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GOVERNMENT OF WESTERN AUSTRALIA

GEOLOGY OF THE COORAGOORA 1:100 000 SHEET

by I. R. Williams

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Cover photograph:
Weathered sandstone stacks (4–5 m high) of the Callawa Formation (AMG 067429), Great Sandy Desert, COORAGOORA 1:100 000 sheet.

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by

I. R. Williams

Abstract

The COORAGOORA 1:100 000 sheet is situated on the northeast margin of the Archaean Pilbara Craton. The craton is only exposed in the southwestern corner. The remainder of the sheet (94% by area) is covered by a thin Mesozoic succession that consists of the exposed Jurassic–Cretaceous Callawa Formation and Cretaceous Parda Formation and, in the northern half, subsurface Jurassic Wallal Sandstone and Jarlemai Siltstone. The Mesozoic rocks occupy the Lambert Shelf of the Westralian Superbasin. They also mask, in the northeastern quarter, the subsurface faulted contact between the Archaean Pilbara Craton and the Lower Permian Grant Group rocks of the Palaeozoic Canning Basin. The Grant Group occupies the Wallal Embayment of the Canning Basin.

The exposed Pilbara Craton consists mainly of the Muccan Granitoid Complex (c. 3443 Ma) unconformably overlain by the Gorge Creek Group (< 3235 Ma). The Gorge Creek Group, comprising the basal Nimingarra Iron Formation, epiclastic Cundaline Formation, and Coonieena Basalt, is, in turn, disconformably overlain by the De Grey Group. This contact is intruded by the layered mafic Shay Intrusion.

The De Grey Group consists of the mixed epiclastic and volcaniclastic Cattle Well Formation and the conformably overlying epiclastic Cooragoora Formation. In the Pilbara region, the dubiofossil *Eozoon canadense* Dawson 1864 was first identified in stromatolitic chert of the Cattle Well Formation.

The De Grey Group is unconformably overlain by the Eel Creek Formation, a postulated correlative of the Neoproterozoic Tarcunyah Group (< 800 Ma) that rims the eastern margin of the Pilbara Craton. The Eel Creek Formation is intruded by many large dolerite sills.

The Nimingarra Iron Formation is host to numerous small iron ore deposits that are distributed along the Nimingarra and Sunrise Hill – Shay Gap ridges. These have been mined almost continuously since 1972.

COORAGOORA has been explored for base metals, gold, uranium, manganese, bauxite, and diamonds.

KEYWORDS: Muccan Granitoid Complex, Gorge Creek Group, De Grey Group, Eel Creek Formation, Mesozoic, regional geology, iron ore.

Introduction

The COORAGOORA* 1:100 000 geological map sheet (SF 51-1, 2957), bounded by latitudes 20°00'S and 20°30'S and longitudes 120°00'E and 120°30'E, is situated in the southwestern corner of the Great Sandy Desert and on the northeastern margin of the Pilbara Craton. The sheet area derives its name from the abandoned Cooragoora Bore on the Wallal pastoral lease (AMG 126831†). COORAGOORA occupies the northwestern corner of the YARRIE 1:250 000 sheet.

Most of COORAGOORA is vacant land, although pastoral leases encroach on the northern (Wallal Station), western (Pardoo Station), and southern (Yarrie Station) margins of the sheet.

In the southwestern corner of COORAGOORA, BHP Iron Ore Pty Ltd (BHP) is currently (1999) operating the Sunrise Hill West No. 7 iron ore pit (AMG 691368), 3.5 km southeast of Nimingarra (AMG 879388). The iron ore is crushed and loaded at Nimingarra from where it is railed 166 km west to Finucane Island, Port Hedland. The Nimingarra operations are linked to the Port Hedland – Yarrie mine standard-gauge railway, which crosses the southwestern corner, by a 4.5 km spur line.

Numerous abandoned iron ore openpits lie along the ridge between Sunrise Hill West No. 7 mine and the abandoned Shay Gap mines on the southern margin of

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

† 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.

COORAGOORA. Similar abandoned pits also lie north and south of the Nimingarra loading facilities.

Over 90% of COORAGOORA is devoid of tracks. The main access comes from the Muccan – Pardoo Roadhouse road that crosses the southwestern corner and the Boreline road that extends northward from the Muccan – Pardoo Roadhouse road, 2 km north of the abandoned Shay Gap townsite, to the Shay Gap Borefield and the Great Northern Highway on SHOONTA. The Muccan – Pardoo Roadhouse road is sealed between the abandoned townsite of Shay Gap (AMG 045310) and the gated turn-off (AMG 900435) to the Nimingarra mining operations (AMG 879398).

Nineteen kilometres east of the Pardoo Roadhouse (on PARDOO), the Great Northern Highway cuts the extreme northwestern corner of COORAGOORA. Some local station tracks in this area link wells and artesian bores to the highway.

A number of roads and tracks give access to abandoned and operating iron ore openpits in the southwestern corner of COORAGOORA. These include a sealed road linking the Shay Gap substation to the Muccan – Pardoo Roadhouse road, the Nimingarra – Yarrie mine access road, and the railway maintenance track that follows the Port Hedland – Yarrie railway. All the roads are privately maintained by BHP and have restricted access.

A number of exploration cut-lines were identified from aerial photographs (1994) in the northeastern quadrant. Unfortunately, such cut-lines quickly become overgrown unless in continual use. Cross-country driving is difficult on COORAGOORA due to heavy sand and thick, mainly *Acacia*, scrub.

The Shay Gap Bore Field (AMG 074520) supplies potable water via a 42 km-long pipeline southeast to the Yarrie mines and village on MUCCAN (Williams, 1999). A 66 000 V transmission powerline from Port Hedland connects to two substations, one 4 km north (AMG 901420) of Nimingarra loading facilities, and the other 2 km north (AMG 974331) of Shay Gap West opencut mine. The former substation supplies Nimingarra, whereas the latter supplies the Shay Gap Bore Field and Yarrie Village and mines, both via 22 000 V powerlines.

Previous and current investigations

In 1866, Assistant Surveyor James Cowle crossed the northwestern corner of COORAGOORA whilst searching for suitable grazing country along the northwestern coast (Fraser, 1906). Alexander Forrest, accompanied by geologist Fenton Hill, followed a similar route in 1879 on an exploratory expedition from Nickol Bay in the west Pilbara region to the Kimberley region and beyond (Feeken et al., 1970). Alfred W. Canning reconnoitred the area in 1903 and, in 1905, surveyed a line for the proposed No. 1 Rabbit Proof Fence. This fence, constructed under Canning's supervision in 1907, crossed COORAGOORA from the southeast corner on a bearing of approximately 292° (Broomhall, 1991). The fence was abandoned in 1948 and only remnants were found during recent fieldwork.

Very few references to the geology of COORAGOORA are found in publications prior to the 1950s. The banded iron-formation (BIF) ridge between Shay Gap and Nimingarra appears on some early maps (Smith, 1898; Maitland, 1908). The first real interest in the area arose in the late 1940s when the search for oil in Australia was extended to the western parts of what was then called the Desert Basin (or later, Canning Basin; Reeves, 1949, 1951). The first reconnaissance geological investigation of COORAGOORA was carried out by the Bureau of Mineral Resources (BMR) in 1954 (Traves et al., 1956). This mapping was included in the YARRIE 4-mile Geological Series map (Wells, 1959). The geology of the region was further summarized in Veevers and Wells (1961). Around 1960, a number of exploration companies began to take an interest in the iron ore potential of the BIF around Shay Gap and Nimingarra.

During the mid-1970s, the northwestern quadrant of COORAGOORA was subjected to resistivity and seismic refraction studies and follow-up borehole logging of 15 rotary boreholes (Rowston, 1976) as part of a hydrogeological appraisal of the groundwater potential of the western part of the Canning Basin (Leech, 1979a,b). The Geological Survey of Western Australia (GSWA) remapped the Precambrian component of COORAGOORA in 1974 (Hickman and Chin, 1977). Similarly, the Canning Basin component was remapped in 1977 by the BMR (Towner and Gibson, 1980, 1983). All these data were reproduced in the YARRIE 1:250 000 sheet (Hickman et al., 1983). The Precambrian geology component was also included in GSWA Bulletin 127 on the Pilbara Craton (Hickman, 1983).

Goldsworthy Mining Associates commenced mining iron ore in the Shay Gap – Sunrise Hill areas early in 1972, and later at Nimingarra in 1989 (Podmore, 1990). BHP took over these operations in 1990. The mining town of Shay Gap (AMG 045310), the centre for these earlier operations, was subsequently closed and dismantled in 1993. However, BHP has continued to operate small iron ore pits in the Nimingarra and Sunrise Hill areas, albeit intermittently up to 1999. These operations are serviced from the Yarrie mines to the southeast.

The BMR, now the Australian Geological Survey Organisation (AGSO), released a preliminary Bouguer anomaly map in 1979 (BMR, 1979), a radiometric total count contours map (AGSO, 1993a), and a preliminary total magnetic intensity (TMI) contours map (AGSO, 1993b) in 1993 for the YARRIE 1:250 000 sheet including the COORAGOORA area. A coloured total magnetic intensity (reduced to pole) map of the Pilbara region, released in 1997, also covers COORAGOORA (Mackey and Richardson, 1997).

In 1997, GSWA reappraised and updated the Precambrian component of the sheet. COORAGOORA was compiled from 1:25 000 colour aerial photographs of COORAGOORA flown in 1996 for the southern half and 1:50 000 black-and-white aerial photographs of YARRIE (1:250 000) flown in 1994 for the northern half. Apart from some scattered observations, there was no attempt during recent fieldwork to remap the Phanerozoic component of COORAGOORA.

Climate, vegetation, and physiography

The climate on COORAGOORA ranges from arid (desert) in the southern parts to semi-arid–tropical in the north (Beard, 1975). Most rain falls between January and March and is derived from tropical cyclones and thunderstorms. Light rains may also fall in autumn and the early winter months (May–June). The mean annual rainfall is about 330 mm, whereas evaporation is about 3400 mm per annum. Apart from the cyclone season (December–April), humidity is low, although there is a noticeable increase in humidity northward towards the coast. Summers are very hot with mean maximum temperatures in the low forties (°C), and the winters mild with mean minimum temperatures around 13°C (Pink, 1992).

Apart from a small area in the northwestern corner, which is assigned to the Dampier Botanical District of the Northern Botanical Province, COORAGOORA falls within the Eremean Botanical Province (Beard, 1975).

The Dampier Botanical District is distinguished by a mixture of scattered trees, including *Eucalyptus zygophylla* and desert walnut (*Owenia reticulata*), shrubs, including thickets of various *Acacia* sp., and spinifex (mainly *Triodia pungens*). Low-lying areas contain claypans with samphire marsh (including *Arthrocnemum benthamii*) and scattered clumps of tea-tree (*Melaleuca* sp.) marking the edge of the sandplain country (Burbidge, 1944; Beard, 1975; Fig. 1).

The Eremean Botanical Province on COORAGOORA is unevenly divided between the Canning Botanical District, which corresponds to the Great Sandy Desert, and the Fortescue Botanical District, which corresponds to the Pilbara region (Fig. 1).

The Canning Botanical District is mainly a shrub steppe dominated by *Acacia pachycarpa* and soft spinifex (*Triodia pungens*). Scattered throughout the sandplain are sandstone mesas and buttes. These are very sparsely vegetated with small clumps of *Triodia pungens* and very scattered *Eucalyptus papuana* (forma) and *Acacia* species. The gullies running off the larger mesas commonly contain a rank growth of *Grevillea* and *Acacia* species. Scattered eucalypts (*Eucalyptus setosa* and *Eucalyptus papuana*), together with desert bloodwood (*Corymbia dichromophloia*; Hill and Johnson, 1995), *Hakea* and *Acacia* species, and soft spinifex (*Triodia pungens*) form a tree steppe over areas adjacent to the larger mesas (Beard, 1975).

The Fortescue Botanical District, which is restricted to the southern margin of COORAGOORA, includes a sparse tree steppe of snappy gum (*Eucalyptus brevifolia*), shrubby *Acacia* species, and both buck spinifex (*Triodia brevifolia*) and soft spinifex (*Triodia pungens*) on the prominent ridges in the Shay Gap area in the southwestern corner of COORAGOORA. The colluvium and sheetwash slopes and sandplain on the southwestern side of the ridges is covered with a shrub steppe of kanji (*Acacia pyrifolia*) and soft spinifex (*Triodia pungens*). Scattered river gums (*Eucalyptus camaldulensis*) are found along the larger sandy creeks in the southwestern corner (Beard, 1975).

COORAGOORA covers parts of three natural regions. These are, from north to south, the Pindan region, Great Sandy Desert, and Pilbara region (Beard, 1975; Fig. 1).

A small area of the Pindan region lies in the northwestern corner of COORAGOORA. The region appears to be a southwesterly extension of the Mandora Coastal Plain (Beard, 1975) that parallels the Eighty Mile Beach to the north. This low-lying plain, less than 20 m AHD (Australian Height Datum), contains saline marshes and claypans.

The Great Sandy Desert occupies more than 92% of COORAGOORA. The area can be divided almost equally between: a gently undulating sandplain carrying a few widely spaced longitudinal and chain dunes that trend 290° and are commonly less than 6 km in length; and sandplain that surrounds numerous scattered mesas, buttes, and low, rocky towers and pavements. The maximum height above sea level of the mesas and buttes increases southeastward to about 252 m AHD in the southeastern corner of COORAGOORA. Many of the highest mesas are cliff lined and capped with laterite. This surface is correlated with plateau remnants of the old Hamersley Surface (Campana et al., 1964), a physiographic unit the Great Sandy Desert shares with the adjoining Pilbara region (Fig. 1).

The Pilbara region is restricted to the southwestern corner and small areas along the southern margin of COORAGOORA. Most physiographic divisions described on MUCCAN to the south (Williams, 1999) can be recognized on COORAGOORA.

The plateau division with the old Hamersley Surface is preserved on the erosion-resistant BIFs of the Nimingarra Iron Formation (Williams, 1999) and adjacent mesas of Mesozoic Callawa Formation. The plateau division is separated from the plain and valley division and low granite hills division by an abrupt scarp. The eroded hills and strike-ridge division at the edge of the Great Sandy Desert is the product of headwater erosion by streams flowing south to the De Grey River. The De Grey Drainage Basin on the southern margin of COORAGOORA contains well-defined drainage lines, including Coonieena and Egg creeks (Fig. 1).

Although all creeks are ephemeral, the new base level associated with the large De Grey River to the south is actively encroaching on the gentle, north-flowing Firewood, Planaires, and Wallal palaeodrainage basins. The previously unnamed Firewood and Planaires palaeodrainage basins flowed, in broad valleys, towards the Pindan region in the northwestern corner of COORAGOORA and adjacent PARDOO (Fig. 1). The Firewood Palaeodrainage Basin takes its name from Firewood Creek on PARDOO, whereas the Planaires Palaeodrainage Basin takes its name from the Planaires Banks on SHOONTA to the north, which appears to be the delta region for this drainage. Most of the drainage is now sand choked, except for small incised creeks in the headwater region around the sandstone mesas.

Small incursions of the Wallal Palaeodrainage Basin lie along the eastern margin of COORAGOORA. The

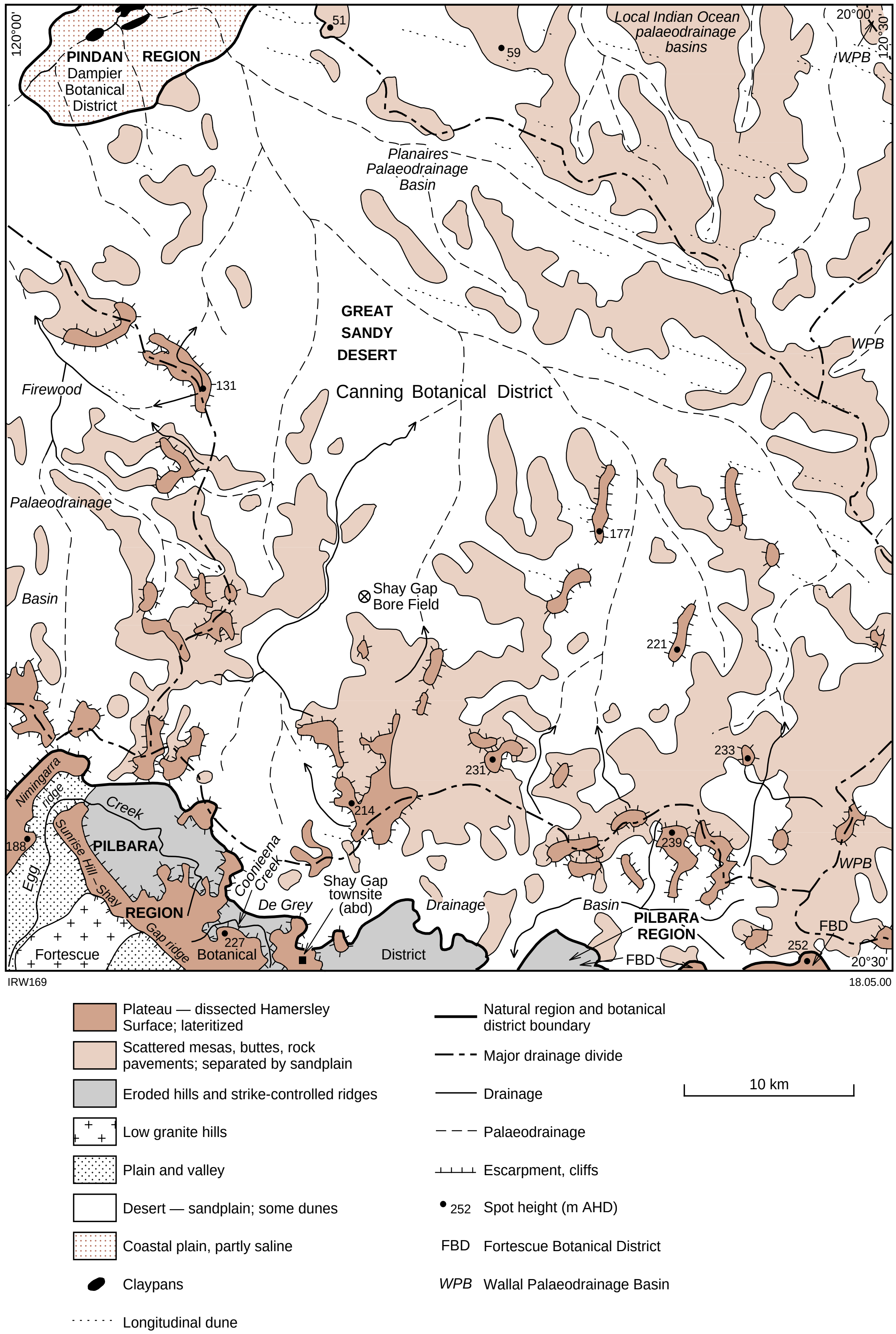

Figure 1. Natural regions, botanical districts, physiography, and drainage map of COORAGOORA

palaeodrainage flowed northeastward towards the Wallal Palaeoriver (van de Graaff et al., 1977). On the northern margin of COORAGOORA, between the Wallal and Planaires palaeodrainage basins, several small unnamed drainage lines flow directly north to the Indian Ocean (Fig. 1).

Regional geological setting

COORAGOORA covers parts of the Mesozoic Westralian Superbasin (Hocking et al., 1994), Pilbara Craton (Trendall, 1990), and a Neoproterozoic sedimentary basin containing the Eel Creek Formation (Williams, 1999). These units cover 95%, 4%, and 1% of the total surface area of COORAGOORA respectively. However, regional magnetic (AGSO, 1993b) and gravity data (BMR, 1979), together with stratigraphic information gathered from water bores (Leech, 1979a,b), indicate that the Westralian Superbasin, represented on COORAGOORA by the Lambert Shelf (Hocking et al., 1994), is only a thin, onlapping Mesozoic succession. The Mesozoic rocks have masked a faulted contact between the Pilbara Craton and the subsurface Canning Basin (Hocking et al., 1994). Lower Permian rocks, the Grant Formation of Leech (1979b) — now Grant Group (Towner and Gibson, 1983) — have been identified in an artesian bore, 3 km north (SHOONTA, AMG 089891) of COORAGOORA alongside the Boreline road. The subsurface Canning Basin, which belongs to the Wallal Embayment structural subdivision (Hocking et al., 1994), appears to underlie at least 18% of COORAGOORA in the northeastern quarter (Fig. 2).

The distribution and configuration of the Eel Creek Formation on the southern boundary also suggests that a Neoproterozoic basin may be sandwiched between the Archaean Pilbara Craton and the unconformably overlying Mesozoic rocks of the Lambert Shelf in the southeastern corner of COORAGOORA.

The regional setting of the tectonic units is illustrated in Figure 2, the major structural elements presented in Figure 3, and a regional total magnetic intensity (TMI) image in Figure 4.

The Pilbara Craton is only exposed in the southwestern corner of COORAGOORA, where it is represented by the Muccan Granitoid Complex (c. 3470–3240 Ma*) and the unconformably overlying and moderately dipping Gorge Creek (< 3235 Ma) and De Grey Groups (< 3048 Ma) of the Shay Gap greenstone belt (Williams, 1999). The Yarrie greenstone belt (Warrawoona Group; > 3430 Ma — Williams, 1999), which separates the Muccan Granitoid Complex from the Warrawagine Granitoid Complex on MUCCAN, is postulated to extend north-northeasterly from MUCCAN. On COORAGOORA the Yarrie greenstone belt also appears to separate the Muccan Granitoid Complex to the west from the Warrawagine Granitoid Complex to the east. On COORAGOORA this inferred relationship is concealed beneath the Neoproterozoic Eel Creek Formation and Mesozoic Callawa Formation (Fig. 3). The Muccan and Warrawagine Granitoid Complexes, together with the Shay Gap and Yarrie greenstone belts, are part of the East Pilbara Granite–Greenstone Terrane of the Pilbara Craton (Hickman et al., in prep.).

The Gorge Creek Group on COORAGOORA consists of well-exposed Nimingarra Iron Formation unconformably overlying the Muccan Granitoid Complex. The iron formation, in turn, is overlain by a few exposures, mainly in the headwaters of Coonieena Creek, of the epiclastic Cundaline Formation and Coonieena Basalt. The Gorge Creek Group occupies a faulted, southeasterly plunging syncline.

The De Grey Group (Hickman, 1990; Williams, 1999) consists of the epiclastic and minor felsic volcaniclastic Cattle Well Formation and the conformably overlying and newly defined Cooragoora Formation. The group disconformably overlies the Gorge Creek Group, although this contact is commonly masked on MUCCAN by the later, layered mafic Shay Intrusion (Williams, 1999) that intrudes both the underlying Coonieena Basalt of the Gorge Creek Group and the overlying Cattle Well Formation of the De Grey Group. The De Grey Group occupies the core of the southeasterly plunging syncline in the underlying Gorge Creek Group (described above).

A large, northeasterly trending mafic dyke belonging to the Black Range Dolerite Suite (c. 2772 Ma; Wingate, 1999) intruded the Muccan Granitoid Complex and overlying Nimingarra Iron Formation.

The easterly dipping Eel Creek Formation of the Neoproterozoic Tarcunyah Group (Williams, 1999) occupies a small area on the southern margin of COORAGOORA. These sedimentary and minor reworked tuffaceous rocks are extensively intruded by dolerite sills.

The Lower Permian Paterson Formation is restricted to one small outcrop in a palaeoglacial valley incised in the Coonieena Basalt. Other Permian rocks (Leech, 1979b) are postulated to occupy the faulted Wallal Embayment (Hocking et al., 1994) of the Canning Basin that, in this area, lies beneath the onlapping Mesozoic rocks (Towner and Gibson, 1983) of the Lambert Shelf (Hocking et al., 1994) in the northeastern quarter of COORAGOORA. The thin, Mesozoic cover, comprising the exposed Jurassic–Cretaceous Callawa Formation and Cretaceous Parda Formation, and the subsurface Jurassic Wallal Sandstone and Jarlemai Siltstone (Towner and Gibson, 1980, 1983; Hickman et al., 1983), extends over 95%, by area, of COORAGOORA.

Table 1 presents a summary of geological events.

Archaean rocks

Exposed Archaean rocks on COORAGOORA are restricted to a small area in the southwestern corner. These include moderately to poorly exposed granitoid rocks (c. 3443 Ma) and a well-exposed greenstone or supracrustal belt (< 3235 Ma); both components constitute part of the East Pilbara Granite–Greenstone Terrane (Hickman et al., in prep.).

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

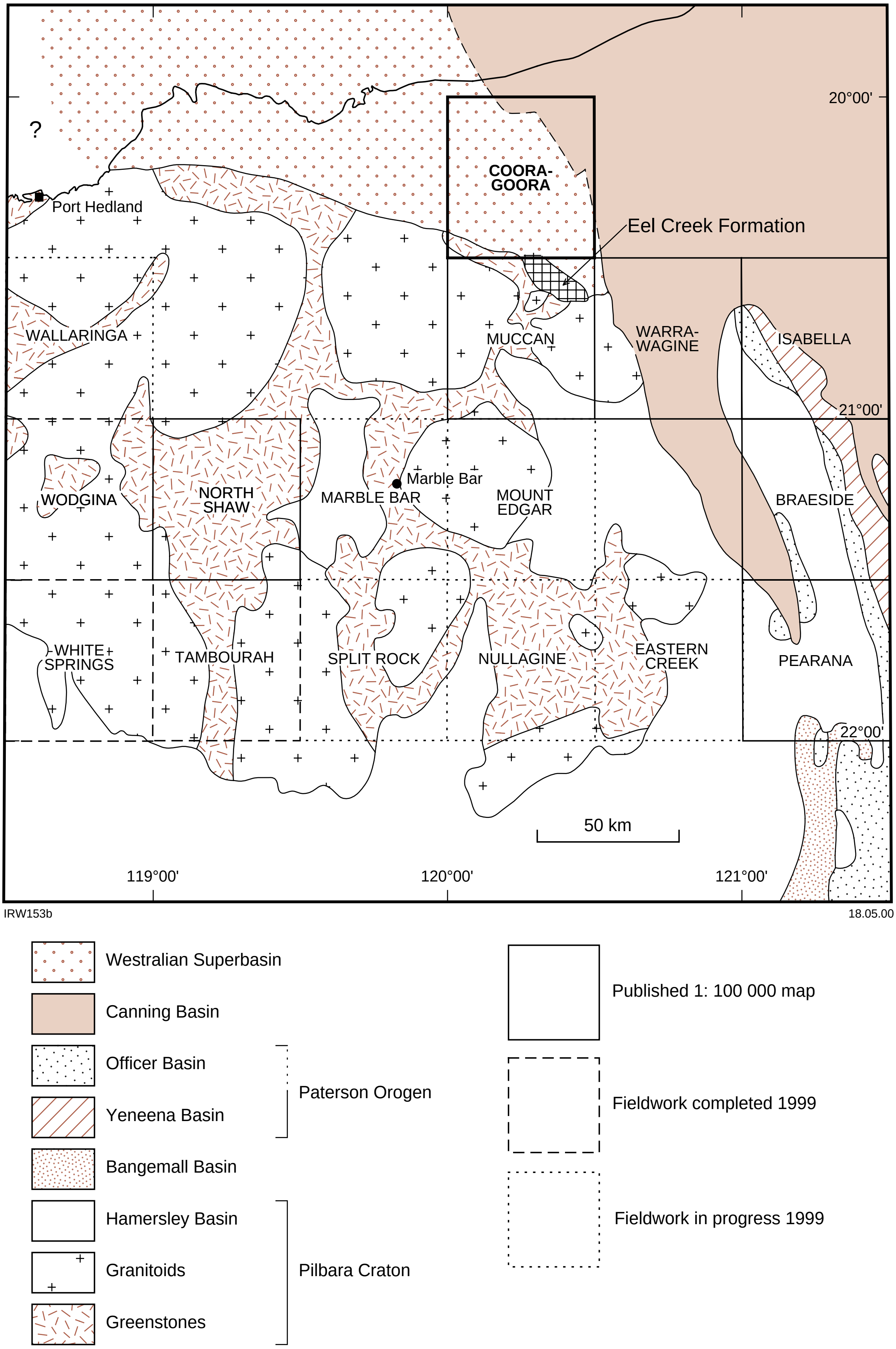

Figure 2. Regional geological setting of Cooragoora

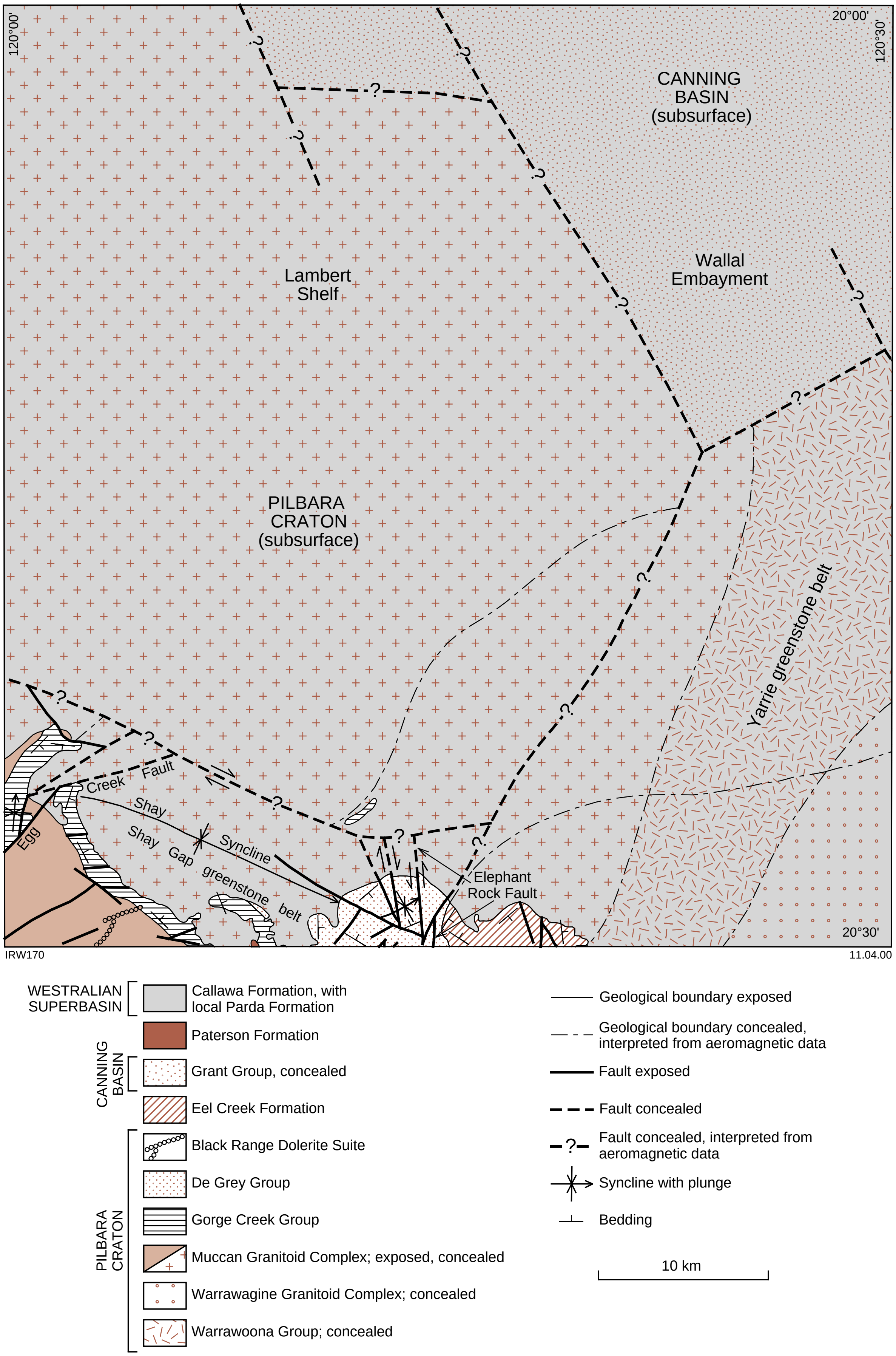

Figure 3. Structural sketch map with major tectonic units for Cooragoora

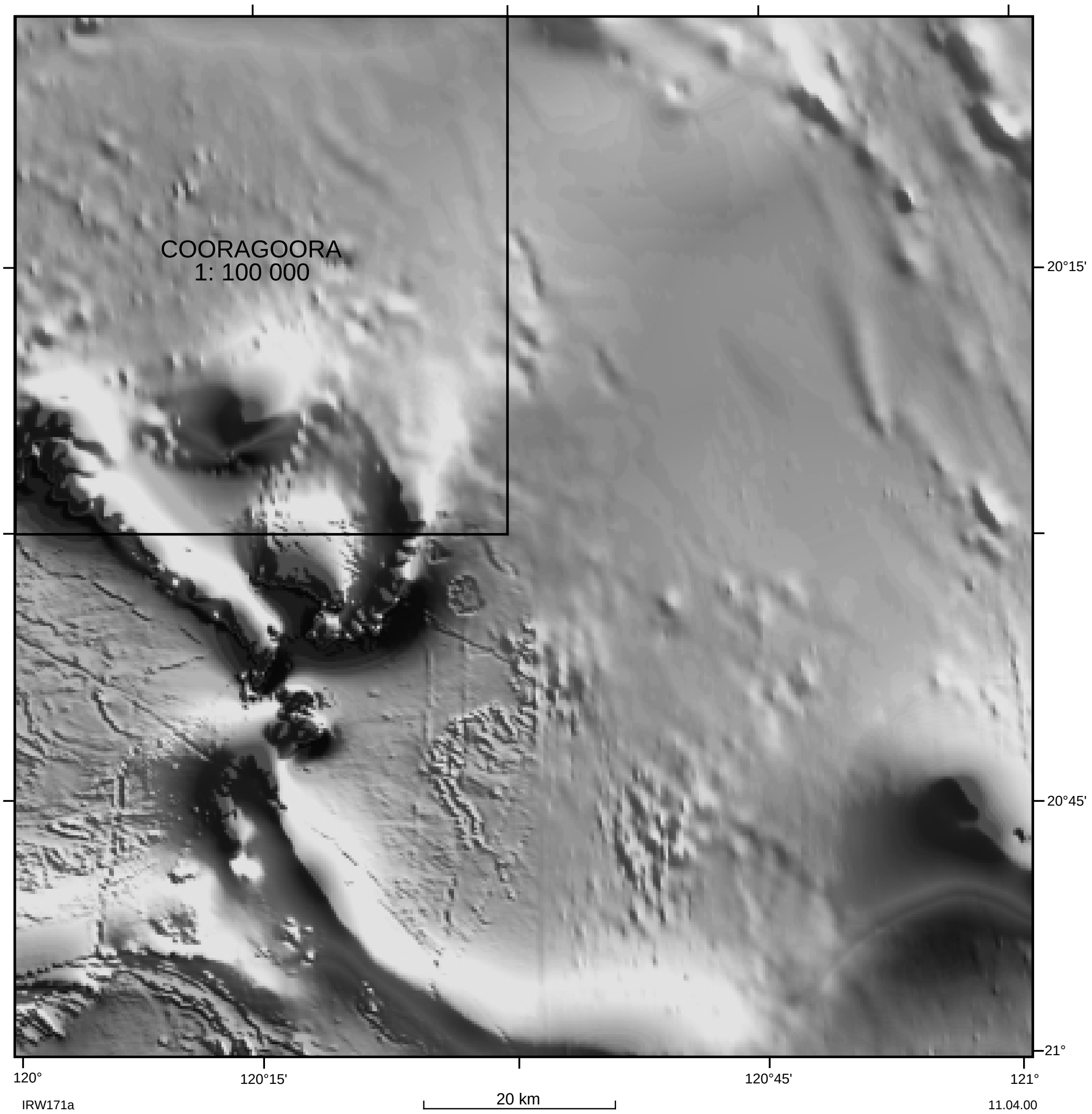

Figure 4. Total magnetic intensity image, regional setting for COORAGOORA

Warrawoona Group (*Aw*)

Warrawoona Group rocks (Lipple, 1975) are not exposed on COORAGOORA. However, it is postulated that the north-northeasterly trending Yarrie greenstone belt, which consists of Warrawoona Group mafic and ultramafic rocks on MUCCAN (Williams, 1999), continues north-northeasterly across the southeastern quarter of COORAGOORA beneath a cover of Gorge Creek Group, De Grey Group, Eel Creek Formation, and Callawa Formation. The configuration of preliminary total magnetic intensity contours (YARRIE (1:250 000); AGSO, 1993b) supports this proposal (Fig. 4). On MUCCAN the Yarrie greenstone belt (> 3430 Ma) separates the Muccan Granitoid Complex from the Warrawagine Granitoid Complex. This relationship is postulated to extend north-northeasterly across COORAGOORA as far as the buried margin of the Canning Basin (Fig. 3).

Granitoid complexes

Although granitoid rocks are exposed on less than 2% of COORAGOORA, preliminary gravity, magnetic, and borehole data indicate that the granitoid basement lies at shallow depths (< 500 m) beneath at least 60% of the sheet area. Non-granitoid basement corresponds to the subsurface Canning Basin in the northeastern quarter and the north-northeasterly trending extension of the Yarrie greenstone belt in the southeastern quarter. The Shay Gap greenstone belt (Gorge Creek and De Grey Groups) in the southwestern corner unconformably overlies the Muccan Granitoid Complex. Unlike the Gorge Creek Group rocks to the south and southeast on MUCCAN (Williams, 1999), there is no evidence to suggest that these rocks, in the southwestern corner, overlie older Warrawoona Group rocks. The Shay Gap greenstone belt, which occupies a southeasterly plunging

Table 1. Summary of the geological history of COORAGOORA

Age range (Ma)	*Geological events*
<3655–3576	Early Archaean felsic plutonism; tonalitic
<3576	Deformation and metamorphism to produce banded tonalite gneiss; now preserved as xenoliths and pendants in middle Archaean, foliated plutons of the Muccan and Warrawagine Granitoid Complexes (subsurface on COORAGOORA)
c. 3470–3430	Eruption and deposition of mafic–ultramafic subaqueous Warrawoona Group (Yarrie greenstone belt — subsurface on COORAGOORA) on older granitoid basement; Warrawoona Group intruded by synvolcanic sills and plutons (c. 3470–3438 Ma). Progressive deformation and metamorphism to amphibolite facies
c. 3325–3300	Widespread felsic plutonism (mainly monzogranite); major period of inflation for Muccan and Warrawagine Granitoid Complexes; accompanied by uplift and followed by erosion and unroofing of granitoid complexes and removal of greenstone belt cover
c. 3252–3235	Further felsic plutonism; mainly monzogranite and granite plutons in Muccan and Warrawagine Granitoid Complexes
	------ *Regional unconformity* ------
<3235	Epiclastic, chemical and mafic volcanic deposition, under shallow- to moderate-depth, marine shelf or basin conditions, of the Gorge Creek Group (Shay Gap greenstone belt). Intermittent deformation and erosion, producing local unconformities, greenschist-facies metamorphism
	------ *Regional disconformity* ------
<3048	Deposition of epiclastic and volcaniclastic De Grey Group (Shay Gap greenstone belt), initially under shallow-marine shelf conditions, with stromatolite development, and later under prograding high-energy, fluvial conditions; moderate deformation with very low grade metamorphism
	Emplacement of the mafic layered Shay Intrusion along the disconformity between the De Grey and Gorge Creek Groups
	------ *Regional unconformity* ------
c. 2772	Intrusion of Black Range Dolerite Suite, and probable extrusion of Mount Roe Basalt (not preserved on COORAGOORA)
	------ *Regional unconformity* ------
<800	Deposition of epiclastic and minor volcaniclastic Neoproterozoic Eel Creek Formation in a shallow-marine basin or marginal-shelf embayment; weak deformation
	Intrusion of large dolerite sills in Eel Creek Formation; congruent northwesterly and east-northeasterly trending mafic dykes in Pilbara Craton; weak deformation
	------ *Regional unconformity* ------
Early Permian	Faulting along northeastern margin of Pilbara Craton; Wallal Embayment of Canning Basin includes fluvioglacial sedimentary rocks; similar rocks are found in palaeoglacial valleys carved into Pilbara Craton
	------ *Regional unconformity* ------
Jurassic–Cretaceous	Transgressive–regressive marine deposits alternating with fluvial and continental deposits on the Lambert Shelf

synclinal structure, probably extends to moderate depths (approximately 5 km).

Warrawagine Granitoid Complex (*Agw*)

Preliminary magnetic (AGSO, 1993b) and gravity data (BMR, 1979) strongly suggest that the Neoproterozoic Eel Creek Formation and Jurassic–Cretaceous Callawa Formation in the southeastern corner of COORAGOORA (Fig. 3) are underlain by the Warrawagine Granitoid Complex. The nearest exposure of the complex lies about 10 km south on MUCCAN (AMG 390206), where xenolith-rich foliated and gneissic granitoids are exposed in low hills.

Although the Warrawagine Granitoid Complex encompasses a wide spectrum of granitoid rocks, ranging from banded tonalite gneiss with zircon populations as old as c. 3655 Ma, to granodiorite and porphyritic monzogranite plutons c. 3242 Ma in age, the bulk of the complex consists of foliated biotite monzogranite plutons with U–Pb zircon ages clustering around c. 3313 Ma and c. 3303 Ma (Williams, in prep.).

Muccan Granitoid Complex (*AgM*, *AgMm*)

Exposed areas of the Muccan Granitoid Complex (*AgM*) are restricted to the southwestern corner of COORAGOORA. The mixed granitoid unit (*AgMm*), the only component mapped on the sheet, consists of dykes and small intrusions of weakly foliated medium- to coarse-grained, grey-white to pink-grey biotite monzogranite and granodiorite, similar to the c. 3313 Ma granodiorite collected from near Don Well (AMG 958257) on MUCCAN (Williams, 1999). These plutons are emplaced within older, strongly foliated and gneissic, medium-grained monzogranite and granodiorite and minor leucocratic, fine-grained granite. Pegmatite and, in some areas, pink aplite are a common component of the older granitoid rocks. In less deformed areas, the pegmatites form criss-cross dyke patterns and large, zoned sheets.

At the abandoned Sunrise Hill West 4 iron ore pit (AMG 909361), a foliated, medium-grained biotite granodiorite, collected from immediately beneath the unconformity (a nonconformity) with the Nimingarra Iron Formation of the Gorge Creek Group, yielded a SHRIMP U–Pb zircon age of 3443 ± 6 Ma (Nelson, 1996). The detailed geological relationships in this area and possible regional implications of this age data are discussed in Dawes et al. (1995a,b). This date is similar to a 3438 ± 4 Ma age obtained for a foliated biotite granodiorite (AMG 167224) collected north of Yarrie Village, 28 km to the southeast on MUCCAN (Nelson, 1998; Williams, 1999).

As with the Warrawagine Granitoid Complex to the southeast, the Muccan Granitoid Complex consists of a variety of plutons with ages ranging from c. 3470 Ma granodiorite gneiss to c. 3244 Ma for porphyritic monzogranite (Nelson, 1998). Although some c. 3313 Ma and c. 3303 Ma plutons are also present, the strongly foliated c. 3440 Ma granitoid rocks appear to be widespread in the eastern part of the Muccan Granitoid Complex (Nelson, 1999).

Granitoid rocks are also in the abandoned Deposit A iron ore pit at the northern end of the Nimingarra Ridge (AMG 906424). At this locality, weathered granitoid rock is faulted against the Nimingarra Iron Formation. The widespread extent of granitoid basement beneath Mesozoic cover north of the Nimingarra and Sunrise Hill – Shay Gap ridges can be ascertained from basement intersections in water boreholes. A hydrogeological study and accompanying geophysical survey (Leech, 1979a,b; Rowston, 1976) drilled six successful, widely spaced boreholes that intersected granitoid basement in the northwestern quarter of COORAGOORA. The deepest hole, No. 24A Bore (AMG 088782), terminated in granitoid rocks 267 m below the surface. In addition, the Shay Gap Borefield, which supplies potable water to the iron ore operations at Yarrie, intersected granitoid rocks between 108 and 140 m below the surface (Rowston, 1976).

It is postulated that the granitoid rocks north of Nimingarra and Sunrise Hill – Shay Gap ridges are a continuation of the Muccan Granitoid Complex. The Gorge Creek Group, which occupies a south-easterly plunging syncline, unconformably overlies the older (c. 3440 Ma) granitoid rocks. No exposures of the younger c. 3240 Ma plutons have been observed close to the unconformity. Recent studies on NORTH SHAW have shown that the Gorge Creek Group disconformably overlies the c. 3255–3235 Ma Sulphur Springs Group (Van Kranendonk, 1998, in prep.).

Unassigned ultramafic rocks within granitoid complexes (*Aut*)

Two broad, northeasterly trending shear zones cut the granitoid rocks (*AgMm*) south of the Port Hedland – Yarrie railway. The shear zones contain, in places, discontinuous, linear zones of tremolite–chlorite schist (*Aut*). These have been interpreted as metamorphosed ultramafic dykes. The ultramafic schist is capped with secondary, grey carbonate in places.

Gorge Creek Group (*AG*)

The Gorge Creek Group is confined to the southwestern corner of COORAGOORA. The regional stratigraphy for the group was redefined on MUCCAN (Williams, 1999). Recent work on NORTH SHAW (Van Kranendonk, 1998, in prep.) showed that the group disconformably overlies the Sulphur Springs Group and is, therefore, younger than c. 3235 Ma. On COORAGOORA the Gorge Creek Group is disconformably overlain by the De Grey Group, a contact almost completely masked by the later, layered mafic Shay Intrusion on MUCCAN (Williams, 1999).

A volcaniclastic rock, probably a reworked dacite tuff, was collected from the overlying Cattle Well Formation of the De Grey Group. The sample yielded a date of 3048 ± 19 Ma, which is interpreted to represent the maximum possible age for the deposition of a detrital component within the volcaniclastic rock (Nelson, 1999). This places a rather poor constraint on the upper limit to the age of the underlying Gorge Creek Group.

The Gorge Creek Group on COORAGOORA comprises well-exposed Nimingarra Iron Formation, some small outcrops of the overlying epiclastic Cundaline Formation, and a small area of well-exposed Coonieena Basalt.

Nimingarra Iron Formation (*AGn*, *AGna*)

The Nimingarra Iron Formation (Williams, 1999) consists of BIF, jaspilite (banded hematite and red jasper), black and white banded and ferruginous chert, black (pyritiferous) shale, and grey mudstone (*Agn*). A detailed account of the local stratigraphy between the Shay Gap West openpit and Sunrise Hill openpit, and of the Nimingarra area, is presented in Podmore (1990). The Nimingarra Iron Formation is about 1000 m thick on COORAGOORA.

The BIF in this area hosts a number of small and widely dispersed iron ore deposits that extend 11 km northwest from the Shay Gap West openpit (AMG

976313) and along the Nimingarra ridge on the western edge of COORAGOORA (see **Economic geology**).

A northeasterly trending ridge of black and white banded chert and brown to grey cherty BIF lies 2–5 km northeast (AMG 078384) of the pumping station on Boreline road. This steeply dipping ridge, which is completely surrounded by the Jurassic–Cretaceous Callawa Formation, is interpreted to be an inlier of the Nimingarra Iron Formation. The inlier corresponds to a large magnetic anomaly that has been unsuccessfully investigated by a number of exploration companies for its iron ore potential (Fell, 1992). Along strike, north from outcrops, percussion drilling has intersected banded black and white chert 150 m beneath the Callawa Formation.

In early publications (Hickman, 1983; Hickman et al., 1983; Horwitz, 1990; Podmore, 1990; Krapez, 1993) it was commonly assumed that granitoid rocks intruded the base of the Gorge Creek Group, although it was also pointed out by some workers that, in places, the contact was faulted, and that regional considerations favoured erosion for the juxtaposition of the Gorge Creek Group with the granitoid rocks (Hickman et al., 1983; Hickman, 1984).

Continued exploration and development, however, of new mines in the Yarrie district on MUCCAN (Waters, 1998), revealed the presence, albeit discontinuous, of coarse- to fine-grained epiclastic rocks beneath the BIF. These rested directly on the granitoid rocks. For this reason Dawes et al. (1995a,b) carried out a detailed study of the contact relationships between the Nimingarra Iron Formation and the underlying granitoid basement. This study showed conclusively that the contact is an unconformity and that it had been disrupted, in many places, by later faults. Reported granitoid intrusions within the BIF were shown to be tectonic interleaving of the granitoid rock with the BIF.

This unconformable relationship was further investigated on MUCCAN (Williams, 1999), where it was traced eastward across both the Muccan and Warrawagine Granitoid Complexes, as well as southward to the Coppin Gap Syncline, where the Gorge Creek Group unconformably overlies the Warrawoona Group.

The unconformity is well exposed in the abandoned Sunrise Hill West 4 openpit (AMG 909361) where a matrix-supported conglomerate, containing small boulders and cobbles of granitoid rock, overlies weathered granodiorite (Dawes et al., 1995b). The conglomerate is overlain by sandstone, siltstone, and shale (*AGna*). This unit, in turn, is conformably overlain by BIF or, in some cases, hematitic iron ore.

Cundaline Formation (*AGu*)

There are small exposures of the Cundaline Formation (Williams, 1999) in the headwaters of Coonieena Creek (AMG 979320) and on the north wall of the deep Shay Gap 7 openpit (abandoned; AMG 945337) east of Sunrise Hill. At both localities the formation is unconformably overlain by the Jurassic–Cretaceous Callawa Formation.

The steeply dipping Cundaline Formation consists of interbedded, metamorphosed, grey-green shale, siltstone, and thin-bedded wacke (*AGu*). It appears to be conformable on the underlying chert and ferruginous shale of the Nimingarra Iron Formation. The formation is intruded by thin mafic and serpentinized ultramafic dykes in the Shay Gap 7 openpit near Sunrise Hill.

Coonieena Basalt (*AGo*)

The Coonieena Basalt (Williams, 1999) is well exposed along Coonieena Creek on the southern margin of COORAGOORA. It consists of massive and pillowed, metamorphosed tholeiitic basalt (*AGo*). There are good pillow structures, indicating way-up to the northeast, along Coonieena Creek (AMG 022312). About 1 km to the north (AMG 022324), the Coonieena Basalt is disconformably overlain by interbedded metamorphosed wacke, sandstone, and siltstone of the Cattle Well Formation (Gorge Creek Group). This contact is intruded by a quartz gabbro, 1 km to the south-southeast, which is probably part of the layered mafic Shay Intrusion (Williams, 1999).

A faulted inlier of Coonieena Basalt, comprising fine-grained metabasalt, lies 7 km east of the Muccan – Pardoo Roadhouse and Boreline road junction. Metabasalt was also intersected beneath 70 m of Callawa Formation (not exposed) in an exploratory hole drilled for iron ore 5.5 km northeast (AMG 925418) of the Nimingarra loading facilities (Benn, 1992). This locality is close to the Egg Creek Fault (Fig. 3).

Serpentinized ultramafic dyke (*AGus*)

An unusual serpentinized dyke (*AGus*) has intruded the contact between the Nimingarra Iron Formation and Cundaline Formation in the western wall of the abandoned Shay Gap 7 openpit (AMG 945337), east of Sunrise Hill. In thin section, the rock consists of serpentine intergrown with skeletal remnants of clinopyroxene and talc. Some serpentine is also pseudomorphic after olivine crystals. Talc shows marginal replacement by pleochroic green chlorite.

Some thin, altered (chlorite–quartz) dolerite dykes also cut both formations in the openpit. Both the ultramafic and mafic dykes are possible feeder dykes to the overlying Coonieena Basalt. The serpentinite dyke is probably related to the minor, high-Mg basalt component of the Coonieena Basalt (Williams, 1999).

De Grey Group (*AD*)

Epiclastic and volcaniclastic rocks of the De Grey Group are exposed, in a small area, on the southern margin of COORAGOORA, mainly east of the Muccan – Pardoo Roadhouse road. The regional stratigraphy for the group in this area was redefined on MUCCAN (Williams, 1999). The group consists of a lower, poorly exposed, mixed epiclastic and volcaniclastic Cattle Well Formation (< 3048 Ma) and an upper, well-exposed epiclastic Cooragoora Formation. These formations are equivalent to, and replace, the Lallah Rookh Sandstone (Hickman, 1990), previously attributed to this area.

The De Grey Group disconformably overlies the Gorge Creek Group. Most of this contact on MUCCAN (Williams, 1999) has been subsequently intruded by the layered mafic Shay Intrusion. To the east, the De Grey Group is unconformably overlain by the Neoproterozoic Eel Creek Formation.

Cattle Well Formation (*ADa*)

There are scattered outcrops of the Cattle Well Formation (Williams, 1999) along Coonieena Creek (AMG 022324) and close to the southern margin of COORAGOORA, east of the Muccan – Pardoo Roadhouse road (around AMG 061318). The former outcrop disconformably overlies the Coonieena Basalt of the Gorge Creek Group, whereas the outcrop in the latter area is conformably overlain by the Cooragoora Formation of the De Grey Group. In both areas the Cattle Well Formation is unconformably overlain by scattered outliers of the Jurassic–Cretaceous Callawa Formation.

The limited outcrop of the Cattle Well Formation on COORAGOORA consists of interbedded, yellow, fawn, brown, grey, and green-grey siltstone, fine- to coarse-grained sandstone and wacke interbedded with laminated mudstone, and tuffaceous shale and siltstone. Graded-bedded and cross-bedded sandstones consistently indicate way-up to the east and northeast. The volcaniclastic components, in the upper parts of the formation, are exposed along strike from similar rocks described on MUCCAN (Williams, 1999). Detrital zircons, obtained from the volcaniclastic rocks, yielded a SHRIMP U–Pb zircon date of 3048 ± 19 Ma. This has been interpreted as the maximum possible age for the deposition of the detrital component within the volcaniclastic sedimentary rock (Nelson, 1999).

A less typical outcrop of the Cattle Well Formation lies on the southern boundary of COORAGOORA, 7.8 km east (AMG 131308) of the Muccan – Pardoo Roadhouse road. At this locality the Cattle Well Formation is unconformably overlain by the Neoproterozoic Eel Creek Formation. The outcrop consists of a low mesa (< 30 m) capped with gently north-northwesterly dipping blue, grey, and white chert and vuggy chert breccia. The cherts overlie and are interbedded with maroon and pink calcareous mudstone, shale, and blue-grey, resedimented felsic-tuff horizons. The latter can be correlated with similar, volcaniclastic horizons in the Cattle Well Formation on MUCCAN, 4 km to the west-southwest (Williams, 1999).

The chert and chert breccia horizons are considered to be silicified carbonate rocks and, in some instances, may be possible evaporite horizons. In addition, the chert contains poorly preserved silicified stromatolites. The stromatolites are weakly columnar with smooth, parabolic laminae. The morphology is emphasized by alternating white and grey silica. Individual columns are up to 10 cm high and 5 cm in width. There is some evidence for umbellate branching.

The stromatolites are associated with unusual laminated rocks where thin, rhythmic, pancake-like layers of alternate grey- and white-coloured chert are emphasized by differential weathering of the silica. This may have been a primary silica–carbonate banding. This material most closely resembles some of the structures (Fig. 5) exhibited by the megascopic dubiofossil *Eozoon canadense* Dawson 1864. An inorganic origin has been proposed for this distinctive type of fabric (Hofmann, 1971). On COORAGOORA, the *Eozoon canadense* fabric is recognized in cherts that, in some areas, form the substrate upon which the stromatolites have grown. Such cherty material may be siliceous replacement of evaporites.

The epiclastic and volcaniclastic rocks of the Cattle Well Formation have been subjected to very low grade metamorphism. The formation was deposited under shallow-marine shelf or marginal-basin conditions.

Cooragoora Formation (*ADo*)

Outcrops of the Cooragoora Formation (defined herein) occupy about 18 km^2 on the southern margin of COORAGOORA, 4 km east (AMG 090320) of the junction between the Muccan – Pardoo Roadhouse and Boreline roads. The formation is named after the abandoned Cooragoora Bore (AMG 126831). The Cooragoora Formation conformably overlies the Cattle Well Formation and is, in turn, unconformably overlain by the Jurassic–Cretaceous Callawa Formation.

The formation consists predominantly of well-exposed, red to red-brown, medium- to coarse-grained sandstone, pebbly sandstone, lithic wacke, and matrix-supported, polymictic conglomerate. Maroon siltstone is minor and cream-brown orthoquartzite beds are locally prominent in the upper parts of the succession. A poorly exposed, thick unit of grey-black, carbonaceous shale carrying finely disseminated pyrite was encountered in shallow exploratory drilling (Weir, 1990). This unit roughly divides the arenaceous succession into two parts.

The poorly sorted conglomerates consist of subangular to subrounded cobbles and pebbles of white vein quartz, coloured chert, banded black and white chert, jasper, and siliceous BIF. The chert and BIF are similar to those in the underlying Nimingarra Iron Formation.

The conglomerates occupy channels, and angularity and poor sorting of the clasts suggest that they are fanglomerates deposited under high-energy conditions. The interbedded sandstone and orthoquartzite are commonly trough cross-bedded. Heavy mineral layers are present in the orthoquartzite. The sandstone and conglomerate succession exhibit both upward-fining and upward-coarsening sequences.

Type areas for the Cooragoora Formation are 3 km east-southeast (AMG 075319) and 4.5 km east (AMG 093324) of the junction between the Boreline and Muccan – Pardoo Roadhouse roads. It is estimated from the outcrop that the formation is at least 2000 m thick; the top of the formation has been removed by erosion.

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Figure 5. *Eozoon canadense* Dawson 1864; a megascopic dubiofossil in chert, Cattle Well Formation

The Cooragoora Formation, together with the underlying Cattle Well Formation, occupies a shallow-dipping, east-northeasterly plunging regional syncline. In a similar manner to the Cattle Well Formation, the Cooragoora Formation has undergone very low grade, regional metamorphism.

In earlier mapping, the rocks of the Cooragoora Formation were included in the Lalla Rookh Formation (Hickman, 1990). The Cooragoora Formation appears to be a high-energy fluvial–deltaic deposit prograding onto a shallow-marine basin or shelf.

Shay Intrusion (*AaYo*)

A small exposure of quartz gabbro alongside the Yarrie – Port Hedland powerline (AMG 035317) is probably part of the layered mafic Shay Intrusion. This intrusion, described in detail on MUCCAN (Hickman et al., 1983; Williams, 1999), consists of a basal ultramafic pyroxenite successively overlain by norite, gabbronorite, gabbro, and quartz gabbro layers. The quartz gabbro exposure on COORAGOORA, which lies along strike from the MUCCAN exposures, indicates that the Shay Intrusion continued a further 2 km to the northwest beneath the Callawa Formation. However, 1 km further to the northwest, the intrusion is absent from the disconformity between the Coonieena Basalt and Cattle Well Formation.

Black Range Dolerite Suite (*AFdb*)

A single, large northeasterly trending, metamorphosed medium- to coarse-grained dolerite dyke cuts the Muccan Granitoid Complex in the southwestern corner of COORAGOORA. The dyke penetrates, for a short distance, the unconformably overlying Nimingarra Iron Formation.

This dyke, which passes through Black Hill (AMG 883259) on MUCCAN to the southwest, is up to 200 m wide. The dyke is the northernmost example of the Black Range Dolerite Suite, originally described from the MARBLE BAR (1:250 000) area (Lewis et al., 1975).

The metadolerite consists of a subophitic intergrowth of randomly oriented plagioclase and anhedral clino-pyroxene crystals. Large, scattered orthopyroxene crystals are pervasively altered to chlorite.

The Black Range Dolerite Suite has been dated, using SHRIMP U–Pb baddeleyite geochronology, at 2772 ± 2 Ma (Wingate, 1999).

Structure

Only limited structural data are available for Archaean rocks on COORAGOORA. An attempt has been made, using published regional TMI (AGSO, 1993b) and Bouguer anomaly maps (BMR, 1979) coupled with exploration drilling data (Leech, 1979a,b), to interpret the basement beneath the thin Mesozoic cover that underlies 95% of the sheet area (Figs 3 and 4).

Structures assigned to the D_1 deformation are confined to the Muccan Granitoid Complex (Hickman, 1983; Hickman et al., 1983; Williams, 1999). These are small isoclinal folds, preserved in xenoliths and rafts of banded gneiss and gneissic granitoids, enclosed within the c. 3440 Ma foliated granodiorite.

The regional configuration of the granite–greenstone terrane in the east and northeast Pilbara is characterized by ovoid or complex, bulbous granitoid complexes surrounded by folded and faulted, curvilinear and cuspate synclinoria that contain the greenstones or supracrustal rocks. This dominant structural form has been attributed to the main deformation episode, D_2 (Hickman, 1983, 1984; Hickman et al., 1983). The genesis of this distinctive morphology in this area was postulated to be the product of the tectonic–magmatic interaction of rising, diapiric granitoid bodies in conjunction and commensurate with the sinking or sliding-off (or both) of the adjacent and overlying volcano-sedimentary supracrustal rocks or greenstones into the zones or regions between the rising granitoid complexes (Collins, 1989; Collins et al., 1998; Van Kranendonk and Collins, in press). However, such events took place progressively over a long time interval. In the northeast Pilbara, such processes can be traced back to at least c. 3470 Ma, which corresponds to the deposition of the felsic volcanic and volcaniclastic Duffer Formation (Warrawoona Group) and emplacement of related, synvolcanic tonalite–trondhjemite–granodiorite sills and plutons. However, the maximum period of inflation of the granitoid complexes, that is, the greatest volume influx of granitoid material in the northeast Pilbara, appears to correspond to large, mainly monzogranite plutons with a c. 3324–3235 Ma time range (Nelson, 1998; Williams, 1999; Van Kranendonk, in prep.).

It is now firmly established that the successively younger Warrawoona, Gorge Creek, and De Grey Groups in the northeast Pilbara are separated by regional unconformities (Dawes et al., 1995b; Williams, 1999; Van Kranendonk, in prep.). The groups show decreasing metamorphic grade and structural complexity, and increasing percentage content of siliceous, epiclastic rocks with time. The latter observation is interpreted to be related to the progressive unroofing and erosion of the granitoid complexes. With the continued erosion over time, deeper crustal levels and a wider range of rock types are exposed. This premise is supported by data collected from MUCCAN where the oldest detrital zircons to be identified in the basal Nimingarra Iron Formation of the Gorge Creek Group were dated at c. 3458 Ma (Nelson, 1998; Williams, 1999). In contrast, the oldest detrital zircons found in the younger Cattle Well Formation of the De Grey Group were dated at c. 3555 Ma (Nelson, 1999; Williams, 1999).

On COORAGOORA the oldest, exposed supracrustal material is the basal Nimingarra Iron Formation of the Gorge Creek Group. This group, together with the disconformably overlying De Grey Group, constitute the Shay Gap greenstone belt (Williams, 1999). This belt occupies the broad, east-southeasterly plunging Shay Syncline (Fig. 3). The southern limb of the syncline, defined by the Nimingarra Iron Formation, dips moderately to steeply northeast to east. The northern limb, now covered by the later Jurassic–Cretaceous Callawa Formation, appears, from TMI data, to be dextrally displaced along an east-southeasterly trending fault that has an apparent movement of about 14 km. The westernmost outcrop (the Nimingarra ridge), which includes the easterly plunging axial zone of the syncline, is displaced southwards along the sinistral, strike-slip Egg Creek Fault (Fig. 3; Podmore, 1990). Local structural complexities in the Shay Gap, Sunrise Hill, and Nimingarra areas are discussed in detail by Podmore (1990).

The unconformity between the Gorge Creek Group and underlying Muccan Granitoid Complex on COORAGOORA and MUCCAN (Dawes et al., 1995b), and between the Gorge Creek Group and the Warrawagine Granitoid Complex on MUCCAN (Williams, 1999) adds a further dimension to the spatial and temporal relationships between the granitoid complexes and adjacent greenstone belts. In earlier publications, it was pointed out that the successively younger greenstone belts or supracrustal rocks were focused on pre-existing synclinoria zones that carried older greenstone material between the granitoid complexes (Hickman 1983, 1984; Hickman et al., 1983). An example was the Coppin Gap Syncline, where the Gorge Creek Group unconformably overlies the Warrawoona Group (Williams, 1999). Although it is possible that the Shay Syncline (Fig. 3) overlies a cuspate, buried keel of older greenstones, no field observations have been found to support this proposal. Hence, the large area of granitoid rocks intersected in drill holes north of the Shay Syncline (Leech, 1979a,b) is most likely a continuation of the Muccan Granitoid Complex.

In contrast, the Yarrie greenstone belt (Williams, 1999) on MUCCAN separates the Muccan Granitoid Complex from the Warrawagine Granitoid Complex. The strongly foliated, metamorphosed mafic and ultramafic rocks of this belt are intruded by c. 3438 Ma foliated granodiorite (Williams, 1999). The north-northeasterly trending Yarrie greenstone belt is postulated to continue onto COORAGOORA beneath the Gorge Creek Group. A broad magnetic high on TMI data (Fig. 4) suggests that the belt extends north-northeasterly across COORAGOORA, along strike from the exposed Yarrie greenstone belt (Fig. 3).

The De Grey Group disconformably overlies the Gorge Creek Group in the core of the Shay Syncline. The De Grey Group rocks are folded about an open syncline that plunges towards the east-northeast. Both the Gorge Creek and De Grey Group rocks have a weak axial-planar cleavage.

Neither group is intruded by granitoid rocks on COORAGOORA or MUCCAN, although there is an unusual aegirine-bearing sodic porphyry dyke in the Cattle Well Formation near Cattle Well (AMG 106276) on MUCCAN to the south. This dyke may be related to late Archaean alkaline rocks, such as the felsic porphyries of the Bamboo Creek Member (c. 2756 Ma).

The Shay Gap greenstone belt was presumably folded during further uplift and inflation of the Muccan and Warrawagine Granitoid Complexes, and concomitant sinking of the supracrustal rocks post-c. 3048 Ma — the maximum depositional age of the Cattle Well Formation.

The sinistral strike-slip Egg Creek Fault and the northern extension of the sinistral strike-slip Elephant Rock Fault (Williams, 1999) are D_3 faults. The latter fault is prominent on MUCCAN to the south where it is conjugate to the large dextral strike-slip Kennedy Gap Fault. These faults mark the boundaries of a north-directed pop-up wedge, which has been squeezed out from between the Muccan and Warrawagine Granitoid Complexes by east–west directed compression (Williams, 1999).

Proterozoic rocks

On COORAGOORA exposed Proterozoic rocks are restricted to a small area on the southern margin centred about 12.5 km east-southeast (AMG 173314) of the Muccan – Pardoo Roadhouse and Boreline road junction.

Tarcunyah Group

Shallow-dipping epiclastic sedimentary and minor reworked tuffaceous rocks, assigned to the Eel Creek Formation (Hickman et al., 1983), strongly resemble rocks in the Neoproterozoic Tarcunyah Group (< 800 Ma) exposed 70 km to the east on the eastern margin of the Pilbara Craton (Williams and Trendall, 1998a,b,c).

The Tarcunyah Group (Williams et al., 1996; Williams and Bagas, 1999) is considered to be a northwesterly extension of the Officer Basin (Bagas et al., 1995; Perincek, 1996; Stevens and Grey, 1997; Bagas et al., 1999).

Eel Creek Formation (*#Ue*)

On COORAGOORA the Eel Creek Formation (Hickman et al., 1983; Williams, 1999) consists mainly of poorly exposed, multicoloured shale and siltstone. In some areas, interbedded, red-brown micaceous siltstone and buff, grey, and brown, thin-bedded, fine- to medium-grained sandstone predominate. Some shales and siltstones have a tuffaceous component (Williams, 1999). The interbedded sandstones and siltstones exhibit a wide variety of sole marks, including flute casts, and tool marks, such as grooves, and prod and bounce marks. Small-scale ripple marks, cross-beds, including rib-and-furrow structures, and mudcracks are also preserved in some sandstone and siltstone beds. Palaeocurrent directions are mainly towards the south.

The Eel Creek Formation appears to have been deposited in a shallow-marine basin, or possibly a marginal-shelf embayment, overlying a Pilbara Craton basement.

The western margin of the Eel Creek Formation on COORAGOORA unconformably overlies the De Grey Group of the East Pilbara Granite–Greenstone terrane (Hickman et al., in prep.). The formation, in turn, is unconformably overlain along the northern and eastern boundaries by the Jurassic–Cretaceous Callawa Formation. The formation dips shallowly away from the Archaean basement towards the east and southeast.

Mafic intrusive rocks (*#de*)

The Eel Creek Formation hosts thick sills and feeder dykes of fine- to coarse-grained dolerite. The dolerite is subophitic textured with randomly oriented plagioclase laths and interstitial clinopyroxene, minor hornblende, and sparse olivine. The coarse-grained sills contain patchy myrmekitic intergrowths of K-feldspar and quartz in places. Baddeleyite has been identified in thin section.

The dolerite intrusions have baked the host shale and siltstone, producing a blue-black contact metamorphic hornfels.

Unassigned dolerite dykes (*d*) and quartz veins (*q*)

Several thin, linear, but commonly short (about 1 km), fine-grained dolerite dykes (*d*) intruded the Muccan Granitoid Complex in the southwestern corner of COORAGOORA. The mafic dykes trend in two directions: northwesterly and east-northeasterly. The northwesterly trending dykes may be part of the Round Hummock Suite (Hickman, 1983). The east-northeasterly trending dykes are probably part of the Mundine Well Suite (Hickman, 1983) that has been recently dated, using SHRIMP U–Pb baddeleyite geochronology (Wingate, 1999), at 755 ± 3 Ma.

Several short, but prominent, veins of massive, cryptocrystalline quartz (*q*) occupy a major northeasterly trending shear zone about 3 km east of Cabbage Gum Well (AMG 873319). Small quartz-filled veinlets are common in tension gashes in some granitoid outcrops.

Phanerozoic rocks

As stated in the **Introduction**, recent fieldwork on COORAGOORA did not include remapping of the Phanerozoic component of the map sheet. However, some additional observations have been recorded in areas close to exposed Pilbara Craton units and a reassessment of the structural framework, in the light of recent publications (Hocking et al., 1994), has been attempted (Fig. 3).

Permian rocks

On COORAGOORA, Permian rocks are limited to one exposure of Lower Permian Paterson Formation on the southern boundary, and the postulated subsurface occurrence of Lower Permian rocks (Grant Group) within the Wallal Embayment of the Canning Basin (Hocking et al., 1994) in the northeastern quarter of the sheet (Fig. 3).*

Grant Group (*Pg*)

No. 25C Bore, an artesian bore (Leech, 1979a,b) located 3 km north of the COORAGOORA boundary and just southwest of the Boreline road – Great Northern Highway junction on SHOONTA (AMG 089891), intersected non-marine Permian sandstone, siltstone, and claystone between 341 and 696 m (Backhouse, 1975; Leech 1979a,b). In the initial reports, this interval was equated with the 'Grant Formation' (Leech, 1979a,b). Later workers upgraded the 'Grant Formation' to Grant Group (Crowe and Towner, 1976; Towner and Gibson, 1983; Apak and Backhouse, 1998).

A second artesian bore, No. 24A Bore, situated 11 km south of No. 25C Bore and on the western side of Boreline road (AMG 088782) on COORAGOORA, failed to intersect Permian rocks before it entered weathered granitoid rocks of the Muccan Granitoid Complex at 257 m (Leech, 1979a,b). The YARRIE TMI contour map (AGSO, 1993b) shows that between No. 24A Bore and No. 25C Bore there is a radical change in magnetic signature. This is interpreted as a rapid deepening of the basement, probably brought about by faulting. This supposition is supported by the change in the stratigraphy recorded between the No. 25C and No. 24A Bores.

The Lower Permian rocks occupy the fault-controlled Wallal Embayment of the Canning Basin (Hocking et al., 1994), the probable extent of which is shown in Figure 3. The Grant Group falls within depositional Sequence PZ5 (Middleton, 1990).

Paterson Formation (*Pa*)

A small area of Paterson Formation (Traves et al., 1956; Towner and Gibson, 1980) is exposed on the southern boundary of COORAGOORA, 500 m west of Coonieena Creek (AMG 018307). The outcrop is sandwiched between the underlying Coonieena Basalt and the unconformably overlying Jurassic–Cretaceous Callawa Formation. The rather poor outcrop consists of sandstone, pebble conglomerate, and diamictite carrying occasional striated and faceted cobbles and small boulders. These fluvioglacial rocks occupy a palaeoglacial valley incised in the Coonieena Basalt. This valley continues to the south and east, and is part of the palaeoglacial valley described on MUCCAN (Williams, 1999).

The Paterson Formation belongs to depositional Sequence PZ5 (Middleton, 1990) and has recently been assigned an early Sakmarian – Asselian age (Mory and Backhouse, 1997).

Jurassic rocks

Jurassic rocks are not exposed on COORAGOORA, but have been intersected in a number of deep bores over a wide area in the northwestern quarter of the sheet (Leech, 1979a,b; Hickman et al., 1983). The Jurassic is represented by the basal Wallal Sandstone and the disconformably overlying Jarlemai Siltstone. These Jurassic rocks have been assigned to the Lambert Shelf of the Westralian Superbasin (Hocking et al., 1994).

Wallal Sandstone (*Jl*)

The Wallal Sandstone (Towner and Gibson, 1980; Hickman et al., 1983) has been intersected in ten boreholes in the northwestern quarter of the sheet, where it unconformably overlies weathered granitoid rocks of the Muccan Granitoid Complex. The unit thickens northward across COORAGOORA, and is more than 200 m thick on the northern boundary.

The unit consists of fine- to very coarse grained sandstone with interbedded conglomerate units increasing towards the base (Leech, 1979a). The unit has been interpreted as a continental to marginal-marine deposit (Hickman et al., 1983).

The Wallal Sandstone is a major aquifer and the water source for the Shay Gap Borefield (AMG 074520; Rowston, 1976).

The Wallal Sandstone belongs to depositional Sequence MZ2 and is Middle to Late Jurassic in age (Middleton, 1990).

Jarlemai Siltstone

The Jarlemai Siltstone (Brunnschweiler, 1954; Towner and Gibson, 1980; Hickman et al., 1983) has been recorded from five waterbores in the northwestern quarter of the sheet (Leech, 1979a,b)*. The unit consists of light-grey to black silty mudstone and minor thin beds of fine-grained sandstone and siltstone. It appears to disconformably overlie the Wallal Sandstone on COORAGOORA (Leech, 1979a). A maximum thickness of 74 m was intersected in No. 24A Bore (AMG 088782). The unit is disconformably overlapped by the Callawa Formation south of No. 19A Bore (AMG 969635). It is a shallow-marine (subtidal) deposit (Towner and Gibson, 1983).

The Jarlemai Siltstone belongs to depositional Sequence MZ3 and is Late Jurassic in age (Middleton, 1990).

Jurassic–Cretaceous rocks

Callawa Formation (*JKc*)

The Callawa Formation (Reeves, 1951; Traves et al., 1956; Towner and Gibson, 1980; Williams, 1999) is widely distributed across COORAGOORA. The formation is a cliff-

* The rock code for the Grant Group, Pg, is erroneously shown as #g on the face of the Simplified Geology diagram on the COORAGOORA map.

* The Jarlemai Siltstone was omitted from the legend of the accompanying COORAGOORA map because it is not exposed nor is it present in the area depicted in Diagrammatic Section C–D.

forming unit that is exposed in numerous mesas, buttes, and small, but prominent, rocky outcrops sprinkled amongst the red desert sand. It unconformably overlies the Jurassic Jarlemai Siltstone and Wallal Sandstone. Along the southern margin of COORAGOORA, the formation unconformably overlies Permian, Neoproterozoic, and Archaean rocks. Between Shay Gap West opencut mine (AMG 976313) and Egg Creek (AMG 914398), the unconformable onlap of the Callawa Formation on the Nimingarra Iron Formation is well exposed along the northeastern side of the ridge, particularly in some opencut mines around Sunrise Hill and at Shay Gap 7 openpit (AMG 947338).

Recent studies (Williams, 1999) have shown that the Callawa Formation can be divided into a lower and an upper part. The lower part on COORAGOORA is exposed in the headwaters of Egg Creek and around the base of high mesas in the Shay Gap area. In earlier mapping, a small area of Permian rocks had been mapped in the headwaters of Egg Creek (Hickman et al., 1983). This could not be confirmed in this study. However, some Callawa Formation conglomerates in this area carry rare faceted, white quartzite boulders and cobbles, similar to those in the fluvioglacial Permian Paterson Formation near Shay Gap on MUCCAN (Williams, 1999). Such quartzite boulders in the Egg Creek area are thought to be derived from the Paterson Formation and reworked during deposition of the fluvial Callawa Formation.

The lower part consists of interbedded fine- to coarse-grained sandstone, conglomerate, siltstone, and claystone. Plant fossils have been found in ferruginous sandstone, just above the basal conglomerate, 10.5 km east of the junction between the Muccan – Pardoo Roadhouse and the Boreline road (AMG 150324). Towards the top of the lower part, beds of mottled, red-white, bioturbated clayey sandstone carry prominent trace fossils. These are commonly burrows up to 12 cm long, oriented roughly at right angles to the bedding. There are good exposures in an opencut mine, ‘Deposit A’, at the northern end of the Nimingarra ridge (AMG 906426) and in several places along the track to the Shay Gap microwave tower on MUCCAN (AMG 036309).

Some sandstones in the lower part are cross-bedded; these indicate a wide range of palaeocurrent directions. Ripple marks and synaeresis cracks have been recorded from finer grained sandstone.

The upper part of the Callawa Formation onlaps the Nimingarra Iron Formation and makes up the erosion-resistant capping of the mesas and buttes. It consists of thick beds of matrix-supported, pebble to boulder conglomerate, separated by commonly trough cross-bedded or massive, medium- to coarse-grained sandstone and pebbly sandstone. Some minor intercalations of white claystone carry plant fossils (Traves et al., 1956). Conglomerate clasts include chert, jasper, BIF, vein quartz, quartzite, and minor granitoid rocks derived from the Archaean Pilbara Craton to the south. The sandstone trough cross-beds reveal a persistent northwesterly to northerly directed palaeocurrent.

A maximum thickness of about 100 m has been proposed for the Callawa Formation (Hickman et al., 1983). Reeves (1951) recorded a thickness of 94 m for Callawa Formation boulder beds in the No. 3 Desert Bore* (AMG 262527).

The Callawa Formation is part of depositional Sequence Mz4 (Middleton, 1990) and is Late Jurassic or Early Cretaceous in age. It is a component of the Lambert Shelf of the Westralian Superbasin (Hocking et al., 1994).

Cretaceous rocks

Parda Formation (*Kp*)

The Parda Formation (Lindner and Drew, in McWhae et al., 1958; Towner and Gibson, 1983; Hickman et al., 1983) disconformably overlies the Callawa Formation. Outcrops have a distinctive white photo-pattern and the formation is commonly capped by laterite (*Czrf*). Small outcrops cap widely scattered mesas and buttes in the southern half of COORAGOORA. The formation consists of thin-bedded to massive white mudstone and claystone, with some fine-grained sandstone and siltstone lenses. It is about 20 m thick on COORAGOORA (Hickman et al., 1983).

During this study, the first recorded ammonoid from the Parda Formation was found in a white, porcelanous, fine-grained claystone. The claystone, overlain by laterite, caps a small butte, 2.5 km east-southeast (AMG 094496) of the Shay Gap Bore Field pumping station. The ammonoid, in the form of a mold, has been tentatively identified as *Eofalciferella condoni* Brunnschweiler 1959 (Backhouse, 1999). This ammonite has been recorded from the Windalia Radiolarite of the Carnarvon Basin. The Parda Formation is a probable shallow-marine deposit.

The Parda Formation is part of depositional Sequence Mz5 (Middleton, 1990) and is probably of late Aptian age (Backhouse, 1999). The formation is the youngest preserved component to be deposited on the Lambert Shelf of the Westralian Superbasin (Hocking et al., 1994) on COORAGOORA.

Cainozoic rocks

Cainozoic rocks, predominantly desert sand, cover more than 90% of COORAGOORA. Superficial material includes semiconsolidated alluvial, colluvial, and residual deposits and unconsolidated Quaternary alluvial, colluvial, eluvial, and widespread eolian deposits.

A small patch of valley calcrete (*Czak*) is exposed in a south-flowing drainage on the southern margin (AMG 121314). The calcrete is a poorly silicified, crumbly, grey-white limestone.

Consolidated colluvium (*Czc*), comprising poorly stratified and cemented clay, silt, sand, and pebbly sand, is dissected in a broad valley between mesas of Callawa

* Incorrectly shown as No. 3 Desert Well on the COORAGOORA map.

Formation in the southeastern corner (AMG 325315) of COORAGOORA. The dissection is due to headwater erosion of old scree deposits by a south-directed drainage system.

Dissected consolidated iron-cemented scree (*Czcf*) commonly forms inclined aprons around laterite-capped mesas and low hills. This ferruginous scree unit is widely scattered over COORAGOORA and consists of recemented broken laterite rubble and ironstone pebbles mixed with sand, silt, and clay. A ferruginous duricrust surface (*Czrf*), comprising mainly massive, pisolitic and nodular laterite, caps some of the largest and highest mesas on COORAGOORA. It overlies the Callawa and Nimingarra Iron Formations in the headwaters of Coonieena and Egg creeks. Low laterite-capped mesas are common around No. 18 and No. 19A Bores west of Boreline road. In this area, and eastwards across COORAGOORA, the laterite preferentially caps the Parda Formation.

Quaternary deposits

The dominant Quaternary deposit on COORAGOORA is red-brown, fine- to medium-grained eolian sand (*Qs*). The unit occupies a vegetated, undulating sandplain marked by widely separated, west-northwesterly trending longitudinal dunes. Medium- to coarse-grained quartz and feldspar sand, characterized by a thin veneer of scattered quartz pebbles and granitoid rock fragments (*Qrg*), is adjacent to exposures of the Muccan Granitoid Complex in the southwestern corner of COORAGOORA.

Recent colluvium (*Qc*), in the form of unconsolidated sandy scree and talus, is developed in hilly areas underlain by the De Grey and Gorge Creek Groups along the southern margin. It also forms coarse outwash fans at the contact between the scarp, formed by the Nimingarra Iron Formation, and the subdued landsurface of the Muccan Granitoid Complex. A pebbly sand adjacent to claypans in a broad valley north of Slab Well (AMG 919827) is a colluvium unit (*Qc*) formed by active erosion of the sandplain.

Some low-gradient sheetwash deposits (*Qw*), characterized by a small quartz and ironstone pebble veneer and a speckled or striped vegetation pattern, lie distal to the lee side of high mesas of Callawa Formation or lateritized Parda Formation, for example, in the No. 3 Desert Bore area (AMG 262527). A similar low-gradient sheetwash deposit, this time carrying a veneer of white quartz pebbles and weathered granitoid rock fragments (*Qwg*), overlies the Muccan Granitoid Complex in the southwestern corner. Sheetwash deposits lack defined drainage lines.

The fluvial unit code (*Qaa*) is used for silt, sand, and gravel, in creeks where the channel fill, overbank, and floodplain deposits are not distinguished. It also includes broad sandy drainage lines in the Great Sandy Desert area. Although these drainages sometimes develop incised channels, all eventually disappear into the sandplain. The large channel of Egg Creek is filled with coarse sand and gravel banks (*Qaas*). The overbank deposits (*Qao*) adjacent to the channel fills (*Qaas*) consist of clay, silt, and silty sand. Some floodplain areas adjacent to the main channels are covered with small claypans (*Qaoc*).

Several individual red-brown claypans (*Qlc*) in sheetwash (*Qwg*) lie north of Cabbage Gum Well (AMG 873319). Mixed eolian and lacustrine deposits (*Qls*) and vegetated gilgai-surfaced claypans (*Qlb*) are in the Planaires Palaeodrainage Basin (Fig. 1) north of Slab Well (AMG 919827) in the northwestern corner of COORAGOORA. The mixed eolian and lacustrine unit (*Qls*) occupies the lowest elevation point (4 m, AHD) on COORAGOORA. The claypans in this area contain a sticky, grey-white saline clay.

Economic geology

Mineral exploration on COORAGOORA has concentrated on the discovery, development, and subsequent mining of many small iron ore deposits hosted by the Nimingarra Iron Formation of the Gorge Creek Group (Podmore, 1990). The Gorge Creek and De Grey Groups of the Pilbara Craton have also been the subject of base metal, gold, uranium, manganese, and bauxite exploration, whereas diamond and bauxite exploration has been carried out on the Mesozoic rocks of the adjacent Lambert Shelf.

Exploration company data, submitted to the Department of Minerals and Energy (DME) since 1967, are held in the Western Australian mineral exploration (WAMEX) open-file system at the DME library. This information for COORAGOORA is summarized in Appendix 1. Six-monthly updated data on mines and mineral deposits in Western Australia are held in the DME mines and mineral deposits information (MINEDEX) database (Townsend et al., 1996).

Iron ore

The Nimingarra and Sunrise Hill – Shay Gap ridge areas in the southwestern corner of COORAGOORA (Fig. 1) host more than 27 openpit iron ore mines (see **Previous and current investigations**).

Individual deposits in these areas are typically of 1 to 10 million tonnes (Mt). A total of 79 Mt of ore at about 62.7% iron was produced from the area between 1972 and 1989. There are further available ore reserves (pre-JORC code figure) of about 138 Mt assaying 59.8% iron, 9.4% silica, 1.53% alumina, and 0.0151% phosphorus (Podmore, 1990). In 1995, proven reserves of 3.5 Mt at 62.8% iron were announced for the Nimingarra area (Wilkinson and Young, 1998).

The iron ore deposits are in two distinct forms: Archaean lode and Mesozoic to Tertiary crustal types. The lode-type ore is stratigraphically controlled and confined to three distinct horizons, designated the Upper, Middle, and Lower horizons (Brandt, 1966). The lode-type ore is in the form of conformable, steeply dipping hematite or hematite–goethite lenses. These lenses have been traced to depths of 320 m, but, in general, are about 50 to 150 m deep, 50 to 100 m wide, and up to 1000 m long (Podmore, 1990).

Crustal-type ores are irregular-shaped masses of platy, fissile hematite. They form tabular bodies beneath the weathered laterite zone, where they may vary from a few metres to 25 m thick (Podmore, 1990).

Road material

Gravel pits for road material are situated at irregular intervals along the Muccan – Pardoo Roadhouse and Boreline roads. The ferruginized colluvium (*Czf*) is favoured for surfacing the graded roads in sandy areas.

Graded waste from the iron ore deposits is used to ballast the Yarrie–Nimingarra – Port Hedland railway line.

Water resources

Between 1972 and 1977 the northwestern quarter of COORAGOORA, west of the Boreline road, was subjected to detailed hydrogeological (Leech, 1979a,b) and groundwater geophysical surveys (Rowston, 1976). The rationale for these projects was to assess the groundwater potential and investigate the subsurface stratigraphy of what was then designated the southwestern part of the Canning Basin.

A total of 14 stratigraphic holes (some abandoned) in two north–south lines about 13 km apart were drilled on COORAGOORA. A maximum depth of 276 m was reached in No. 24A Bore (AMG 088782) where it intersected granitoid rock. During recent fieldwork (1997) artesian water was still flowing from No. 24A and No. 21A Bores (AMG 960786).

The Shay Gap Bore Field (AMG 074520; Rowston, 1976), now maintained by BHP, supplies water to Yarrie Village and minesite on MUCCAN to the south via a 42 km-long pipeline. The aquifer for the borefield is the Wallal Sandstone (Hickman et al., 1983). Further information on the water supplies for COORAGOORA are given in Hickman et al. (1983).

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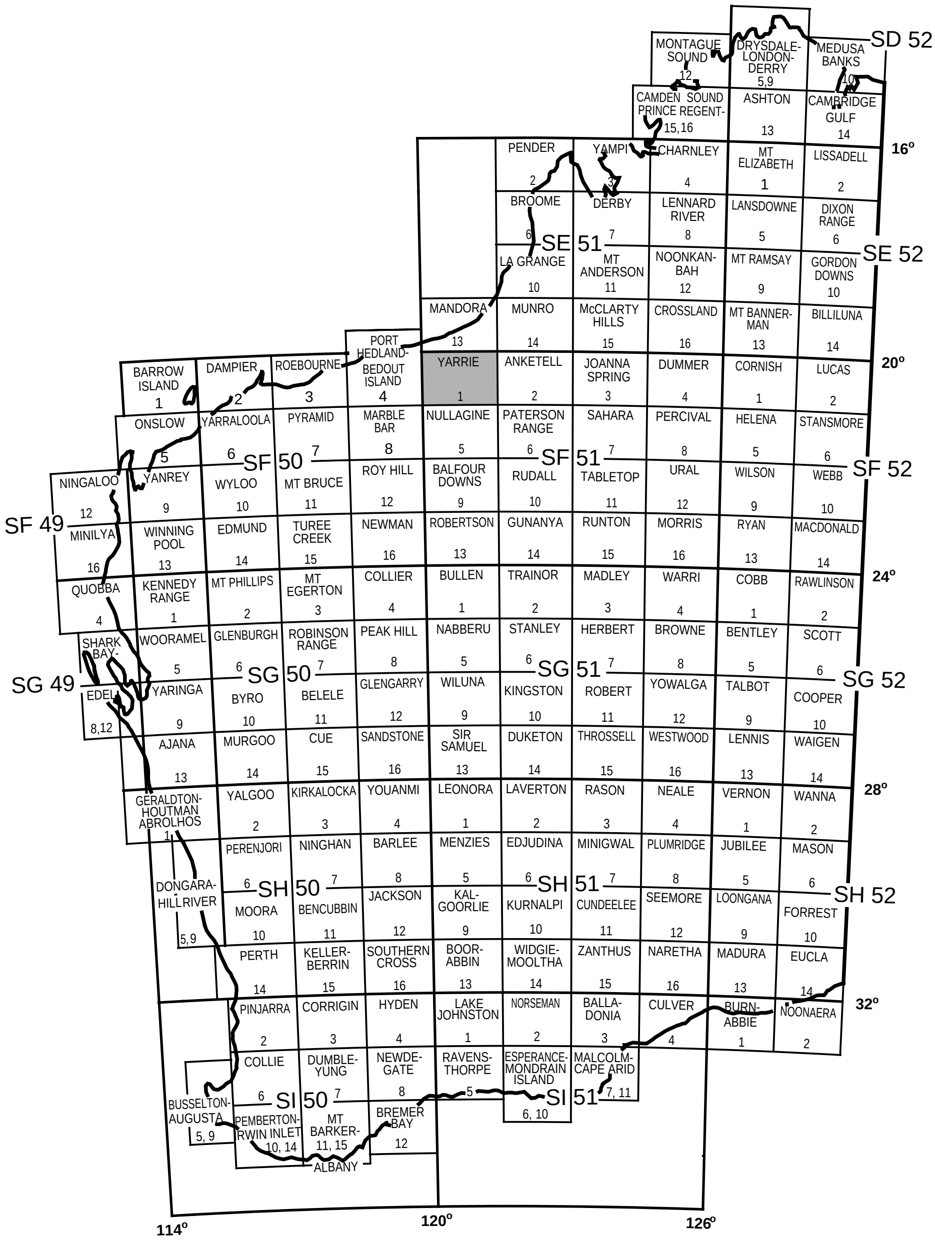
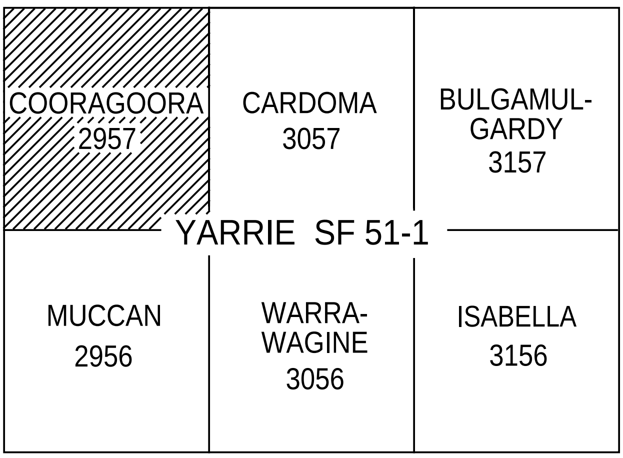
Appendix

Company data on WAMEX open file for COORAGOORA

WAMEX Item number [(a)]	*Duration*	*Title*	*Company*
1942	1961–1967	Nimingarra iron–manganese exploration	Kakiuchi and Company, Kokan Mining Company
2742	1962–1964	Nimingarra iron ore exploration	Metal Traders Aust
1308	1967–1968	Fence iron–nickel–copper exploration	Sentinel Mining Company
2412	1978	Yarrie bauxite reconnaissance	CSR Exploration
1328	1981	Shay Gap base metals exploration	Pennzoil of Australia, Picon Explorations
4017	1986–1989	Cattle Gorge gold exploration	CRA Exploration
4044	1988–1989	Shay gold–uranium exploration	CRA Exploration
6778	1988–1992	Nimingarra iron ore exploration	BHP Iron Ore
7274	1991–1993	Cooragoora iron ore exploration	BHP Iron Ore
7577	1993	Cooragoora diamond exploration	CRA Exploration

NOTES: (a) Item numbers refer to the open-file statutory mineral exploration reports held in the WAMEX (Western Australian mineral exploration) database held at the Department of Minerals and Energy's library





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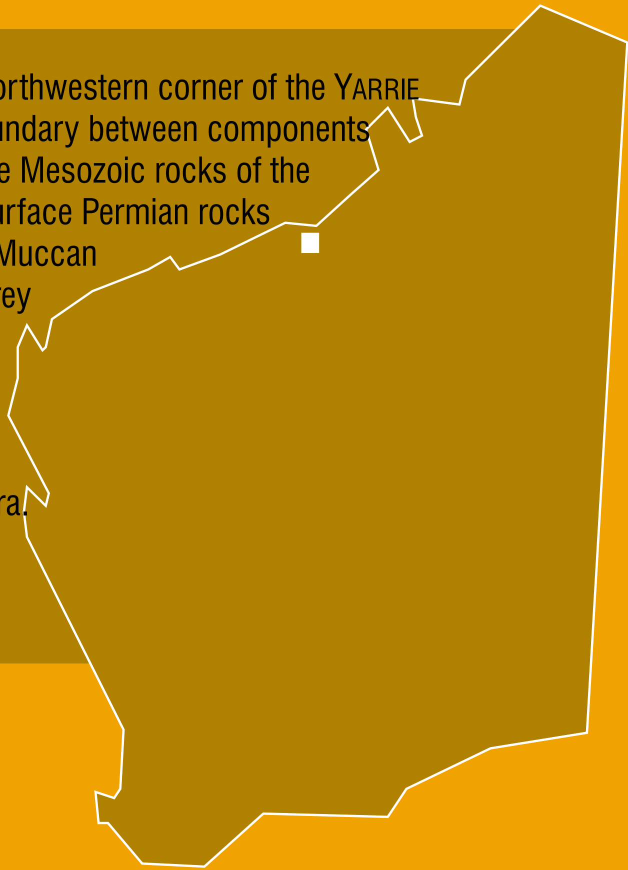
The COORAGOORA 1:100 000 sheet occupies the northwestern corner of the YARRIE 1:250 000 sheet. It straddles the northeastern boundary between components of the East Pilbara Granite–Greenstone Terrane, the Mesozoic rocks of the Lambert Shelf (Westralian Superbasin), and subsurface Permian rocks of the Canning Basin. Exposures of the Archaean Muccan Granitoid Complex, Gorge Creek Group, and De Grey Group, and Neoproterozoic Eel Creek Formation, are restricted to the southwestern corner and southern margin. A new unit, the Cooragoora Formation of the De Grey Group, is defined. Iron ore is currently being mined around Nimingarra. The area has been explored for base metals, gold, uranium, manganese, bauxite, and diamonds.



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

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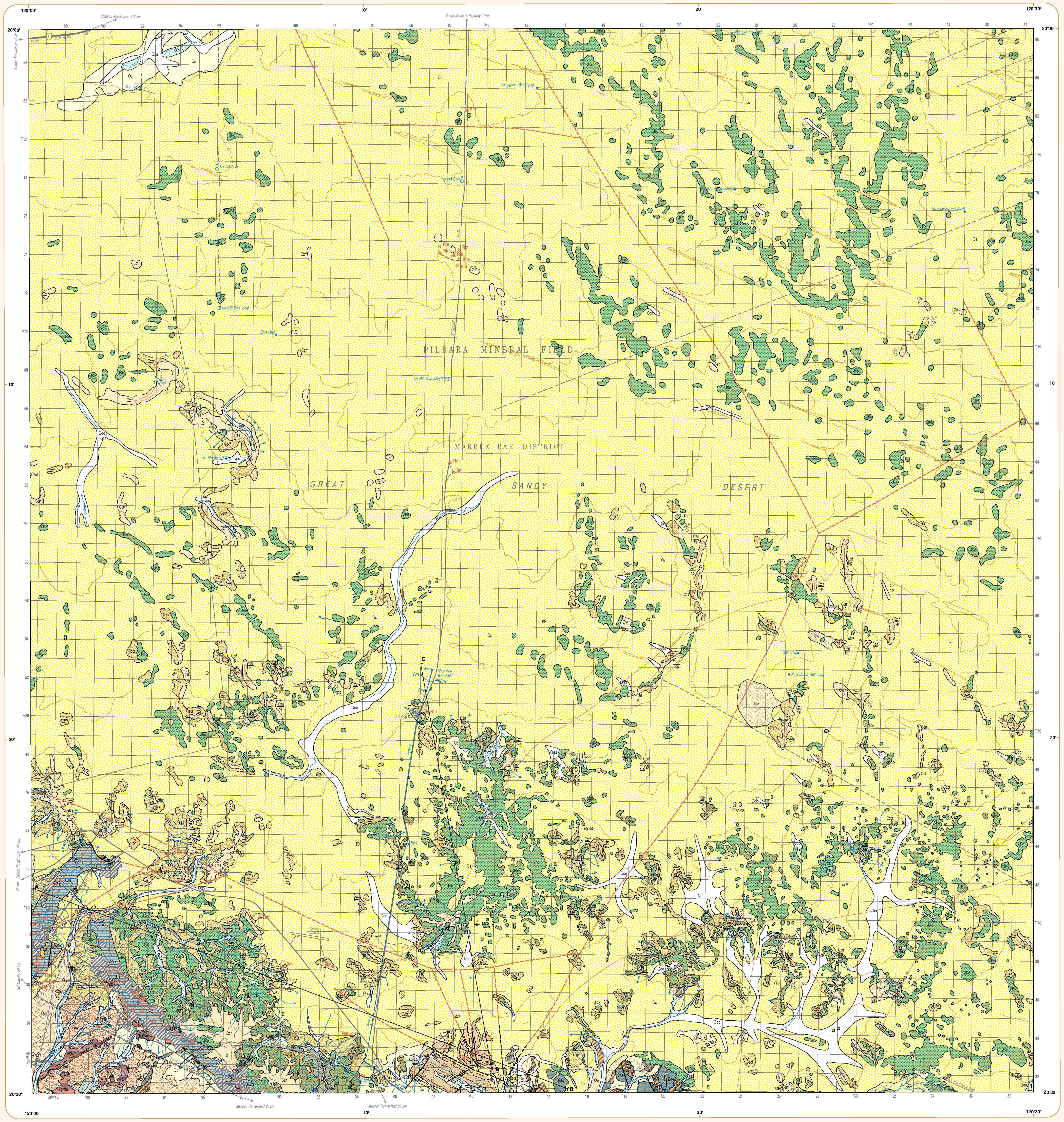
AUSTRALIA 1 : 100 000 GEOLOGICAL SERIES

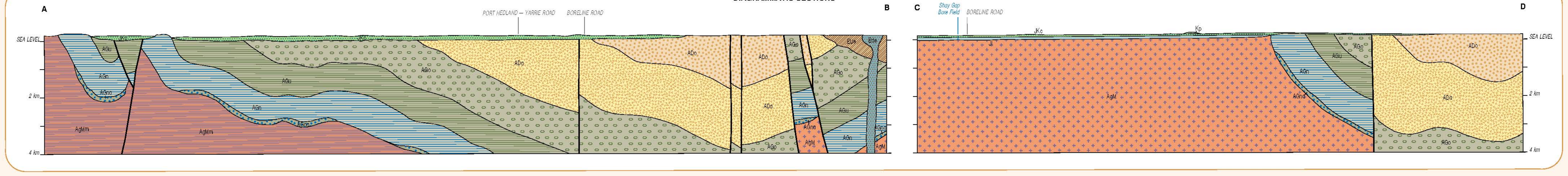
COORAGOORA

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET 2957



DIAGRAMMATIC SECTIONS



Reference

CAINOZOIC — QUATERNARY

- Qlc Lacustrine clay, silt, and sand in large, non-vegetated claypans
- Qlt Lacustrine clay and silt with gilgai (crabhole) surface in claypans; generally vegetated
- Qa Mixed lacustrine and eolian deposits; clay, silt, and sand
- Qaa Alluvium—unindurated clay, silt, and gravel in rivers and creeks
- Qaa Unconsolidated sand, silt, and gravel in discrete channel beds
- Qao Overbank deposits—alluvial sand, silt, and clay on floodplains adjacent to main drainage channels
- Qaa Alluvial sand, silt, and clay; mixed floodplain deposits (Qao) characterized by numerous small claypans
- Qw Sheetwash deposits—silt, sand, and pebbles on distal fans
- Qwg Sheetwash sand and quartz pebbles overlying and derived from granitoid rocks
- Qc Colluvium—sand, silt, and gravel on outwash fans; scree, talus; proximal mass-wasting deposits
- Qg Quartzofeldspathic eluvial sand, with quartz and rock fragments; overlying and derived from granitoid rock
- Qs Eolian sand—light to dark-red sand in sheets, and longitudinal (seif) and chain dunes; local ironstone pebble veneer
- Czk Calcrete—massive, nodular, and cavernous limestone, variably silicified; dissected valley calcrete
- Czc Colluvium—dissected consolidated clay, silt, and sand deposits, derived from adjacent rock outcrop
- Czf Dissected consolidated ferruginous deposits; recemented, broken laterite rubble, ironstone pebbles, clay, silt, and sand
- Czl Ferruginous duricrust—massive, pisolitic, and nodular laterite

MESOZOIC — CRETACEOUS / JURASSIC (WESTERN SUPERBASIN)

- **PARDA FORMATION:** white, thin-bedded, and massive mudstone and claystone, and minor lenses of fine-grained sandstone; macrofossils; shallow-marine deposits
- **CALLAWA FORMATION:** very fine- to coarse-grained sandstone, ferruginous towards base, siltstone and conglomerate interbeds; plant and trace fossils; mainly fluvial deposits
- J **WALLAL SANDSTONE:** sandstone with minor siltstone and conglomerate; continental and marginal marine deposits (not on map)

PALAEOZOIC — PERMIAN (CANNING BASIN)

- **PATERSON FORMATION:** diamictite, mudstone, siltstone, sandstone, and minor conglomerate; fluvioglacial deposits

PROTEROZOIC — NEOPROTEROZOIC

- d Dolerite dyke, various ages
- q Quartz vein, various ages
- Ede Fine- to medium-grained dolerite and quartz dolerite sills and dykes in **EEL CREEK FORMATION**
- EUe **EEL CREEK FORMATION:** black, blue, green, and grey mudstone, shale, siltstone, and thin-bedded sandstone; minor glauconitic and tuffaceous sandstone, and rhyolite tuff (Tarcunyah Group)

ARCHAEAN (PILBARA CRATON)

- AFdb **Black Range Dolerite Suite:** dolerite and medium- to coarse-grained gabbro dykes; weakly metamorphosed
- AaYo **Shay Intrusion:** metamorphosed gabbro, epidotized gabbro, and quartz gabbro

Pilbara Supergroup — De Grey Group

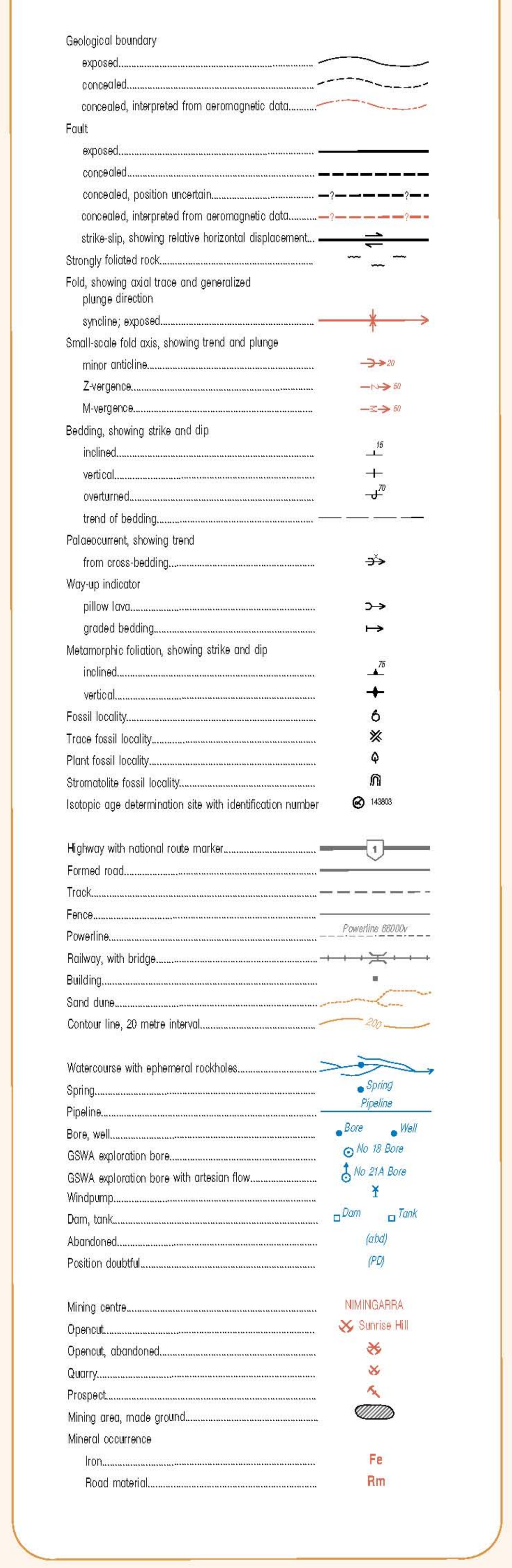
- ADo **COORAGOORA FORMATION:** fine- to coarse-grained sandstone, siltstone, shale, conglomerate, and feldspathic and lithic wacke; weakly metamorphosed
- ADa **CATTLE WELL FORMATION:** interbedded dacite tuff, welded tuff, and tuffaceous siltstone and shale, and thin-bedded sandstone, siltstone, wacke, and carbonate rock; weakly metamorphosed

Pilbara Supergroup — Gorge Creek Group

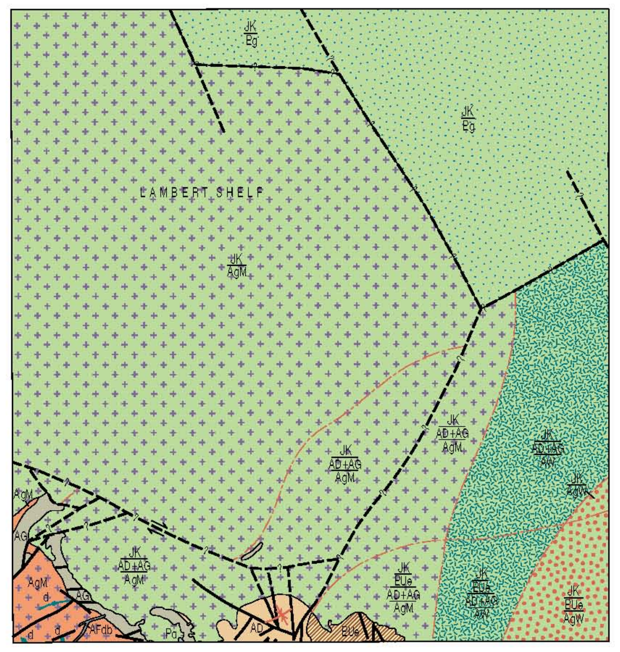
- AGus Serpentinized ultramafic dyke
- AGo **COONIEENA BASALT:** pillowed and massive basalt, hyaloclastic breccia, and silicified basaltic andesite; metamorphosed
- AGu **CUNDALINE FORMATION:** weathered brown, grey-green shale, siltstone, lithic wacke, and sandstone; metamorphosed
- AGn **NIMINGARRA IRON FORMATION:** banded iron-formation, jaspilite, banded and ferruginous chert, and black carbonaceous shale; metamorphosed
- AGna Basalt pebble- to cobble-conglomerate, sandstone, siltstone, and shale; metamorphosed

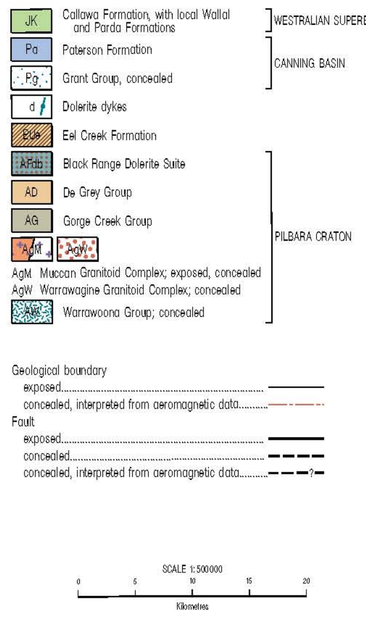
- Aut Tremolite—serpentine—chlorite(—talc) schist; metamorphosed ultramafic rock
- AgM **MUCCAN GRANITOID COMPLEX:** metamorphosed fine- to coarse-grained monzogranite, syenogranite, granodiorite, and tonalite; massive seriate and porphyritic varieties; foliated to gneissic; minor banded granitoid gneiss (not on map)
- AgMm Mixed monzogranite to granodiorite; fine- to coarse-grained; well foliated to gneissic; minor banded granitoid gneiss

c.3443 Ma



SIMPLIFIED GEOLOGY





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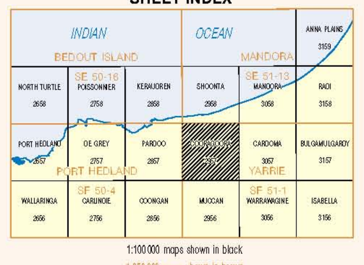

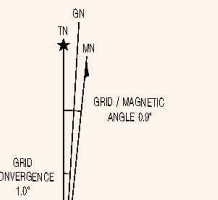

True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1998 and moves easterly by about 0.1° in 3 years.

GOVERNMENT OF WESTERN AUSTRALIA

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NGMA — PRODUCT OF THE NATIONAL GEOSCIENCE MAPPING ACCORD

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SCALE 1:100 000

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HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1984
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Geology by I. R. Williams 1997

Edited by N. Tetlaw and G. Loan

Cartography by T. Lenane and S. Collopy

Topography from the Department of Land Administration Sheet SF 51-1, 2957, with modifications from geological field survey

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COORAGOORA

SHEET 2957 FIRST EDITION 1999