0.5–1 km. The dunes are predominantly longitudinal (straight-crested), although chain longitudinal dunes (Crowe, 1975) are also present. They are oriented in a northeasterly direction parallel to the prevailing winds. The last major period of eolian activity was probably about 15 000 years ago (Hocking and Cockbain, 1990). The sandplain is mainly underlain by granite, and is presumably sourced partly from deep weathering of this rock type, and partly from the sandstone of the eastern Bangemall and northwestern Officer Basins.

Elevated areas of outcrop and associated scree slopes mark resistant rock units such as quartzite and iron formation and associated duricrust. These can be distinguished from floodplains which have lower, more even relief. Steep-sided ridges characterize resistant rocks of the Frere Formation and sandstones in the Chiall Formation. Rounded gentle slopes occur in areas of shallow-dipping and softer strata. Low-lying areas between resistant ridges and in the adjacent lowlands mostly define areas of recessive shaly units. Granite is characterized by a low irregular topography where the old duricrusted surface (mostly silcrete over kaolinized granite) has been variably eroded. The result is a landscape of low breakaways with fresher material in flat, scree-covered valley floors. Granite is exposed in sparse outcrops and along stream beds.

The extensive sheetwash deposits in the central and southern parts of FAIRBAIRN form a distinct physiographic domain (Fig. 2). The sheetwash is transected by lines of recent alluvial deposits, defining the present drainage pattern. This is marked by concentrations of calcrete and locally incised channels, where seasonally flowing streams cut into the sheetwash deposits. The playa lakes in the extreme southwestern and southeastern part of the map mark the northern edge of the Lake Gregory – Lake Nabberu palaeoriver system.

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

† Climatic data from Australian Bureau of Meteorology website, for stations nearest to FAIRBAIRN.

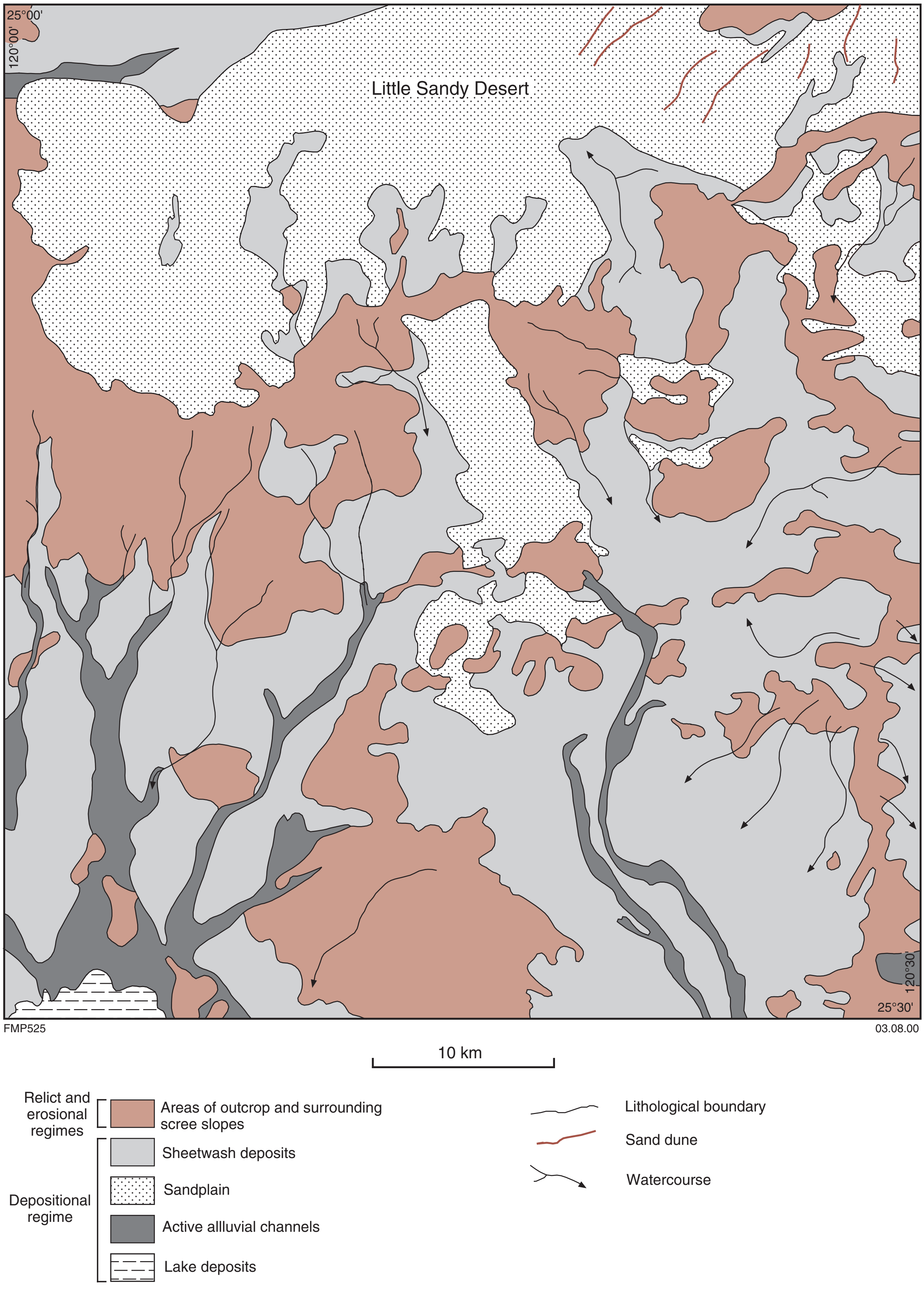

Figure 2. Physiographic map of Fairbairn

Previous investigations

One of the earliest geological accounts was that of Talbot (1920), who recognized the unconformity between the Bangemall Supergroup and older Proterozoic rocks, and between the latter and Archaean basement.

Prior to the 1990s, all Palaeoproterozoic sedimentary rocks along the northern margin of the Yilgarn Craton were placed in a single sedimentary basin, the Nabberu Basin. This was subdivided into the Glengarry Sub-basin in the west and the Earaheedy Sub-basin in the east (Hall and Goode, 1975, 1978; Hall et al., 1977). The nomenclature applied to the Earaheedy Group at that time is largely retained, but with some important modifications. Hall and Goode (1978) provided detailed descriptions of the iron formations of the Nabberu Basin, whose textural features were correlated with formations of the Lake Superior and Labrador Provinces of North America. The iron formations of the Frere Formation were described in further detail by Goode et al. (1983). Gee (1990) presented a summary of the Nabberu Basin, but clearly foresaw the need for stratigraphic revision.

FAIRBAIRN was mapped as part of the NABBERU 1:250 000 sheet by Bunting et al. (1982), and was further discussed in a review of the eastern part of the Nabberu Basin (Bunting, 1986). In the latter work, Grey described stromatolites from the Earaheedy Group, later discussed in more detail by Grey (1995). Regolith geochemistry sampling at a scale of 1:250 000 on NABBERU included FAIRBAIRN (Morris et al., 1997).

Regional geological setting

FAIRBAIRN, located on the northern margin of the Archaean Yilgarn Craton (Myers and Swager, 1997), covers the eastern portion of the Archaean Marymia Inlier, the western part of the Palaeoproterozoic Earaheedy Basin, and the southeastern margin of the Mesoproterozoic Collier Basin (part of the Bangemall Superbasin; Martin et al., 1999; Fig. 1).

The Marymia Inlier is an elongate fragment of Archaean granite–greenstone basement approximately 150 km long and 40 km wide (Bagas, 1999). It is oriented in a northeasterly direction, and its western end is affected by the tectonic activity associated with the Glenburgh (c. 2.0 Ga) and Capricorn (c. 1.8 Ga) Orogenies (Occhipinti et al., 1999b). Tectonic reworking is evident along the fault zone that separates the inlier from the Earaheedy Group (Fig. 1), in northwestern FAIRBAIRN, where granitic rocks are deformed. The Marymia Inlier is probably an extension, beneath Proterozoic cover, of the Eastern Goldfields Province, which occupies the eastern one-third of the Yilgarn Craton (Bagas, 1999; Griffin, 1990). The Merrie greenstone belt outcrops on MERRIE, about 25 km to the south of the FAIRBAIRN map boundary (Adamides, 2000; Farrell and Adamides, 1999). The greenstone belt possibly extends northwards beneath Proterozoic cover. On the basis of aeromagnetic data, it is interpreted to subcrop beneath Quaternary ferruginous gravel on the western edge of FAIRBAIRN (AMG 980005), where it is interpreted to be in fault contact with the Marymia Inlier (Fig. 3).

The northwestern portion of the Earaheedy Basin is exposed on FAIRBAIRN, which, together with the Yerrida, Bryah and Padbury Basins (Pirajno et al., 1998; Pirajno et al., 2000; Pirajno and Adamides, 2000), the Gascoyne Complex to the west (Williams, 1986; Occhipinti et al., 1998, 1999a; Sheppard et al., 1999), and the Ashburton Basin to the north (Thorne, 1990; Tyler and Thorne, 1990; Thorne and Seymour, 1991) constitute the Capricorn Orogen (Gee, 1979). The Capricorn Orogeny resulted from the convergence and subsequent oblique collision between the Yilgarn and Pilbara Cratons at approximately 1800 Ma (Tyler and Thorne, 1990; Tyler et al., 1998; Occhipinti et al., 1999b).

In northern FAIRBAIRN there are small outcrops that belong to the southeastern part of the Collier Basin (Muhling and Brakel, 1985; Cooper et al., 1998; Martin et al., 1999), a major intracratonic volcano-sedimentary basin, which developed over the suture between the Yilgarn and Pilbara Cratons between 1600 and 1100 Ma (Myers et al., 1996).

Archaean geology

The northern part of FAIRBAIRN is underlain by poorly exposed, commonly weathered and/or silicified monzogranite of the Marymia Inlier. On the western edge of the sheet, the aeromagnetic response of the area approximately 11 km west of No. 17 Bore (AMG 980000), which is covered by ferruginous gravel (*Qwf*), is characteristic of subcropping greenstones (Fig. 3). These possibly represent the northern extension of the Merrie greenstone belt (Adamides, 2000). This interpretation is supported by the presence of outcrops of amphibolite and ultramafic rocks near Baumgarten Reward on MARYMIA to the west (Bagas, 1998).

Granite (*Ag, Agm, Agmk*)

Undivided granitoid rocks (*Ag*) on FAIRBAIRN are commonly weathered and exposed in patchy outcrops or breakaways. Relatively fresh monzogranite (*Agm*) consists of microcline megacrysts set in a matrix of feldspar, quartz, biotite, muscovite, sericite, chlorite, and titanite. The quartz is commonly granular and recrystallized, with sericite and chlorite replacing feldspar and biotite. The monzogranite is generally deformed and exhibits cataclastic textures.

Examination of drill cuttings from several boreholes revealed that locally the monzogranite is affected by potassic alteration (*Agmk*), which has resulted in the formation of biotite with strong green pleochroism. The biotite is hydrothermal in origin, and fills microfractures or replaces feldspar. In other cases, greisen-type alteration of monzogranite is revealed by the presence of medium-grained quartz–muscovite. This alteration is probably related to the event that deformed the granite.

Structure and metamorphism

Prominent structures, such as faults and aeromagnetic lineaments in Archaean rocks, trend in an easterly and northeasterly direction. On FAIRBAIRN, metamorphism of the granitoid rocks is low grade. Deformed and cataclastic monzogranite exhibits greenschist facies mineral phases, including sericite, chlorite, and titanite.

A northeasterly striking foliation fabric is developed in the monzogranite, which becomes weaker towards the southeast. The deformation fabrics (foliation, cleavage) that affect the Marymia Inlier on FAIRBAIRN can be correlated with similarly oriented fabrics in the Earaheedy Group, along the northern margin of the Earaheedy Basin, that are part of the Stanley Fold Belt.

Proterozoic geology

Dolerite dykes (*#dy*)

Subcropping dykes, interpreted from aeromagnetic data, have a northeasterly orientation and are probably of Proterozoic age (*#dy*). Similarly trending dykes that crop out on adjacent MARYMIA, to the west, contain an assemblage of actinolite, chlorite, epidote, and albite (Bagas, 1998).

In the north-central part of the area, a major aeromagnetic lineament marking the continuation of the Lockeridge Fault (Bunting, 1986) is partly utilized by a dyke. This fault was repeatedly activated in Proterozoic times, as indicated by displacement of Earaheedy Group rocks. The fault itself is the northern continuation of the Ninnis Fault (Westaway and Wyche, 1998).

Earaheedy Group

The stratigraphy of the Earaheedy Group was formalized by Hall et al. (1977), who divided the group into a lower Tooloo Subgroup and an upper Miningarra Subgroup, based on the presence of two distinct cycles of sedimentation. The Tooloo Subgroup included the Yelma, Frere, and Windidda Formations. The Miningarra Subgroup included the Wandiwarra Formation, Princess Ranges Quartzite, Wongawol Formation, Kulele Limestone and Mulgarra Sandstone. This nomenclature was modified slightly by Bunting et al. (1982) and Bunting (1986).

The current program of geological mapping on FAIRBAIRN and adjacent map sheets (Adamides et al., in prep.; Jones and Hocking, in prep.; Pirajno and Jones, in prep.) has resulted in the modification of the previous stratigraphy. The current stratigraphy was defined by Hocking et al. (2000) and is shown in Figure 4.

The newly established Chiall Formation includes the upper, sandstone-rich part of the Wandiwarra Formation and the Princess Ranges Quartzite, both of which are reduced to member status. Shaly and silty rocks overlying the Frere Formation in the western Earaheedy Basin were previously assigned to the Wandiwarra Formation. These are now placed in a separate member of the Chiall Formation, the Karri Karri Member. The FAIRBAIRN map pre-dates the latest of the stratigraphic changes, and shows the Karri Karri Member as part of the Windidda Formation rather than as the basal part of the Chiall Formation. A further addition is the Sweetwaters Well Member of the Yelma Formation, which contains stromatolitic dolomite and associated chert breccia in the upper part of the formation, near and at the contact with the Frere Formation (Jones et al., 2000).

The Earaheedy Group contains clastic and chemical sedimentary rocks which were deposited in the Earaheedy Basin. The Earaheedy Basin is exposed in an east-southeast-plunging, south-verging, asymmetric syncline. There are minor outliers in several localities west of the main basin, unconformably overlying the rocks of the Yerrida Group to the southwest on MOUNT BARTLE sheet. On FAIRBAIRN the Earaheedy Group unconformably overlies Archaean granitoid rocks of the Marymia Inlier. The unconformity is exposed at a number of localities near and along the vermin-proof fence, and in the central parts of the map area.

The basal unit of the Earaheedy Group is the Yelma Formation (Fig. 5), a succession of clastic and chemical sedimentary rocks. This is conformably overlain by the Frere Formation, predominantly composed of granular iron-formation of the Lake Superior type, interbedded with ferruginous shale and minor banded iron-formation. The contact between the Yelma Formation and the Frere Formation is locally defined by stromatolitic dolomite of the Sweetwaters Well Member.

The Chiall Formation conformably overlies the Frere Formation, and on FAIRBAIRN consists of laminated siltstone and shale and minor lenses of quartz sandstone (Karri Karri Member) overlain by sandier rocks (Wandiwarra Member).

Younger units of the Earaheedy Group, namely the Wongawol Formation, Kulele Limestone and Mulgarra Sandstone (Fig. 4), are not exposed on FAIRBAIRN, but are well represented to the southeast. Sedimentological features of the Earaheedy Group suggest a shallow marine to coastal depositional environment, which deepened towards the north.

Geochronology

The geochronology of the Earaheedy Group is summarized in Table 1. The Earaheedy Group is unconformably overlain by sandstones of the Collier Group (Bangemall Supergroup*; Martin et al., 1999), which is older than 1020 Ma, and probably also pre-dates the Miles Orogeny at 1130 Ma (Tyler et al., 1998). Horwitz (1975) reported an age of 1685 ± 35 Ma from glauconite in sandstone of the Wandiwarra Member. Richards and Gee (1985) reported lead isotope ages of 1700 Ma from galena within stromatolitic dolomite of the Sweetwaters Well Member (Yelma Formation). Nelson (1996) obtained a U–Pb

* Note that since the publication of FAIRBAIRN, the Bangemall Group has been given Supergroup status (Martin et al., 1999).

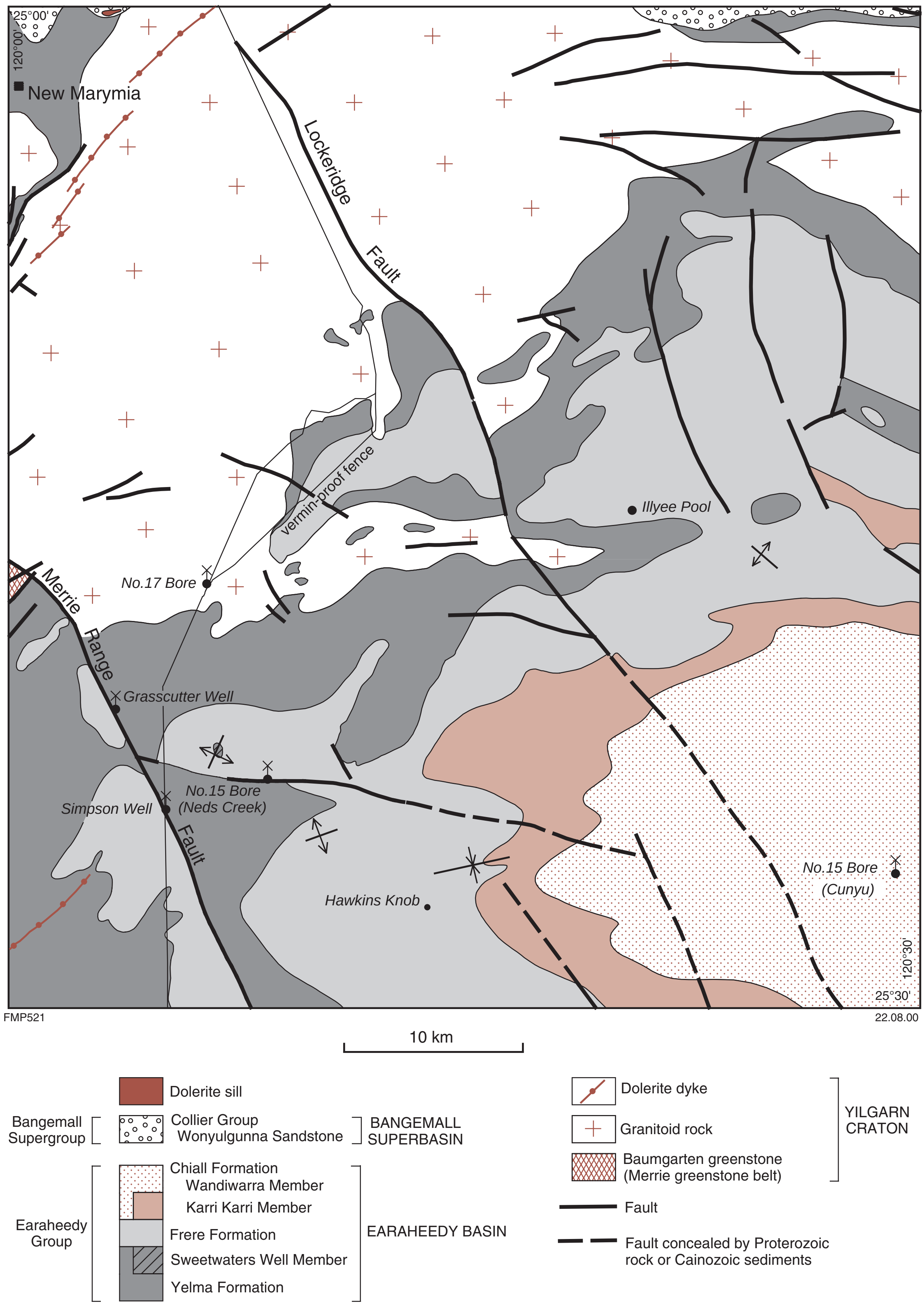

Figure 3. Interpreted bedrock geology of Fairbairn

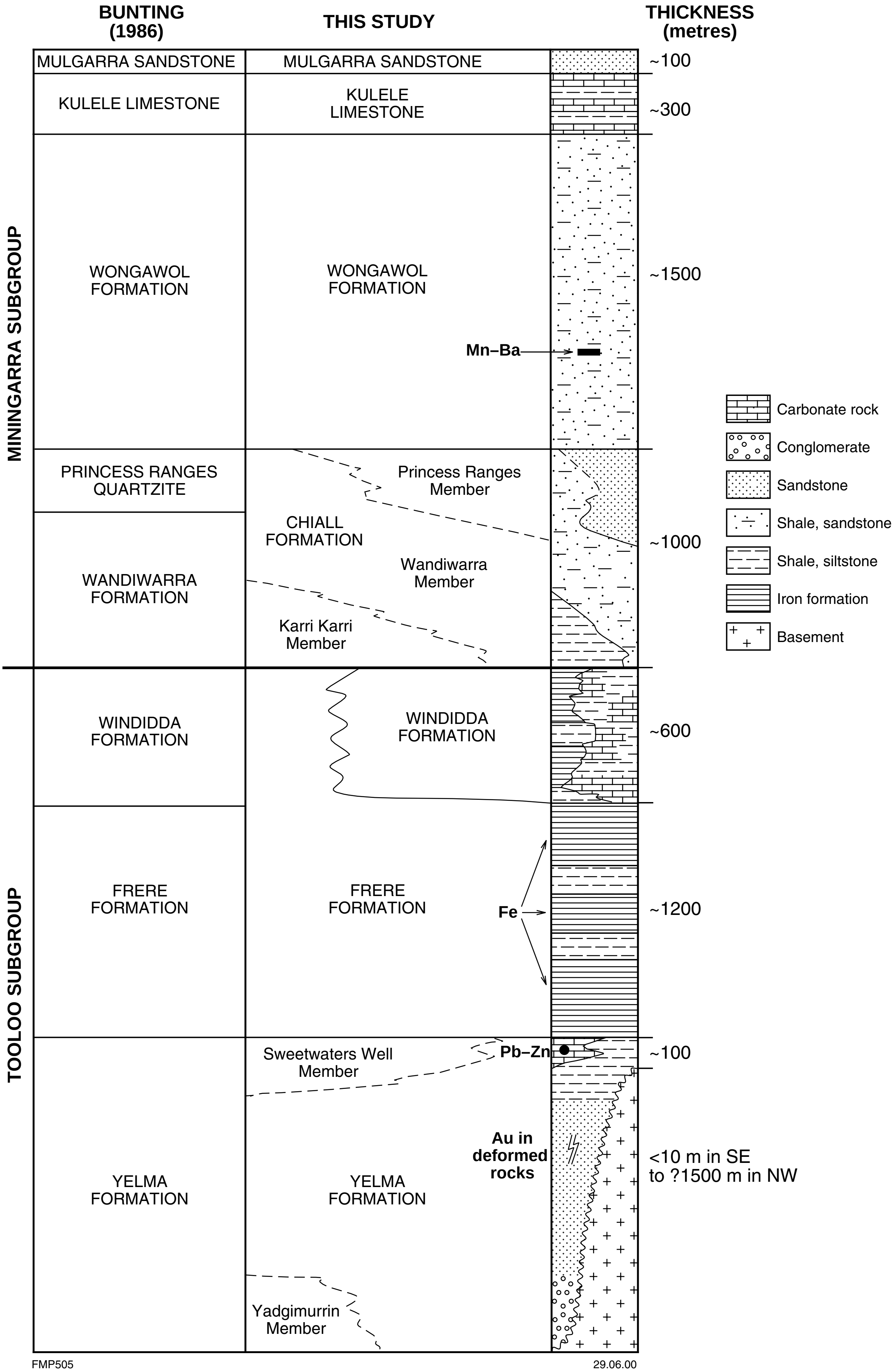

Figure 4. Stratigraphy of the Earaheedy Group

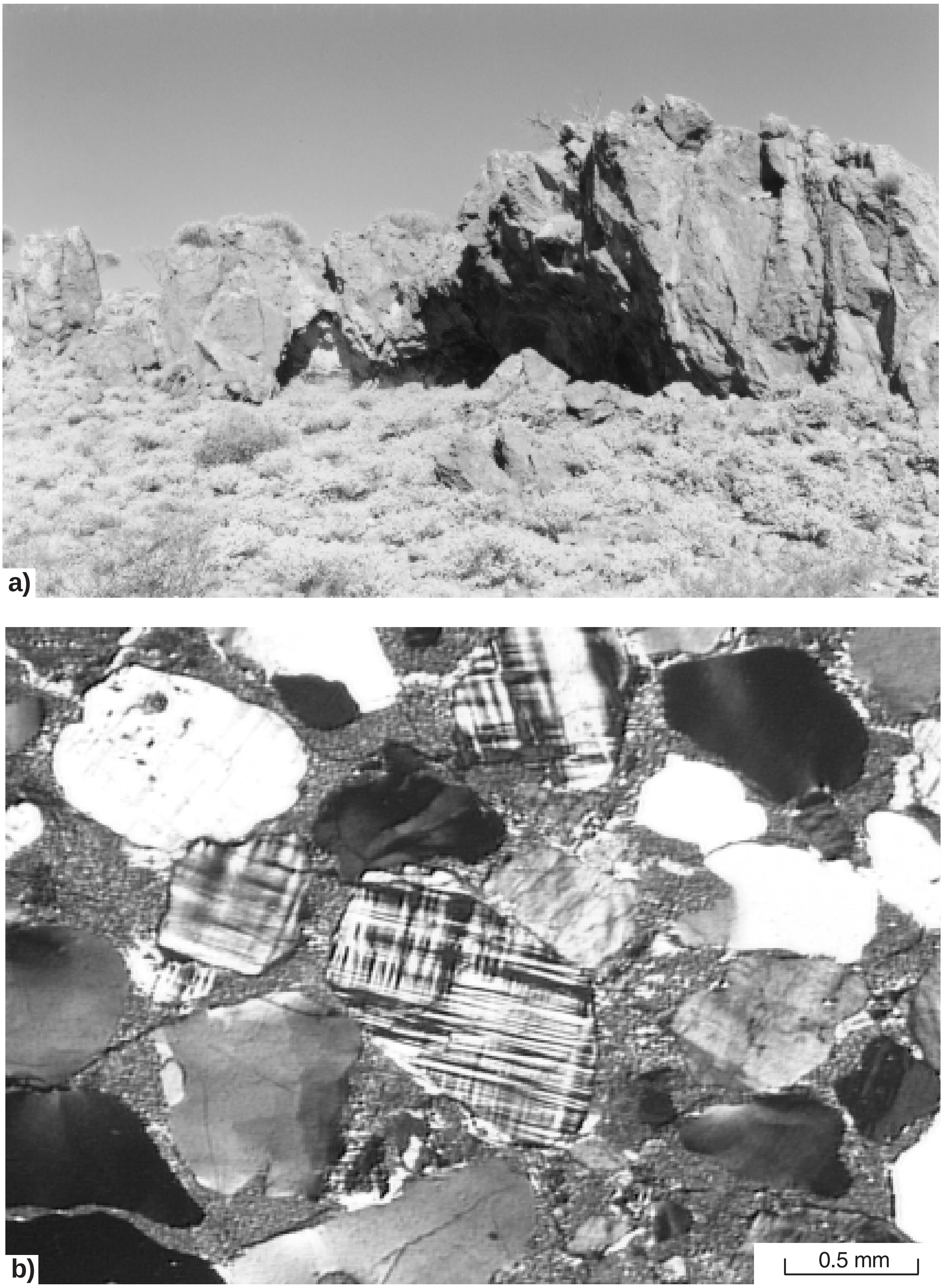

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Figure 5. The nature of the Yelma Formation on FAIRBAIRN: a) Coarse arkosic conglomerate of the basal Yelma Formation, 20.5 km north-northeast of Illyee Pool (AMG 384240); b) Thin section of arkosic sandstone, showing subrounded quartz and potassium feldspar in a kaolinitic matrix. Central FAIRBAIRN (AMG 252018); GSWA 149364, crossed polars, field of view is 3.5mm

Table 1. Geochronological data for the Earaheedy Group

Formation	*Locality*	*Coordinates*	*Rock/mineral*	*Age (Ma)*	*Method*	*Reference*
Shoemaker Impact Structure	NABBERU 1:250 000, NABBERU 1:100 000	na	quartz–albite rock	~1630	Rb–Sr	Bunting et al. (1980)
Chiall Formation, Wandiwarra Member	KINGSTON 1:250 000, WONGAWOL 1:100 000	121°57'E, 26°14'S	glauconite	1685 ± 35	K–Ar	Horwitz (1975)
Yelma Formation, Sweetwaters Well Member	NABBERU 1:250 000, MERRIE 1:100 000	na	galena	~1700	Pb–Pb	Richards and Gee (1985)
Yelma Formation	Northeast DUKETON 1:250 000, DE LA POER 1:100 000	na	glauconite	1556–1674	Rb–Sr	Preiss et al. (1975)
	NABBERU 1:100 000	120°56'33"E, 25°53'11"S	detrital zircon	2027 ± 23	U–Pb SHRIMP	Nelson (1997)

NOTES: na: not available

sensitive high-resolution ion microprobe (SHRIMP) age of 1785 ± 11 Ma on detrital zircons from the Mount Leake Formation, which is tentatively correlated with the Yelma Formation. More recently, Nelson (1997) reported a SHRIMP age of 2027 ± 23 Ma for the youngest populations of zircons from a sample of quartz sandstone from the Yelma Formation.

Stromatolite biostratigraphy does not provide a more 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 (1500–1800 Ma) from the McArthur Basin (Northern Territory). Grey highlighted the similarities between two of the Earaheedy Group taxa (*Asperia digitata* and *Pilbaria deverella*) and taxa in older (1840–1890 Ma) successions such as the Duck Creek Dolomite (Wyloo Group). On the basis of this evidence, Grey (1995) suggested that the age of the Earaheedy Group may lie between 1800 and 1900 Ma.

In summary, the age of the Earaheedy Group is constrained by the age of the Collier Group, probably older than 1130 Ma, and that of the Yerrida Group (2100–2200 Ma), with a possible age of around 1800 Ma.

Yelma Formation (*#Ey, #Eyw, #Eyc, #Eys, #Eya, #Eyy*)

The Yelma Formation is a succession of conglomerate, sandstone, stromatolitic dolomite, and shale. It varies in thickness from about 10 m in the southeast of the basin to about 1500 m in western STANLEY (1:250 000), along the Stanley Fold Belt, although much of this thickness may be the result of structural repetition. The base of the formation is everywhere defined by an unconformity, either with Archaean basement, or, further west, with the older rocks of the Yerrida Group (Pirajno et al., 1996). On FAIRBAIRN, the Yelma Formation is exposed in the northeastern and central parts of the map sheet, except for a small outcrop of the Yadgimurrin Member on the western boundary of the map sheet.

The basal units of the Yelma Formation in northeastern FAIRBAIRN are pebble, cobble and boulder conglomerate, and sandstone. Further to the west, shale overlies the basal unconformity, and is associated with chert breccia and arkosic sandstone. Arkosic boulder conglomerate is present close to the basal unconformity (not exposed) in the area 20.5 km north-northeast of Illyee Pool (AMG 384240). The conglomerate is immature (Fig. 5a), and contains clasts up to 50 cm in diameter, mainly of quartz but also of sandstone, set in a kaolinitic matrix. In a series of outcrops extending to the northeast to the edge of the map (~ AMG 463263), the Yelma Formation fines to interbedded pebble conglomerate, sandstone, and shale. The rocks have a steep, variably dipping cleavage. Quartz sandstone (Fig. 6) varies from whitish to grey and, in places, contains brown spots around 5 mm in diameter, probably after carbonate. The sandstone is thinly bedded, medium grained, and well sorted with predominantly angular quartz grains. Where it is strongly deformed, a granulated texture is developed. Rare cross-bedding can be seen in sandstone units. Herring-bone cross-stratification is locally present, indicating tidal flow. The conglomeratic units are normally graded, with dense concentrations of clasts at the base of the beds and only sparse clasts at higher levels. On METHWIN to the east, pebbly sandstones are present, but no conglomerate has been recognized (Jones and Hocking, in prep.).

Siltstone and shale (*#Eys*) overlie granite in central and western FAIRBAIRN. These rocks are predominantly well cleaved with a sericitic sheen and local crenulations. Individual bedsets may be up to one metre thick, and the shales are locally interbedded with grey quartz sandstone. At outcrops 10–15 km north of No. 17 Bore along the vermin-proof fence (e.g. AMG 175150), flat-bedded, highly cleaved carbonaceous shale rests on monzogranite, and shows evidence of at least two deformation events.

Arkosic cobble conglomerate is interbedded with pebble-conglomerate and sandstone (*#Eya*) in northeastern FAIRBAIRN. In central FAIRBAIRN shale (*#Eys*) and chert breccia derived from carbonate rocks (*#Eyc*) are present. Although these rock types may be interbedded in the same area, coarse-grained conglomerate is prevalent in the northern outcrops. Shales are interbedded with quartz sandstone and conglomerate. In less-deformed areas further west, the shales typically display a laminated texture modified by cleavage subparallel to the bedding, and a metamorphic assemblage of quartz, sericite, minor porphyroblastic pyrite, and traces of euhedral tourmaline. In deformed outcrops, the shales are characterized by an assemblage of quartz and sericite, resulting from the dynamic recrystallization of the clay matrix.

In central FAIRBAIRN, coarse arkosic sandstone units (*#Eya*), each about 0.5 m thick and crudely bedded, overlie the unconformity 16 km east of No. 17 Bore (AMG 252018). The sandstone is compositionally very immature, composed of subrounded quartz and potassium feldspar, with abundant microcline, enclosed within a kaolinitic matrix (Fig. 5b), suggesting a proximal granitic source. The sandstone passes upwards into coarse angular breccia. Nearby, the basal units are grey shale and an angular breccia consisting of grey chert, vein quartz and fine-grained quartzite in a kaolinitic silcretized matrix.

The Yelma Formation is interpreted as a coastal deposit, based on bedding styles and lithology. Barrier bar, lagoonal, and washover sequences occur on western METHWIN (Jones and Hocking, in prep.), immediately east of FAIRBAIRN. Syndepositional fault movements triggered local braided-fluvial progradation and conglomeratic fans.

Yadgimurrin Member (*#Eyy*)

The Yadgimurrin Member is a localized conglomeratic member at the base of the Yelma Formation (Bunting, 1986). It is recognized adjacent to its type area, approximately 6.5 km northwest of Grasscutter Well, along the boundary with MARYMIA (AMG 982954). The member consists of more than 100 m of boulder conglomerate with clasts up to 1 m across, of granite, quartzite and chert, enclosed in an arkosic matrix. Pods and veins of jasperoidal chert and quartz are associated with this conglomerate. These pods and veins probably

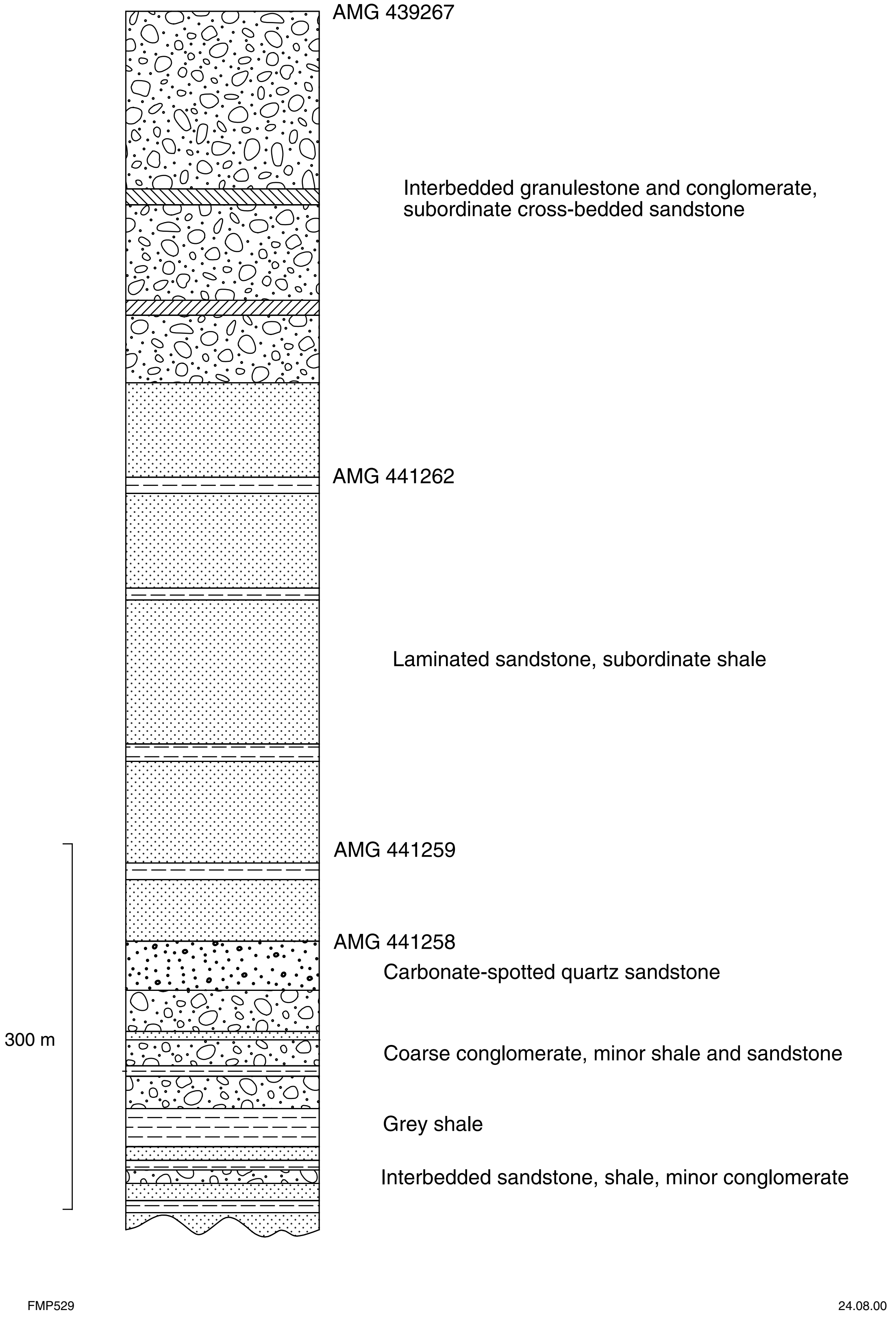

Figure 6. Lithology of the Yelma Formation as exposed in stream sections in area 25 km northeast of Illyee Pool (AMG 439267–441258)

resulted from hydrothermal fluids channelled along the tectonized contact zone between the Marymia Inlier and the Yelma Formation. The member is interpreted as a local conglomeratic fan, associated with syndepositional fault movements.

Sweetwaters Well Member (#Eyw)

The Sweetwaters Well Member (*#Eyw*) that forms part of the uppermost part of the Yelma Formation is about 100 m thick (Jones et al., 2000). The type locality for the member is on MERRIE, 3.5 km southeast of Sweetwaters Well, where it is represented by a well-bedded sequence of stromatolitic dolomite (Adamides, 2000). Stromatolite associations, bedding styles, and possible evaporitic textures point to deposition in a saline coastal lagoon. The upper contact with the Frere Formation is marked by hematitic siltstone.

On FAIRBAIRN, the only outcrop of the Sweetwaters Well Member is 5.8 km east-southeast of Grasscutter Well (at AMG 094908). In this area, the member is exposed in the core of an anticlinal structure with a northeasterly trending axial plane. From the base upward the sequence consists of laminated dolomite, microbial dolomite, dolomite with chert nodules, ferruginous dolomite, and stromatolitic dolomite. The succession is capped by a dark-brown clastic unit (possibly a dolarenite), containing doughnut-shaped concretions. A schematic illustration of this sequence is shown in Figure 7.

Frere Formation (*#Ef, #Efg, #Efs, #Efi*)

The Frere Formation is characterized by a strong aeromagnetic signature resulting from its composition of granular iron-formation, interbedded with ferruginous shale. Around Hawkins Knob (AMG 215822), three iron formation units are exposed, separated by three shale bands (Fig. 8). In northeast FAIRBAIRN, the stratigraphy of the Frere Formation is complicated by structural repetition, which is the result of thrusting in the Stanley Fold Belt.

The lower contact of the Frere Formation with the Yelma Formation is placed at the first occurrence of iron formation. The upper contact of the Frere Formation with the Chiall Formation is placed at the last occurrence of iron formation (Bunting, 1986). On MERRIE (Adamides, 2000), where a more complete sequence is exposed, the upper part of the Frere Formation is represented by shales with local bands of laminar iron-formation. In the southeastern Earaheedy Basin on KINGSTON and STANLEY 1:250 000 sheets, the Frere and Chiall Formations are separated by the Windidda Formation. The latter is now recognized as a lateral correlative of the upper Frere Formation rather than as a younger formation (Hocking et al., 2000).

The total thickness of the Frere Formation on FAIRBAIRN is at least 500 m. Elsewhere in the Earaheedy Basin the Frere Formation is estimated to reach 1200 m (Bunting, 1986; Fig. 4). A composite section 2 km thick was suggested by Robinson and Gellatly (1978; Fig. 9).

The Frere Formation is subdivided on the printed map into three lithotypes: granular iron-formation (*#Efg*), shale and siltstone (*#Efs*), and supergene-enriched iron-formation (*#Efi*). The term granular iron-formation is applied to rocks that have a granular texture to the unaided eye, and are characterized by an intraclastic or peloidal texture. These textures were described in detail by Hall and Goode (1978), Goode et al. (1983), and Bunting (1986). The consensus of opinion is that the peloidal and intraclastic textures of the granular iron-formation are the result of the deposition of iron-rich sediments in a shallow water environment, and the subsequent breakup by wave action of the freshly deposited layers (Beukes and Klein, 1990, 1992). Intraclastic granular iron-formation typically shows an association of iron-rich and iron-poor facies (Fig. 10a).

Granular iron-formation (*#Efg*) is typically represented by beds 10–50 cm thick, interbedded with ferruginous shale and siltstone (cover photograph). Layers are lensoidal, with pinch-and-swell structures along strike. The granular iron-formation forms resistant units, with the interbedded shales being recessive. Layers of granular iron-formation locally contain chert intraclasts, which are angular, and several centimetres in length. The presence of chert intraclasts suggests that breakup occurred after lithification (Fig. 11a). Hall and Goode (1978) reported the presence of microbanded, non-peloidal chert, intercalated with the granular layers, and they ascribed this feature to periods of quiet conditions alternating with periods of wave or storm activity.

In places, jasper bands up to 5 cm thick take the place of the chert layers. Other sedimentary structures common in the granular iron-formation are parallel lamination in the upper parts of beds, local shallow cross-lamination, rare trough lamination, and scour channels. Sediment winnowing has produced common sorting and grain-size grading.

The granular iron-formation consists of rounded, subrounded, or tabular peloids or granules up to 2–3 mm in diameter of microplaty hematite, magnetite, and jasper (cryptocrystalline silica with finely disseminated hematite). Magnetite is often partly to pervasively altered to martite or maghemite. The iron oxide minerals and clasts are cemented by orthochemical chert or allochemical chalcedony or carbonate. Shrinkage cracks in the peloids are present locally, and are filled with quartz.

Siltstone and shale (*#Efs*) are intercalated in at least three stratigraphic levels within the Frere Formation (Fig. 8). The shale is typically well cleaved, dark grey to purple–grey, and weakly sericitic and commonly ferruginous. Individual beds are approximately 10–30 cm thick. The shales are commonly interbedded with thin-bedded granular iron-formation, or, more rarely, with thin chert bands. They are parallel-laminated or, more rarely, low-angle cross-laminated. Siltstone is parallel-laminated, with individual laminae from 1 to 10 mm thick. On the basis of bedding and lithology, the shales are interpreted as low-energy subwave base deposits, with minor bottom currents responsible for cross-laminated layers. Bunting et al. (1982) noted a steady increase in the abundance of granular iron-formation relative to shale from east to west

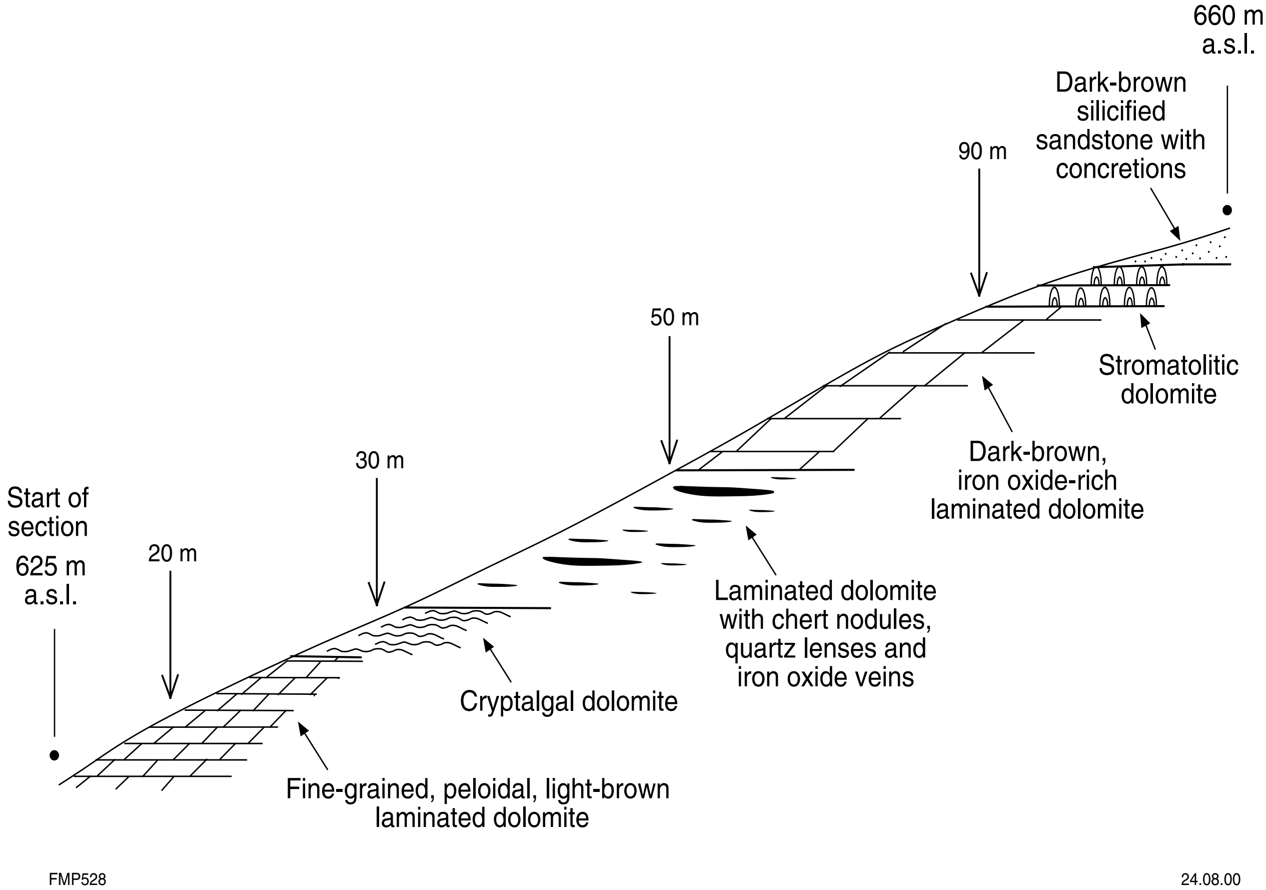

Figure 7. Field sketch, looking west, of Sweetwaters Well Member 4 km northeast of Simpson Well (AMG 094908). Distances, in metres, from start of section are shown

in the Earaheedy Basin. These ratios vary from 1:9 in the east to 4:1 in the west; however, on FAIRBAIRN this ratio is estimated at approximately 1:4.

On FAIRBAIRN, the original mineralogy of the shales interbedded with the granular iron-formation is not preserved as a result of weathering. However, examination of drillcore material from NABBERU shows that, in that area, the shales contain quartz, iron-rich chlorite, and disseminated iron oxides. Locally, peloids composed of stilpnomelane and greenalite are associated with the shales. These associations are identical to assemblages from Superior-type iron-formations in Canada (Gross, 1972; French, 1973) and suggest similar conditions of formation.

Units of banded iron-formations (*#Efi*), commonly displaying strong supergene enrichment in iron and manganese oxides, form distinct ridges in an area about 2.5 km northeast of Hawkins Knob (AMG 228848).

Windidda Formation (not present on map sheet)

The Windidda Formation is a sequence of carbonate and fine-grained clastic rocks between the Frere and Chiall Formations, which is present in the southeastern part of the Earaheedy Basin. A dominantly shaly succession in the western parts of the basin above the Frere Formation was assigned to the Karri Karri Member (*#Edk*; Jones et al., 2000), and this was thought to be the lower energy, deeper water, lateral equivalent of the Windidda Formation to the southeast. Hocking et al. (2000) recognized that the Windidda Formation is actually a lateral correlative of the upper Frere Formation, not a later unit, and as a consequence they assigned the Karri Karri Member to the base of the overlying Chiall Formation.

Chiall Formation

The Chiall Formation (Jones et al., 2000) includes rocks previously assigned to the Wandiwarra Formation and the Princess Ranges Quartzite (Hall et al., 1977). Both of these units have been relegated to member status. As noted above, the Karri Karri Member is now assigned to the Chiall Formation, rather than to the Windidda Formation as shown on the FAIRBAIRN map, so the symbol shown on the map is *#Edk* instead of *#Eck*. Only the lower portion of the Chiall Formation is present on FAIRBAIRN, in a series of outcrops at the southeastern corner of the sheet.

Karri Karri Member (#Edk, #Edka, #Eck)

Rocks placed in the Karri Karri Member were previously assigned to the Wandiwarra Formation (Jones et al.,

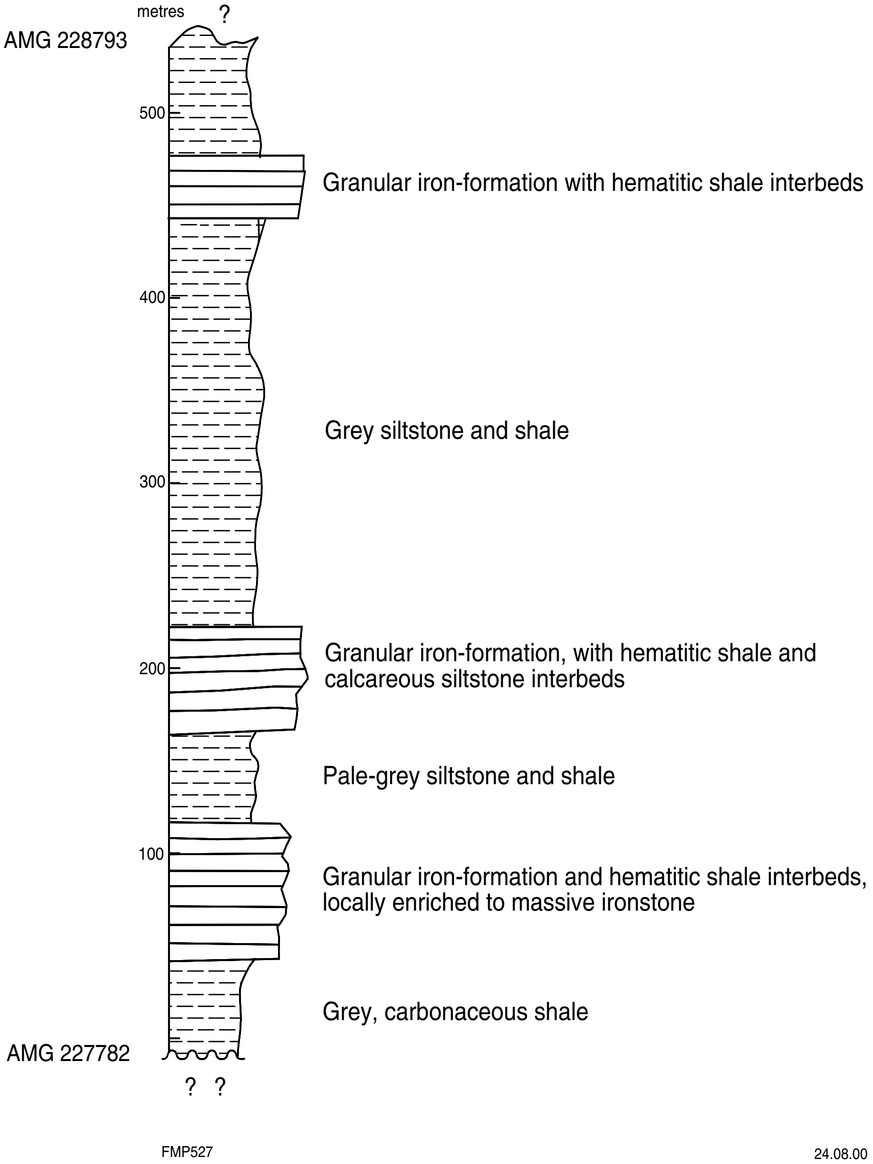

Figure 8. Section exposed along the old mine shaft track between AMG 227782 and AMG 228793, showing the main lithological features of the Frere Formation

2000)*. On FAIRBAIRN, the Karri Karri Member (*#Edk*) outcrops only in the southeastern corner of the sheet. The main rock type is fine-grained, thinly laminated siltstone. In better exposed areas to the east (e.g. METHWIN, RHODES, EARAHEEDY), a thin striped pattern is characteristic of these siltstones. Deposition probably took place below wave base. Lenses and scattered beds of sandstone (*#Edka*) within the siltstones are either massive, or hummocky cross-stratified. They were probably deposited during storm events, partly at storm wave base, and partly as mass flows.

Wandiwarra Member (#Ec, #Ecw, #Ecwa, #Ecws)

The Wandiwarra Member (*#Ecw*) is subdivided into predominantly silt- or shale-rich (*#Ecws*) and sand-rich (*#Ecwa*) units. The sandstone forms a comparatively small proportion of the total, and occurs mainly in the form of lenses within the shale. The best outcrops are on breakaways, with the resistant sandstone beds occupying the high ground, and the shales exposed on the face of breakaways.

The siltstones are generally laminated, in shades of grey and purple, and are little different to the underlying Karri Karri Member. Laminations are typically defined by quartz-rich and clay-rich layers and local erosional truncations are present in some beds. The siltstones were deposited in quiet water, below wave base.

The sandstone units are several tens of centimetres to a few metres thick, with a generally lenticular profile. In exceptional cases, as in the area 6 km northwest of No. 15 Bore (Cunyu: AMG 443897), they are up to 100 m in thickness, and consist of stacked beds each up

* The code shown on the map *#Edk*, reflects this previous assignment, but since publication of the map, the unit has been recoded to *#Eck*.

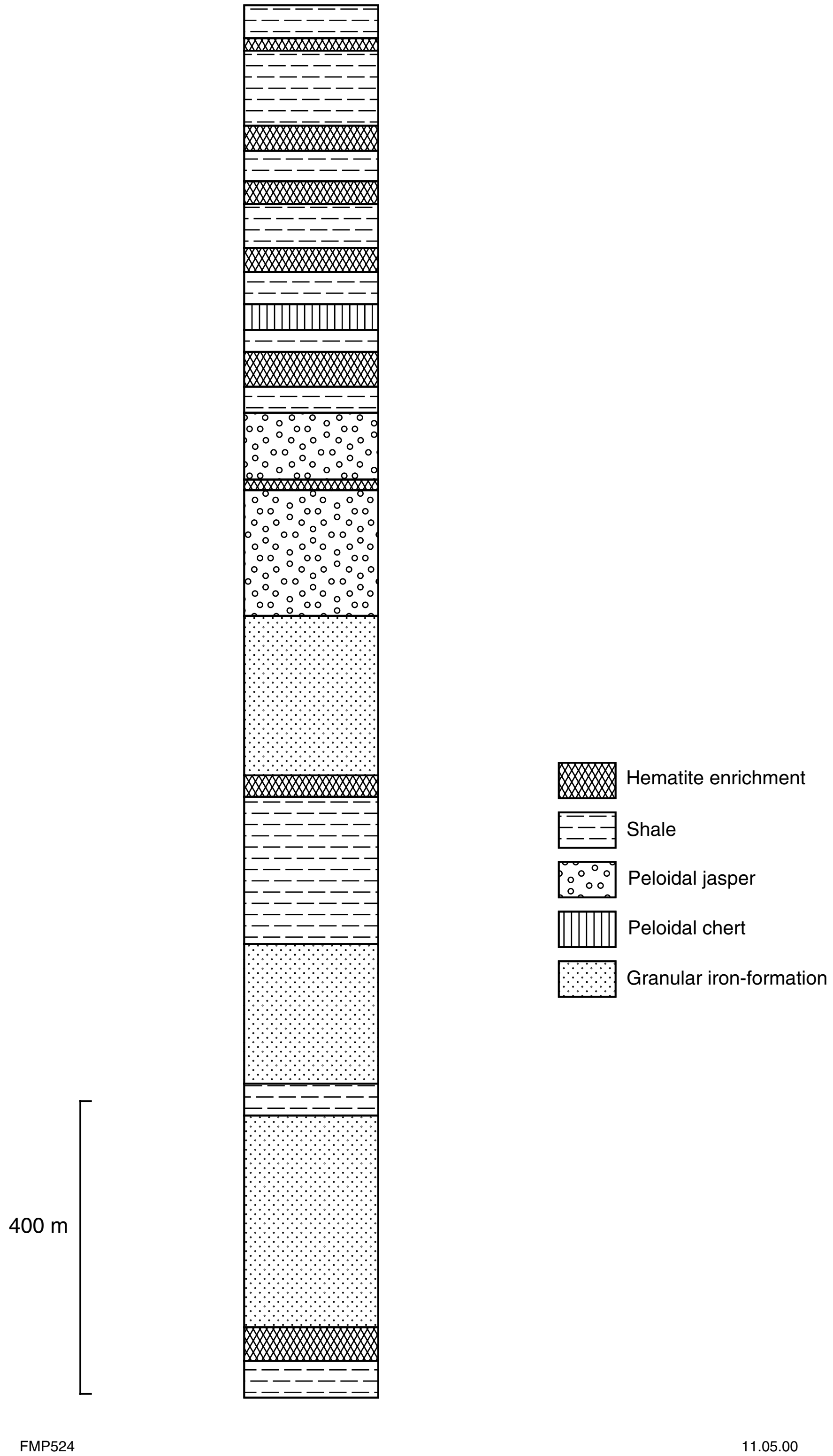

Figure 9. Composite section through the Frere Formation showing location of main hematite occurrences. Redrawn after Robinson and Gellatly (1978)

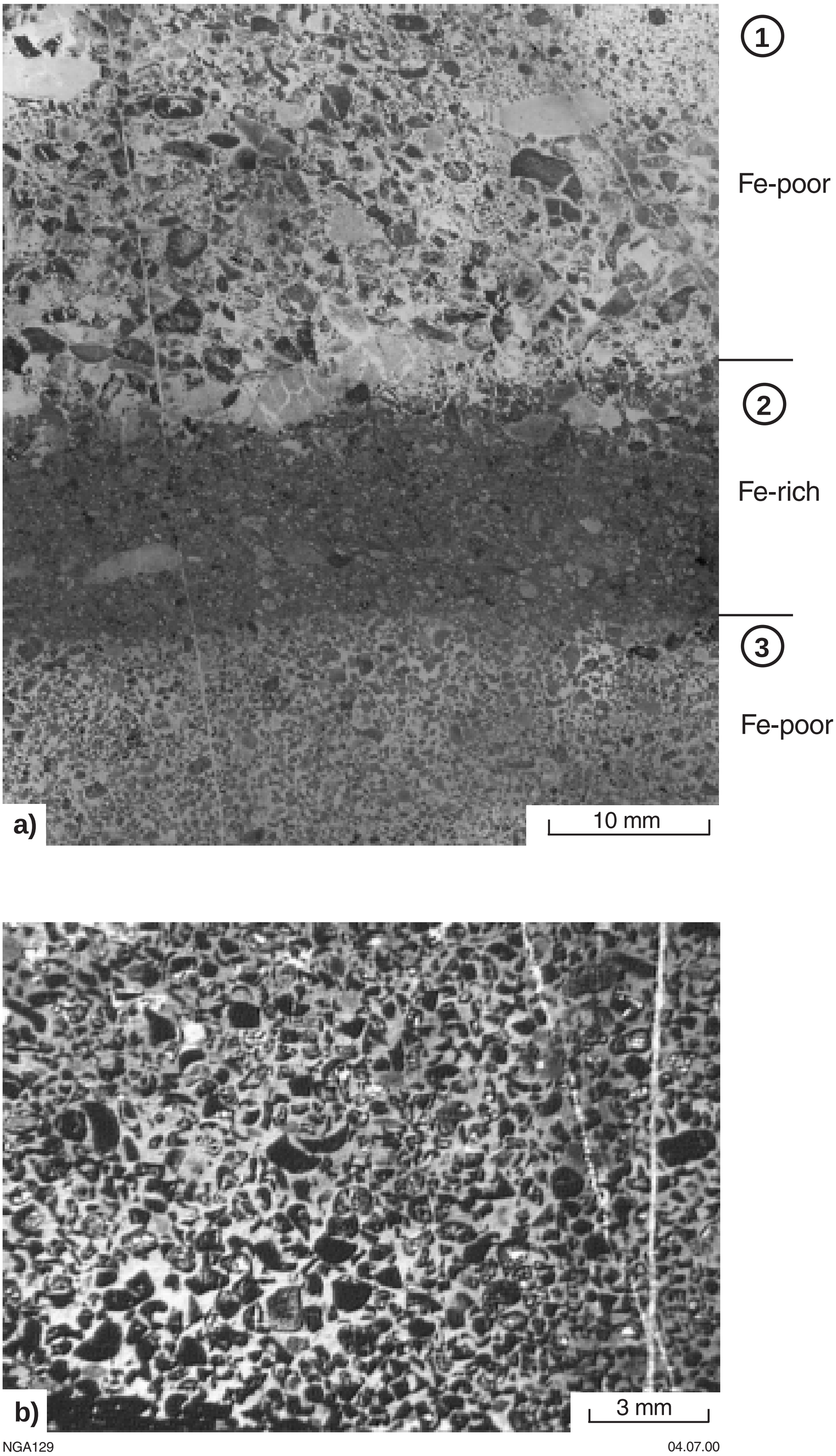

Figure 10. Granular iron-formation textures (Frere Formation): a) Showing association of coarse mainly cherty intraclastic (1), ferruginous (2) and finer peloidal facies (3). Polished section, GSWA 149328, field of view is 4.5 cm; b) Typical peloidal texture. Polished section, GSWA 149328, field of view is 1.8 cm

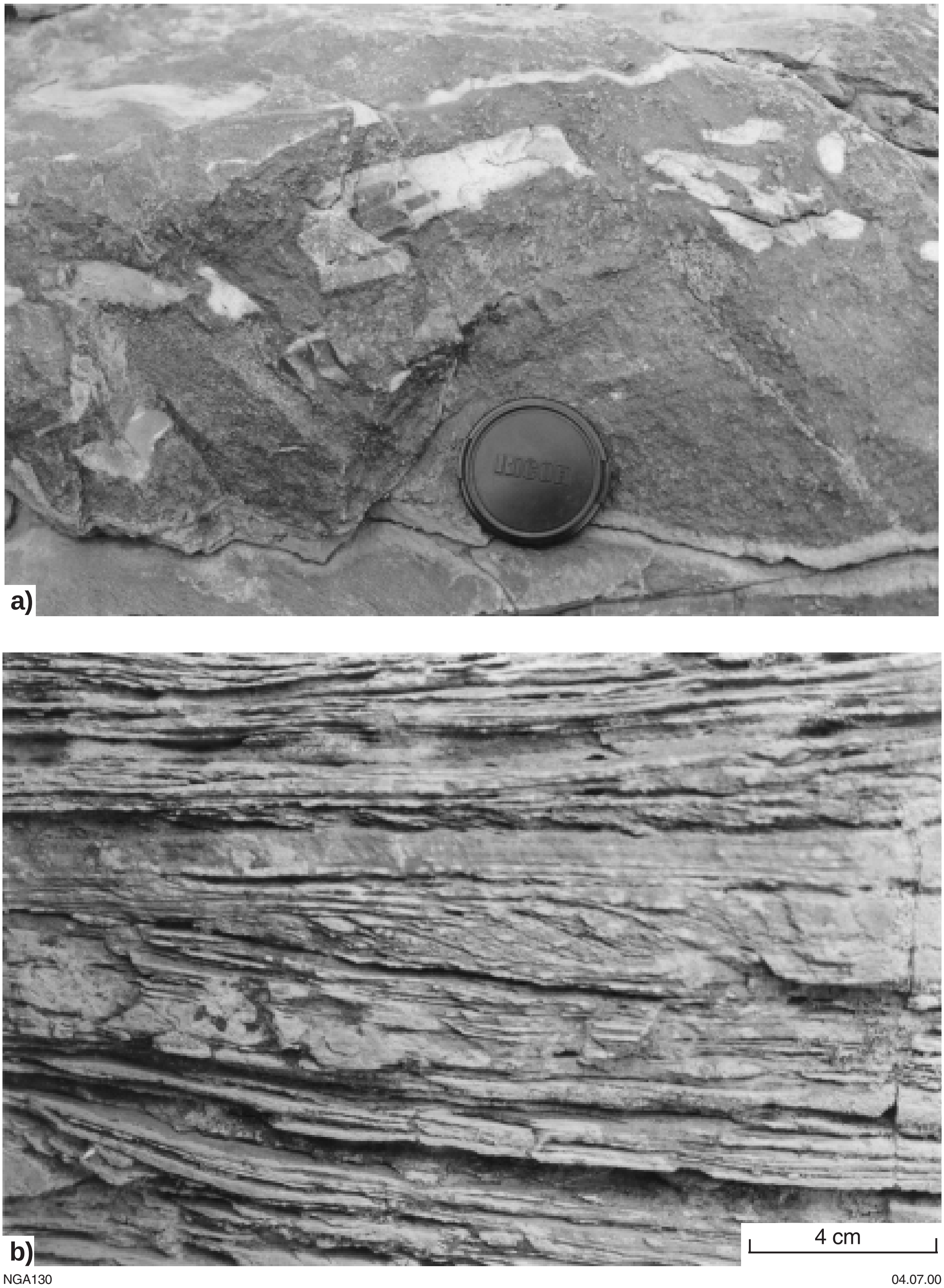

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Figure 11. Lithological features of the Frere Formation: a) Chert intraclasts in granular iron-formation, 3.7 km southeast of Clay Hole (AMG 410022). Diameter of lens cap is 5.5 cm; b) Shallow cross-laminations in granular iron-formation, 4 km northwest of Clay Hole (AMG 366080). Field of view is 20 cm

to 50 cm thick. The sandstones are generally poorly sorted, and largely composed of monocrystalline and strained subrounded quartz grains, with subordinate polycrystalline and sparse mylonitic clasts. Mudstone and kaolinitic siltstone intraclasts are widespread. Accessory minerals are mostly angular green tourmaline, and the matrix contains locally abundant 5–10 micron-sized chlorite platelets. Concentrations of cubic crystals up to 2 cm in size are present on bedding planes and joints, and are probably pseudomorphs after pyrite.

Hummocky cross-stratification, flute marks, current lineations, fluid-escape structures, and, in thicker sandstone beds, irregular load casts indicate rapid, probably storm-related, deposition on a marine shelf. Current lineations show a dominant northeasterly orientation with a subordinate west-northwesterly component.

Structure and metamorphism

The Earaheedy Basin is deformed into a regional east to east-southeasterly trending, south-verging, asymmetric syncline, which plunges gently towards the southeast. FAIRBAIRN occupies most of the western closure of this syncline (Fig. 1). The northern margin of the basin and parts of the Marymia Inlier are deformed in the Stanley Fold Belt, which forms the northern limb of the syncline. The fold belt is characterized by strike-slip faulting, development of foliation fabrics, tight folding, and possibly reverse faulting. On FAIRBAIRN, northwesterly and northerly trending faults cut across both Archaean and Proterozoic rocks. The continuation of the northwesterly trending Merrie Range Fault is located in southwest FAIRBAIRN.

On FAIRBAIRN, the Earaheedy Group is characterized by open, generally gentle folding, locally with associated axial-plane cleavage. This folding is associated with widespread quartz veining in the axial zones. As also noted for the granitoid rocks, this deformation increases northward, towards the Stanley Fold Belt. A northeasterly trending axial-plane cleavage is well developed in the shaly units of the Wandiwarra Member (Fig. 12). Its orientation is probably related to the presence of stable granitic basement to the northwest, which controlled the distrib-ution of strain. The folds vary from upright to inclined, with subhorizontal to moderate plunges. Axes of minor folds and bedding–cleavage intersection lineations plunge to the southeast.

East of the Merrie Range Fault (Fig. 3), rocks of the Earaheedy Group are deformed into a series of small open folds, with axial planes trending eastward and dipping northward at 40–50°. In northwestern FAIRBAIRN, the unconformity between the Yelma Formation (the basal unit of the Earaheedy Group) and the Marymia Inlier is

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Figure 12. Small-scale folding and associated axial-plane cleavage in siltstones of the Wandiwarra Member, southeast FAIRBAIRN, AMG 452820

tectonized, with development of mylonites, locally interleaved with sheared monzogranite. Mafic dykes, quartz veins and breccia zones in western and northwestern FAIRBAIRN trend in the same direction as the foliation and mylonite zones.

Sedimentary rocks of the Earaheedy Group generally are weakly metamorphosed, only attaining lower greenschist grade locally. Typical metamorphic assemblages in fine-grained rocks are sericite, muscovite, and chlorite.

Bangemall Supergroup — Collier Group

The Collier Group (Bangemall Supergroup; Martin et al., 1999) unconformably overlies the Earaheedy Group along the northern margin of FAIRBAIRN. The only formation present is the Wonyulgunna Sandstone, the basal siliciclastic interval of the Collier Group.

Wonyulgunna Sandstone (*#MCw*)

The Wonyulgunna Sandstone forms resistant rounded ridges rising several tens of metres above the surrounding sandplain. The unconformity with the Earaheedy Group is exposed in northeastern FAIRBAIRN (AMG 397321), where chert breccia of the Yelma Formation (probably after stromatolitic carbonate) is overlain by quartz sandstone. The sandstone is locally strongly silicified, especially near faults, with fine euhedral quartz on fracture planes. The silicification is locally pervasive, but more commonly consists of quartz stockworks grading into unsilicified rock. This probably developed by hydraulic brecciation associated with post-Collier Group deformation.

Exposures are predominantly well-bedded, silica-cemented sandstone. The sandstone is dominantly quartz, variably very fine to coarse grained, and poorly to well sorted. Grains are subrounded to rounded. Scattered clay pellets are present, and well-rounded tourmaline is a prominent accessory mineral. Individual beds are generally around 30–50 cm thick. Asymmetrical wave-ripple marks are common, and indicate variable, predominantly northeastward palaeocurrents. Interbedded conglomeratic units (for example at AMG 349322) are up to 4 m thick. These vary from matrix-supported to clast-supported, with a sandstone matrix. Clasts are mostly cobble-sized, but range up to 30 cm in diameter. They are predominantly of resistant rock types, including iron formation from the Frere Formation.

More extensive exposures of the Wonyulgunna Sandstone on METHWIN indicate that the depositional facies was predominantly braided fluvial, laid down in a coastal setting. Tidal sand flat deposits are present in eastern METHWIN (Jones and Hocking, in prep.). Giant cross-bedding, preserved at the base of the formation in the Carnarvon Ranges, is now interpreted as avalanche deposits on very large fluvial bars, rather than marine sand waves as proposed by Muhling and Brakel (1985).

Structure and metamorphism

The Wonyulgunna Sandstone post-dated the deformation of the Stanley Fold Belt. The sandstone is gently deformed, with dips around 10–15°, although brittle fracturing occurs along strongly silicified fault zones. These faults are oriented in orthogonal directions (northeasterly and northwesterly) and appear to be associated with similarly oriented photolineaments on BULLEN 1:250 000 sheet to the north (Williams, 1995). The effects of metamorphism are not apparent in the rocks; clastic grains are devoid of suturing, and the original clay component of the rock (kaolinite) is generally preserved with only minor recrystallization to illite.

Dolerite (#dc)

Dolerite (*#dc*) is interpreted to intrude Bangemall Supergroup rocks in northwestern FAIRBAIRN (AMG 030315). This dolerite is medium grained and consists of plagioclase and augite, typically in an ophitic texture. Minor amounts (5% by volume in total) of magnetite, ilmenite, and pyrite are present.

Cainozoic geology

Most of FAIRBAIRN is covered by surficial deposits. Active and unconsolidated deposits are generally shown as Quaternary (*Q*), and more stable, commonly dissected deposits are shown as undivided Cainozoic (*Cz*).

Areas of outcrop are fringed by colluvium (*Czc*), a mixture of consolidated gravel, sand, silt and rock fragments. This colluvium generally occupies areas of high slope, and at lower levels it is reworked by recent sheetflood processes, resulting in non-channelized sheetwash deposits (*Qw*). These commonly show a distinctive ‘tiger bush’ vegetation pattern on aerial photographs (Wakelin-King, 1999), which contrasts with the smoother airphoto pattern of colluvium and channelized alluvium (*Qa*). Sheetwash composed primarily of angular vein quartz fragments (*Qwq*) occurs adjacent to quartz blows and veins. Alluvial channels are commonly lined with calcrete (*Qak*), formed by precipitation below the water table under conditions of low rainfall and high evaporation (Hocking and Cockbain, 1990). The calcrete commonly shows alteration to opaline silica. Claypans (*Qac*) are present in low-lying areas of sheetwash and alluvium, where clay and silt have settled from suspension after heavy rain.

Ferruginous duricrust (*Czrf*, the uppermost part of a laterite profile) is rarely preserved on FAIRBAIRN. Where present, ferricrete has a massive, nodular or fragmentary texture. This, and the Proterozoic iron formations, are commonly reworked to proximal colluvium which consists of angular and pisolitic ferruginous fragments (*Czcf*). These deposits pass laterally into finer grained ferruginous sheetwash (*Qwf*). Lateritic ironstone (*Czri*), resulting from percolation of iron-rich waters in fault zones, is commonly massive to rubbly in outcrop and is often associated with quartz veins. Silcrete (*Czrz*) is composed of angular quartz grains set in a siliceous aphanitic matrix. It is common in granite terrain, and gives rise to an angular bouldery scree. In the area 10 to 12 km west of Illyee Pool (AMG 205023), the formation of silcrete is spatially associated with an easterly trending fault zone. The deeply weathered nature of the Archaean granite suggests that this ferricrete layer has been largely stripped off.

Lakes and smaller playas present in the southwestern and southeastern corners of the map are floored by saline mud, silt, and sand (*Ql*). Lake areas are commonly characterized by a distinct vegetation, with samphire communities being prominent. Lacustrine calcrete (*Qlk*) is 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). Gypsiferous and saline deposits (*Qlg*), commonly bedded, fringe the lakes, together with dunes and intermixed dune-and-playa terrain (*Qld*). Dunes are dominantly fine-grained, red-brown angular quartz sand, with some lateritic ironstone grains. Gypsum dunes are rare. Dune deposits form gentle mounds a few metres high that are vegetated mainly by mulga.

Quartz sand (*Qs*) forms extensive plains in the northern half of FAIRBAIRN, with dunes up to 14 m high and as much as 6 km long. The sand generally overlies areas of granite or quartz-rich sedimentary rocks.

Economic geology

Iron

The Earaheedy Basin was considered to have a very high potential for iron ore of the Hamersley type (Broken Hill Proprietary, 1978) as a result of similarities with the Hamersley Basin. Several Temporary Reserves were granted in the period 1973–1978, and targets included the Hawkins Knob area on FAIRBAIRN, and Mount Deverell area on MERRIE. Zones of enrichment within banded iron-formation were located in these areas.

Broken Hill Proprietary (1978) subdivided the Frere Formation into a lower pelletal (or granular) iron-formation, and an upper banded iron-formation which was considered similar to the iron formations of the Hamersley Basin. The pelletal iron-formation was estimated to be 300 m in thickness, and the overlying banded iron-formation less than 150 m in thickness. The two units are separated by shale.

Grab samples collected from the supergene-enriched banded iron-formation assayed up to 66.1% Fe and were generally low in phosphorus (<0.06%). Subsequent drilling 5 km south of Miss Fairbairn Hills, however, returned a highest assay for iron of 50.3% (with 0.035% P) over a 9 m intersection in peloidal iron-formation. The highest manganese value was 16.1% over 6 m in independent intersections. One sample of fresh granular iron-formation, collected 3.5 km south of Hawkins Knob during the current mapping, was analysed by X-ray fluorescence for major elements and by atomic absorption spectrometry for trace elements. Results gave 21.54% Fe, 67.33% SiO_2, 0.74% Al_2O_3, 0.01% TiO_2, 0.05% MnO, 0.02% CaO, 0.011% P, 0.022% S, 0.01% MgO, 0.02% K_2O, 0.55% LOI; 5 ppm Co, 7 ppm Cu, 16 ppm Ni, 28 ppm Pb, and 25 ppm Zn.

Robinson and Gellatly (1978) described occurrences of platy hematite in the Miss Fairbairn Hills area. The hematite varies in texture from laminated to massive, with most of the hematite occurrences found in a predominantly shaly sequence near the top of the Frere Formation (Fig. 9). Iron enrichment is interpreted as the result of localized chemical weathering. Drilling in the Miss Fairbairn Hills area indicated that the high-grade zones encountered during surface sampling were small, and in addition, contain deleterious sulfur impurities.

Gold

FAIRBAIRN contains part of the eastern extension of the Baumgarten greenstone belt, and as such may be prospective for greenstone-associated gold mineralization. On MARYMIA, gold mineralization in this belt is contained within steeply dipping quartz lenses, and is associated with sericite–carbonate alteration (Bagas, 1998).

Base metals

The Sweetwaters Well Member of the uppermost Yelma Formation has been explored for base metals. Encouragement was provided by the presence of subeconomic amounts of galena in stromatolitic dolomite at the type locality on MERRIE (Adamides, 2000) and on NABBERU (Pirajno and Jones, in prep.). The Sweetwaters Well Member on FAIRBAIRN is prospective for similar mineralization.

A number of ironstone samples collected during mapping were analyzed for trace elements, iron and manganese (Table 2). Some of these samples show anomalous abundances in copper and zinc, and to a lesser extent in cobalt, nickel, and barium. The highest values obtained, but not in the same sample, were: 1739 ppm Cu, 609 ppm Zn, 231 ppm Ni, 110 ppm Co, and 1600 ppm Ba. These ironstones, in the southeastern parts of the map sheet, are associated with quartz veining, generally following cleavage. The high metal abundances in these samples may be the result of fluid circulation, during deformation related to the Stanley Fold Belt.

Diamonds

An exploration program for diamonds was carried out by Stockdale Prospecting, during 1989–1997. The area investigated covered the northern extension of the Yilgarn Craton, and part of the Yerrida and Earaheedy Basins. A number of LANDSAT and airphoto anomalies were identified, and subsequent work located several small kimberlite dykes and stringers. Chrome spinels were recovered from soil and stream sediment samples. Subsequent drilling and trenching recovered diamonds; however, the exploration failed to upgrade any of the

Table 2. Trace element geochemistry of samples on FAIRBAIRN

GSWA No *Grid reference* *Lithology*	*149302* *452012* *sandstone*	*149311* *436793* *sandstone*	*149313* *452820* *ironstone*	*149316* *467858* *ironstone*	*149318* *445831* *ironstone*	*149319* *442884* *quartz vein*	*149322* *423933* *ironstone*	*149324* *410933* *ironstone*	*149332* *315102* *ironstone*	*149354* *296137* *ferruginous band*	*149355* *277119* *quartz vein*	*149359* *448798* *siltstone*	*Units*	*Detection limit*	*Analytical method*
Ag	–	–	–	0.2	–	–	–	–	0.1	0.2	0.2	0.2	ppm	0.1	A/MS
As	5	1	21	7	12	17	45	22	3	2	–	6	ppm	0.1	A/MS
Au	1	–	–	–	2	–	–	1	1	1	1	1	ppb	1	FA*/MS
Ba	36.8	37.4	32.2	167.6	231.1	105.4	137.5	118.5	78	1600	86	275	ppm	0.1	A/MS
Bi	0.24	0.31	4.45	0.2	0.02	0.05	0.13	0.06	0.1	0.14	0.68	3.8	ppm	0.01	A/MS
Co	1.5	0.7	0.5	29.7	32.3	22.2	66.5	39.5	1.7	11.4	1.9	110	ppm	0.1	A/MS
Cr	8	9	21	6	14	2	9	9	3	82	14	20	ppm	2	A/OES
Cu	5	11	93	393	544	1739	197	409	x	12	12	620	ppm	1	A/OES
Mo	0.9	0.3	0.3	22.1	0.7	0.5	1	0.8	0.1	0.2	0.3	0.8	ppm	0.1	A/MS
Ni	5	3	6	126	104	82	231	90	7	29	11	155	ppm	1	A/OES
Pb	4	5	11	22	19	5	17	23	4	8	6	14	ppm	2	A/MS
Pd	x	x	x	x	x	x	x	x	2	x	x	5	ppb	1	FA*/MS
Pt	x	x	x	x	x	x	x	x	1	x	x	2	ppb	1	FA*/MS
Se	x	x	x	x	x	2	x	x	x	x	x	x	ppm	2	A/MS
Sn	0.4	0.5	0.6	0.8	0.8	0.7	0.5	0.3	0.7	1.9	0.6	1.6	ppm	0.1	A/MS
Th	2.28	1.62	1.58	3.82	4.54	3.52	3.18	1.8	6.7	12	3.1	8.4	ppm	0.01	A/MS
U	0.18	0.38	0.65	13.47	9.46	24.05	6.71	12.68	0.56	0.88	0.28	6.2	ppm	0.1	A/MS
V	9	3	12	21	20	21	23	13	38	–	–	–	ppm	2	A/OES
W	0.8	0.3	0.3	0.6	0.6	0.6	0.4	0.2	0.7	1	0.4	1	ppm	0.1	A/MS
Zn	13	9	7	393	463	488	609	461	14	68	11	430	ppm	1	A/OES
Mn	0.013	0.013	0.005	0.017	0.027	0.008	0.020	0.020	0.009	46	35	11.2	ppm	1	A/OES
Fe	8.34	0.99	3.12	36.10	24.47	41.63	45.94	35.34	52.95	10.8	2.35	–	%	0.01	A/OES

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
x: Not analysed
–: Below limit of detection

anomalies. Details of the exploration history are contained in company reports submitted to the Geological Survey of Western Australia (WAMEX database).

Groundwater

The most promising areas for groundwater are the thick alluvial deposits and associated calcrete along the main drainage channels. Most of the wells on FAIRBAIRN are located within these deposits in the western half of the map sheet, with the eastern half lacking wells. This apparent imbalance is not due to the geology, but is due mainly to the fact that the eastern part of the area is non-pastoral crown land. Apart from alluvial sediments, fractured or weathered rocks also have some groundwater potential.

A regional survey of the area (Sanders and Harley, 1971) indicated an increase in salinity of the water from 650 ppm TDS (total dissolved solids) in areas away from the Nabberu lake system to 3000 ppm in areas close to the lake, reaching a maximum of 5000 ppm TDS in the lake sediments. The water table is generally a few metres (3–15 m) below the ground surface, but may be deeper in zones of fractured rocks.

Regolith geochemistry

Regolith was sampled over FAIRBAIRN at a density of one sample per 16 km^2, as part of the NABBERU 1:250 000 regolith geochemistry program (Morris et al., 1997). One sample, near greenstone rocks along the sheet boundary with MARYMIA, contains anomalous amounts of gold. Anomalous palladium values in the central part of FAIRBAIRN appear to be associated with the northwesterly trending Lockeridge Fault. An interesting multi-element anomalous concentration (manganese, bismuth, lead, antimony, tungsten, and arsenic) was recorded in southeastern FAIRBAIRN near the closure of the Earaheedy synclinorium, in an area underlain by the Frere and Chiall Formations, which is cross cut by northwesterly and easterly trending faults.

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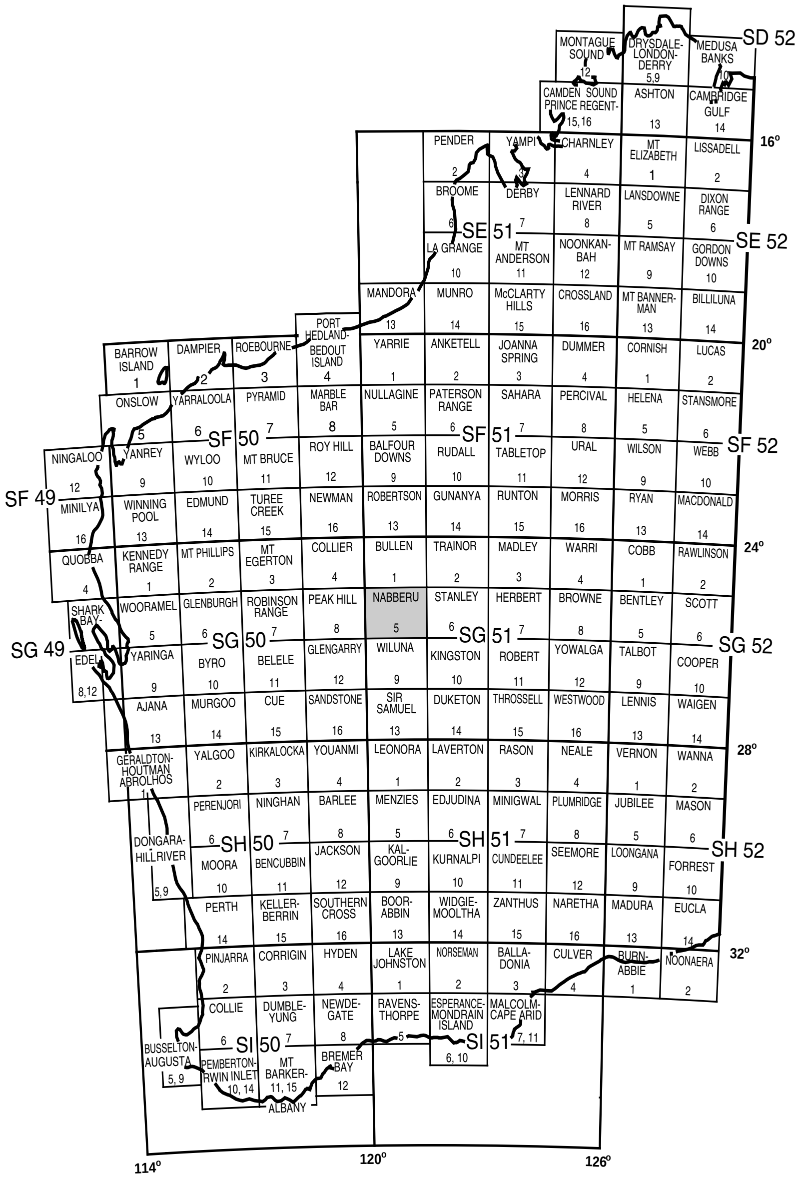
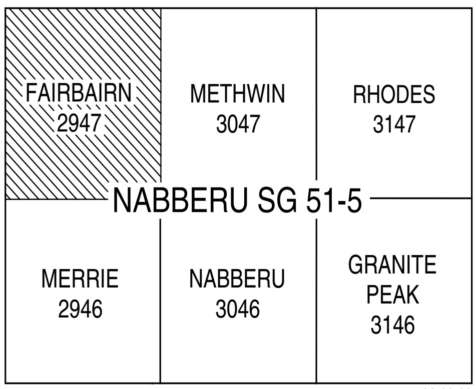
Appendix

Gazetteer of localities mentioned in text

Locality	*Latitude (S)*	*Longitude (E)*	*Zone*	*AMG (E)*	*AMG (N)*
Baumgarten Reward	25°16'23"	119°58'00"	50	798800	7201500
Carnarvon Ranges	25°15'44"	120°41'47"	51	268000	7204000
Cunyu Homestead	25°42'27"	120°20'43"	51	233600	7154000
Cunyu Woolshed	25°49'08"	120°10'09"	51	216200	7141300
Grasscutter Well	25°21'07"	120°03'29"	51	203900	7192800
Hawkins Knob	25°27'04"	120°13'46"	51	221400	7182200
Illyee Pool	25°15'07"	120°20'32"	51	232300	7204500
Lake Gregory	25°37'07"	119°55'00"	50	793000	7167000
Lake Nabberu	25°36'00"	120°07'00"	51	210400	7165400
Marymia Homestead	25°00'40"	120°07'00"	51	209000	7230700
Meekatharra	26°36'00"	118°30'00"	50	649400	7057000
Miss Fairbairn Hills	25°14'00"	120°21'00"	51	233000	7206600
Mount Deverell	25°35'06"	120°21'07"	51	234000	7167600
Neds Creek Homestead	25°28'52"	119°38'52"	50	766200	7179100
New Marymia Homestead	25°02'25"	120°00'20"	51	197800	7227250
No. 17 Bore	25°17'20"	120°06'30"	51	208800	7199900
No. 15 Bore (Cunyu)	25°25'59"	120°29'15"	51	247300	7184700
Simpson Well	25°24'05"	120°05'08"	51	206800	7187400
Sweetwaters Well (abd)	25°35'33"	120°22'18"	51	236000	7166800
Vermin-proof fence	25°56'11"	120°02'41"	51	204000	7128000
Wiluna	26°35'39"	120°13'25"	51	223500	7055500





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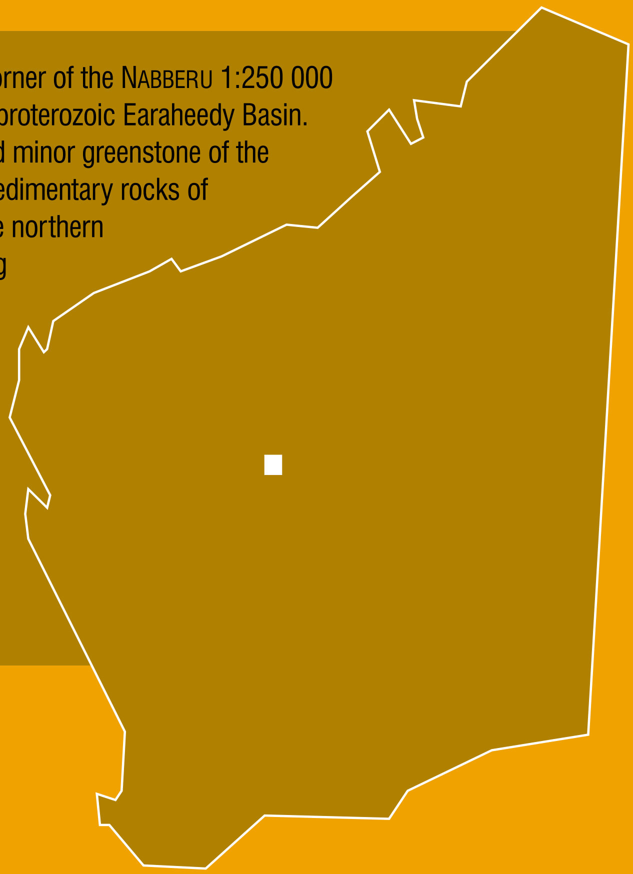
The FAIRBAIRN 1:100 000 sheet occupies the northwestern corner of the NABBERU 1:250 000 sheet, and covers part of the northwestern end of the Palaeoproterozoic Earaheedy Basin. The area is underlain by poorly exposed Archaean granite and minor greenstone of the Marymia Inlier. These rocks are unconformably overlain by sedimentary rocks of the lower part of the Palaeoproterozoic Earaheedy Group. The northern margin of the Earaheedy Group sediments, and the underlying Archaean rocks, are deformed in the Stanley Fold Belt. Along the northern edge of the sheet, Mesoproterozoic sandstone of the Collier Group forms part of the Bangemall Supergroup. Extensive Cainozoic sandplain and sheetwash deposits cover much of the area. Prospecting on FAIRBAIRN has shown some anomalous values for base metals and other elements. Carbonate rocks of the Yelma Formation may be prospective for lead and zinc. The Frere Formation has potential for iron ore deposits.



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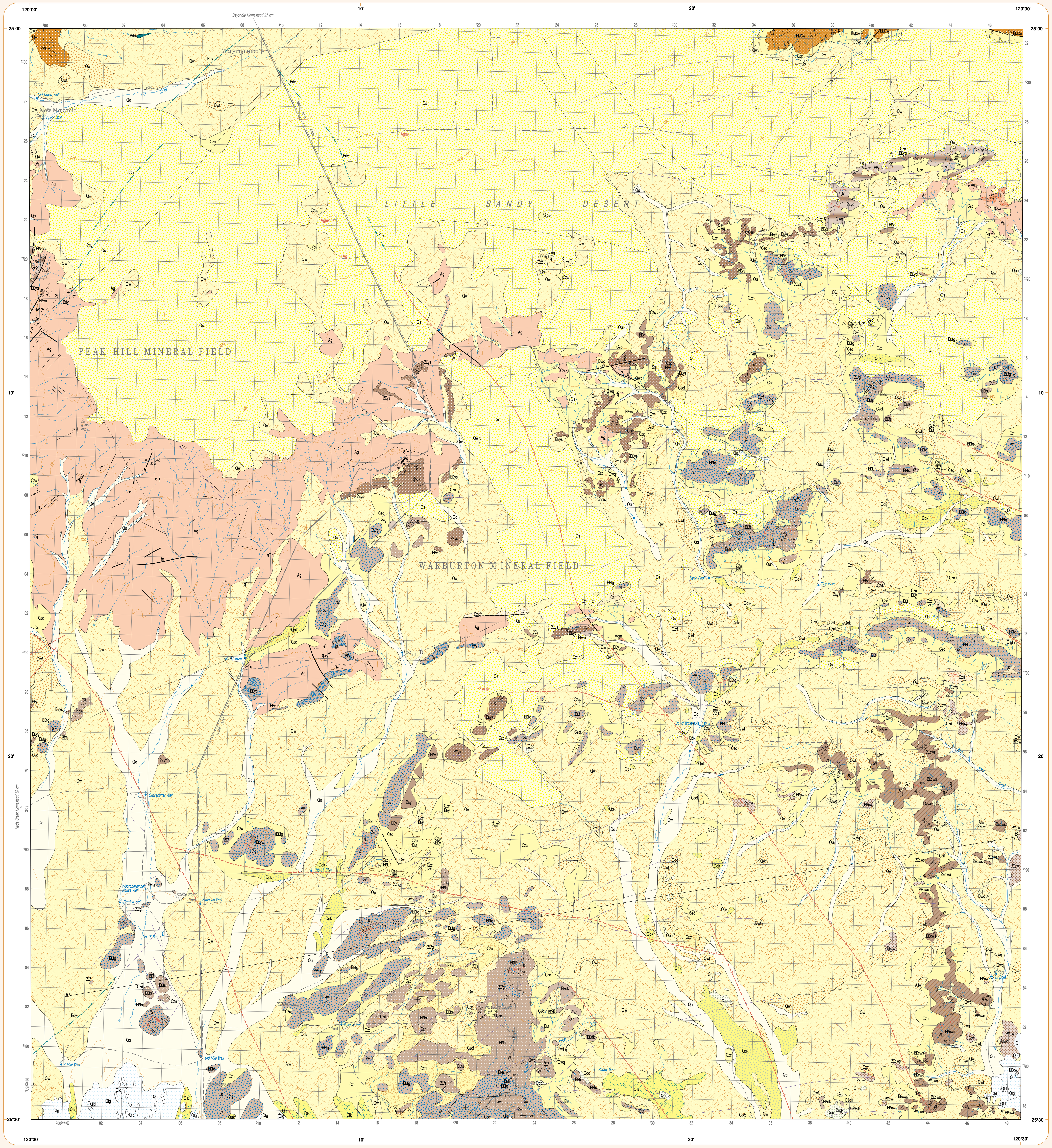
FAIRBAIRN

AUSTRALIA 1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET 2947



PHANEROZOIC — CAINOZOIC — QUATERNARY

Ql	Qld	Qlg	Qlk	Qa	Qac	Qak

Ql Lacustrine deposits — saline silt, mud, and minor sand in playa lakes, primarily associated with palaeodrainages
Qld Sand in dunes on and around playa lakes
Qlg Gypsiferous and saline bedded deposits adjacent to playa lakes
Qlk Calcrete and gypcrete deposits in and around playa lakes
Qa Alluvium — sand, silt, and gravel in channels and channel systems
Qac Clay and silt in non-saline claypans
Qak Calcrete associated with palaeodrainage and active drainage systems; locally silicified

Qw Sheetwash deposits — sand, silt, and gravel
Qwf Ferruginous gravel
Qwq Quartz rubble and debris adjacent to quartz veins
Qs Sandplain and dunes — unconsolidated sand and minor silt and clay

Czc Colluvium — loose to consolidated gravel, sand, and silt; locally dissected
Czcf Ferruginous pisoliths and nodules; subordinate ferruginized rock and ironstone rubble

Czrf Ferruginous duricrust; nodular, pisolitic, and massive ferricrete (laterite) and associated debris
Czri Ironstone; ferruginized rock, massive to rubbly; includes degraded ferruginous duricrust
Czrz Siliceous duricrust; nodular, pisolitic, and laminar silcrete, and intensely silicified bedrock

q Quartz veins and pods; various ages

go Gossan, or gossanous rock

PROTEROZOIC — MESOPROTEROZOIC

Ᵽdc Dolerite sill

Bangemall Group — Collier Subgroup — BANGEMALL BASIN

ᏢMCw **WONYULGUNNA SANDSTONE:** quartz sandstone, cross-bedded and commonly ripple-marked; minor siltstone and conglomerate

PALAEOPROTEROZOIC — Earaheedy Group — EARAHEEDY BASIN

ᏢEc **CHIALL FORMATION:** sandstone, siltstone, and shale
ᏢEcw **Wandiwarra Member:** sandstone, siltstone, and shale
ᏢEcwa Dominantly sandstone; minor interbedded shale and siltstone
ᏢEcws Dominantly shale and siltstone

WINDIDDA FORMATION
ᏢEdk **Karri Karri Member:** siltstone and shale, locally varvoid; minor sandstone
ᏢEdka Sandstone lenses

ᏢEf **FRERE FORMATION:** granular iron-formation, granular siliceous iron-formation, siltstone, and shale; minor banded iron-formation
ᏢEfg Granular iron-formation and granular siliceous iron-formation, in places peloidal; minor siltstone and shale
ᏢEfs Siltstone and shale; minor granular iron-formation
ᏢEfi Banded iron-formation; supergene enriched iron-formation

ᏢEy **YELMA FORMATION:** quartz sandstone, siltstone, shale, and associated chert breccia
ᏢEyw **Sweetwaters Well Member:** stromatolitic dolomite, microbial limestone, and chert breccia derived from dolomite
ᏢEyc Stromatolitic dolomite and dolomitic sandstone; includes chert breccia derived from dolomite
ᏢEys Siltstone and shale; minor chert
ᏢEya Quartz sandstone and pebble conglomerate
ᏢEyy **Yadgimurrin Member:** polymictic conglomerate, matrix supported

ARCHAEAN — MARYMIA INLIER — YILGARN CRATON

Ᵽdy Mafic dyke, interpreted from aeromagnetic data; intruded into Archaean rock

Ag Granitoid rock; lateritized, silcretized, and kaolinized
Agm Predominantly monzogranite; locally cataclastic and silcretized
Agmk Monzogranite with potassic alteration (subsurface only)

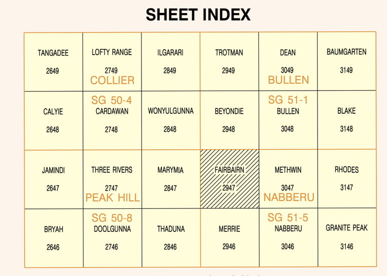
Geological boundary
exposed
concealed
Structural symbols are labelled according to the sequence of deformation events, where known
Local deformation
Capricorn Orogeny
D_1, D_2
Fault
exposed; tick on downthrown side, showing dip — 64
concealed
concealed, interpreted from aeromagnetic data
breccia — br
strongly foliated rock
Fold, showing axial trace and generalized plunge direction
anticline; exposed
syncline; exposed
Small-scale fold axial surface, showing strike and dip
inclined — 68
Small-scale fold axis, showing trend and plunge
anticline — 20
syncline — 20
S-vergence — 30
Z-vergence — 20
Bedding, showing strike and dip
inclined — 20
horizontal
interpreted from aerial photographs
amount of dip 0–15°
Palaeocurrent, showing trend and sense of direction
from cross-bedding, direction known
from asymmetrical ripple marks, direction known
from current lineation, direction not known
Metamorphic foliation, showing strike and dip
inclined — 50
vertical
Cleavage, showing strike and dip
inclined — 50
vertical
Crenulation cleavage, showing strike and dip
inclined — 50
Mineral lineation, showing trend and plunge direction
inclined — 18
Intersection lineation, showing direction of plunge
inclined — 20
horizontal
Axis of crenulation
Slickenside, showing direction and plunge — 20
Fracture or joint showing strike and dip
inclined — 50
Airphoto lineament
unspecified
bedding trend
Aeromagnetic lineament
Stromatolite locality

Track
Fence, generally with track — vermin - proof fence
Homestead — New Marymia
Building
Yard — Yard
Horizontal control; major
Breakaway
Sand dune
Contour line, 20 metre interval — 580
Abandoned — (abd)

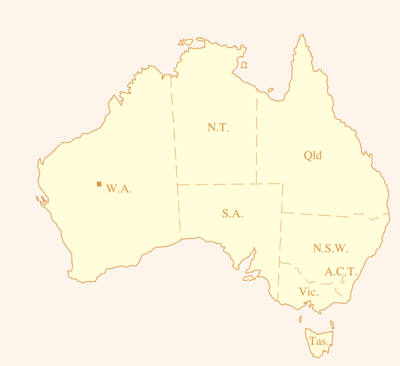
Watercourse with ephemeral pools or waterholes
Bore — Bore
Well — Well
Windpump

Mineral field boundary
Mineral exploration drillhole showing subsurface data — ᏢEys

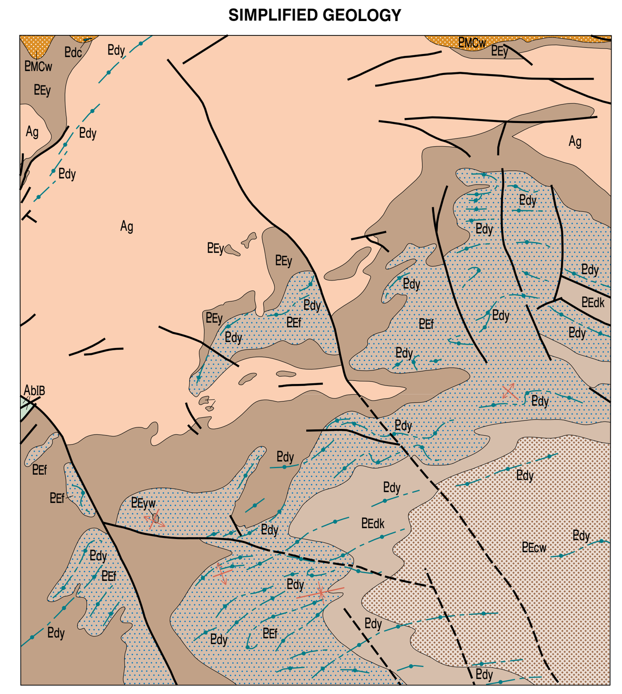
SHEET INDEX



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



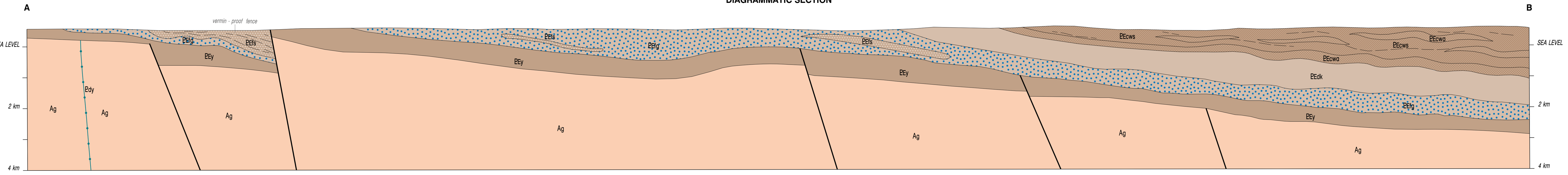
SIMPLIFIED GEOLOGY

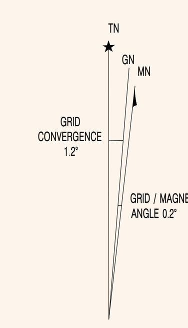


SCALE 1:500 000
0 5 10 15 20
Kilometres

Ᵽdc Dolerite sill
Bangemall Group — ᏢMCw Collier Subgroup, Wonyulgunna Sandstone — BANGEMALL BASIN
Earaheedy Group — EARAHEEDY BASIN
ᏢEcw Chiall Formation, Wandiwarra Member
ᏢEdk Windidda Formation, Karri Karri Member
ᏢEf Frere Formation
ᏢEyw Sweetwaters Well Member
ᏢEy Yelma Formation
YILGARN CRATON
Ᵽdy Dolerite dyke; dash indicates dyke concealed by Proterozoic rock
Ag Granitoid rock
AblB Baumgarten greenstone belt
Fault concealed by Proterozoic rock

DIAGRAMMATIC SECTION





True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1997 and moves easterly by about 0.1° in 2 years.

Geology by F. Pirajno, N. G. Adamides, and R. M. Hocking 1997

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L.C. RANFORD, DIRECTOR GENERAL

GOVERNMENT OF WESTERN AUSTRALIA
HON. NORMAN MOORE, M.L.C.
MINISTER FOR MINES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:100 000

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

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Australian Map Grid Zone 51

FAIRBAIRN

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