



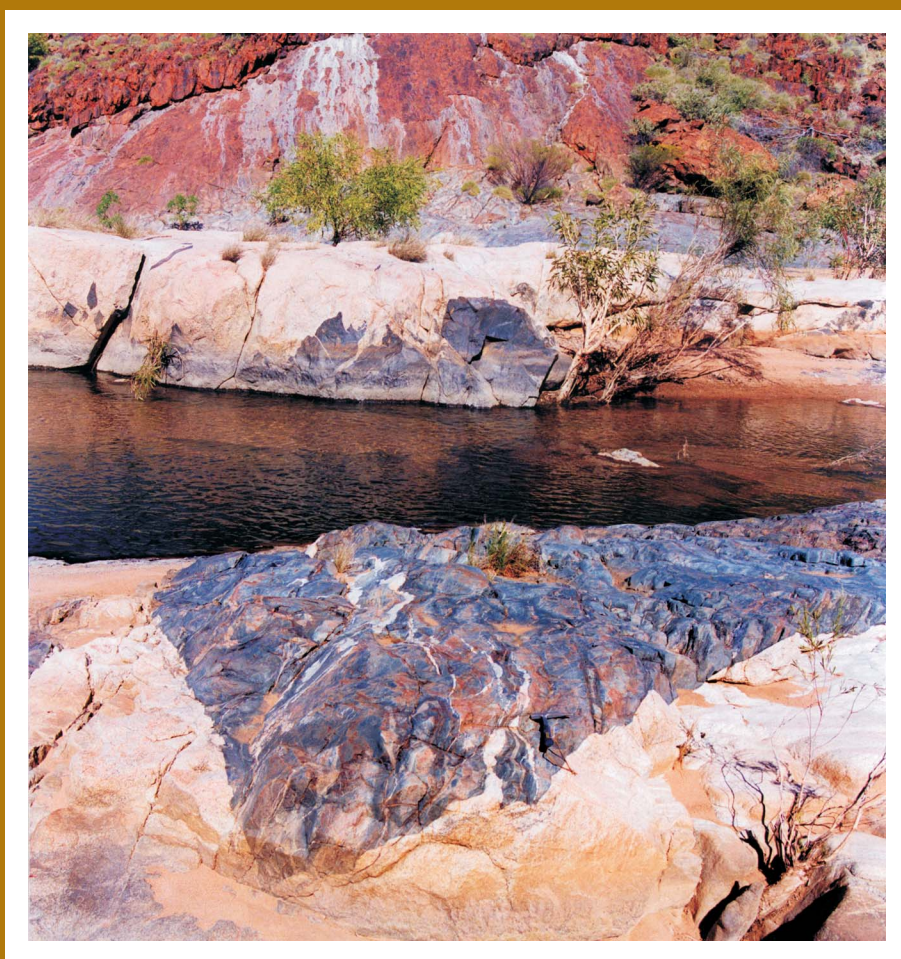
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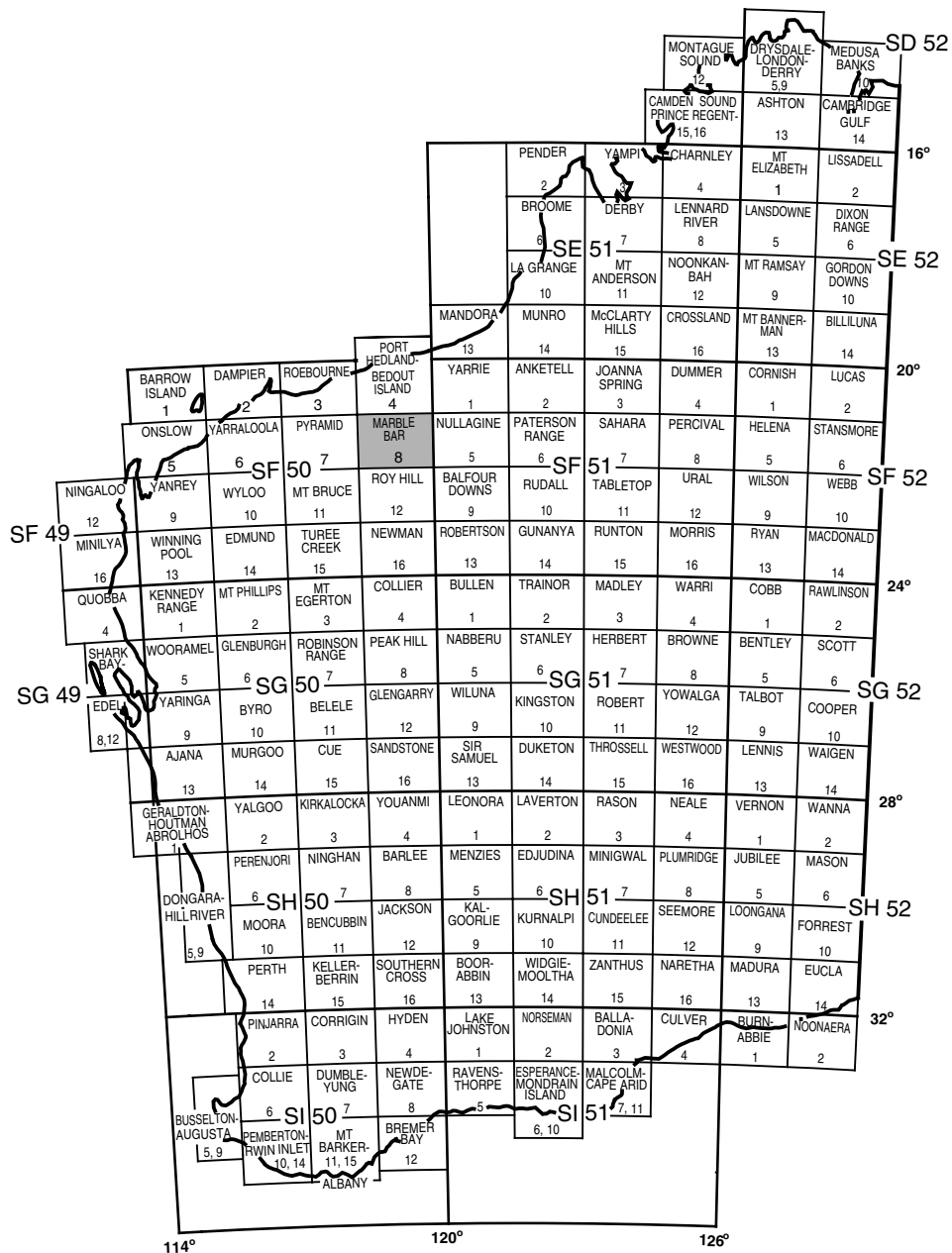
GEOLOGY OF THE SPLIT ROCK 1:100 000 SHEET

by L. Bagas, M. J. Van Kranendonk, and M. Pawley

1:100 000 GEOLOGICAL SERIES



Geological Survey of Western Australia



WODGINA 2655	NORTH SHAW 2755	MARBLE BAR 2855
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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE SPLIT ROCK 1:100 000 SHEET

EDITION 1, MAP VERSION 2

by

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Cover photograph:

Granitic sheets and stockwork vein arrays intruding foliated amphibolite of the Euro Basalt at Warrery Gap (MGA 784100E 7612300N).

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Geology of the Split Rock 1:100 000 sheet

by

L. Bagas, M. J. Van Kranendonk, and M. Pawley¹

Abstract

The SPLIT ROCK 1:100 000 sheet is in the southeastern part of the Palaeoarchaeon to Mesoarchaeon East Pilbara Granite–Greenstone Terrane (EPGGT) and the northeastern part of the Neoarchaeon Hamersley Basin. The EPGGT comprises greenstone successions of the Pilbara Supergroup, and domical granitic complexes. The Hamersley Basin succession unconformably overlies the EPGGT and on SPLIT ROCK consists of the Fortescue Group of the Mount Bruce Supergroup.

On SPLIT ROCK the Pilbara Supergroup is preserved in the Coongan and Kelly greenstone belts and consists of metamorphosed mafic, ultramafic, and felsic volcanic rocks, and sedimentary rocks. The c. 3490–3319 Ma, dominantly basaltic Warrawoona Group includes interbedded felsic volcanic formations that were deposited during intrusion of early phases of the Shaw and Corunna Downs Granitoid Complexes. The complexes were emplaced in progressive stages during intervals of felsic magmatism over a 600 m.y. period between 3468 and 2850 Ma. The Warrawoona Group is unconformably overlain by the c. 3308 Ma Budjan Creek Formation of coarse volcanoclastic and clastic metasedimentary rocks, which in turn is unconformably overlain by clastic metasedimentary rocks of the younger-than-3240 Ma Gorge Creek Group. All of the supracrustal rocks were intruded by a suite of ultramafic rocks before deposition of the unconformably overlying volcanic and sedimentary rocks of the Fortescue Group between 2770 and 2720 Ma.

Seven deformation events have been recognized on SPLIT ROCK. The first event, D₁, is manifest as a nonconformity between the c. 3474–3467 Ma Duffer and c. 3433 Ma Panorama Formations on the western limb of the Coongan Syncline. D₂ structures (c. 3317–3308 Ma) include tilting and large-scale open to tight folding, the development of a penetrative foliation and lineation in the Coongan Syncline, and layer-parallel normal and reverse faults in the Warrawoona Group. Other D₂ structures include the Split Rock Shear Zone inside the eastern margin of the Shaw Granitoid Complex. D₃ deformation involved tilting of the Budjan Creek Formation and Gorge Creek Group away from the Corunna Downs Granitoid Complex. The D₄ event (c. 2770–2756 Ma) involved faulting during the early deposition of the Fortescue Group and related dolerite dyke intrusion. The D₅ event (<2756 Ma) involved folding of the lower formations of the Fortescue Group. D₆ deformation (<2719 Ma) included late, east-side-down normal faults affecting the Fortescue Group. Two suites of dolerite dykes are younger than the Fortescue Group, the younger of which is associated with local faulting (D₇).

Base metal mineralization (dominantly copper) in the Kelly greenstone belt is hydrothermal in origin and probably related to igneous activity associated with the c. 3308 Ma Budjan Creek Formation and contemporaneous magmatism within the Corunna Downs Granitoid Complex. The Coongan greenstone belt hosts several small epigenetic gold prospects and mines in shear zones parallel to, but offset from, the main shears in the area. Tin and tantalum have been mined from alluvial placer deposits in and adjacent to the 2850 Ma Cooglegong Monzogranite in the Shaw Granitoid Complex, and there is minor tin mineralization within the Corunna Downs Granitoid Complex.

KEYWORDS: Archaeon, Pilbara Craton, Warrawoona Group, Budjan Creek Formation, Gorge Creek Group, Fortescue Group, lithostratigraphy, geochronology, structure, metamorphism, mineralization.

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Introduction

The SPLIT ROCK* 1:100 000 sheet (SF 50-8, 2854) is in the southeastern part of the MARBLE BAR 1:250 000 sheet (SF 50-8), between latitudes 21°30'S and 22°00'S and longitudes 119°30'E and 120°00'E (Fig. 1), and lies within the East Pilbara Mineral Field. SPLIT ROCK is in the central-eastern part of the Pilbara Craton (Fig. 1) at the boundary between the southeastern part of the well-exposed East Pilbara Granite–Greenstone Terrane (EPGGT; Hickman, 2001a) and the northeastern part of the Hamersley Basin (Griffin, 1990; Trendall, 1990a). The area is underlain by early to late Archaean (c. 3650–2850 Ma) volcanic, sedimentary, and granitic rocks of the EPGGT, with unconformably overlying volcanic and sedimentary rocks of the late Archaean (c. 2770 Ma) Fortescue Group of the Mount Bruce Supergroup (MacLeod et al., 1963; Trendall, 1990a, 1995).

These Explanatory Notes describe the regional geological setting, lithostratigraphy, structure, metamorphism, geochronology, and mineralization on SPLIT ROCK (version 2; Bagas et al., 2003).

Access, climate, and vegetation

Access on SPLIT ROCK is provided by intermittently maintained pastoral tracks across the Corunna Downs Granitoid Complex, the graded track from Bamboo Springs to Hillside that traverses the map area in the southwest, and mining exploration tracks that extend from the Nullagine – Marble Bar Road to the abandoned Copper Hills and Kellys mining areas†, and from the Marble Bar – Hillside – Woodstock track to the abandoned Corboy mining centre and areas farther south (Fig. 2). Much of the area is only accessible by four-wheel-drive vehicle on and off tracks, but rugged terrain in the central-south and southwest is not accessible by four-wheel-drive vehicle.

The area covered by SPLIT ROCK has an arid climate, with a mean annual rainfall of about 300 mm and an average annual evaporation of about 3600 mm (Pink, 1992), leaving the region dry during the late winter to early summer months. Rainfall is erratic, with little precipitation during the winter months, but the area is subject to floods during cyclonic and thunderstorm activity between November and March. Average summer temperatures range from daily minima of about 30°C to maxima in the low forties (°C), whereas daily winter temperatures typically vary between minima of around 12.5°C and maxima of about 25°C (Pink, 1992). The prevailing winds blow from the east and southeast.

Several species of spinifex grass (*Triodia*) grow on SPLIT ROCK, with the largest species inhabiting creek beds or banks. Elsewhere, the size and species of spinifex

depends on the availability of near-surface water and when the area was last burned. Sandy areas and some valleys contain *Grevillea*, wattles (*Acacia*), soft shrubs (*Crotalaria*), eucalypts, tea tree (*Melaleuca*), and Sturt Desert Pea. Creeks and rivers contain large eucalypts and grasses, and areas of rock outcrop include small shrubs, grasses, mulga, stunted eucalypts, and fig trees. Mixed outcrop and colluvium have spinifex, small shrub, grasses, and *Acacia*.

Physiography

The physiography of SPLIT ROCK is largely influenced by the bedrock geology. Units within the Coongan and Kelly greenstone belts outcrop as strike-controlled ridges and valleys, whereas granitic rocks of the Shaw and Corunna Downs Granitoid Complexes have a more-subdued, undulating topography. These geological regions correspond to the 'Range' and 'Low hills' topographic divisions shown on Figure 2, respectively. The ranges form steep-sided plateaus and strike-ridges that are capped by ferruginized and silicified duricrust. These surfaces represent a relict weathering peneplain known as the Hamersley Surface in the Hamersley Ranges (Campana et al., 1964). Northeasterly trending, black-weathered dolerite ridges are exposed throughout SPLIT ROCK, most spectacularly in the Shaw and Corunna Downs Granitoid Complexes.

The highest point elevation on SPLIT ROCK is 605 m above mean sea level (MGA 793600E 7578050N) in the Kelly greenstone belt halfway between Budjan Creek and Cookindina Pool. The lowest point elevation is 250 m in the Corunna Downs Granitoid Complex in the northernmost part (MGA 781665E 7619570N). Volcanic and sedimentary rocks of the Fortescue Group underlie the plateau in the southeast. Major creeks and rivers draining northward incise the greenstone belts and granitic complexes, and form plains and valleys, but these watercourses are commonly dry, except during and soon after the wet summer months.

Previous investigations

Alluvial gold discovered east of SPLIT ROCK near Nullagine in 1888 gave impetus to the exploration for gold and other precious metals in the region, which continues to this day. Noldart and Wyatt (1962) and Hickman (1983) gave details of the early history of exploration, mining, and geological studies on the MARBLE BAR 1:250 000 sheet, on which SPLIT ROCK is located.

Hickman and Lipple (1978) mapped the MARBLE BAR 1:250 000 sheet (second edition) in 1972 during a Geological Survey of Western Australia (GSWA) remapping program in the east Pilbara. The granite–greenstone section of the Pilbara Craton was then referred to as 'Pilbara Block' and the geology of this area was subsequently described by Hickman (1983, 1984). The same unit was later called the 'northern Pilbara granite–greenstone terrane' (Griffin, 1990), and the 'North Pilbara Terrain' (Van Kranendonk et al., 2002). The 'north Pilbara granite–greenstone terrane' was divided into five tectonic

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

† MGA coordinates of localities mentioned in the text are listed in Appendix 1.

units by Hickman (2001a), the central and largest of which is the East Pilbara Granite–Greenstone Terrane (EPGGT).

Hickman (1983) grouped the oldest volcano-sedimentary rocks across the ‘Pilbara Block’ into the ‘Archaean Pilbara Supergroup’ and proposed that the lower part of the supergroup formed a single, layer-cake stratigraphy across the northern part of the craton. The stratigraphic

correlations between the greenstone belts were based on either continuity of beds or similarity of the lithological successions. However, subsequent detailed mapping and geochronology have shown that the greenstones of the region are more laterally variable than previously thought (e.g. see Thorpe et al., 1992a; Morant, 1995; Buick et al., 1995; Vearncombe et al., 1995; Van Kranendonk and Morant, 1998; Van Kranendonk et al., 2002).

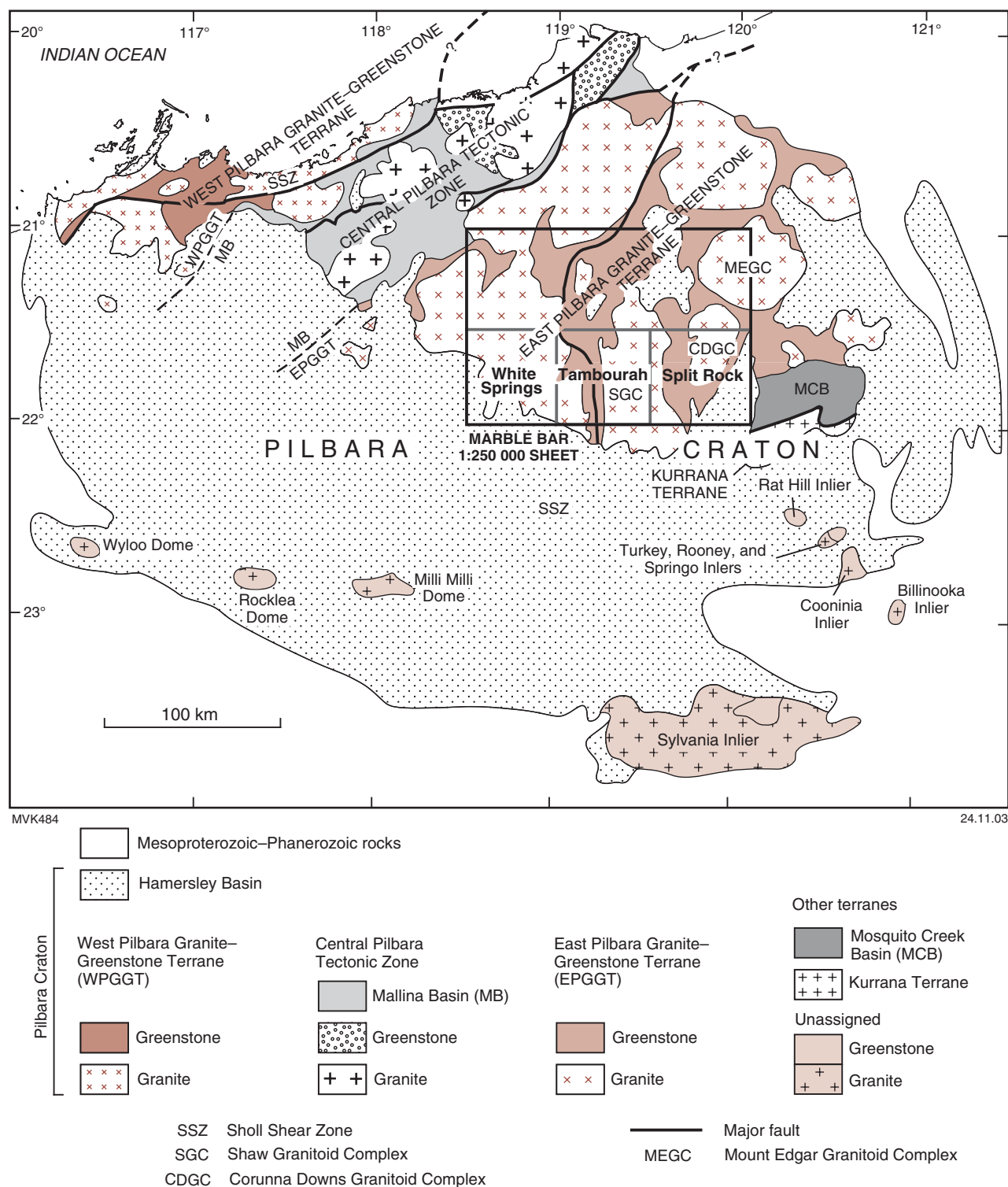


Figure 1. Regional geological setting of Split Rock in the northern Pilbara Craton

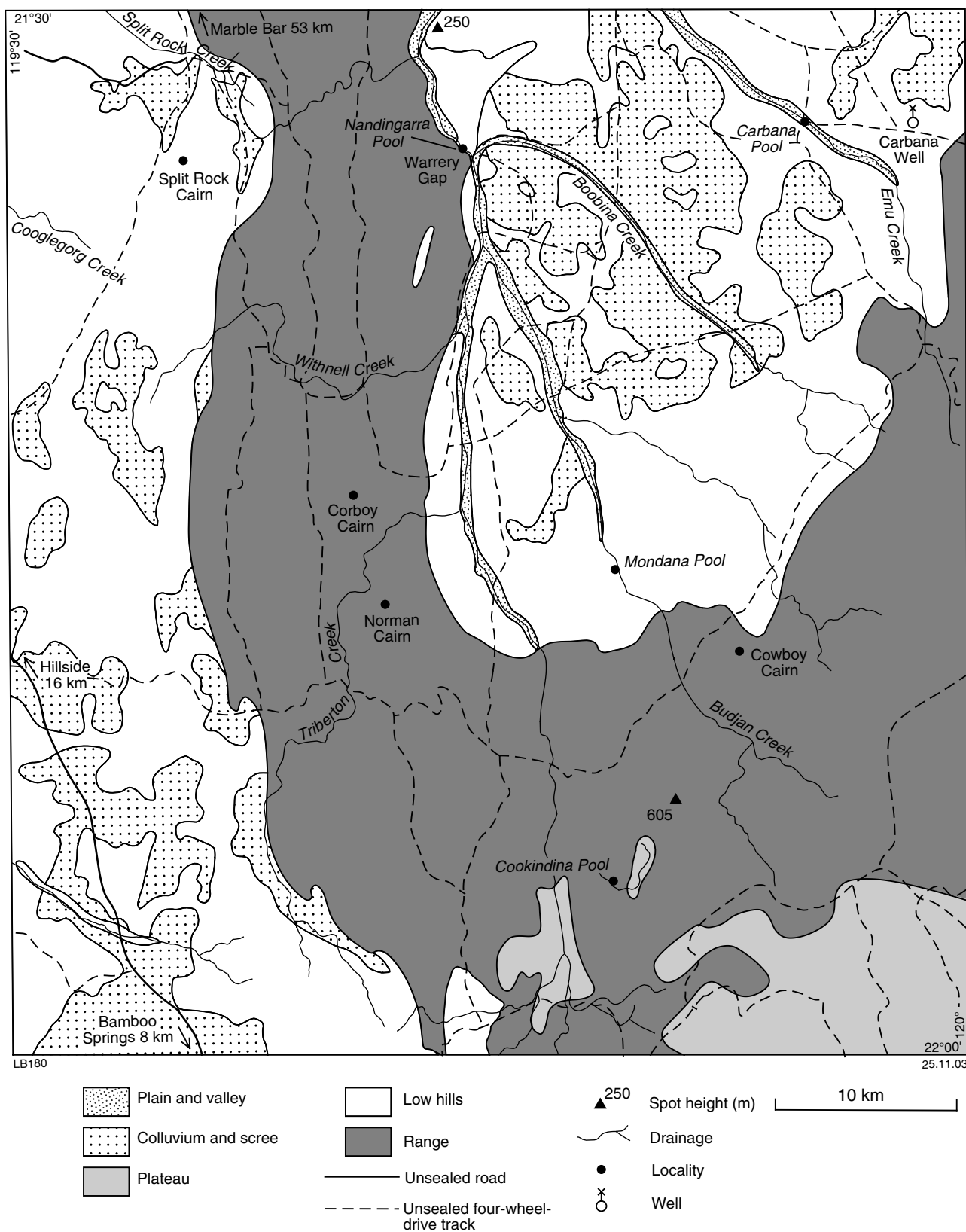


Figure 2. Physiography and access on SPLIT ROCK

The lithostratigraphy of the Pilbara Supergroup (Hickman, 1983) was modified by Hickman (1990) to separate the De Grey Group from the Gorge Creek Group. A major revision was made by Hickman (1997) to distinguish the greenstone succession of the west Pilbara from that of the east Pilbara. Following further mapping and geochronology, Van Kranendonk et al. (2002) redefined the Warrawoona Group so that the Duffer Formation was included in the Talga Talga Subgroup, and all younger volcanic rocks, including the Panorama Formation, up to the top of the Euro Basalt were included in the Salgash Subgroup.

Bettenay et al. (1981) described the Shaw Granitoid Complex and its protracted, complex tectonothermal history, identifying several phases of granitic intrusion and four phases of deformation (see **Pre-Fortescue Group deformation**). Hickman (1983) recognized seven plutons within the complex, intrusive into gneissic to migmatitic monzogranite and granodiorite, and identified the abnormally sodic composition of the early gneisses. The major tectonic structures of the region were interpreted as the result of solid-state diapirism of the Archaean granitic complexes (Hickman, 1983).

Bickle et al. (1985) challenged the solely diapiric model for the tectonic evolution of the EPGGT, and suggested that an early period of Alpine-style thrusting affected the western part of the Shaw Granitoid Complex. Zegers et al. (1996) used this interpretation to suggest that structures along the eastern margin of the Shaw Granitoid Complex and in the Coongan greenstone belt supported c. 3467 Ma development of the Shaw Granitoid Complex. However, the existence of the detachment zone of the proposed metamorphic core complex was disputed on NORTH SHAW (Van Kranendonk, 2000). Van Kranendonk et al. (2002) observed that structures attributed to Alpine-style deformation by Bickle et al. (1985) post-dated younger-than-3235 Ma deposition of the Gorge Creek Group, and thus did not produce crustal thickening before the proposed metamorphic core complex development.

Bickle et al. (1983) described the c. 3500 Ma calc-alkaline North Shaw Suite in the Shaw Granitoid Complex, and compared these rocks to modern calc-alkaline igneous suites in subduction settings, derived from melts in equilibrium with garnet in the lower crust. Smithies (2000) showed that the compositions are incompatible with an origin from slab melting in a modern-style steep subduction setting, and suggested instead that tonalite–trondhjemite–granodiorite–granite (TTG) rocks were more likely to be generated by melting of lower mafic crust. Hickman (1983 and references therein), Bickle et al. (1989), and Collins (1993) presented geochemical evidence that late- to post-tectonic granitic rocks in several granitic complexes in the EPGGT were derived by partial melting of pre-existing sialic crust. Davy (1988) presented the results of a detailed geochemical study of the Corunna Downs Granitoid Complex, the lower half of which outcrops on SPLIT ROCK. Geochemical data on the volcanic rocks of SPLIT ROCK were included in reports by Glikson and Hickman (1981) and Glikson et al. (1986, 1987).

On MARBLE BAR and MOUNT EDGAR, Williams and Collins (1990) described high-grade, high-strain structures around the Mount Edgar Granitoid Complex that are synchronous with widespread granitic magmatism at 3310 Ma (Collins, 1989; Collins et al., 1998) and are locally associated with high-grade metamorphism (Collins and Van Kranendonk, 1999).

Van Haaften and White (1998) interpreted shear zones in the Marble Bar greenstone belt on MARBLE BAR and COONGAN as evidence of c. 3300–3000 Ma tectonic stacking. However, Van Kranendonk et al. (2001a) questioned the significance of the shear zones in terms of the proposed model of horizontal thrusting, and Van Kranendonk et al. (2001b, 2002) showed that the Marble Bar greenstone belt was a right-way-up, upward-younging autochthonous succession.

Blake (1993, 2001) applied sequence-stratigraphic principles to the stratigraphy of the Mount Bruce Supergroup that unconformably overlies the EPGGT and includes the Fortescue Group, whereas Thorne and Trendall (2001) retained a strictly lithostratigraphic nomenclature in their overview of the Fortescue Group.

These Explanatory Notes, and the accompanying SPLIT ROCK 1:100 000 geological map, are based on regional mapping carried out during 1999 and 2000 using 1:25 000-scale colour aerial photographs, with interpretation of available regional magnetic and radiometric data.

Regional geological setting

The Pilbara Craton has an exposed area of about 183 000 km² and is composed of the 3655–2830 Ma granite–greenstones, which constitute the northern third of the exposed craton, and is subdivided into the West and East Pilbara Granite–Greenstone Terranes (Fig. 1). These successions are unconformably overlain by the 2770–2400 Ma Hamersley Basin in the south (Trendall, 1990a; Blake, 2001).

SPLIT ROCK is in the southeastern part of the EPGGT. In this region the elliptical and domical Shaw and Corunna Downs Granitoid Complexes with long axes of between 60 and 110 km characterize the EPGGT (Fig. 1). The intervening, arcuate Coongan and Kelly greenstone belts comprise dominantly greenschist-facies volcanic rocks of the c. 3490–3319 Ma Warrawoona Group (Table 1), and lesser amounts of metamorphosed sedimentary rocks, and mafic, felsic, and ultramafic intrusive rocks of younger stratigraphic units. The Warrawoona Group is intruded and locally contact metamorphosed to hornblende–hornfels facies by granitic rocks of the Shaw and Corunna Downs Granitoid Complexes, and unconformably overlain by the c. 3308 Ma Budjan Creek Formation. This is unconformably overlain by the dominantly clastic sedimentary rocks of the younger-than-c. 3240 Ma Gorge Creek Group (Table 1).

All Archaean volcano-sedimentary rocks on SPLIT ROCK dip and young away from the margins of the domical granitic complexes (see Fig. 3 and interpreted bedrock

Table 1. Archaean stratigraphy on SPLIT ROCK

<i>Group</i>	<i>Subgroup</i>	<i>Formation</i>
Fortescue		Tumbiana Formation (c. 2719 Ma)
		Kylena Formation
		Hardey Formation (c. 2764–2756)
		Bamboo Creek Member (c. 2756 Ma)
		Mount Roe Basalt (c. 2770 Ma) and Black Range Dolerite suite (c. 2772 Ma)
~~~~~		
Gorge Creek		Budjan Creek Formation (c. 3308 Ma)
	~~~~~	
	Kelly Subgroup	Wyman Formation (c. 3325–3319 Ma)
		Euro Basalt (3350–3325 Ma)
	~~~~~	
	Salgash Subgroup	Strelley Pool Chert
		Panorama Formation (c. 3433 Ma)
		Apex Basalt
	~~~~~	
	Talga Talga Subgroup	Towers Formation
		Duffer Formation (c. 3470 Ma)
		Mount Ada Basalt
		McPhee Formation (c. 3477 Ma)
		North Star Basalt (c. 3490 Ma)

NOTES: ~~~~~~ unconformity
 conformity

geology figure on map). Furthermore, successively younger stratigraphic units have shallower dips away from the centres of the domes. Hickman (1975, 1984) explained this gradual shallowing of units as due to progressive granite diapirism during the deposition of the groups. The preservation of synclinal remnants of the Fortescue Group (Arndt et al., 1991; Nelson, 1998) over synclinal greenstone belts between domical granitic complexes indicates that doming continued until after deposition of the Fortescue Group (c.f. Hickman, 1984).

The igneous rocks in the Shaw and Corunna Downs Granitoid Complexes range in age from c. 3490 to 2830 Ma (Bickle et al., 1983, 1989; Van Kranendonk et al., 2002). Gneisses and TTGs form the oldest component of the Shaw Granitoid Complex, and on SPLIT ROCK range in age from 3470 to 3410 Ma, similar to felsic volcanic rocks in the Warrawoona Group (Thorpe et al., 1992a). This older component was not seen in the Corunna Downs Granitoid Complex on SPLIT ROCK, although remnants of these rocks are present in this complex farther north on MARBLE BAR with ages of c. 3427–3408 Ma (Bagas et al., 2003). Younger and variably foliated granitic rocks, which range in age from 3319 to 3307 Ma, form most of the Corunna Downs Granitoid Complex, and crystallized shortly after the deposition of felsic volcanic rocks of the c. 3325–3319 Ma Wyman Formation of the Warrawoona Group (Nelson, 2001, 2002).

Several generations of younger granitic rocks dated at c. 2928 and c. 2850 Ma (Nelson, 1998, 1999, 2000) intruded the Shaw Granitoid Complex on TAMBOURAH and NORTH SHAW. The Neoproterozoic Fortescue Group (c. 2770–2630 Ma) is the oldest component of the Mount Bruce Supergroup in the Hamersley Basin (Trendall, 1990a), and

unconformably overlies the EPGGT on southeastern SPLIT ROCK (Fig. 1). The crustal evolution of SPLIT ROCK is summarized in Table 2.

Archaean rocks

All Archaean rocks on SPLIT ROCK have been deformed and metamorphosed, although many are extremely well preserved despite their antiquity. In these Explanatory Notes, original rock terminology is used where possible and rocks have been placed within a lithostratigraphic context. However, in some areas, deformation and metamorphism have so obscured primary features that identification of the protolith is uncertain and rocks are identified solely by their metamorphic lithology.

Warrawoona Group

The Warrawoona Group (Lipple, 1975) on SPLIT ROCK is subdivided from base to top into the Talga Talga Subgroup, Towers Formation, Salgash Subgroup, and Kelly Subgroup (Table 1; interpreted bedrock geology figure on map). Granitic rocks intrude the base of the group, and the top is either obscured by faulting or unconformably overlain by rocks of the Budjan Creek Formation, Gorge Creek Group, or Fortescue Group.

Talga Talga Subgroup

The Talga Talga Subgroup on SPLIT ROCK consists of the dominantly basaltic rocks of the North Star Basalt,

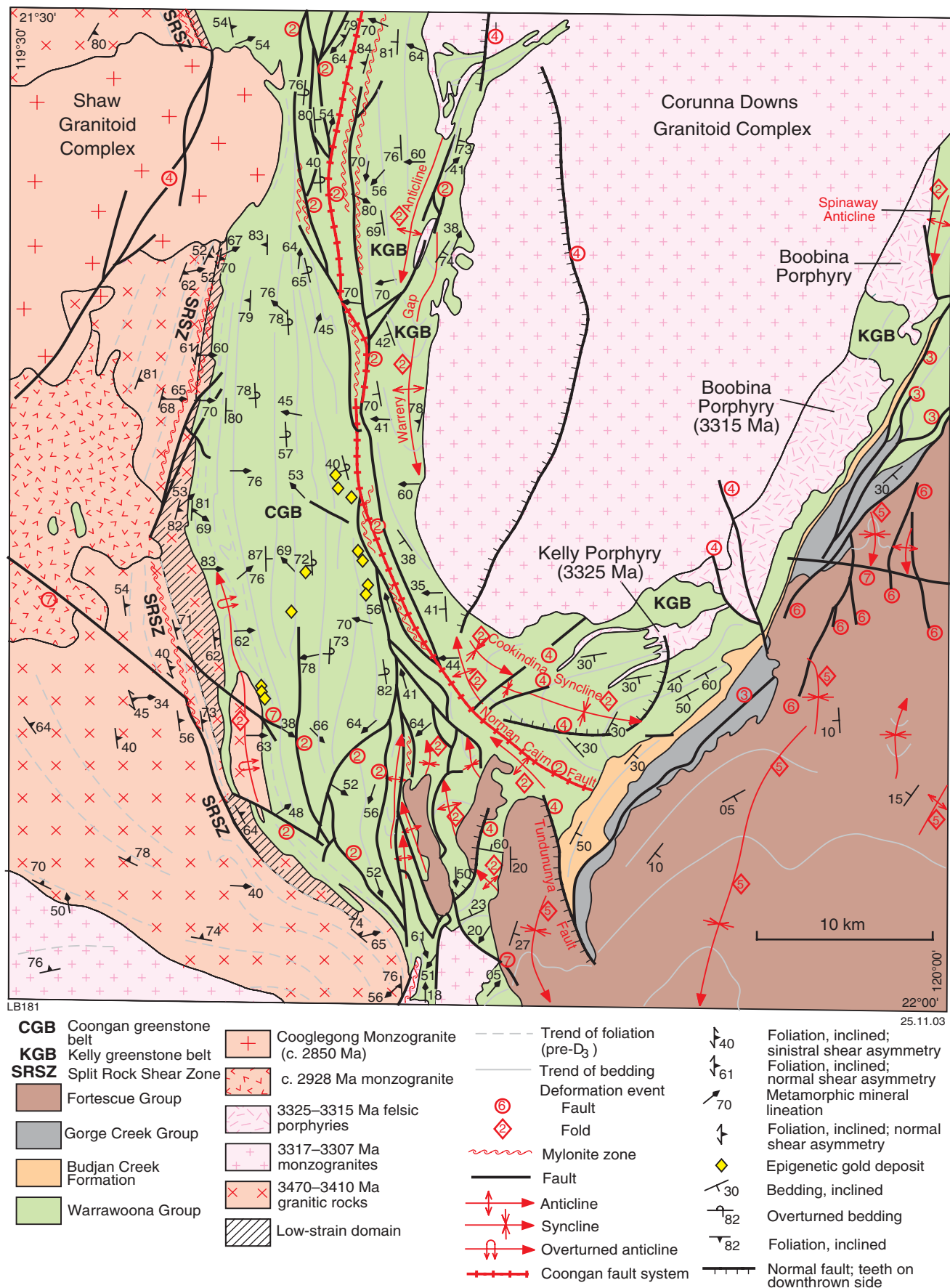


Figure 3. Simplified structural geological map of SPLIT ROCK

Table 2. Summary of the major geological events on SPLIT ROCK

Age range (Ma)	Geological events
c. 3490–3420	Deposition of the Talga Talga and Salgash Subgroups of the Warrawoona Group in the Coongan and Kelly greenstone belts
c. 3490–3410	Emplacement of early components of the Shaw and Corunna Downs Granitoid Complexes and D ₁ deformation
c. 3420–3319	Deposition of the Kelly Subgroup of the Warrawoona Group in the Coongan and Kelly greenstone belts
c. 3317–3300	Major doming (D ₂) during emplacement of the Corunna Downs Granitoid Complex and Bamboo Springs Monzogranite of the Shaw Granitoid Complex, accompanied by folding and faulting of the Warrawoona Group and shearing in the Split Rock Shear Zone
c. 3308	Deposition of the Budjan Creek Formation after D ₂ deformation
c. 3240–2950	Deposition of the Gorge Creek Group
c. 2940–2930	Renewed doming (D ₃) of the granitic complexes, and greenschist-facies shear reactivation of greenstones
c. 2850	Post-tectonic intrusion of the Cooglegong Monzogranite, and associated tin–tantalum–lithium mineralization
c. 2772	Deposition of the Mount Roe Basalt and intrusion of dolerite dykes
c. 2770–2756	Faulting (D ₄) of the Mount Roe Basalt and Hardey Formation before deposition of the Tumbiana Formation during west-directed lithospheric extension; (?)Au mineralization
<2719	Early folding and faulting (D ₅) of the Fortescue Group after deposition of the Tumbiana Formation, contemporaneous with continued doming of the granitic complexes
<2719	Late (D ₆), southeast-side-down normal faults
?Proterozoic	Brittle faulting (D ₇), mylonite development, and quartz veining associated with east-southeasterly striking dolerite dyke (<i>d</i> , <i>Edw</i>) emplacement

McPhee Formation, and Mount Ada Basalt, and the felsic volcanic rocks of the Duffer Formation (Table 1; interpreted bedrock geology figure on map).

North Star Basalt (*AWNba*, *AWNb*, *AWbk*, *AWnc*, *AWNbc*)

The North Star Basalt (Hickman, 1977) is in contact with the eastern margin of the Shaw Granitoid Complex and is the stratigraphically lowest preserved formation in the Coongan greenstone belt. The granitic rocks intrude the greenstones, and both granites and greenstones have been affected by later shearing. At the contact, rocks of the North Star Basalt include foliated and medium-grained amphibolite after basalt (*AWNba*). These rocks commonly weather to a dark-brown colour and are speckled black and white on fresh surfaces, reflecting the effects of medium-grade metamorphism on originally tholeiitic rocks. Layers 20 to 50 m thick interbedded with the metatholeiite are composed of chlorite–tremolite schist and talc–carbonate rock, representing magnesium-rich precursors. Original volcanic textures are not preserved in these rocks.

At a distance of about 2 km from the granite contact, the grade of metamorphism decreases to greenschist facies and original volcanic textures are locally preserved, including pillow structures and varioles (*AWNb*). The metabasalt is composed of actinolite, chlorite, epidote, plagioclase, and opaque minerals, with or without carbonate and quartz. Subordinate magnesium-rich layers are interlayered with the tholeiitic rocks, but at too small a scale to show on the map. About 9.5 km east of Pinnacle Well, in the stratigraphically middle part of the formation, is a lens-shaped unit derived from altered metakomatiitic basalt (*AWNbk*) that includes carbonate–tremolite–chlorite schist and talc–carbonate rock.

The top of the formation, for 18 km along strike, is marked by a layer of white and brown layered chert, granular and banded iron-formation, and quartz sandstone

(*AWnc*), which varies from a few metres to 150 m in thickness. Where thickest, the chert is composed of two closely spaced horizons separated by mafic schist. The chert includes delicately layered white and brown chert, layered grey and brown chert, and quartz sandstone with hematitic layers. Another thin chert unit which can be traced continuously for 13 km along strike, largely at the top of the metamorphosed komatiitic basalt lens described above, is also composed of layered black and white chert with intervals of quartz-rich sandstone. Some of these chert units are regarded as having been deposited hydrothermally (Van Kranendonk, 2003).

Immediately beneath the main chert at the top of the unit, basaltic rocks of the North Star Basalt have been extensively affected by hydrothermal alteration during chert deposition, resulting in the development of carbonate-altered metabasalt (*AWNbc*) over a thickness of up to 600 m.

McPhee Formation (*AWhb*, *AWhbc*, *AWhbk*, *AWhc*)

The McPhee Formation (Hickman, 1977) outcrops in the western half of the Coongan greenstone belt on SPLIT ROCK, and is about 1 km thick. The formation is conformably underlain by the North Star Basalt, and conformably overlain by the Mount Ada Basalt. A phase of the c. 2850 Ma Cooglegong Monzogranite of the Shaw Granitoid Complex (*AgScge*) locally intrudes the lower part of the formation. Nelson (1999) obtained a U–Pb SHRIMP (sensitive high-resolution ion microprobe) age of 3477 ± 2 Ma from a thin unit of felsic tuff (GSWA 148498) in the McPhee Formation on MARBLE BAR.

Rock types on SPLIT ROCK include metamorphosed fine- to medium-grained, pillowed (locally variolitic) to massive basalt and minor mafic tuff (*AWhb*); carbonate-altered, chloritic basalt and associated schist (*AWhbc*); and

medium- to coarse-grained carbonate–tremolite–chlorite schist and talc–carbonate(–chlorite) rocks (*AWhbk*), with locally preserved pyroxene–spinifex textures indicating derivation from altered and metamorphosed komatiitic basalt.

Grey and white layered chert beds and pale-green chert (*AWhc*) outcrop between basalt units and at the top of the formation. In the far southernmost part of the Coongan greenstone belt (MGA 775500E 7573400N to 780300E 7567500N), white and brown layered chert has sucrosic textures possibly reflecting recrystallization during contact metamorphism induced by intrusion of granites in the Shaw Granitoid Complex. Local massive white quartzite beneath the chert may be metamorphosed quartz sandstone or metamorphosed massive white chert.

Mount Ada Basalt (*Awmb*, *Awmbh*, *Awmbm*, *Awmc*)

The Mount Ada Basalt (Hickman, 1977) is a massive unit of metamorphosed, commonly pillowed tholeiitic basalt (*Awmb*), between 1 and 1.5 km thick, which outcrops in the western half of the Coongan greenstone belt. Over most of the map area the formation conformably overlies the McPhee Formation and is conformably overlain by the Duffer Formation. In places, the c. 2850 Ma Cooglegong Monzogranite of the Shaw Granitoid Complex intrudes the lower part of the Mount Ada Basalt, with the metamorphic grade reaching the hornblende–hornfels facies. Locally, the compositions of tholeiitic metabasalt (*Awmbh*) and high-Mg metabasalt (*Awmbm*) have been interpreted based on differences in weathering colour, mineralogy, and geochemistry of the units (Glikson et al., 1986). Interbedded with the basaltic rocks, and separating tholeiitic from high-Mg flow units, are thin horizons of undivided chert (*Awmc*), commonly with black and white or grey and white layering, but also containing green massive chert that is interpreted to represent silicified basalt and ultramafic rock.

Duffer Formation (*AWd*, *AWdr*, *AWdp*, *AWdpb*)

The Duffer Formation (*AWd*; Lipple, 1975) is composed of metamorphosed felsic volcanic and volcanoclastic rocks that on SPLIT ROCK outcrop in the western half of the Coongan greenstone belt. The formation conformably overlies the Mount Ada Basalt and includes units of metamorphosed massive rhyolite, which are dominantly intrusive sills, but possibly partly extrusive (*AWdr*), in the lower levels of the formation. The formation is conformably overlain by chert of the Towers Formation along most of its strike length, but is locally overlain by younger rocks of the Apex Basalt (e.g. MGA 773600E 7592000N), Panorama Formation (MGA 774200E 7607000N), and Euro Basalt (MGA 774000E 7594000N). The Duffer Formation reaches a maximum thickness of 1 km near the northern edge of the map sheet and thins dramatically over a distance of 5 km to the south, where it becomes tectonically thinned and excised by regional shearing and faults related to intrusion of the c. 2850 Ma Cooglegong Monzogranite. South of the Cooglegong Monzogranite exposures, the formation forms a 28 km-

long lens-shaped unit, which is terminated by faults (at MGA 773400E 7584000N).

The bulk of the Duffer Formation on SPLIT ROCK consists of felsic schist and minor metamorphosed sedimentary and volcanoclastic rocks (*AWd*), with local agglomeratic and tuffaceous textures, including relict *fiamme*. Some parts of the unit also contain quartz or feldspar phenocrysts (or both), and small black chert clasts. Most of the unit is interpreted to be dacitic to rhyolitic. One precise U–Pb SHRIMP age determination of 3464 ± 3 Ma was obtained on zircon from a unit of medium-grained quartz–sericite schist on the south bank of Withnell Creek (GSWA 169008; Nelson, 2002).

Well-preserved volcanoclastic rocks, including volcanic tuff and volcanoclastic sandstone with chert and rhyolite fragments, are preserved along a 10.5 km-long strike section in the Coongan greenstone belt (*AWd*; from MGA 7607500N to 7597000N). Farther south (MGA 773200E 7589500N), a unit of homogeneous felsic (quartz–sericite) schist is overlain by 400 m of rhyolite (*AWdr*) including muscovite-rich schist, porcellanite, quartz–porphyritic volcanic rocks, and fine-grained ash tuffs near the stratigraphic top of the Duffer Formation. The Duffer Formation reaches a maximum thickness of about 1 km in the middle of the map area.

About 3 km west-northwest of Corboy Cairn (near MGA 773300E 7595000N), a thick suite of metamorphosed synvolcanic rhyodacitic sills consists of quartz–porphyritic quartz–sericite rock (*AWdp*). This unit also intrudes rocks beneath the Duffer Formation in the southern two-thirds of the Coongan greenstone belt (south of MGA 771500E 7601600N) and is thickest where the extrusive rocks of the Duffer Formation are also the thickest (MGA 773000E 7595000N). Narrow sheeted dacite sills with numerous interlayers of amphibolite have been mapped as a separate unit (*AWdpb*).

Towers Formation (*AWtc*, *AWti*)

The Towers Formation (Hickman, 1977) consists of chemical sedimentary rocks interbedded with basaltic rocks, and represents a depositional break between extrusion of felsic rocks of the Duffer Formation of the Talga Talga Subgroup and basaltic rocks of the overlying Apex Basalt of the Salgash Subgroup (Van Kranendonk et al., 2002).

Chert units of the Towers Formation conformably overlie felsic volcanic rocks of the Duffer Formation along three segments in the western half of the Coongan greenstone belt (see the interpreted bedrock geology figure on map). In the north, the Duffer Formation is capped by a thin unit (<10 m) of grey and white layered chert (*AWtc*) that contains interlayers of felsic ash tuff (e.g. MGA 774900E 7619000N). Farther south, the Towers Formation includes a thin unit of layered grey and white chert (silicified tuff) immediately on top of felsic volcanoclastic rocks of the Duffer Formation (e.g. MGA 773900E 7606000N). The formation thickens to the south, reaching a maximum of 150 m (MGA 774000E 7598600N) closest to the interpreted felsic extrusive centre of the underlying

Duffer Formation. Along this section the formation is dominated locally by units of brown and red, thinly bedded, banded, low-grade iron-formation (*AWti*) that are interbedded with minor felsic tuff and sandstone. Farther south (MGA 773700E 7588000N), up to 150 m of layered grey-blue and white chert (*AWtc*) caps the Duffer Formation.

Salgash Subgroup

The Salgash Subgroup consists of the Apex Basalt, Panorama Formation, and Strelley Pool Chert (see the interpreted bedrock geology figure on map).

Apex Basalt (*Awabs*, *Awabh*, *Awastq*)

The Apex Basalt (Hickman, 1977) is exposed between the Duffer and Panorama Formations in the Coongan greenstone belt and north of Warrery Gap in the northern part of the sheet. The lower part of the Apex Basalt at Warrery Gap is discordantly intruded and metamorphosed to hornblende-hornfels or amphibolite facies by the Corunna Downs Granitoid Complex, but elsewhere the formation is affected by lower greenschist-facies regional metamorphism.

The Apex Basalt in the Coongan greenstone belt is typically poorly exposed and consists mainly of strongly sheared chloritic schist (*Awabs*) forming low-lying drainage valleys in between higher flanking ridges of felsic volcanic rocks and chert. North of Warrery Gap, rare pillow structures in metamorphosed amphibolite-facies tholeiitic basalt interlayered with minor dolerite (*Awabh*) have been identified. Within these rocks are thin chert beds (not defined on the map) and 10 m-thick units of thick-bedded metamorphosed quartz sandstone (*Awastq*).

Panorama Formation (*Awpt*, *Awpa*, *Awpstq*, *Awps*, *Awpc*)

The Panorama Formation (Lipple, 1975) consists of felsic volcanoclastic rocks, with subordinate felsic lavas and chert. The formation outcrops in the Kelly greenstone belt at the northeastern boundary of SPLIT ROCK where it is intruded by the Corunna Downs Granitoid Complex. On the western margin of the Corunna Downs Granitoid Complex, it is folded around the Warrery Gap Anticline (Fig. 3) and intruded by granitic rocks. It also outcrops in the western half of the Coongan greenstone belt.

A sample of dark-grey, fine- and even-grained rhyolite with quartz phenocrysts within a kilometre-thick unit of agglomerate from the core of the Warrery Gap Anticline (GSA 168915) has a SHRIMP U–Pb zircon age of 3432 ± 2 Ma (Nelson, 2001). This is within error of a SHRIMP U–Pb zircon age of 3430 ± 4 Ma (GSA 160221; Nelson, 2002) for rhyolite from the Panorama Formation in the Coongan greenstone belt just north of SPLIT ROCK on MARBLE BAR. These ages are similar to the 3433 ± 2 Ma age obtained by Nelson (2000) on a rhyolite (GSA 148502) from the Panorama Formation in the Kelly greenstone belt east of the Corunna Downs Granitoid Complex on NULLAGINE.

The Panorama Formation on SPLIT ROCK is largely composed of weakly metamorphosed fine-grained felsic tuff and minor felsic agglomerate (*Awpt*), and weakly metamorphosed felsic agglomerate and minor tuff (*Awpa*; Fig. 4a). Tuffaceous rocks in both these units are cross-bedded in places, and include volcanoclastic sandstone and conglomerate, and thinly bedded pumiceous deposits. Felsic tuff and minor felsic agglomerate (*Awpt*) in the northeastern part of the Kelly greenstone belt and in the Coongan greenstone belt commonly have lithic fragments of dacite and rhyolite (Fig. 4b). The tuff is locally silicified, and consists of plagioclase, quartz, biotite, hornblende, epidote, and chlorite, with minor K-feldspar, secondary sericite, and carbonate, and accessory titanite and apatite. The proportion of interbedded agglomerate increases along strike farther northeast on NULLAGINE (Bagas, in prep.). Felsic agglomerate and minor tuff (*Awpa*) outcrops at Warrery Gap (MGA 780600E 7612000N), with subangular fragments of dacite up to 150 mm in size. Elsewhere, the agglomerate is finer grained and composed of subrounded fragments of dacite

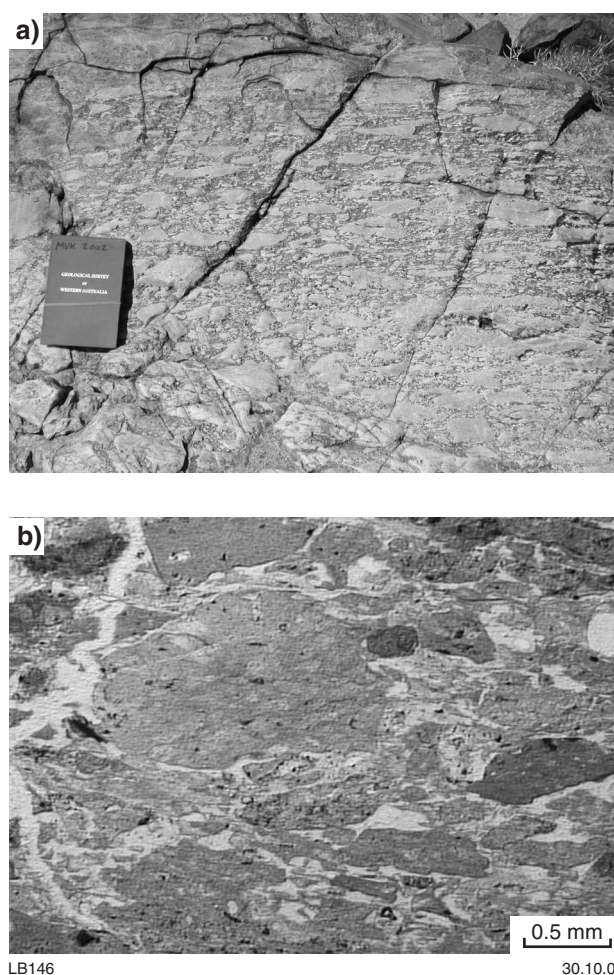


Figure 4. The Panorama Formation: a) Foliated felsic agglomerate (*Awpa*) from the Panorama Formation in the core of the Warrery Gap Anticline (MGA 783000E 7613000N); b) Felsic tuff (*Awpt*) of the Panorama Formation with dacite (dark) and rhyolite (light) clasts, western part of the Coongan greenstone belt; plane-polarized light

and rhyolite. Interbedded with and grading into the agglomerate are weakly bedded quartz sandstone (*AWpstq*) and volcanoclastic rocks. The sandstone is composed of 90% rounded grains of clear volcanic quartz, derived from erosion of felsic volcanic rocks.

The Panorama Formation in the western part of the Coongan greenstone belt is composed dominantly of locally medium grained and poorly bedded felsic volcanoclastic sandstone and conglomerate, and minor felsic schist (*AWps*). These are commonly characterized by fragments of chert, mainly blue-black in colour, but including layered green chert, pale grey-blue chert, and rare jasper. A unit of layered grey-blue and white chert and minor massive cream chert (*AWpc*) is near the base of the formation in one locality (MGA 773400E 7584500N).

Strelley Pool Chert (*AWs*, *AWsch*, *AWsa*)

The Strelley Pool Chert (*AWs*; Lowe, 1983; Van Kranendonk and Morant, 1998) is recognized across the EPGGT as a discontinuous unit of chert, sandstone, conglomerate, and minor felsic ash that is up to 30 m thick (Van Kranendonk et al., 2001b). On NORTH SHAW and NULLAGINE the chert commonly has pseudomorphs after evaporites and well-developed wavy to domical laminates with local conical stromatolites (Van Kranendonk, 2000; Van Kranendonk et al., 2001b; Bagas, in prep.). The base of the formation on SPLIT ROCK shows evidence of an irregular topography and erosion of the underlying Panorama Formation, resulting in pinching and swelling of the Strelley Pool Chert in both the Coongan and Kelly greenstone belts, and in the local absence of the Strelley Pool Chert.

The Strelley Pool Chert in the northern parts of the Coongan and Kelly greenstone belts is lithologically highly variable along strike. In the Coongan greenstone belt, the typical white, grey, and blue-black layered chert with local fine wavy laminae and stromatolites (*AWs*) passes laterally into massive black chert with a fine network of white chert veins (MGA 775200E 7616300N). Farther south (MGA 774000E 7606000N), grey and white layered chert overlies thin, short (<5 m wide by 200 m long) veins of massive to brecciated black chert (*AWsch*; MGA 774400E 7601700N) that are interpreted to be feeder veins. White, grey, and blue-black layered chert (*AWs*), with local interbeds of sandstone, overlies the Panorama Formation in the southern part of the Coongan greenstone belt (MGA 775000E 7575000N) and 3 km west of Warrery Gap (near MGA 780500E 7613000N), where the unit is between 1 and 15 m thick.

South of the eruptive vent in the Duffer Formation (MGA 741000E 7591000N to 741000E 7588000N), the Strelley Pool Chert has a distinctive composition of layered creamy white and grey chert (*AWsa*) that has a faint granular texture and is interpreted as a silicified felsic tuff. In this unit the layering is irregular and planar to wavy, with local faintly visible, low-angle cross-stratification defined by undulate, 1–12 mm-thick grey layers.

Sucrosic textures are preserved in a lens of hornfelsed Strelley Pool Chert in contact with the Boobina Porphyry

in the northeastern part of the Kelly greenstone belt (MGA 809800E 7610000N). Farther northeast along strike on NULLAGINE, the unit grades into white and grey layered chert with millimetre-scale wavy laminates and rarely preserved stromatolites.

Kelly Subgroup

Deposition of the Strelley Pool Chert is interpreted as coinciding with a hiatus in volcanism across most of the EPGGT (Van Kranendonk et al., 2002). Volcanism resumed with deposition of komatiite, komatiitic basalt, basalt, and felsic volcanic rocks of the Euro Basalt (Hickman, 1977; Van Kranendonk, 2000). The precise time at which this volcanism resumed is unknown, but may have been c. 3420–3410 Ma, when a significant episode of metal deposition (Thorpe et al., 1992b) and zircon overgrowths (Zegers, 1996) is recorded across the EPGGT. The duration of volcanism in the Euro Basalt is constrained by ages of 3350 ± 3 Ma (Nelson, 2003) at the base, and 3325 ± 2 Ma (Nelson, 2002) at the top.

The inclusion of the Wyman Formation in the Warrawoona Group has been a problem since the 1970s (Hickman, 1983, p. 96). On the sole basis of aerial photo interpretation, Hickman (1980) suggested that the Wyman Formation unconformably overlies the Euro Basalt on SPLIT ROCK and thus should be excluded from the group. The current mapping shows that the Wyman Formation conformably overlies the Euro Basalt on SPLIT ROCK across a transitional zone of interbedded mafic and felsic volcanic rocks that is less than 100 m thick (e.g. MGA 791500E 7580900N), and data from elsewhere in the east Pilbara show that the Euro Basalt is overlain by more basaltic rocks, and thus the Wyman Formation has been included within the Kelly Subgroup of the Warrawoona Group.

Euro Basalt (*Aweuc*, *Awebk*, *Awebh*, *Awebm*, *Awed*, *Awebc*, *Awebms*, *Awebs*, *Awec*, *Awebhx*, *Aweft*, *Awecp*, *Awech*, *Awebn*, *Aweskc*)

The Euro Basalt (Hickman, 1977) is the dominant stratigraphic unit in the greenstone belts across SPLIT ROCK. It conformably overlies the Strelley Pool Chert and is either conformably overlain by the 3325–3319 Ma Wyman Formation (e.g. MGA 791500E 7581000N), unconformably overlain by the c. 3308 Ma Budjan Creek Formation (MGA 790800E 7578000N), intruded by younger granitic rocks of the Corunna Downs Granitoid Complex (between MGA 786000E 7617000N and 799000E 7586000N), or in faulted contact with ultramafic intrusive rocks (along the eastern margin of the Coongan greenstone belt).

The Euro Basalt reaches a maximum stratigraphic thickness of 5 km in the central part of the Coongan greenstone belt (MGA 777000E 7584000N), where it is exceptionally well preserved. South of the Kellys copper mine, east of the Corunna Downs Granitoid Complex, the formation is less than 4 km thick, but this is a minimum thickness as the top of the formation is faulted out in places and the base of the formation is intruded by the Corunna Downs Granitoid Complex.

The base of the Euro Basalt is characteristically composed of carbonate-altered ultramafic rock that is probably after komatiite (*AWeuc*) and komatiitic basalt (*AWebk*). The basal carbonate-altered ultramafic unit in the Coongan greenstone belt is up to 500 m thick (MGA 774500E 7590500N) or up to 800 m thick where interbedded with high-Mg basalt (MGA 780100E 7615500N). The high-Mg character of some of the flows is corroborated by pyroxene-spinifex textures (e.g. MGA 783000E 7587000N) and by geochemical analyses that indicate 10–15% MgO (Glikson et al., 1986; Arndt et al., 2001).

The bulk of the Euro Basalt consists of tholeiitic basalt (*AWebh*, Fig. 5), with minor massive high-Mg basalt that is interbedded with massive, ocellar, and locally vesicular high-Mg basalt with minor tholeiitic basalt (*AWebm*). Pillow structures are common in these rocks and in general face away from the granitic complexes, consistently younging eastward on the western limb of the Coongan Syncline (Coongan greenstone belt), westward on the eastern limb of the Coongan Syncline (Kelley greenstone belt), and to the south around the southern margin of the Corunna Downs Granitoid Complex.

Tholeiitic basalt (*AWebh*) is fine grained, commonly pillowed, and variably amygdaloidal, with amygdaloids containing quartz, chalcedony, or carbonate. Pillows have chilled margins, vesicular rims, concentric cooling cracks, intrapillow hyaloclastite breccia, pillow tails, and pillow breccia. The basalt consists of a recrystallized assemblage of actinolite, plagioclase (variably sericitized), and quartz with minor chlorite, epidote, and carbonate. Interbedded with the pillowed rocks are massive basalt, columnar-jointed basalt (in places), and rare sills and dykes of dolerite.

High-Mg basalt (*AWebm*) commonly has ocelli texture and consists of tremolitic amphibole, albite, chlorite, epidote, microcrystalline titanite, sparsely disseminated pyroxene altered to chlorite and epidote, and relics of olivine. The relics of olivine are less than 1 mm in diameter and serpentinized, and contain inclusions of magnetite. Large plagioclase laths up to 1.5 mm long are



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Figure 5. Steeply dipping pillowed tholeiitic Euro Basalt (*AWebh*) from the northeastern part of SPLIT ROCK (MGA 708600E 7597150N)

altered to clinozoisite with minor albite. Komatiitic basalt (*AWebk*) has pyroxene-spinifex texture composed of skeletal pyroxene rods up to 40 mm long, and scattered augite phenocrysts (about 1 mm long) in a fine-grained intergrowth of fibrous amphibole, chlorite, epidote, serpentine, and carbonate (calcite and dolomite). These mineral assemblages reflect metamorphism at greenschist facies.

A set of northwesterly trending, medium-grained, metamorphosed tholeiitic dolerite and local gabbro dykes (*AWed*) that cut through the Panorama Formation in the Coongan greenstone belt (e.g. around MGA 780500E 7613500N) and stop in the Euro Basalt are interpreted as feeder dykes for the Euro Basalt.

Other mafic rocks of the formation are schists derived from volcanic protoliths, including intensely carbonate-altered and metamorphosed pillowed basalt with local chlorite–carbonate schist (*AWebc*), chlorite–tremolite schist derived from high-Mg basalt (*AWebms*), and strongly sheared mafic schist after tholeiitic basalt (*AWebss*) that consists of chlorite–epidote–albite–quartz–carbonate.

Several units of chert are distributed throughout the Euro Basalt, including thinly layered white, grey, and blue-black chert, and local massive blue-grey chert (*AWec*) that replaced fine-grained basaltic protoliths. The upper part of the Euro Basalt in the northeastern part of the Kelly greenstone belt also contains thinly bedded and locally massive chert (*AWec*), tholeiitic tuff (*AWebhx*), fine- to medium-grained, thin-bedded felsic tuff locally interbedded with grey and white chert from silicified ash (*AWeft*), and chert interbedded with silicified pelite and ashfall tuff (*AWecp*). A sample of silicified ashfall tuff from about 1.5 km west of the Copper Hills mining centre (MGA 806750E 7602550N; GSWA 168909; Nelson, 2001) contains zircon populations at 3363 ± 6 Ma (2 of 22 zircons), 3346 ± 6 Ma (14 of 22 zircons), and 3311 ± 9 Ma (6 of 22 zircons). The largest zircon population at c. 3346 Ma has igneous textures and this is interpreted as the depositional age of the tuff, whereas the slightly older population at c. 3363 Ma is interpreted to represent inherited xenocrysts. The age of the youngest zircon population is within error of the age for the Boobina Porphyry (*AgObo*), which outcrops about 500 m to the south, and is interpreted as the age of an overgrowth event associated with the porphyry intrusion. A sample of quartzite from a thick unit of variably silicified tuff, volcanoclastic sandstone, and quartzite (*AWeft*) within the middle of the formation at the southwestern contact of the Corunna Downs Granitoid Complex (GSWA 168999; MGA 781900E 7588100N), yielded a maximum age of deposition of 3335 ± 7 Ma (Nelson, in prep.).

Veins and dykes of hydrothermal black chert (*AWech*) crosscut the formation beneath their correlative bedded chert units and locally fill steeply dipping fault zones. Basaltic host rocks surrounding these veins, and underlying the contemporaneous bedded chert, are locally affected by intense hydrothermal alteration and have been transformed into quartz–sericite schist (*AWebn*).

A unit of cyclic couplets of interbedded carbonate rock and chert (*AWeskc*) outcrops 2.5 km south of Norman

Cairn (MGA 778500E 7586000N). Carbonate beds are up to 1 m thick, and grade up into quartzite beds (0.2 – 0.3 m thick) that have sharp top (eastern) contacts with the next carbonate bed. Carbonates display crude bedding at centimetre scale, and some quartzite units show centimetre-scale graded bedding. Bedding features become more prominent higher up in the unit, with some carbonate units containing cross-bedding. Thin sections indicate that these rocks are dominantly hydrothermal in origin. Carbonates are composed of millimetre-sized, euhedral to subhedral dark-brown carbonate rhombs (?siderite) in a fine matrix of green chlorite and minor chert. The carbonate rhombs display delicate growth zoning on their outer margins (Fig. 6a) and contain coarse radiating fan-shaped crystals in the centres of the rhombs that radiate out from a central nucleus (Fig. 6b). The quartzite members of the cyclical couplets contain an apparent clastic texture in thin section (Fig. 6c), but individual ‘grains’ are elongate prismatic crystals with radiating extinction (Fig. 6d), indicating that these crystals grew in situ within a fine-grained cherty matrix. The quartz crystals can form clumps that grew out from a single nucleating point (Fig. 6e), and the matrix of the quartzite has a distinctive petal-like texture of clots of radiating small quartz crystals in a fine-grained quartz–chlorite matrix (Fig. 6f).

Wyman Formation (Awwa, Awwt, Awwp, Awws, Awwsh, Awwx, Awwci, Awwstq, Awwc, Awwch)

The c. 3325–3319 Ma felsic volcanic Wyman Formation (Hickman and Lipple, 1978; Lipple, 1975; Thorpe et al., 1992a; McNaughton et al., 1993) on SPLIT ROCK is up to 1 km thick and conformably overlies the Euro Basalt across a transitional zone of interbedded mafic and felsic volcanic rocks that is less than 100 m thick and too small to show at the map scale (e.g. MGA 791500E 7581000N). The formation is unconformably overlain by the c. 3308 Ma Budjan Creek Formation (*Arsc*; MGA 808000E 7599500N) and is intruded by the c. 3315 Ma Boobina Porphyry (*AgObo*; MGA 806000E 7597000N). The Wyman Formation has a conventional zircon age of 3325 ± 4 Ma (Thorpe et al., 1992a), and SHRIMP U–Pb zircon ages of 3323 ± 3 Ma (GSWA 168910; Nelson, 2001), and 3319 ± 6 Ma (GSWA 169000; Nelson, 2002). These ages are within error of the 3324 ± 4 Ma U–Pb zircon SHRIMP age obtained from felsic rocks of the informally named Kelly porphyry that intrude the Euro Basalt (McNaughton et al., 1993). This supports the interpretation of synchronous volcanism and subvolcanic intrusions in the Kelly greenstone belt, and magmatism in the Corunna Downs Granitoid Complex. Buick et al. (2002) reported a 3315 ± 3 Ma age for an intrusive or extrusive porphyry in a similar stratigraphic position in the Warrawoona Syncline north of the Corunna Downs Granitoid Complex on MARBLE BAR.

The Wyman Formation is dominated by felsic agglomerate and minor tuff (*Awwa*; Fig. 7a) that contains fine-grained angular porphyritic rhyolite and rhyodacitic fragments, up to 0.5 m in diameter, in a recrystallized fine-grained matrix of actinolite–chlorite–epidote–quartz. Felsic tuff in the northern part of the Kelly greenstone belt

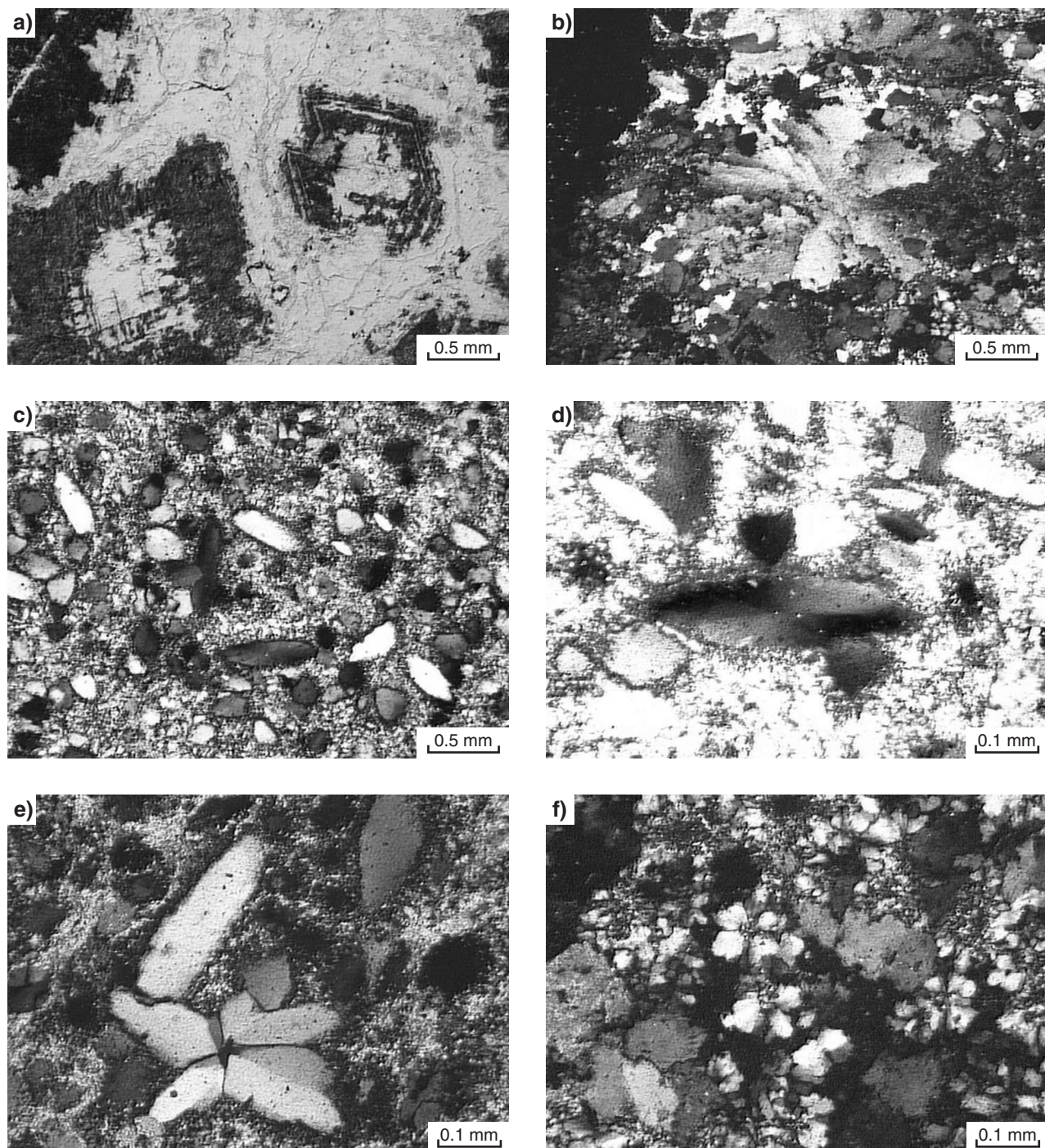
(*Awwt*; MGA 810000E 7603200N) contains interbeds of agglomerate with thin layers of sandstone.

Porphyritic rhyolitic lava units of the Wyman Formation (within *Awwt*) are typically massive, but with columnar joints in places (e.g. at Budjan Creek, MGA 796000E 7582300N, Fig. 7b). The columnar joints are up to 200 mm across and up to 20 m in length. The lava units are commonly porphyritic, with quartz and plagioclase phenocrysts up to 1 mm long in a fine quartzofeldspathic groundmass, and are difficult to distinguish from the intrusive Boobina Porphyry where they are silicified and sericitized. Plagioclase phenocrysts in the lava are replaced by sericite, albite, and quartz, and the groundmass contains the assemblage sericite–quartz–albite–epidote–chlorite–leucoxene, and lamellar leucoxene-rich pseudomorphs of probable biotite flakes (up to 0.5 mm long). These mineral assemblages are indicative of regional metamorphism at greenschist facies. Felsic tuff includes cross-bedded tuff, very fine grained porcellanite, and fine-grained cherty tuff, which contain shards of clear crystalline quartz and devitrified felsic glass. Geochemistry (Glikson and Hickman, 1981; Glikson et al., 1986) indicates that most of the rhyolite is ultrapotassic, and derived by partial melting of sialic crust (Hickman, 1983) or possibly mafic crust (Glikson et al., 1987).

The Wyman Formation in the Coongan greenstone belt in the northern part of the sheet area is commonly represented by bedding-parallel sheets of rhyodacitic porphyry with phenocrysts of quartz, plagioclase, and local hornblende (*Awwp*) and felsic schist (*Awws*) of undetermined intrusive or extrusive origin. A 1 to 2 m-thick unit of felsic tuff (*Awwt* at MGA 776250E 7614500N) outcrops immediately beneath finely bedded red, greenish-grey, and cream-coloured shale (*Awwsh*), and contains clasts up to 2 mm across of clear volcanic quartz, chert, and fine-grained rhyolite (Fig. 7c).

The Wyman Formation in the southern part of the Coongan greenstone belt is dominated by volcanoclastic rocks, including thinly bedded, fissile, grey- to cream-coloured shale, and fine- to medium-grained felsic tuff (*Awwt*). Underlying these rocks locally is a red and green shale (*Awwsh*). Also common are subvolcanic intrusions including massive quartz porphyry (*Awwp*) and non-bedded porphyry containing plagioclase phenocrysts and rounded xenolithic fragments (up to 0.3 m in size) of porphyry, vesicular rhyolite, and grey-green chert (*Awwx*). In this area, shale (*Awwsh*) and finely layered red and black banded iron-formation (*Awwci*) are interpreted to belong to the Wyman Formation because these rocks are unconformably overlain by the Budjan Creek Formation and the Gorge Creek Group farther south.

Rhyodacitic porphyry (*Awwp*), previously referred to as the ‘Kelly Formation’ (Lipple, 1975; Hickman and Lipple, 1978), intrudes the Apex Basalt west of the Kellys copper mine, and has been dated at 3324 ± 4 Ma (McNaughton et al., 1993). The porphyry contains phenocrysts of quartz, plagioclase, and hornblende in a quartzofeldspathic groundmass. Also present is a porphyritic microgranite with plagioclase phenocrysts in a groundmass of K-feldspar, biotite, and hornblende. The



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Figure 6. Textural features of the carbonate–chert couplets (*Aweskc*) in the Euro Basalt, indicating a hydrothermal origin for this unit:

- a) carbonate rhombs surrounded by chert, which have finely zoned outer margins; plane-polarized light;
- b) coarse radiating carbonate crystals (centre) in the core of a carbonate rhomb surrounded by granular chert; cross-polarized light;
- c) pseudoclastic texture of a chert layer, defined by randomly oriented elongate crystals of quartz in a fine-grained chert matrix; cross-polarized light;
- d) single quartz crystal in the chert layer. Note the radiating fibrous extinction pattern in the crystal, here seen perpendicular to the C-axis; cross-polarized light;
- e) chert layer with radiating quartz crystals from a central nucleus; cross-polarized light;
- f) petal-like quartz crystallization texture in a chert layer; cross-polarized light

porphyry was previously interpreted as an extrusive unit in places (Hickman and Lipple, 1978; McNaughton et al., 1993), but clearly intrudes the Euro Basalt in the Kelly greenstone belt, crosscutting basalt and chert horizons of that formation (e.g. MGA 793000E 7584500N).

Quartz sandstone (*AWwstq*), which forms a 100 m-thick unit at the top of the formation near the eastern edge of the sheet area (e.g. MGA 808000E 7595750N), fines upward and includes silicified quartz-rich siltstone.

A unit of layered grey and white chert, with subordinate interbeds of felsic tuff and quartz-sericite schist (*AWwc*) forms a ridge along the main axial fault of the Coongan Syncline along the boundary between the Coongan and Kelley greenstone belts in the southern part of the sheet area (MGA 786000E 7578750N). This unit represents a fine-grained felsic volcanoclastic unit that has been partly silicified by fluids related to faulting. A vein of massive black chert (*AWwch*) that cuts through the Euro Basalt in the core of the Cookindina Syncline (MGA 790800E 7581000N) is interpreted as a hydrothermal vein associated with Wyman Formation felsic volcanism.

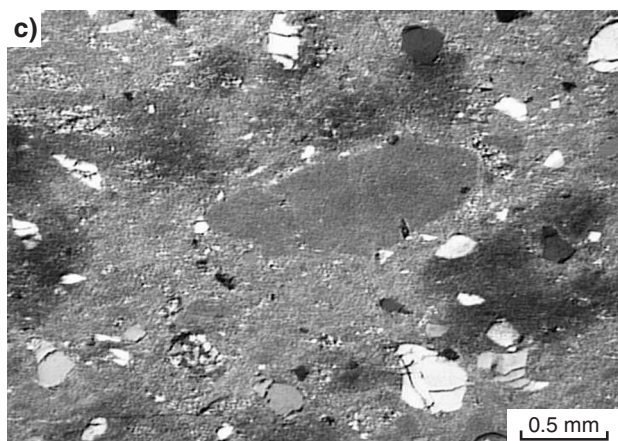
Unassigned metamorphosed basalt and high-Mg basalt

Strongly deformed and structurally isolated mafic rocks of uncertain stratigraphic position are exposed in several places on SPLIT ROCK.

Unassigned hornfels and medium- to coarse-grained amphibolite and amphibolite schist (*Aba*) form rafts in the central and northern parts of the Corunna Downs Granitoid Complex. The rafts consist of disseminated clinopyroxene, plagioclase locally replaced by clinozoisite and epidote, rare green to brown hornblende, and minor disseminated titanite. Chlorite-tremolite schist and talc-carbonate rock probably derived from komatiitic precursors (*Abm*) outcrops immediately north of the abandoned Kellys copper mine.

Budjan Creek Formation (*Arsc*, *Arsw*, *Arft*, *Arfa*)

The Budjan Creek Formation (Noldart and Wyatt, 1962; Lipple, 1975) unconformably overlies the Warrawoona



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Figure 7. Outcrop and petrographic features of the Wyman Formation: a) agglomerate (*Awwa*) with angular fragments of dacite about 100 mm across (MGA 810000E 7603200N); b) columnar-jointed rhyodacite (*Awwt*) in the Wyman Formation (MGA 796000E 7582300N); c) quartz-porphyrific felsic tuff (*Awwt*) from a 2 m-thick unit in the northern part of the western limb of the Coongan greenstone belt (MGA 776250E 7614550N); cross-polarized light

Group and is overlain by the Gorge Creek Group with a low-angle unconformity. The formation is an upward-fining succession of conglomerate interbedded with sandstone, siltstone, and shale (*Arsc*); lithic wacke interbedded with siltstone, conglomerate, felsic tuff, and volcanogenic sandstone (*Arsw*); felsic tuff locally interbedded with fine-grained quartzite (*Arft*); and rare felsic agglomerate (*Arfa*).

South of Kellys mine, the basal part of the Budjan Creek Formation is a 1.2 km-thick succession starting with a matrix-supported boulder conglomerate (Fig. 8) that fines upward into a pebble conglomerate interbedded with arkosic sandstone, siltstone, and shale (*Arsc*). The clasts in the conglomerate predominantly consist of vein-quartz and chert with rare felsic volcanic rocks, and are consistent with derivation from a local Warrawoona Group source. The arkosic composition of the sandstone is consistent with derivation from granitic rocks. Sandstone beds in the basal unit contain planar cross-beds and rare trough cross-beds that indicate palaeocurrents trending towards the south and southeast, which suggests that the source for the formation was the Warrawoona Group and possibly the Corunna Downs Granitoid Complex to the north.

The basal clastic unit is conformably and sharply overlain by an approximately 600 m-thick marker horizon, which extends north of the Copper Hills mine and consists of lithic wacke, siltstone, minor conglomerate, felsic tuff and fine-grained volcanogenic sandstone (*Arsw*). The stratigraphically highest units in the formation are felsic agglomerate (*Arfa*) and felsic tuff with minor fine-grained quartzite (*Arft*). The felsic agglomerate (MGA 705000E 7594000N) is bedded at metre scale, is highly silicified, and contains subangular and subrounded pebble-sized clasts of porphyritic dacite and massive rhyodacite in a rhyodacitic matrix.

A sample of crystal-lithic tuff (GSA 168908 collected from interbedded lithic wacke, siltstone, and minor conglomerate, felsic tuff and volcanogenic



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Figure 8. Matrix-supported cobble to pebble conglomerate (*Arsc*) from the base of the Budjan Creek Formation (MGA 791200E 7578400N). The boulder in the bottom right-hand corner of the photograph is about 0.5 m across



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Figure 9. Thinly bedded ferruginized siltstone and chert (*AG(ci)*) from the Gorge Creek Group in the eastern part of SPLIT ROCK (MGA 806700E 7595100N)

sandstone — *Arsw*), contained a main population of 16 zircons dated at 3308 ± 5 Ma, which was interpreted as the depositional age of the rock (Nelson, 2001). However, the sample also contained four concordant and younger zircons dated at 3228 ± 6 Ma, which Nelson (2001) suggested records an ancient radiogenic-lead loss. The sample is sericitized and recrystallized, with a groundmass consisting of quartz, sericite, chlorite, carbonate, and leucoxene, and 2 to 7 mm-wide sericitized clasts of coarse ash and lapilli of quartz–plagioclase porphyry. Angular and embayed quartz phenocrysts filled with quartz, sericite, and rare carbonate are common.

Gorge Creek Group (*AG(sc)*, *AG(ci)*, *AG(ck)*)

The Gorge Creek Group (Noldart and Wyatt, 1962; Ryan and Kriewaldt, 1964; Hickman and Lipple, 1978; Hickman, 1983) unconformably overlies the c. 3308 Ma Budjan Creek Formation on SPLIT ROCK, disconformably overlies the c. 3240 Ma Sulphur Springs Group on adjoining NORTH SHAW and TAMBOURAH (Van Kranendonk, 2000, 2003; Van Kranendonk and Morant, 1998), and is unconformably overlain by the c. 2770 Ma Mount Roe Basalt. Elsewhere, the group is unconformably overlain by the c. 2950 Ma De Grey Group (Van Kranendonk et al., 2002), and is therefore interpreted to be aged between c. 3240 and 2950 Ma.

The Gorge Creek Group on SPLIT ROCK is at least 750 m thick. In the Kelly greenstone belt, it consists of a lensoidal, upward-fining, clast- to matrix-supported, cobble to pebble conglomerate interbedded with sandstone, siltstone, and shale at the base of the group (*AG(sc)*); banded iron-formation interbedded with silicified and ferruginized siltstone and chert (*AG(ci)*, Fig. 9); and banded and ferruginous chert, black carbonaceous shale, and minor siltstone (*AG(ck)*). The basal conglomerate contains clasts of chert, felsic porphyry, and rare mafic volcanic rocks, which are identical to rocks in the underlying Warrawoona Group.

The contact between the Budjan Creek Formation and the Gorge Creek Group is a low-angle unconformity, and is best seen 6 km south of the Copper Hills mining area (around MGA 806000E 7595600N), 9 km south of Copper Hills (around MGA 804600E 7593600N), and south of Budjan Creek (around MGA 792200E 7577000N) where sedimentary and volcanogenic units in the Budjan Creek Formation are transgressed by conglomerate at the base of the Gorge Creek Group (*AG(sc)*).

Unassigned Archaean rocks

Ultramafic rocks (*Aup*, *Aupd*, *Aus*, *Auc*, *Aux*)

A variety of ultramafic rocks in the Coongan and Kelly greenstone belts on SPLIT ROCK cannot be stratigraphically correlated and are unassigned. Most of the serpentinized peridotites (*Aup*) and dunites (*Aupd*) probably belong to the intrusive c. 3000 Ma Dalton Suite (Van Kranendonk, 2000; Van Kranendonk et al., 2002). However, some of the serpentinized peridotite schists (*Aus*) in the core of the Coongan Syncline may represent high-Mg to komatiitic volcanic rocks, possibly related to the Sulphur Springs Group, as suggested by the presence of folded bedding and interbeds of chert (e.g. MGA 776400E 7606000N).

Serpentinized peridotite and serpentine–chlorite schist (*Aup*) outcrops along the core of the Coongan Syncline. Local, apparently conformable contacts with basaltic komatiite of the Euro Basalt (MGA 775600E 7606000N) suggest that some of the peridotite may form flows of this formation. Elsewhere, serpentinized peridotite-derived serpentine schist, and metadunite are interfingered with the Wyman Formation and Gorge Creek Group, indicating that they are younger intrusions that are tentatively correlated with the Daltons Suite on NORTH SHAW (Van Kranendonk, 2000). The peridotite contains serpentinized olivine, oikocrysts of clinopyroxene, minor amounts of inter-cumulus orthopyroxene, rare brown hornblende rimmed by green amphibole, interstitial serpentine with minor amphibole, and secondary chlorite.

A 200 m-wide by 3 km-long coarse-grained peridotite dyke (*Aup*) cuts west-northwest through the Panorama Formation, Strelley Pool Chert, and lower parts of the Euro Basalt 2 km west of Warrery Gap (MGA 781000E 7614000N). This unit is composed of 55–65% serpentinized olivine, 30–40% clinopyroxene that is extensively affected by bastite alteration, and 5% magnetite. The unit is foliated and cut by c. 3313–3300 Ma granite dykes (*AgOna*) emanating from the Nandingarra Granodiorite of the Corunna Downs Granitoid Complex, as well as by a dolerite dyke included in the Black Range Dolerite suite (*AFdb*). Thus, the massive peridotite dyke probably represents a feeder dyke to komatiitic volcanic rocks of the Euro Basalt.

Serpentinized dunite (*Aupd*) forms extensive outcrops along the axis of the Coongan Syncline and typically has pale yellow-tan weathering surfaces, bright-green fresh surfaces, and cumulate olivine up to 2.5 mm in diameter. The largest unit is in the northeastern part of the belt and extends for 19.5 km south from the northerly boundary of the map sheet. There are local variations in grain size, and

thin zones of peridotite and pyroxenite. The rocks are commonly weakly foliated, or foliated in anastomosing domains. In thin section the olivine phenocrysts are completely replaced by fine-grained serpentine and rimmed by a fine-grained assemblage of carbonate–magnetite–chlorite.

Homogeneous units of distinctive pale-brown-weathering talc–carbonate rock and talc–carbonate–chlorite schist (*Auc*) in the Coongan greenstone belt vary from massive medium-grained rocks to schists. The carbonate in these rocks is magnesite, which forms up to 75% of the rock, the remainder comprising talc, chlorite, and opaque minerals. Along the western side of the belt, several thin (up to 3 m), but locally up to 1.5 km, dykes of schistose talc–carbonate and talc–carbonate–serpentine–chlorite rock intrude the Mount Ada Basalt and Duffer Formation (MGA 773000E 7595000N, 772000E 7596000N, and 769500E 7596000N). These probably represent feeder dykes to high-Mg lavas of the Euro Basalt.

Serpentinite and ultramafic schist (*Aus*) form extensive outcrops along the axis of the Coongan Syncline, where it is interlayered with metamorphosed dunite, peridotite, and dolerite. These rocks are commonly very highly strained, showing good schistosity defined by serpentine, chlorite, tremolite, and talc. Much of the unit may be derived from ultramafic flows of the Euro Basalt, but they have been so deformed as to render protolith recognition impossible.

Metapyroxenite interlayered with diorite (*Aux*) outcrops in dykes along the eastern contact of the Boobina Porphyry in the northeastern part of SPLIT ROCK. These weakly deformed but recrystallized dykes consist of clinopyroxene rimmed by brown hornblende and altered to carbonate, serpentine after orthopyroxene and possibly olivine, and aggregates of quartz, chlorite, carbonate, actinolite, and talc probably after olivine. Pyroxenite southwest of Kellys copper mine is mineralogically similar to the pyroxenite in the northern part of the Kelly greenstone belt, but it is parallel to bedding in the Euro Basalt and may be a flow. A weakly deformed, medium- to coarse-grained pyroxenite outcrops in the northern part of the Coongan greenstone belt, where it cuts the lower part of the Warrawoona Group (MGA 773300E 7608500N).

Mafic rocks (*Ao*, *Aolx*, *Aodm*)

Intrusive mafic rocks that cannot be placed in the stratigraphy with certainty outcrop in several places on SPLIT ROCK. Altered, fine- to medium-grained metadolerite and local metagabbro (*Ao*) are associated with ultramafic units (*Aup* and *Aux*) in the Kelly and Coongan greenstone belts (e.g. MGA 774300E 7613500N and 791000E 7581600N). These rocks consist of relict pyroxene (?clinopyroxene and ?orthopyroxene) altered to chlorite–epidote–actinolite–tremolite, plagioclase altered to albite–sericite–chlorite–epidote–calcite, and accessory amounts of apatite and quartz. A 200 m to 1 km-thick, discontinuous, dolerite sill (*Ao*) is exposed just below the Duffer Formation on the western side of the Coongan greenstone belt. Other doleritic sills intrude higher levels of the stratigraphy farther south, and they probably represent

large subvolcanic intrusions to generations of younger basalt flows. These rocks are typically medium grained and weather to a dark-brown colour. They consist of euhedral plagioclase laths, less than 5 mm long and commonly altered to epidote and sericite, in a matrix of altered clinopyroxene (epidote–actinolite), chlorite, epidote, opaque minerals, and trace amounts of apatite and carbonate. This assemblage indicates regional greenschist-facies metamorphism. Similar units along the western edge of the Corunna Downs Granitoid Complex north of Withnell Creek (MGA 782400E 7605150N) contain abundant prismatic clinopyroxene, as well as serpentine or chlorite as pseudomorphs of orthopyroxene, plagioclase altered to clinozoisite and sericite, and rare iron oxides.

A distinctive unit of pyroxene leucogabbro (*Aolx*) in the northern part of the Coongan greenstone belt (MGA 776000E 7615000N) weathers a deep orange and is light brown on fresh surfaces. It is medium to coarse grained and composed of about 35% augite crystals in a matrix of plagioclase with minor quartz. Low-grade metamorphism has resulted in minor recrystallization of plagioclase to sericite and epidote, and bastite alteration of clinopyroxene.

In the southern part of the Coongan greenstone belt, an orange-weathering, high-Mg dolerite (*Aodm*; MGA 779000E 7588000N) is distinctive from the more-common, dark-brown-weathering dolerite (*Ao*) described above. This unit contains saussuritized plagioclase (epidote–sericite–calcite) and actinolite–chlorite–epidote assemblages after clinopyroxene.

Granitic complexes

The Corunna Downs and Shaw Granitoid Complexes occupy more than half of SPLIT ROCK (Fig. 3) and have commonly intrusive (locally faulted) contacts with their flanking greenstone belts.

Shaw Granitoid Complex

The Shaw Granitoid Complex is a polyphase structural dome with a protracted tectono-thermal history from 3493 to 2850 Ma, including four phases of deformation (Bettenay et al., 1981; Bickle et al., 1983, 1989; 1993; Van Kranendonk, 2000). On SPLIT ROCK the Shaw Granitoid Complex comprises 18 map units that include:

- five pre-tectonic to early syntectonic units with protolith ages between c. 3493 and 3451 Ma (*AgSn*, *AgSnI*, *AgSd*, *AgSco*, *AgSns*);
- two units of derived migmatite with voluminous syntectonic leucogranite melt formed at c. 3445–3410 Ma (*AgSl*, *AgSxn*);
- two units of foliated (c. 3300 Ma) granitic rocks (*AgSbs*, *AgSmv*);
- three units of (c. 2930 Ma) granitic rocks (*AgSmu*, *AgSel*, *AgSilmu*);
- six distinct subtypes of the post-tectonic (c. 2850 Ma) Cooglegong Monzogranite (*AgScgc*, *AgScgpe*, *AgScgg*, *AgScgla*, *AgScgp*, *AgScge*).

Pre-tectonic to early syntectonic sodic granitic rocks (*AgSns*, *AgSn*, *AgSnI*, *AgSco*, *AgSd*)

The oldest component of the Shaw Granitoid Complex is the North Shaw Tonalite (*AgSns*) of the North Shaw Suite (Bettenay et al., 1981), which is an equigranular hornblende tonalite to diorite that locally contains plagioclase phenocrysts. It occupies the eastern margin of the complex from the Cooglegong Monzogranite (*AgScg*) in the north (MGA 770300E 7607000N) for about 20 km south (MGA 769700E 7589000N). The unit intrudes medium-grained amphibolite of the North Star Basalt (*Awnba*; MGA 768700E 7592600N) and was intruded by the protolith to a unit of migmatitic tonalitic orthogneiss (*AgSn*) and associated diatexite and leucogranite (*AgSl*, *AgSnI*) to the west.

The North Shaw Tonalite contains about 40% extensively altered plagioclase, up to 30% quartz, about 20% hornblende, and up to 10% microcline. In thin section, hornblende is largely altered to an intergrowth of green biotite, epidote, titanite, and actinolite. The rock is weakly strained, except at the western edge of the area of outcrop, where it is deformed within the Split Rock Shear Zone (see **Pre-Fortescue Group deformation**). This unit has not been directly dated on SPLIT ROCK, but must be older than the crosscutting c. 3469 Ma Coolyia Creek Granodiorite (*AgSco*; Van Kranendonk, 2003); this date confirms earlier reports of ages between 3493 and 3470 Ma from NORTH SHAW and TAMBOURAH (Williams et al., 1983; McNaughton et al., 1988).

The Coolyia Creek Granodiorite (*AgSco*) outcrops in the northwestern part of SPLIT ROCK, where it intrudes the Coongan greenstone belt and is intruded by c. 3445–3410 Ma leucogranite and by the c. 2850 Ma Cooglegong Monzogranite (*AgScg*). SHRIMP U–Pb dating of zircon from a sample of the Coolyia Creek Granodiorite (GSA 142962) from NORTH SHAW indicated a single population of zircons with an igneous age of 3469 ± 2 Ma (Nelson, 1999). This is within error of the age of another sample from the same intrusion dated by Zegers et al. (2001) just north of SPLIT ROCK on MARBLE BAR, and of the protolith age of 3468 ± 2 Ma from migmatitic orthogneiss in the southern part of the complex on SPLIT ROCK (sample T94/193 at MGA 768750E 7583750N; Zegers et al., 2001).

The composition of the Coolyia Creek Granodiorite (*AgSco*) ranges from tonalitic to granodioritic. It is a grey-weathering, medium-grained rock with a characteristic clotty texture defined by 15–20% elongate and flattened (L–S) clots of mafic minerals, 10–30 mm in length. In thin section the mafic clots consist of green biotite, epidote, chlorite, and opaque minerals, within a medium- to coarse-grained matrix of euhedral to subhedral plagioclase (that is commonly sericitized), K-feldspar (microcline, with <5% myrmekite), and quartz. K-feldspar and quartz are anhedral, with irregular sutured boundaries, and commonly exhibit coarse subgrain development. The quartz also has undulose extinction. Allanite forms fine-grained euhedral to anhedral grains. The granodiorite is cut by relatively straight, less-than-5 mm-wide veins of fine-grained (<0.2 mm) leucogranite that is composed predominantly of a polygonal-textured groundmass of quartz and K-feldspar with millimetre-sized plagioclase

crystals with recrystallized grain boundaries. The leucogranite veins are parallel to the mafic clots.

The origin of the clotty texture is enigmatic. The mafic clots have been affected by the regional tectonic strain, which has deformed originally spherical clots into prolate spheroids. The origin of the spherical mafic mineral clots cannot be explained by assimilation of xenoliths because their distribution and size are too even over most of the unit, and they have fuzzy or weakly gradational margins. Instead, this texture is probably the result of mingling and mixing of comagmatic basaltic and granitic liquids (see Pitcher, 1993, p. 133).

Along the eastern margin of the complex, the Coolyia Creek Granodiorite becomes mylonitized in the Split Rock Shear Zone, where a tectonic foliation associated with shear deformation becomes more intense and quartz ribbons define a strong down-dip lineation. C–S relations and σ -type porphyroclasts of feldspar (e.g. Hanmer and Passchier, 1991) locally indicate an east-side-up sense of shear (see also Zegers et al., 1996), but indicators of normal displacement are also present and symmetrical augen indicative of pure-shear flattening are the most abundant (see **Pre-Fortescue Group deformation**).

Small, scattered inclusions of medium-grained, commonly well-foliated hornblende diorite with local gneissic layering (*AgSd*) in the southern part of the complex are within schlieric, foliated leucogranite (*AgSl*; MGA 779000E 7566000N) and leucogranitic diatexite (*AgSlxn*; MGA 776100E 7569000N). The hornblende diorite is characterized by a distinctive spotty texture of euhedral hornblende porphyroblasts 2 to 5 mm long, and minor amounts of green biotite. The leucocratic material is composed mostly of plagioclase, with 10–20% quartz and up to 10–15% microcline, and trace amounts of apatite. Zegers (1996) obtained a SHRIMP U–Pb zircon age of 3463 ± 2 Ma from a sample of hornblende diorite on TAMBOURAH (Van Kranendonk, 2003).

Migmatitic tonalitic orthogneiss and diatexite (*AgSn*) containing local xenoliths and rafts of amphibolite (*Aba*) underlie large areas of the southeastern part of the Shaw Granitoid Complex. This unit consists of grey, medium-grained biotite tonalite and lit-par-lit veins of leucogranite that were derived both from in situ melting and injection from zones of melting at deeper structural levels (Pawley et al., in prep.). Typically, the grey tonalite is made up of multiple sheeted sills of texturally and compositionally slightly variable units, including weakly plagioclase porphyritic, even-grained, and clotty mafic varieties. The tonalite has been dated at c. 3463–3451 Ma (Zegers 1996; Nelson, 2001) and was subjected to partial melting events at 3427–3415, 3359–3308, and 3251 Ma (Zegers, 1996).

Migmatitic tonalitic orthogneiss with 30 to 50% by volume of leucogranite (*AgSnI*) forms a transitional unit between orthogneiss (*AgSn*) and leucogranite diatexite (*AgSlxn*; e.g. MGA 767500E 7598500N). In the orthogneiss with leucogranite (*AgSnI*), the orthogneiss is a medium- to dark-grey, equigranular rock with equant K-feldspar and plagioclase crystals about 3 mm across, set in a matrix of feldspar, quartz, and biotite, with accessory

apatite and allanite. The matrix has a bimodal grain-size distribution, with a mosaic of equant grains that are about 0.5 mm wide cut by less-than-1 mm-wide anastomosing layers of equant grains that are about 0.05 mm wide. The matrix grains are internally strained, and blades of biotite are partitioned into the finer grained anastomosing layers, resulting in a penetrative foliation. The orthogneiss is characterized by millimetre- to metre-scale leucosome layers composed of massive, coarse- to medium-grained plagioclase, K-feldspar, and quartz with minor biotite. The leucosome layers are texturally and mineralogically similar to the schlieric, foliated leucogranite (*AgSl*), and locally may contain sparse, less-than-5 mm-wide equant crystals of hornblende instead of biotite. The leucosome layers, which are commonly concordant with the foliation in the host, have straight or lobate sharp margins and mafic-rich selvages are common, suggesting that the layers were derived by in situ partial melting. Consequently, the orthogneiss represents stromatic migmatite or metatexite (Milord et al., 2001).

Syntectonic granites (*AgSlxn*, *AgSl*)

Leucogranitic diatexite (*AgSlxn*) is developed where leucogranite derived from melting of orthogneiss forms 50–80% of the rock. Gneissic layering in these rocks is transposed into wispy biotitic schlieren. Medium-grained, homogeneous and schlieric leucogranite (*AgSl*) is interlayered with patches, lenses or layers of granite. The mafic mineral content is commonly less than 2% by volume, but small xenoliths of amphibolite and hornblende–quartz diorite are common. Leucogranite diatexite (*AgSlxn*) contains a component of gneissic and amphibolic palaeosome, irregular melanosome, and biotite schlieren. The leucogranite component within the diatexite consists of medium- to coarse-grained, heterogeneous leucogranite with large, round K-feldspar crystals, irregular transgressive pegmatite veins and patches, and schlieric layering defined by biotite. The mafic schlieren form sinuous, centimetre-wide layers and wispy semi-continuous lenses commonly extend from orthogneiss blocks, these being texturally similar to the relatively unmelted orthogneiss in tonalitic orthogneiss (*AgSnI*). The blocks of gneiss and amphibolite typically have a pre-existing solid-state foliation, defined by alignment of hornblende in the amphibolite, with centimetre-wide, sharp-edged, concordant leucosome layers that are commonly tightly folded and then truncated by leucogranite in the diatexite. The leucogranite commonly contains evenly distributed euhedral hornblende crystals that are about 5 mm wide, producing a locally distinctive spotty texture.

The leucogranite diatexite (*AgSlxn*) commonly have indistinct layering over several metres, defined by medium- to coarse-grained, inequigranular leucogranite and rare biotite schlieren within an equigranular, relatively leucocratic tonalite host. The layering is cut by a series of shear zones that are filled with leucosome layers that are continuous with the concordant leucogranite layers, forming diktyonic structures (e.g. Mehnert, 1968). These structures appear to represent a transitional stage between the stromatic migmatite (*AgSnI*) and the leucogranitic diatexite (*AgSlxn*).

Schlieric foliated leucogranite to massive medium- to coarse-grained leucogranite (*AgSl*) is the dominant lithology along the southeastern margin of the complex and in the southwestern part of SPLIT ROCK north of the Bamboo Springs Monzogranite, where it is relatively homogeneous with only faint traces of relict gneissosity. Van Kranendonk (2000) provided evidence that the generation of leucogranite on the adjacent NORTH SHAW and MARBLE BAR sheets spanned a protracted period from c. 3445 to 3410 Ma (dates from Nelson, 1998 and unpublished SHRIMP U–Pb data). On NORTH SHAW a large sheeted sill of leucogranite was derived by partial melting of the migmatitic orthogneiss and emplaced during doming (Pawley et al., in prep.). In the eastern part of the Shaw Granitoid Complex on SPLIT ROCK, the leucogranite also forms a sheeted complex as most outcrops are characterized by sheets of leucogranite, commonly asymmetric pegmatite dykes (forming selvages to sheets), and screens of the host rock (typically the leucogranitic diatexite, *AgSlxn*) and migmatitic tonalitic orthogneiss (*AgSn*). In the southeastern part of the complex (e.g. 14 km southwest of Norman Cairn at MGA 772200E 7576500N), the leucogranite also intrudes the greenstones as sheets and apophyses.

The leucogranite (*AgSl*) is a leucocratic monzogranite composed of quartz, plagioclase (commonly saussuritized), and K-feldspar, with less than 5% biotite. Accessory minerals include epidote, magnetite, zircon, and myrmekite. Texturally, the leucogranite is extremely variable, ranging from massive to foliated, equigranular to inequigranular, and from medium to very coarse grained (almost pegmatitic). Common centimetre-wide mafic schlieren contain biotite as dispersed, randomly oriented blades and as weakly aligned blades. K-feldspar forms rounded to angular crystals and crystal fragments (suggestive of xenocrysts), and pegmatite patches and dykes are common. The leucogranite possesses a variably developed subsolidus foliation defined by quartz ribbons.

Foliated monzogranite (*AgSbs*, *AgSmv*)

The Bamboo Springs Monzogranite (*AgSbs*; Hickman, 1983) is a well-foliated, coarse-grained, biotite monzogranite with elongate, prismatic K-feldspar phenocrysts up to 20 mm long. It is restricted to the southern part of the Shaw Granitoid Complex and is separated from older rocks in the main part of the complex by a 100 to 200 m-wide sliver of amphibolite and amphibolite schist (*Aba*) with interbedded quartzite. The monzogranite also underlies the main part of the small promontory of granitic rocks in the far southeast of the complex, where it is in faulted contact with amphibolite-facies greenstones of the Euro Basalt.

Texturally, the monzogranite varies from seriate to porphyritic, with very large (10–20 mm-wide), elongate to equant feldspars that have compositional zoning. Locally, the matrix consists of coarse-grained, subhedral to anhedral feldspars and interstitial quartz, with medium-grained biotite. The monzogranite has a variably developed solid-state foliation defined by flattened quartz aggregates, and is locally mylonitic. In the southeast of the complex (MGA 780000E 7565800N), the monzogranite has a very strong solid-state foliation and moderate

mineral lineation defined by elongate quartz aggregates. The lineation has an oblique plunge (39° to 246°), with C–S relations indicating a sinistral, east-side-up sense of shear.

In places, the Bamboo Springs Monzogranite has an schlieric texture defined by layers of more-melanocratic monzogranite; it may also be transected by swarms of pegmatitic dykes, but it lacks the melt veins that are characteristic of the older orthogneiss. From this, and because the Bamboo Springs Monzogranite is lithologically similar to the c. 3315 Ma Carbara Monzogranite in the Corunna Downs Granitoid Complex (*AgOca*), it is interpreted to be similar in age. Contacts with adjacent granitic units are not exposed, but the Bamboo Springs Monzogranite is intruded by small dykes and sheets of the c. 2928 Ma Mulgandinnah Monzogranite (*AgSmu*), which is a fine- to medium-grained, magnetite-bearing biotite monzogranite.

A 200 m-wide sheet of foliated, fine- to medium-grained muscovite monzogranite (*AgSmv*) intrudes amphibolite-facies contact-metamorphosed basalts of the Coongan greenstone belt in the northern part of SPLIT ROCK (MGA 771600E 7619500N). The monzogranite sheet transgresses lithological layering in the basaltic host rocks, was foliated together with the basaltic rocks during regional metamorphism, and is cut by the c. 2850 Ma Cooglegong Monzogranite (*AgScg*). A conventional U–Pb zircon date of 3321 ± 3 Ma obtained from the granitic sheet on MARBLE BAR is within error of a Pb–Pb age of c. 3316 Ma from galena in the nearby Mount Ada mine (age data from Thorpe, R., Geological Survey of Canada, 1992, written comm.).

Late-tectonic granitic plutons (*AgSel*, *AgSmu*, *AgSilmu*)

Numerous small kopjes and larger areas of well-exposed granitic rocks are typical of the central part of the Shaw Granitoid Complex. These consist of typically homogeneous, moderately to well-foliated monzogranite with a foliation striking typically 020°, perpendicular to the maximum shortening direction during regional compressional deformation at c. 2940–2930 Ma (see **Pre-Fortescue Group deformation**).

The c. 2930 Ma Eley Monzogranite (*AgSel*; Hickman, 1983) is a weakly to moderately foliated K-feldspar porphyritic, biotite monzogranite with equant K-feldspar crystals up to 10 mm across. This unit is best exposed in the western-central part of the map (around MGA 765000E 7593000N), and continues to the south of Coolgarrack Creek (MGA 759600E 7575600N). The monzogranite intruded orthogneiss and diatexite (*AgSn*, *AgSnI*, *AgSlxn*) and is intruded by K-feldspar-porphyritic rocks of the Cooglegong Monzogranite (*AgScgp*).

A series of small plutons and related dykes of the 2928 ± 2 Ma (GSWA 142882; Nelson, 1998) Mulgandinnah Monzogranite (*AgSmu*) intruded gneisses (*AgSn*, *AgSnI*, *AgSd*), leucogranite and leucogranite diatexite (*AgSn*, *AgSlxn*), and the Bamboo Springs Monzogranite (*AgSbs*) across the map area, particularly in the south (e.g. MGA 765000E 7580400N). The fine- to medium-grained

monzogranite is blue-grey in colour and weathers to a dark chocolate-brown rind on rounded boulder kopjes above the surrounding, flat granitic terrain. The unit is commonly weakly to penetratively foliated, with foliation defined by elongate quartz and aligned biotite in outcrop, and by the formation of subgrains of quartz and a fracture cleavage through feldspars in thin section. Oligoclase forms 40% of the rock, and typically has heavily saussuritized cores. Microcline forms 25% of the rock and there is also local myrmekite. Accessory minerals include titanite, apatite, magnetite, and allanite, the latter two minerals forming conspicuous dark spots in the rock that are mantled by white feldspar. Zircon is abundant as very fine grains, and there is secondary growth of epidote, sericite, carbonate, and chlorite after biotite.

A small area of schlieric leucogranite (*AgSl*) with remobilized migmatitic tonalitic orthogneiss (*AgSn*), that has been intruded by voluminous sheets of K-feldspar megacrystic monzogranite (*AgSilmu*), is along the western edge of the sheet area (MGA 759000E 760000N).

Post-tectonic Cooglegong Monzogranite (*AgScge*, *AgScgp*, *AgScgla*, *AgScgpe*, *AgScgc*, *AgScgg*)

The post-tectonic Cooglegong Monzogranite forms a thick, subhorizontal, easterly striking sheet, with a subhorizontal basal contact against older granitic rocks further west on TAMBOURAH (e.g. Van Kranendonk, 2003) and a steeper easterly contact against supracrustal rocks of the Warrawoona Group of the Coongan greenstone belt on SPLIT ROCK (see map cross section A–B). Crosscutting relations were observed between some phases of the Cooglegong Monzogranite, whereas other phases grade into one another. None of the rocks belonging to this intrusion has a tectonic foliation, although the monzogranite is locally cut by quartz-filled faults. Nelson (1998) obtained a date of 2851 ± 2 Ma on the Spear Hill Monzogranite (GSWA 142879), which is a satellite pluton of the Cooglegong Monzogranite on TAMBOURAH. A Pb–Pb whole-rock age date of 2822 ± 37 Ma was obtained by Bickle et al. (1989) from samples of the Spear Hill and Cooglegong Monzogranites.

The main component of the Cooglegong Monzogranite is a coarse-grained, equigranular biotite monzogranite (*AgScge*) that is interlayered with K-feldspar-porphyritic to megacrystic biotite monzogranite (*AgScgp*). Contacts between these two units are gradational and reflect metre-scale igneous layering. An outer rind of fine- to medium-grained leucogranite (*AgScgla*) is along most of the eastern margin of the intrusion. On the southern margin of the Cooglegong Monzogranite (MGA 767000E 7606500N), the coarse-grained, equigranular monzogranite phase (*AgScge*) grades into coarse-grained, equigranular, biotite monzogranite to pegmatitic monzogranite (*AgScgpe*), in which euhedral K-feldspar crystals are up to 0.4 m across with graphic intergrowths of quartz (Fig. 10). A small area in the southwest of the intrusion is composed of coarse-grained biotite monzogranite with common pegmatitic patches (*AgScgc*). The pegmatitic patches are commonly irregular in shape and variable in size, but have characteristically very large (up to 0.4 m) K-feldspar crystals with



Figure 10. Very coarse grained pegmatite of the Cooglegong Monzogranite at the southern margin of the body (MGA 767000E 7606500N), showing 'patchwork quilt' texture with 0.2 m-wide, euhedral K-feldspar crystals

graphic quartz intergrowths. In places, large single K-feldspar crystals with graphic intergrowth textures are scattered throughout coarse-grained monzogranite, giving the rock the appearance of a patchwork quilt (e.g. MGA 766850E 7606750N). Pegmatitic monzogranite dykes (*AgScgpe*) form a locally dense swarm along the north-central contact of the Cooglegong Monzogranite at Hartigans mining area (MGA 764300E 7618400N), where tin, tantalum, and lithium were mined from alluvial placer deposits (see **Economic geology**).

Cutting across the main part of the Cooglegong Monzogranite are pale-green to yellowish quartz–sericite greisen veins (*AgScgg*) that form particularly dense swarms in the lower central (MGA 764000E 7609500N) and eastern (MGA 770000E 7613000N) parts of the intrusion. These veins extend for a short distance into basaltic rocks of the Mount Ada Basalt (e.g. MGA 773800E 7612600N). The yellowish to green colour is most likely related to the presence of fine mica within the quartz that has caused potassic alteration of wallrocks.

The contact between the Cooglegong Monzogranite and the Coongan greenstone belt is well exposed in a creek section in the northern part of SPLIT ROCK (MGA 773550E 7613700N), where it is characterized by a series of intersecting subhorizontal and subvertical granitic sheets. These sheets also cut and isolate large (greater than metre-scale) angular blocks of strongly foliated Coolyia Creek Granodiorite (*AgSco*) with characteristic flattened aggregates of fine-grained mafic minerals (mostly chlorite after biotite). From west to east, the sheets become less abundant and their thickness decreases from about 10 m to less than 1 m in the belt away from the monzogranite contact. The thicker sheets to the west are massive and composed of coarse-grained equigranular monzogranite, whereas the thinner sheets to the east are composed of massive, leucocratic fine- to medium-grained monzogranite that have sharp, relatively straight contacts with the host rocks. The coarse-grained sheets are commonly zoned with leucocratic fine-grained selvages

that have sharp crosscutting contacts with the host rock and a diffuse (millimetre-scale) contact with the coarse-grained core of the sheet. The coarse-grained phase also cuts the fine-grained selvage. The fine-grained, leucocratic selvage is interpreted as the quenched equivalent of the coarser grained phase. Based on these observations, the Cooglegong Monzogranite is interpreted to have been emplaced in rigid crust as a large tabular body with abundant dykes at its extremities.

Corunna Downs Granitoid Complex

The Corunna Downs Granitoid Complex is a moderately well exposed ovoid-shaped body that tapers to the south, with its southern half exposed on SPLIT ROCK. Rocks of monzogranitic compositions dominate the complex, although it includes rare tonalite, trondhjemite, granodiorite, monzogranite, and syenite (Davy, 1988; Bagas et al., 2003).

The Corunna Downs Granitoid Complex can be subdivided into several units based on field mapping and geochemistry. In some areas of petrographically similar monzogranite and in areas of poor outcrop, geochemical data (Bagas et al., 2003) have led to the recognition of additional, geographically distinct units (e.g. *AgOmh*).

Hickman and Lipple (1978) subdivided the Corunna Downs Granitoid Complex into the former 'migmatite complex' in the north, the 'Carbana Pool Adamellite' in the east, and the 'Mondana Adamellite' in the south. The 'migmatite complex' is now subdivided into the Nandingarra Granodiorite (new name, Appendix 2) in the northwest and the redefined Carbana Monzogranite in the central part of the complex. The former 'Mondana Adamellite' is subdivided into the Triberton Granodiorite (new name; Appendix 2) and the Mondana Monzogranite to the southeast (Fig. 11).

The granitic rocks show typical calc-alkaline trends with Na_2O decreasing and K_2O increasing as silica contents increase (Davy, 1988; Bagas et al., 2003). Most of the granitic rocks fall in the high-K calc-alkaline field of Le Maître (1989), with tonalitic to granodioritic rocks that fall in the medium-K field comprising about 20% of the outcrop area of the Corunna Downs Granitoid Complex. These rocks outcrop along the western margin of the complex on SPLIT ROCK.

Available geochronological data indicate that the Corunna Downs Granitoid Complex contains granitic rocks that are predominantly aged between 3317 and 3300 Ma (discussed below), the oldest identified being tonalite within Nandingarra Granodiorite on southern

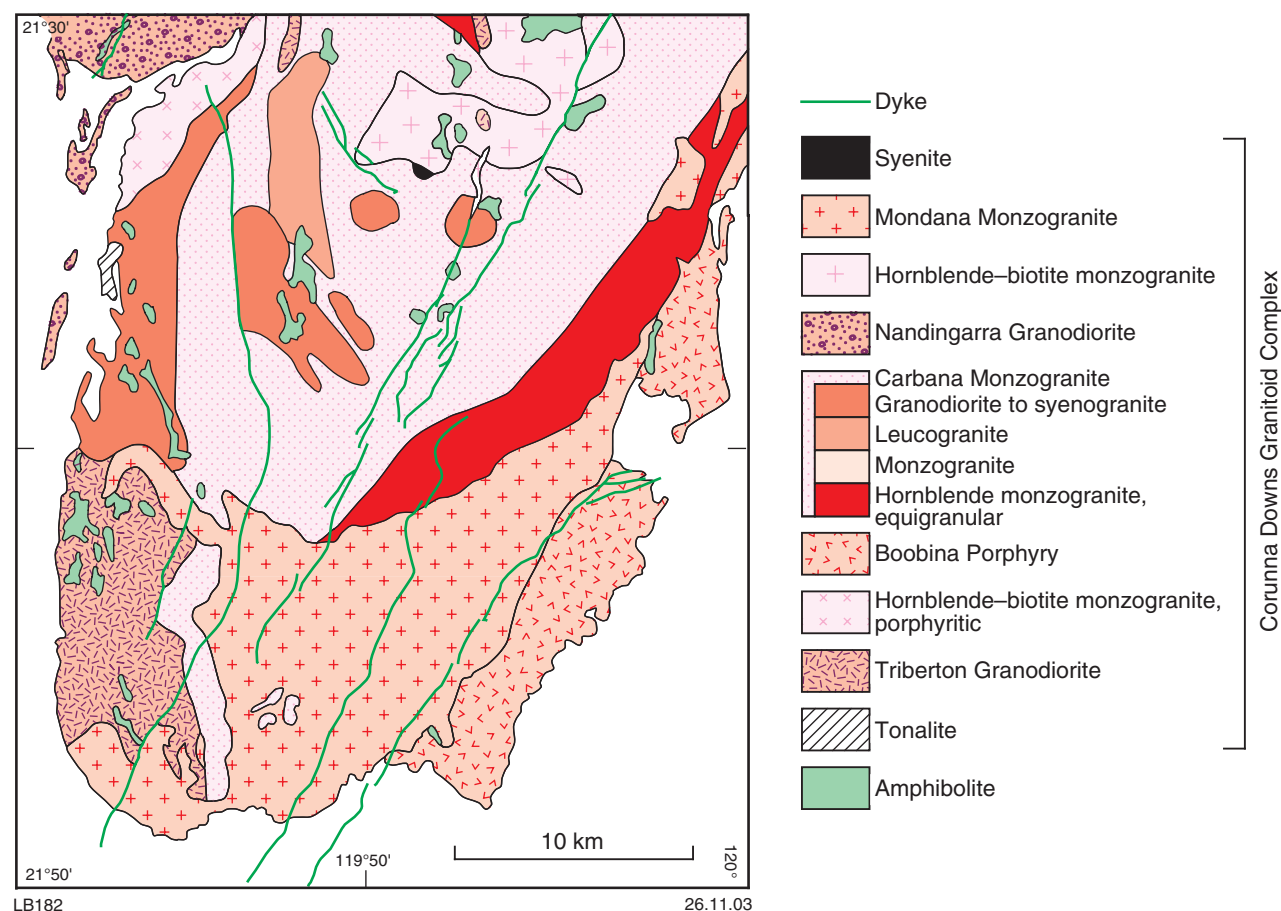


Figure 11. Interpreted bedrock geology of the Corunna Downs Granitoid Complex (modified after Bagas et al., 2003)

MARBLE BAR, which has a U–Pb zircon SHRIMP age of 3427–3408 Ma (Nelson, 2002). In the Mount Edgar Granitoid Complex, which is about 10 km northeast of SPLIT ROCK, Collins (1993) provided geochemical evidence suggesting that granitic rocks were formed from melting of older (c. 3450 Ma) banded tonalitic gneisses at c. 3315 Ma. Gneisses as old as c. 3450 Ma have not yet been recognized in the Corunna Downs Granitoid Complex; however, Nd-isotopic data (GSWA unpublished data) for tonalitic to monzogranitic rocks in the complex have a mean crustal residence age (T_{DM}) of c. 3480 Ma.

Triberton Granodiorite (*AgOtr*, *AgOtrmh*; new name)

The Triberton Granodiorite (*AgOtr*) intrudes the c. 3317 ± 2 Ma (Barley and Pickard, 1999) Carbana Monzogranite and is intruded by the c. 3300 Ma (Nelson, in prep.) Mondana Monzogranite. This indicates that most of the rocks included in the Triberton Granodiorite are between 3317 and 3300 Ma.

The Triberton Granodiorite (*AgOtr*) is a porphyritic, medium- to coarse-grained biotite–hornblende granodiorite with minor medium-grained tonalite and porphyritic monzogranite. It contains abundant mafic xenoliths.

A unit of hornblende monzogranite (*AgOtrmh*), along the far southwestern edge of the complex (MGA 783500E 7587500N), is similar in composition to monzogranite in the Triberton Granodiorite, except that it is rich in amphibolite xenoliths derived from the adjacent Euro Basalt. An Ar–Ar age of c. 3400 Ma obtained on hornblende from amphibolite within the immediate contact-metamorphic aureole of the Triberton Granodiorite (sample CC18 at MGA 780800E 7594900N; Davids et al., 1997) suggests that the western part of the Triberton Granodiorite may include older components. However, an Ar–Ar biotite age from the Triberton Granodiorite near the contact is 2987 ± 10 Ma (sample T93/122 in Zegers et al., 1999), but the significance of this result is uncertain.

Boobina Porphyry (*AgObo*, *AgObop*)

The Boobina Porphyry (*AgObo*; Lipple, 1975) intrudes the Panorama Formation, Strelley Pool Chert, Euro Basalt, and Wyman Formation along the eastern margin of the Corunna Downs Granitoid Complex. South of the Copper Hills mine the Boobina Porphyry hosts a number of crosscutting copper-mineralized quartz veins within a distance of 4 km (see **Economic geology**). The Boobina Porphyry is a hornblende-bearing quartz–feldspar porphyry (*AgObo*) that is in places strongly sericitized (*AgObop*). In thin section, the quartz-feldspar porphyry shows albitized plagioclase phenocrysts that are up to 2 mm long in a groundmass of fine-grained quartz, sericite, minor disseminated chlorite, and leucoxene, and accessory amounts of zircon, iron oxide, apatite, tourmaline, carbonate, and rutile.

A conventional U–Pb zircon age of 3307 ± 19 Ma (Pidgeon, 1984) has been obtained for the porphyry, but a more-precise U–Pb zircon SHRIMP age of 3315 ± 4 Ma (Barley and Pickard, 1999) is interpreted to better reflect

the age of this body. This latter age is within error of the age for the Carbana Monzogranite (Nelson, in prep.) exposed to the northwest, which is separated from the Boobina Porphyry by the younger Mondana Monzogranite.

Carbana Monzogranite (*AgOca*, *AgOcal*, *AgOcag*, *AgOcamh*)

The Carbana Monzogranite includes fine- to coarse-grained plagioclase-porphyritic biotite monzogranite (*AgOca*) with mafic xenoliths and minor pegmatitic dykes; coarse-grained leucogranite (*AgOcal*) with minor biotite, muscovite, and hornblende; medium-grained, equigranular granodiorite to syenogranite (*AgOcag*); and fine- to medium-grained, equigranular to slightly porphyritic hornblende monzogranite (*AgOcamh*).

Four samples from the Carbana Monzogranite have been dated from SPLIT ROCK, with U–Pb zircon SHRIMP ages of 3317 ± 2 Ma (UWA sample 96-19b of *AgOcamh*; Barley and Pickard, 1999), 3313 ± 9 Ma (UWA sample 96-19a of *AgOca*; Barley and Pickard, 1999), 3315 ± 7 Ma (GSWA 169027 of *AgOcag*; Nelson, in prep.) and 3314 ± 4 Ma (GSWA 169028 of *AgOcag*; Nelson, in prep.). The Carbana Monzogranite is locally intruded by hornblende-bearing monzogranite (*AgOmh*) with a U–Pb zircon SHRIMP age of 3307 ± 4 Ma (GSWA 142978; Nelson, 2000).

Biotite monzogranite (*AgOca*) is plagioclase-phyric and commonly contains mafic xenoliths. This monzogranite consists of perthitic microcline, porphyritic plagioclase altered to albite–sericite–epidote, quartz, biotite partly altered to chlorite, and rare stilpnomelane, titanite, apatite, brownish-green hornblende partly altered to chlorite and epidote, and zircon. Minor pegmatitic granite forms dykes and small intrusions in amphibolite.

Medium-grained and even-grained granodiorite to syenogranite (*AgOcag*) consists of perthitic microcline with inclusions of sericite-clouded plagioclase, anhedral quartz grains, sparse plagioclase phenocrysts altered to albite and sericite, biotite replaced by chlorite and epidote, minor epidote and allanite, and rare zircon and titanite.

Fine- to medium-grained, even-grained to slightly porphyritic hornblende monzogranite (*AgOcamh*) has quartz, perthitic orthoclase, plagioclase altered to albite–sericite–epidote–quartz, biotite altered to chlorite and epidote, and brownish-green to brown hornblende. The groundmass contains weakly sericitized plagioclase, quartz, disseminated hornblende, chloritized biotite, and accessory epidote, titanite, and apatite.

Nandingarra Granodiorite (*AgOna*; new name)

The Nandingarra Granodiorite (*AgOna*) is named after the Nandingarra Pool on the Coongan River in the northern part of SPLIT ROCK. The unit forms the northwestern part of the Corunna Downs Granitoid Complex, intrudes the hinge region of the Warrery Gap Anticline in the Coongan greenstone belt, and forms an elongate body just south of Warrery Gap Anticline. The main part of the Nandingarra Granodiorite in the far northwestern part of the complex

forms an elliptical body of fine- to coarse-grained equigranular granodiorite to tonalite and consists of quartz, plagioclase altered to sericite–albite–epidote, biotite altered to chlorite and epidote, minor amounts of microcline and antiperthite, and accessory titanite, zircon, and allanite. The unit has been dated at 3313 ± 4 Ma (GSA 160212; Nelson, 2002) and 3300 ± 3 Ma (GSA 160208; Nelson, in prep.), but an age of 3427 ± 4 Ma (GSA 160211; Nelson, 2002) indicates that the unit includes older granites, which are probably inclusions within the c. 3313–3300 Ma intrusion.

The main part of the Nandingarra Granodiorite is linked to granitic rocks in the hinge of the Warrery Gap Anticline by northerly striking granodiorite dykes that cut across the Apex Basalt and Panorama Formation in the core of the fold, and across a coarse-grained peridotite dyke (*Aup*) on the western limb of the fold. The granodiorite dykes are undeformed, and the granite in the hinge of the fold contains a weak foliation in contrast to the strong foliation and lineation developed in the host volcanic rocks that it cuts. The low-strain nature of the granite dyke swarm that crosscuts the hinge zone of the fold (Fig. 12) indicates that the granite was emplaced late in the history of fold development. Similarly, a small, elongate body of granodiorite occupies what is essentially a syn- to post-tectonic tension gash in the faulted southern extension of the eastern limb of the Warrery Gap Anticline (MGA 781450E 7607650N), but has undeformed intrusive contacts with amphibolite-facies pillow basalts (Fig. 13).

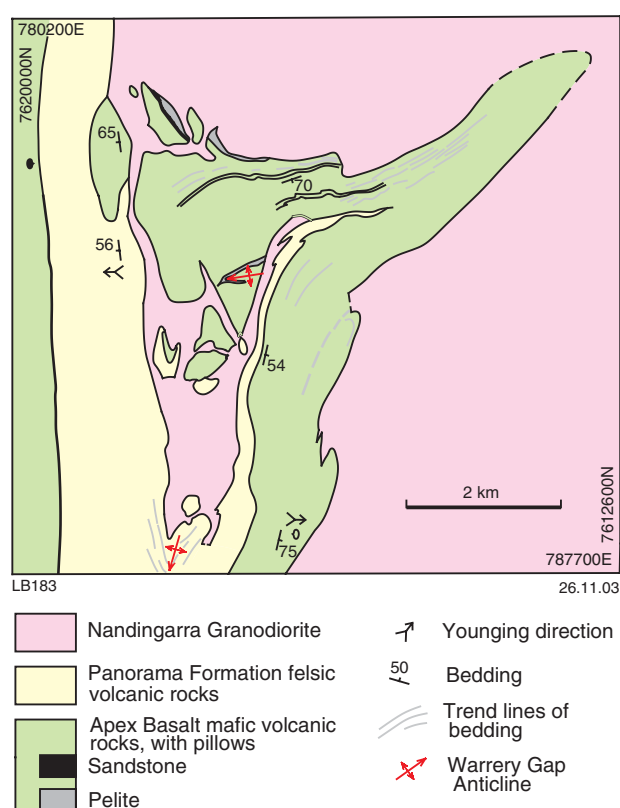


Figure 12. Simplified interpreted solid geology map of the Warrery Gap Anticline, showing the undeformed dyke swarm that fed the granite body emplaced syntectonically into the hinge region of the fold



Figure 13. Undeformed intrusive contact of the satellite pluton of the Nandingarra Granodiorite (AgOna; MGA 781100E 7605500N)

Mondana Monzogranite (AgOmo, AgOmoa)

The Mondana Monzogranite (*AgOmo*) intrudes both the Triberton Granodiorite and the Boobina Porphyry in the southeastern part of the Corunna Downs Granitoid Complex (see also Davy, 1988), and extends as a series of narrow bodies along the northeastern margin of the complex. It is a very fine to medium-grained leucogranite (*AgOmo*) with abundant aplite dykes (*AgOmoa*) that are quartz rich. The leucogranite has sparse microcline phenocrysts that are up to 4 mm long with inclusions of quartz and plagioclase, saussuritized plagioclase altered to albite–sericite–epidote, and quartz. The groundmass is quartz rich and contains plagioclase, microcline, and biotite altered to chlorite–epidote.

Unassigned rocks in the Corunna Downs Granitoid Complex (AgOt, AgOmhp, AgOmh, AgOs)

Mafic tonalite or quartz diorite (*AgOt*) outcrops near the western edge of the Corunna Downs Granitoid Complex (MGA 784700E 7609000N). It is fine to medium grained and consists of saussuritized plagioclase altered to albite–sericite–epidote, quartz as interstitial poikilitic grains, minor amounts of hornblende rarely containing residual clinopyroxene, biotite with prehnite parallel to cleavages, and accessory apatite, epidote, titanite, and iron oxide.

Cutting across the northern part of the eastern limb of the Warrery Gap Anticline is a unit of hornblende–biotite monzogranite (*AgOmhp*). This medium- to coarse-grained rock is equigranular and weakly to moderately foliated and was emplaced during the late stage of folding (see **Pre-Fortescue Group deformation**).

Fine- to medium-grained, seriate to plagioclase–porphyritic, hornblende–biotite monzogranite (*AgOmh*) intrudes the Carban Monzogranite in the central-northern part of the Corunna Downs Granitoid Complex on SPLIT ROCK. The monzogranite is massive and has a U–Pb zircon SHRIMP age of 3307 ± 4 Ma (GSA 142978; Nelson, 2000).

A small and isolated outcrop of fine- to medium-grained, equigranular to porphyritic syenite (*AgOs*) in the centre of the Carbara Monzogranite (at MGA 796000E 7613500N) consists of microcline, euhedral plagioclase commonly altered to epidote–sericite–albite–carbonate, relic biotite altered to chlorite, and less than 10% quartz.

Other Archaean rocks

Gossan (*go*)

Two areas of dark-brown to black weathered rocks have been mapped as gossan (*go*) on SPLIT ROCK. The largest is a sinuous unit, up to 100 m wide, of massive to brecciated, black to dark reddish-brown, smooth-weathering, hard rock within serpentinite–chlorite schist (*Aup*) that is interlayered with slivers of shale and banded iron-formation near the top of the Wyman Formation, about 8.5 km south-southeast of Norman Cairn (MGA 782700E 7581500N). A sample from a 25 × 75 m lens of this gossan in ultramafic rocks (MGA 782500E 7581250N) contains 98 ppm Cr, 90 ppm Cu, 1080 ppm Ni, 104 ppm V, and 1040 ppm Zn. A second unit of similar gossan outcrops as a large sinuous ridge about 3 km south of the previous gossan, in the southern part of the Coongan greenstone belt (MGA 783550E 7577900N), and contains 82 ppm Cu, 320 ppm Ni, 24 ppm V, and 275 ppm Zn.

A second type of gossan outcrops at the top of a black hydrothermal chert vein (*AWech*) within the upper part of the Euro Basalt about 9 km north of Corboy Cairn (MGA 776750E 7602050N). This vein is one of several sets of hydrothermal chert veins that feed a thin unit of sedimentary chert (*AWec*) east and immediately stratigraphically above the gossan exposure. The gossan is 21 m long by 1.5 m wide and consists of brown-weathering ferruginous material in quartz and has a boxwork pattern indicative of weathered-out sulfides. An assayed sample from this unit contained 3 ppb Au, 195 ppm Cr, 750 ppm Cu, 295 ppm Ni, 790 ppm V, and 180 ppm Zn.

Pre-Fortescue Group deformation

The structural history of the EPGGT is long and complex, and has been the subject of considerable debate between proponents of solely vertical tectonics (diapirism) and those who suggest that the terrane experienced one or more periods of horizontal tectonics. Hickman (1983), and Van Kranendonk (2000) recognized five regional sets of structures associated with vertical movements between greenstones and granitic complexes, including those that affect the Fortescue Group. Other authors, however, have suggested that there have been many more deformation events, including multiple periods of Alpine-style thrusting (e.g. Bickle et al., 1985; Zegers et al., 1996; Blewett, 2002). A thorough review of the proposed structural histories of the EPGGT is outside the scope of this manuscript, but interested readers may refer to Van Kranendonk et al. (2002).

In general terms, greenstones of the Pilbara Supergroup and Fortescue Group (described later) on SPLIT ROCK dip and face progressively away from the margins of the Shaw

and Corunna Downs Granitoid Complexes towards the axes of two main synclines. These include (Fig. 3) the Coongan Syncline between the Shaw and Corunna Downs Granitoid Complexes, and a broad synclinal area affecting the Fortescue Group in the southeastern part of the sheet area, which lies between the Corunna Downs Granitoid Complex and the McPhee Dome to the east on NULLAGINE. This has been used to suggest that there was doming of the granitic complexes during deposition of the groups, as originally proposed for the EPGGT by Hickman (1975, 1983, 1984). The fact that granitic rocks within the Shaw Granitoid Complex become progressively younger towards the core of the dome suggests that doming was not continuous, but episodic (Van Kranendonk et al., 2002). Both of these observations suggest that the domes were gradually enlarging during successive intrusions of magmas, and that this was coeval with sedimentation and volcanism (Hickman, 1975, 1984). Hickman (1975, 1983, 1984) suggested that these features, in combination with several other aspects of the regional structure (e.g. evidence from lithostratigraphy and metamorphic patterns), indicated that the tectonic history of the region was dominated by successive solid-state granite diapirism. This model has since been refined and slightly modified by more-recent detailed studies to include a component of magmatic diapirism, but the punctuated, syndepositional nature of the diapirism has been retained in these models (Collins, 1989; Williams and Collins, 1990; Collins et al., 1998; Collins and Van Kranendonk, 1999; Van Kranendonk et al., 2001b, 2002).

Van Kranendonk et al. (2002) identified five phases of deposition in the EPGGT prior to the deposition of the Fortescue Group, but only three of these affected SPLIT ROCK. Accordingly, deformation events on SPLIT ROCK do not correspond to the same numerical system that applies to the entire EPGGT.

A summary of the structural history of SPLIT ROCK prior to the deposition of the Fortescue Group (D_1 to D_3) is given below. The major structures of the sheet area formed during seven periods of deformation, as illustrated on Figure 3, and summarized in Table 2.

D_1 deformation (c. 3490–3400 Ma)

The first deformation event on SPLIT ROCK, D_1 , is manifest as a nonconformity between the c. 3474–3467 Ma Duffer Formation and c. 3433 Ma Panorama Formation on the western limb of the Coongan Syncline, but D_1 structures have not been directly identified on SPLIT ROCK. This contact is interpreted to represent a significant non-conformity within the Warrawoona Group stratigraphy and contrasts with the type area of the Warrawoona Group in the Marble Bar greenstone belt, where up to 4 km of the Apex Basalt and 400 m of the Panorama Formation separate the Euro Basalt from the top of the Duffer Formation. This difference in stratigraphic thickness along strike suggests that there was significant topographic variation across the EPGGT, as suggested by Hickman (1984). When considered in light of the evidence for early doming gleaned from other parts of the EPGGT (cf. Collins, 1989; Van Kranendonk et al., 2002), the non-conformity in the Coongan greenstone belt suggests that

the Shaw Granitoid Complex had undergone an early period of uplift between 3470 Ma (Duffer Formation) and c. 3420 Ma (base of Euro Basalt; Van Kranendonk et al., 2001b).

Zegers et al. (1996, 2001) interpreted the Split Rock Shear Zone along the eastern margin of the Shaw Granitoid Complex (Fig. 3) as an extensional detachment plane to a rising metamorphic core complex that formed at 3468 Ma during emplacement of the North Shaw Suite. A critical feature of this model is the interpretation that greenstones were foliated prior to intrusion of the c. 3468 Ma Coolyia Creek Granodiorite of the North Shaw Suite along the margin of the Shaw Granitoid Complex in the Split Rock Shear Zone, and this was used to infer that the shear zone developed synchronously with intrusion of the Coolyia Creek Granodiorite.

However, Van Kranendonk et al. (2002) disagreed with this interpretation, noting that the age of shear deformation in the Split Rock Shear Zone is not constrained by the data presented in Zegers et al. (1996, 2001). Direct evidence for the age of the shear fabrics is given by a 3308 Ma zircon overgrowth on 3468 Ma zircons in granite dated within the shear zone (Zegers, 1996) and this accords with the observation from mapping that the solid-state shear fabric of the zone is as strongly developed in c. 3445–3410 Ma leucogranite (*AgSl*) as it is within the Coolyia Creek Granodiorite. A minimum age estimate for the shear deformation is given by Ar–Ar ages on hornblende from undeformed amphibolites adjacent to the zone and on syntectonic hornblendes within the zone, which indicate that the shear zone cooled between 3222 and 2959 Ma (Davids et al., 1997; Zegers et al., 1999).

D₂ structures (c. 3315 Ma)

Deformation associated with the c. 3315 Ma D₂ event includes tilting and large-scale open to tight folding of the Warrawoona Group, the development of a penetrative foliation and lineation in these rocks throughout the Coongan Syncline, and layer-parallel normal and reverse faults within the greenstone belts. Other D₂ structures include the Split Rock Shear Zone inside the eastern margin of the Shaw Granitoid Complex (c. 3308 Ma, see D₁) and coplanar foliation and colinear mineral elongation lineation throughout older-than-3315 Ma rocks in the rest of the complex to the west and south. Age data from three different areas within the map sheet indicate that D₂ structures formed between 3317 and 3308 Ma, synchronous with magmatic emplacement of the Corunna Downs Granitoid Complex and domical reactivation of the Shaw Granitoid Complex. D₂ deformation is interpreted to have been a progressive deformational event, commencing with the development of foliation subparallel to bedding and generally down-dip-plunging lineation in the greenstones (D_{2a}), followed by open to tight folding that was accompanied by the development of shear foliation in the Shaw Granitoid Complex and by shearing and faulting along the synclinal axis of the Coongan greenstone belt (D_{2b}).

D_{2a} structures include foliation and lineation in greenstones on the eastern limb of the Coongan Syncline

and around the Warrery Gap Anticline that have, at least in part, been folded by this D_{2b} structure. The presence of folded foliation around this fold and of subvertical north-northeasterly striking axial-planar foliation within the hinge region of the fold (i.e. MGA 780700E 7608300N) provide evidence for two phases of, or progressive, deformation. A similar interpretation was reached by Cooper et al. (1982) who documented refolded minor folds in migmatized rhyolitic agglomerate (Panorama Formation) in the core of the Warrery Gap Anticline. The presence of steeply west-plunging mineral-elongation lineation on the western limb and moderately northeast-plunging mineral-elongation lineation on the eastern limb also attest to folding of fabrics formed during D_{2a}. Furthermore, the orientation of lineation on the eastern limb of the fold does not match that expected from simple buckle folding of the steep lineation on the less deformed western limb (i.e. they should plunge much more steeply), which also suggests that the lineation on this limb was re-oriented, or recrystallized, during the F_{2b} folding.

The main D_{2b} structures on SPLIT ROCK include the large-scale Coongan Syncline between the Shaw and Corunna Downs Granitoid Complexes, and a pair of south-facing tight anticlines of the Panorama Formation and Euro Basalt on the eastern and western sides of the Corunna Downs Granitoid Complex, known as the Spinaway (MGA 809500E 7606000N) and Warrery Gap (MGA 781000E 7609200N) Anticlines respectively. Pillows face easterly toward the Corunna Downs Granitoid Complex on the eastern limb of the Warrery Gap Anticline. The axis of the Coongan Syncline is a broad zone of high shear strain and splayed faults in ultramafic rocks between the Coongan and Kelly greenstone belts (Fig. 3). The axial trace of the Warrery Gap Anticline to the south is offset by a splayed, south-southwest-striking fault that is intruded by a thin body of synkinematic granite (*AgOna*, see below).

Another major F_{2b} fold structure is the open Cookindina Syncline affecting the Euro Basalt and Wyman Formation south of the Corunna Downs Granitoid Complex (e.g. MGA 790000E 7581000N; Fig. 3), where pillows face east-southeasterly in the core of the Cookindina Syncline (MGA 789000E 7581000N) and cross-bedding in felsic tuff horizons also indicate younging to the east-southeast. An interesting feature of the Cookindina Syncline is that the folded pyroclastic and volcanic rocks of the Wyman Formation commonly dip more steeply (about 60° southeast) away from the Corunna Downs Granitoid Complex than either those of the underlying Euro Basalt (about 40° southeast) or the unconformably overlying Budjan Creek Formation (about 30° southeast; Fig. 14a). Felsic pyroclastic events are renowned for their explosive and abrasive nature and result in mass flow or surge deposits that level the underlying strata and tend to dip away from the volcanic vent at angles between 20° and 30° for subaqueous deposits, or between 30° and 35° for subaerial deposits, as a function of the primary angle of repose of the volcanic flank (McPhie et al., 1993). The steeper bedding measured in the Wyman Formation around the Cookindina Syncline is consistent with deposition on such a primary volcanic slope of up to 20° to the southeast (Fig. 14b), and suggests that the source for the pyroclastic material in the Wyman Formation in this

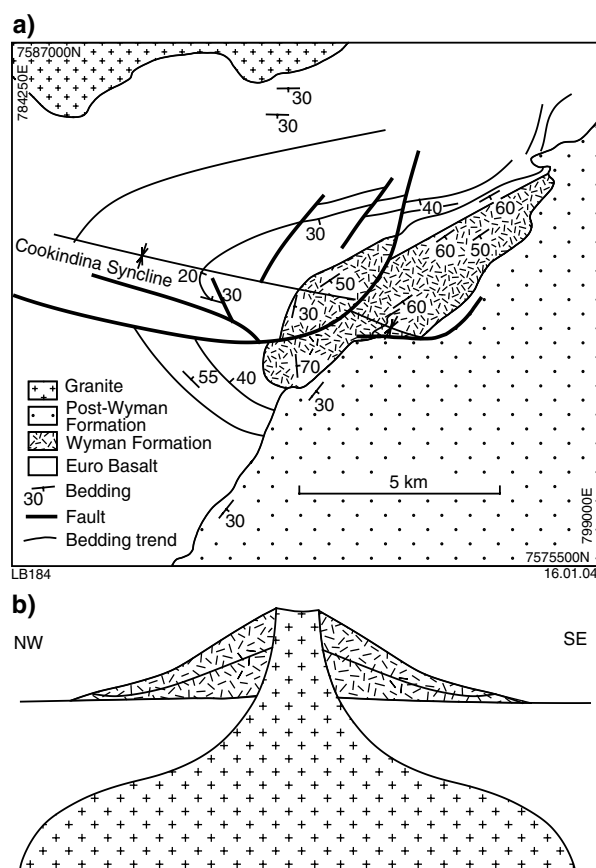


Figure 14. Simplified geological map of the Cookindina Syncline: a) showing dip variations among the major units; b) northwest-southeast schematic cross section of the area depicted in (a), showing deposition of the Wyman Formation on a primary slope of up to 20° southeast

area was northwest of the Cookindina Syncline in the core of the Corunna Downs Granitoid Complex.

The Cookindina Syncline and Warrery Gap Anticline are bound by an arcuate-shaped, multi-segmented fault system within the core of the Coongan Syncline that is parallel to the southwestern and western margins of the Corunna Downs Granitoid Complex. This central Coongan fault system is also interpreted to be a D_{2b} structure because the Budjan Creek Formation that is affected by D_3 structures unconformably overlies them. The set of close to tight, generally north- to doubly-plunging folds to the southwest of the fault system in the south-central part of the map area (MGA 781700E 7577000N) are also interpreted as D_{2b} structures. The Spinaway Anticline is also bound by another arcuate fault segment, but that is slightly younger (D_3 ; see below).

The Norman Cairn Fault (Fig. 3) in the southern part of the Coongan fault system (MGA 788000E 7577500N) juxtaposes northeast-facing Wyman Formation rocks in the southwest against the stratigraphically lower Euro Basalt to the northeast, and being inclined northeast is a reverse fault. Along strike to the north the fault system is oblique

to bedding in the Euro Basalt on either side, at a low angle. Here, there is no obvious stratigraphic offset across the fault system and the preserved kinematic shear sense is commonly sinistral, although Zegers (1996) described reverse, east-side-up displacement followed by normal, east-side-down displacement during greenschist-facies reactivation (D_3). As described below, the normal and sinistral shear sense indicators result from later reactivation (D_3 and younger) of an originally dip-slip system.

Dips obtained from the Coongan fault system indicate that it has a flower-shaped cross section (see cross section A–B on map) and thus, in a general sense, represents a central graben in which stratigraphically higher rocks of the Wyman Formation and intrusive ultramafic rocks have been dropped down and juxtaposed against the underlying Euro Basalt — a common feature of many East Pilbara greenstone belts (Hickman, 2001b). The Norman Cairn Fault is unconformably overlain by the Budjan Creek Formation to the southeast, indicating that the fault was active after the deposition of the Wyman Formation and before deposition of the Budjan Creek Formation, and is a late D_{2b} structure.

As discussed above, the Split Rock Shear Zone in the Shaw Granitoid Complex is herein interpreted to be the result of D_2 deformation at c. 3308 Ma (see **D_1 deformation** above). This zone and the granitic rocks older than c. 2930 Ma throughout the complex to the west contain an east- to northeast-dipping penetrative foliation parallel to the margin of the complex, and east-plunging mineral elongation lineation (Fig. 3). These structural fabric elements are cut by the c. 2930 Ma Eley Monzogranite and are therefore older than regional D_3 deformation defined on NORTH SHAW as c. 2940–2930 Ma (Van Kranendonk, 2000). The shear zone is not directly along the granite–greenstone contact, but at a distance of between 100 and 2000 m from the contact. It is separated from the greenstones by a zone of relatively low-strain, non-migmatitic c. 3468 Ma rocks of the North Shaw Suite. A gradual increase in strain from the granite–greenstone contact to the shear zone is correlated with the onset, and progressively increasing volume, of leucocratic monzogranite melt veins (Agsl) in the North Shaw Suite, which may indicate a component of shear deformation at the time of leucogranite intrusion (c. 3445–3410 Ma).

Although Zegers et al. (1996) described only reverse kinematic indicators from the Split Rock Shear Zone, the current mapping identified a variety of shear senses at various places along the shear zone, including sinistral, reverse, and normal (e.g. MGA 770400E 7606300N and 767250E 7583800N; see Fig. 3). Some localities have more than one type of shear sense, including both normal and reverse indicators in the same outcrop. However, the dominant fabric in the shear zone is of symmetrical feldspar augen bound by a well-developed biotite–quartz ribbon foliation, which indicates that deformation involved principally strong pure-shear flattening, and this is interpreted to account for the variety of shear sense indicators observed.

The principal S_2 foliation in granitic rocks older than c. 2940–2930 Ma west of the Split Rock Shear Zone transects lithological boundaries and overprints melting

textures and local folds developed during D_1 . This fabric gradually dies out in intensity away from the shear zone to the west and south.

Penetrative foliation (S_2) and metamorphic elongation lineation (L_2) extend for a distance of about 5 km into the Coongan greenstone belt to the east of the Split Rock Shear Zone, correlating with higher grades (amphibolite to upper greenschist facies) of metamorphism in the lower part of the stratigraphy (see **Metamorphism in the East Pilbara Granite–Greenstone Terrane**). A tight, north-plunging anticline, overturned to the east and cored by granitic rock along the southeastern margin of the Shaw Granitoid Complex (MGA 771000E 7582500N), is interpreted as a D_2 structure, as are associated minor folds (e.g. MGA 770400E 7590400N). D_2 mineral elongation lineation is commonly very well developed along the eastern margin of the Shaw Granitoid Complex and Coongan greenstone belt, around the Warrery Gap Anticline, and within the axis of the Coongan Syncline, although fabrics are rarely $L>S$ (Fig. 15).

The age of the D_2 deformation on SPLIT ROCK is constrained by several U–Pb SHRIMP dates on zircons from variably deformed supracrustal rocks from the Kelly greenstone belt and granitic rocks from the Corunna Downs Granitoid Complex and associated, coeval, felsic porphyry intrusions. A maximum age for the F_2 Cookindina Syncline and Spinaway Anticline (Fig. 3) is provided by the age of a vitric tuff in the c. 3323 Ma Wyman Formation (Nelson, 2001), which is a litho-stratigraphic unit affected by the folding. A minimum age for the Cookindina Syncline and Spinaway Anticline is provided by the crosscutting Boobina Porphyry, which is 3315 ± 4 Ma (Barley and Pickard, 1999) and is unaffected by F_2 folding. This minimum age for the Cookindina Syncline and central Coongan Syncline fault system is also supported by the unconformably overlying Budjan Creek Formation, from which a dated sample of crystal-lithic tuff yielded a maximum depositional age of 3308 ± 5 Ma (GSWA 168908; Nelson, 2001). These data also suggest that the F_2 folding event and intrusion of the Boobina Porphyry were broadly synchronous at c. 3315 Ma.



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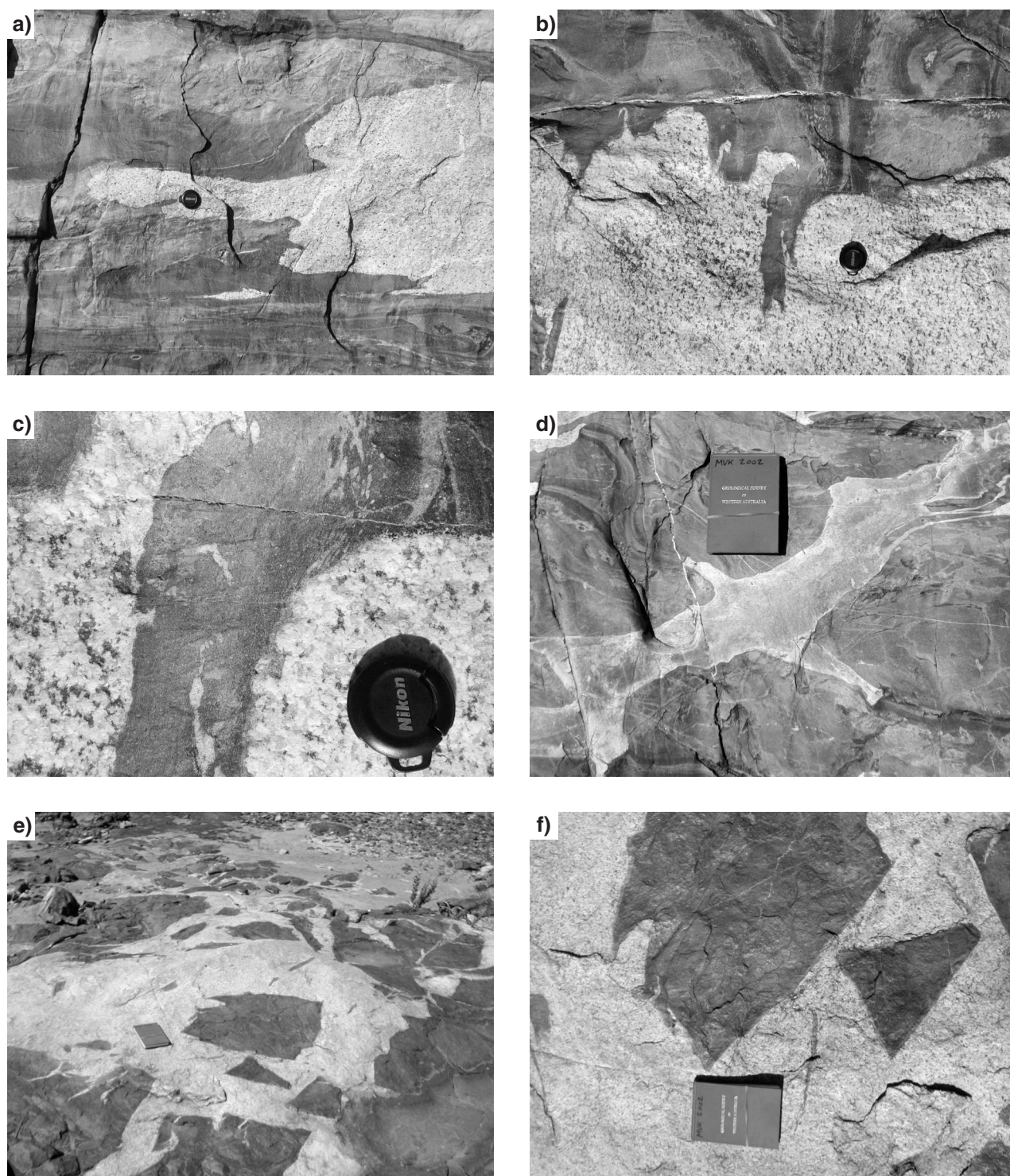
Figure 15. Strong D_2 rodding lineation (with $L>S$) in meta-basalt of the Euro Basalt in the Coongan greenstone belt (MGA 777600E 7576600N)

Similarly, F_2 folded, east-younging rocks of the c. 3346 Ma Euro Basalt on the eastern limb of the Warrery Gap Anticline are intruded by c. 3307 Ma hornblende–biotite monzogranite (*AgOmhp*) of the Corunna Downs Granitoid Complex, indicating that folding must have occurred between these ages. The granitic rocks in the core of the anticline were dated by Rb–Sr at c. 3270 Ma (Cooper et al., 1982), which must be regarded as a minimum age of the granite. An Ar–Ar date on hornblende from amphibolites on the eastern limb of the anticline is 3341 ± 13 Ma (Zegers et al., 1999) and thus the age constraints by these less robust systematics bracket the same, although broader, age range as the zircon data.

The age of the Warrery Gap Anticline is constrained by the fact that the hinge region of the fold is intruded by a syn- to late-tectonic granodiorite, which is linked by a dyke swarm to the main part of the c. 3313–3300 Ma Nandingarra Granodiorite of the Corunna Downs Granitoid Complex (Fig. 12). The emplacement style of the granite sheets varies across the eastern contact of the folded greenstones with the granite complex. At the contact, granite sheets with lobe-and-cusp shaped margins and stockwork vein arrays intrude foliated amphibolite (Fig. 16a,b; also see the cover photo). Penetrative foliation in the amphibolite is locally deflected into cusps between lobes of undeformed to weakly strained granite sheets (Fig. 16c), but is parallel to foliation elsewhere in the granite sheets. The lobe-and-cusp shaped margins between the granite sheets and amphibolite indicate a competency contrast between the rock types, but the single foliation in both rock types indicates that they were deformed together. About 400 m west of the contact, undeformed granite sheets display stepwise fracture emplacement features, characteristic of late syntectonic emplacement, with apophyses emplaced into relict pillow margins (Fig. 16d). Another 100 m farther west, the granite sheets are undeformed and contain angular inclusions of undeformed, but metamorphosed, pillow basalt (Fig. 16e,f). Granitic rocks in the hinge of the anticline are weakly foliated, but show strong primary pinch-and-swell texture indicative of emplacement during late F_2 fold-related compression (Fig. 17).

A maximum age for F_2 folding southwest of the Coongan fault system is provided by a sample of volcanogenic sandstone from the Wyman Formation, which is dated at c. 3319 Ma. The maximum age of D_2 shearing within the western limb of the Coongan greenstone belt, north of the Cooglegong Monzogranite, is constrained by a zircon age on a strongly foliated granitic sheet (*AgSmv*) within the greenstones, at 3321 ± 3 Ma (Thorpe, R., Geological Survey of Canada, 1992, written comm.), whereas a minimum age for shear deformation in the Coongan fault system is 3197 ± 44 Ma (Zegers et al., 1999; sample T93/182).

Most of the dated granitic rocks in the Corunna Downs Granitoid Complex (c. 3317–3307 Ma) fall within the same age range as the available age constraints for the D_2 deformation, indicating contemporaneous development of structures with magmatism and a probable causal relationship. The curvilinear Coongan fault system is broadly parallel to the edge of the Corunna Downs Granitoid Complex, a characteristic used to infer that

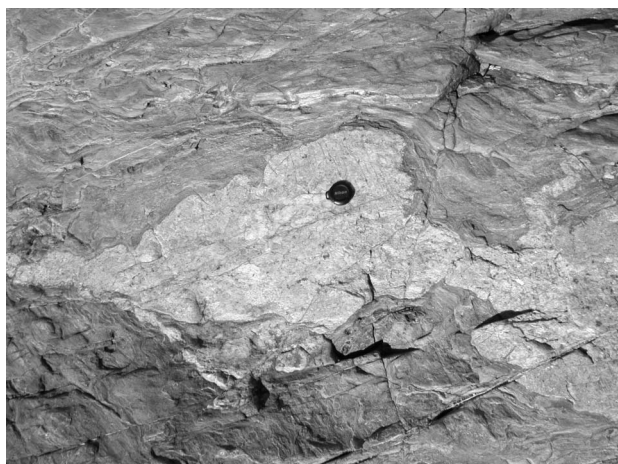


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Figure 16. Emplacement features of granitic rocks of the Corunna Downs Granitoid Complex into the Euro Basalt on the eastern limb of the Warrery Gap Anticline, at Warrery Gap:

- a) horizontal pavement, looking east, with a lobate, weakly foliated syntectonic granite sheet (white) intruding pillow metabasalt of the Euro Basalt. Colour variations in the metabasalt reflect alteration rinds on relict, flattened pillows; lens cap is 20 mm in diameter;
- b) pavement, looking east, with lobe-cusp geometry of foliated granite sheet intruding foliated amphibolite-facies pillowed metabasalt of the Euro Basalt. Note the variolitic texture of the metabasalt; lens cap is 20 mm in diameter;
- c) close-up of (b) above, showing a deflected foliation in metabasalt wrapping around an undeformed granite lobe;
- d) horizontal outcrop surface, looking south, with a granite sheet with apophyses emplaced along pillow rinds in amphibolite-grade pillowed metabasalt of the Euro Basalt;
- e) horizontal outcrop surface, looking south, with an undeformed brittle granite vein network in upper greenschist-facies pillowed metabasalt of the Euro Basalt;
- f) close-up of (e) above. Note that xenoliths are at upper greenschist facies, but have narrow amphibolite-grade contact rinds with the granite sheet



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Figure 17. Syntectonic granite vein (*Agona*) in strongly foliated Panorama Formation felsic schist in the core of the Warrery Gap Anticline, showing primary pinch-and-swell texture indicative of emplacement during shear deformation associated with F_2 fold formation

faulting and syncline formation were caused by continued upward and outward growth of the flanking granite domes during their emplacement as magmatic and (partly) solid-state diapirs (Van Kranendonk et al., 2002). These relationships are similar to those described for the Mount Edgar Granitoid Complex and structures in flanking greenstones (Collins, 1989; Williams and Collins, 1990; Collins et al., 1998). The shallow westerly and southerly dips of greenstones around the southwestern edge of the Corunna Downs Granitoid Complex and low grade of metamorphism suggest that this area is near the top of the granite-cored structural dome, whereas steeper dips and a higher metamorphic grade to the north indicate deeper structural levels. The shallow westerly dips at the southwestern part of the Corunna Downs Granitoid Complex continue west, across the Coongan fault system, into the western limb of the Coongan Syncline, where rocks dip moderately (40° – 50°) to the west, but are overturned (e.g. MGA 775800E 7597400N). Overturned bedding at higher metamorphic grade characterizes much of the western limb of the Coongan greenstone belt. These features can be used to infer that the axial plane of the Coongan Syncline is inclined to the west and that doming reached higher levels in the Shaw Granitoid Complex than in the Corunna Downs Granitoid Complex (Fig. 18).

D_3 deformation (>3308 Ma)

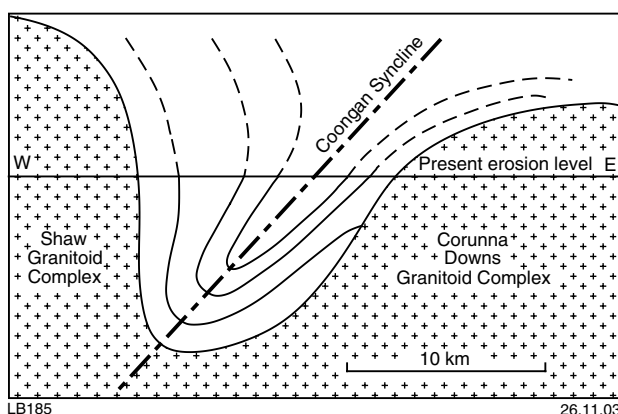
Deformation associated with the D_3 event involved tilting of the Budjan Creek and Gorge Creek Group away from the Corunna Downs Granitoid Complex and thus occurred after c. 3308 Ma, but before deposition of the Fortescue Group at 2772 Ma. This southeasterly dip is indicative of continued doming of the Corunna Downs Granitoid Complex after c. 3300 Ma, although the age of tilting is not constrained by precise geochronology. The Gorge

Creek Group overlies the Budjan Creek Formation with a low angular unconformity (see Gorge Creek Group above), indicating that tilting was intermittent during the deposition of these units.

Other structures that formed after the deposition of the Gorge Creek Group, but before deposition of the Fortescue Group, include a set of splayed northeasterly striking faults in the northeastern part of the Kelly greenstone belt, which locally repeat the stratigraphy of the Kelly Subgroup and Gorge Creek Group as a result of steep reverse, east-side-up displacement. These faults are responsible for bringing the Euro Basalt up over the Budjan Creek Formation southeast of the Copper Hills mining area (e.g. at MGA 808000E 7599000N), the Euro Basalt and Wyman Formation over the Gorge Creek Group (e.g. at MGA 807500E 7596300N), and the Euro Basalt over the Wyman Formation (e.g. at MGA 810000E 7597500N). A tight, upright syncline–anticline pair is associated with these faults in the Wyman Formation and Gorge Creek Group (MGA 805800E 7594700N and 805500E 7593400N). A fault in the Gorge Creek Group about 6 km south-southeast of the Kellys mine (MGA 800150E 7582850N) is cut by the basal unconformity of the Mount Roe Basalt and is interpreted to belong to this set of structures.

Metamorphism in the East Pilbara Granite–Greenstone Terrane

Rocks of the EPGGT are commonly characterized by low to medium grades of metamorphism. Metamorphic grades vary from widespread greenschist facies to amphibolite or hornblende-hornfels facies along contacts with granitic complexes near the base of the Warrawoona Group. In the



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Figure 18. Simplified west–east cross section of the Coongan greenstone belt across the central part of SPLIT ROCK, showing the overturned nature of the Coongan Syncline between the differentially uplifted Shaw (greater) and Corunna Downs (lesser) Granitoid Complexes. Note that this area represents a structurally higher level than farther north in the map area, where the syncline is upright and eroded to deeper levels (see the A–B part of the cross section on the map)

Warrawoona Group, basalt typically contains secondary actinolite, plagioclase (albite), chlorite, and quartz, and high-Mg basaltic rocks commonly contain tremolite (pseudomorphs after pyroxene-spinifex texture), chlorite, and quartz assemblages that are characteristic of greenschist-facies metamorphism. Within about 1 km from the granitic complex contacts, basaltic rocks commonly contain hornblende–titanite–plagioclase–quartz assemblages, retrogressed in places to actinolite–epidote–albite–sericite; pelitic rocks locally contain biotite–garnet–muscovite. These assemblages are characteristic of the hornblende–hornfels facies of contact metamorphism with retrogression to the albite–epidote–hornfels facies. The retrogression suggests that contact metamorphism was a protracted event, as also indicated by results from Ar–Ar dating of metamorphic minerals in this area (Davids et al., 1997; Zegers et al., 1999).

Mafic and ultramafic xenoliths, rafts, and enclaves from the Warrawoona Group are common in the central and northern parts of the Corunna Downs Granitoid Complex, and typically contain clinopyroxene altered to chlorite, chlorite, rare brown hornblende, and plagioclase replaced by albite, clinozoisite or epidote. These mineral assemblages are typical of hornblende–hornfels or slightly higher metamorphic facies (Turner, 1981).

Davy (1988) described chlorite–epidote and prehnite–pumpellyite metamorphism of the Corunna Downs Granitoid Complex on SPLIT ROCK, although the relative ages between these facies could not be determined. The presence of clinozoisite as well as epidote in the granitic rocks indicates widespread greenschist-facies metamorphism.

Greenstones in the Coongan greenstone belt show evidence of two episodes of metamorphism. These include an early period of amphibolite-facies metamorphism, which Ar–Ar dating indicates may be as old as c. 3400 Ma, but is more likely to be 3240 ± 8 Ma (Davids et al., 1997). Greenschist-facies retrograde metamorphism, overprinting shearing in the core of the Coongan greenstone belt, occurred at 3197 ± 44 Ma (Zegers et al., 1999) and 2941 ± 11 Ma (Davids et al., 1997). This is within error of the maximum ages of cooling of granodiorite in the Split Rock Shear Zone at c. 3222 ± 13 Ma (Zegers et al., 1999) and 3206 ± 24 Ma (Davids et al., 1997).

Cooling ages of 2993 ± 21 and 2959 ± 10 Ma from synkinematic metamorphic minerals in the Split Rock Shear Zone indicate shear reactivation during D₃ (Zegers et al., 1999).

Fortescue Group

Igneous and sedimentary rocks of the Neoarchaeon Fortescue Group of the Hamersley Basin (Trendall, 1990a,b) in the southeastern part of SPLIT ROCK (Fig. 1) overlie the Pilbara Supergroup with an angular unconformably. The Fortescue Group on SPLIT ROCK comprises weakly metamorphosed mafic and felsic volcanic rocks and sedimentary rocks (Table 1), which are subdivided into the Black Range Dolerite suite (AFdb), Mount Roe Basalt (AFr), Hardey Formation (AFh), Kylenea Formation

(AFk), Tumbiana Formation (AFt), and undifferentiated dolerite dykes (AF(d)). The group was deposited between c. 2772 and c. 2687 Ma (Arndt et al., 1991; Trendall et al., 1998).

Black Range Dolerite suite (AFdb)

The Black Range Dolerite suite (AFdb; Lewis et al., 1975) is characterized by north-northeasterly trending, medium- to coarse-grained dolerite to gabbro dykes, which form prominent ridges in the Shaw and Corunna Downs Granitoid Complexes, and more-subdued ridges in the greenstone belts.

The dolerite dykes are up to 200 m wide and are characterized by chilled margins that are a few metres wide. Locally, they have hybridized and melted the immediately adjacent country rocks and produced a contact-metamorphic aureole that is typically about 3 m wide and characterized by prominent outcrop of the country rock along the sides of the dykes, whereas the country rocks outside the aureole are topographically more subdued. The dolerite suite has a U–Pb baddeleyite SHRIMP age of 2772 ± 2 Ma (Wingate, 1997; Van Kranendonk, 2000), and is thought to be a feeder dyke system for the Mount Roe Basalt (Williams, 1999).

The Black Range Dolerite and gabbro consist of albitized plagioclase, anhedral clinopyroxene with orthopyroxene cores altered to various combinations of chlorite–epidote–carbonate, and accessory titanomagnetite and disseminated patches of granophyre containing acicular apatite.

Mount Roe Basalt (AFr, AFrba, AFrbm, AFrbt, AFrs)

The Mount Roe Basalt (Kriewaldt, 1964) unconformably overlies the Warrawoona and Gorge Creek Groups, and is up to about 500 m in thickness. It is a massive, porphyritic, vesicular, and amygdaloidal basalt (AFr). The age of the Mount Roe Basalt is constrained by U–Pb zircon dates of 2763 ± 13 and 2775 ± 10 Ma from rhyolitic rocks and lapilli tuff near the base of the formation on ROEBOURNE and WYLOO (Arndt et al., 1991).

Massive porphyritic and pillowed, vesicular, and amygdaloidal basalt (AFr) is the common rock type in the Mount Roe Basalt. The basalt is altered to chlorite and epidote in places, and amygdaloids contain agate, clear quartz or calcite and can be up to 50 mm in diameter. The base of the formation locally consists of interbedded mafic volcanic breccia, mafic agglomerate, and mafic lapilli tuff (AFrba), vesicular high-Mg basalt (AFrbm), basaltic tuff and mafic wacke with thinly interbedded shale (AFrbt), and thickly bedded sandstone, pebbly sandstone and minor polymictic conglomerate (AFrs; MGA 783400E 7575000N). The conglomerate units contain angular to subrounded clasts of black and white chert, vein quartz, and rare clasts of porphyry and mafic volcanic rocks, and grade into medium- to coarse-grained sandstone. Fragments of basalt in a fine-grained basaltic matrix characterize the agglomerate. The overlapping and lensoidal nature of both the sedimentary and agglomerate units

(such as near MGA 783000E 7573500N) indicate that they occupy palaeovalleys eroded in the underlying basement rocks.

Hardey Formation (AFhsh, AFhsw, AFhb, AFh, AFhs, AFhsc)

The Hardey Formation (Thorne et al., 1991) on SPLIT ROCK both disconformably or unconformably overlies the Mount Roe Basalt, and appears to be conformably overlain by the Kylena Formation. Uranium–lead zircon dates from the Hardey Formation (Bamboo Creek Member) are between 2764 ± 16 and 2756 ± 8 Ma (Pidgeon, 1984; Arndt et al., 1991). Thorne and Trendall (2001) reported five main sedimentary facies within the formation: alluvial fan and coarse-grained braided alluvial, sandy braided fluvial, lacustrine, deltaic, and shoreline.

The thickness of the Hardey Formation on SPLIT ROCK ranges from about 1000 m (around MGA 800000E 7577000N) to about 60 m in its most southwesterly exposure (at MGA 787000E 7567000N). The lowermost rocks of the Hardey Formation are interbedded shale (which is ooidal and pisolitic), lithic wacke, and minor tuff (AFhsh); and lithic wacke, poorly sorted sandstone, shale, and siltstone (AFhsw). These basal units are interlayered with or overlain by rhyodacite, with quartz phenocrysts, of the Bamboo Creek Member (AFhb). The uppermost unit is thinly bedded sandstone interbedded with minor conglomerate, shale, tuff, and ooidal and pisolitic beds and rare basalt (AFhs).

Sandstone interbedded with minor amounts of pebble to cobble conglomerate, mudstone, shale, and felsic tuff (AFh) are the most common rock type in the Hardey Formation. The sandstone is feldspathic to arkosic, fine to coarse grained, well sorted or pebbly, and displays local cross-bedding. The conglomerate is polymictic, matrix supported, upward fining, and contains clasts of quartz, chert, and rare mafic volcanic and granitic rocks, and is interbedded with medium- to coarse-grained sandstone (AFhsc).

Bamboo Creek Member (AFhb)

The Bamboo Creek Member (AFhb; Thorne and Trendall, 2001) outcrops in places near the base of the formation, and consists of massive quartz–feldspar porphyry of rhyodacitic composition. It has characteristic subhorizontal joints that probably follow bedding within the unit. Blake (1984, 1993), and Thorne and Trendall (2001) interpreted the porphyry as a sequence of lava flows interlayered with pyroclastic deposits and synvolcanic porphyritic sills and dykes.

Kylena Formation (AFk)

The Kylena Formation (AFk; Kriewaldt and Ryan, 1967; Kojan and Hickman, 1998) is around 600 m thick on SPLIT ROCK and rests conformably on the Hardey Formation. The maximum age for the formation is constrained by the youngest U–Pb zircon date from the underlying Hardey Formation, which is 2756 ± 8 Ma (Arndt et al., 1991). The minimum U–Pb age constraint is 2719 ± 6 Ma, which is

the age of a zircon population in volcanoclastic sandstone in the overlying Tumbiana Formation (Nelson, 2001).

The Kylena Formation on SPLIT ROCK consists of massive, vesicular, and amygdaloidal basalt, and includes some pillow lava, local columnar jointing, and minor basaltic agglomerate. Individual basalt flows are less than 10 m thick, and are amygdaloidal at their top, with amygdales filled with agate, clear quartz or calcite. The basalt commonly contains clinopyroxene, orthopyroxene altered to chlorite, plagioclase, and secondary interstitial actinolite, epidote, sericite, and chlorite.

Tumbiana Formation (AFtt, AFtc)

The Tumbiana Formation (Hickman and Lipple, 1978) conformably overlies the Kylena Formation, is about 500 m thick, and was subdivided by Lipple (1975) into the ‘lower Mingah Tuff Member’ (AFtt), and the upper ‘Carbonate Member’ (AFtc). Thorne and Trendall (2001) renamed these the Mingah Member (AFtt) and the Meentheena Member (AFtc). In the west Pilbara, the formation was dated at 2719 ± 6 Ma (Nelson, 2001), which is in agreement with a more-precise age of 2717 ± 2 Ma from dacite in the overlying Maddina Formation (Nelson, 1998).

Mingah Member (AFtt)

The Mingah Member (AFtt; Thorne and Trendall, 2001) consists of thin- to medium-bedded (up to 2 m) pisolitic tuff interbedded with tuffaceous siltstone, sandstone, and thin carbonate units. The tuffaceous beds include fine-grained basalt flows formed at irregular intervals, pisolitic tuff, accretionary lapilli tuff, crystal tuff, lithic tuff, and vitric tuff. Palaeocurrent directions in cross-bedded tuffaceous sandstone indicate that currents flowed mainly from the northeast.

Although some thin carbonate beds outcrop in the Mingah Member, the first thick (>1 m) carbonate unit is considered to be the basal unit of the conformably overlying Meentheena Member.

Meentheena Member (AFtc)

The Meentheena Member (AFtc; Thorne and Trendall, 2001) transitionally overlies the Mingah Member, and consists of banded dark-grey siliceous, stromatolitic dolomite and limestone beds, minor tuffaceous shale and siltstone, and rare thinly bedded tuff. The limestone beds contain scattered oncolites and stromatolites in bioherms and biostromes, and are oolitic in places.

Dolerite dykes (AF(d))

A suite of north-northeasterly striking, medium- to coarse-grained dolerite dykes of the Fortescue Group (AF(d)) transect the map area at a spacing of 2 to 9 km. The dykes are up to 120 m wide and commonly show evidence of deuteric alteration. Most of the dykes show en-echelon, left-stepping emplacement patterns indicative of a component of sinistral shear parallel to the strike of the dykes during west-northwest – east-southeast extension

(see **D₄ faulting** below). The strike of the dykes, and stepped emplacement pattern is similar to the dated c. 2772 Ma Black Range Dolerite dyke (Wingate, 1997), but observations on NORTH SHAW suggest that at least some of the parallel dykes may be younger than the Kylena Formation (Van Kranendonk, 2000) and thus the dykes are designated as unassigned on this map.

Syn- to post-Fortescue Group deformation

Van Kranendonk et al. (2002) recognized that at least two sets of structures affect the Fortescue Group. The main set developed between deposition of the Mount Roe Basalt and the Hardey Formation, and consists of tight upright folds in the Mount Roe Basalt that are unconformably overlain by the Hardey Formation. A second set of more-gentle folds affects the Hardey and Kylena Formations. These two sets of structures have also been recognized on SPLIT ROCK (labelled 5 and 6 on Fig. 3; Table 2), and are followed by a late set of faults (7 on Fig. 3).

D₄ faulting (c. 2770–2756 Ma)

Several brittle faults (D₄) striking north–south to north-northeast with west- to northwest-side-down displacement deform the Fortescue Group on SPLIT ROCK (Fig. 3). Several of these form the bounding faults to small sub-basins of the Mount Roe Basalt of the Fortescue Group (MGA 784000E 7575000N and 788000E 7574000N) and are interpreted to be synchronous with or younger than the Mount Roe Basalt. Major faults interpreted to belong to this set include a splayed fault that transects the Cooglegong Monzogranite (MGA 767700E 7610500N), a 30 km-long fault in the western part of the Corunna Downs Granitoid Complex (MGA 789000E 7606000N), and minor faults that cut the Boobina Porphyry and overlying greenstones (MGA 799000E 7586000N). These faults typically link together stepped segments of dolerite dykes assigned to the Fortescue Group, and are interpreted to be related to emplacement of the dolerite dykes during regional transtension. The sinistral, en-echelon stepping pattern of the dykes indicates that the regional extension direction during dyke emplacement was west-northwest – east-southeast, but included a component of sinistral wrenching.

A distinctive feature of the Mount Roe Basalt is its significant variation in thickness across the easterly dipping Tundununya Fault (Fig. 3) in the southern part of SPLIT ROCK (e.g. MGA 788500E 7571000N). The formation thins to the east of this fault, whereas the overlying Hardey Formation significantly increases in thickness from a few metres west of the fault to about 900 m east of the fault. This variation implies discordance (disconformity or low-angle unconformity) between the two formations, as also observed elsewhere (Van Kranendonk, 2000, 2003), and it also suggests that the structure was active as a high-angle reverse fault (east-side up) during extrusion of basalts in the Mount Roe Basalt and as a normal fault (east-side down) during deposition of the Hardey Formation. Faulting thus occurred between c. 2770 and 2756 Ma, which are the respective ages of the

Mount Roe Basalt and the Hardey Formation (Arndt et al., 1991). Activity along the fault ceased before extrusion of the basalts in the Kylena Formation, which straddles both sides of the fault without any sign of thickness variation.

D₅ folding of the Fortescue Group (<2719 Ma)

The Fortescue Group is gently folded on shallow south-southwesterly plunging axes in the southeastern quadrant of SPLIT ROCK. Some of these folds have curvilinear traces formed by refolding during D₆, and are cut by eastward-trending faults (D₇) that host dolerite dykes of post-Fortescue Group age (*d*; e.g. MGA 705750E 7589150N). The F₅ folds are open and indicative of east-southeasterly to west-northwesterly directed shortening. As with the D₂ and D₃ structures, this compression is consistent with a period of renewed outward and upward growth of the Corunna Downs Granitoid Complex. These folds are younger than the c. 2719 Ma Tumbiana Formation (Nelson, 2001).

D₆ faulting (<2719 Ma)

Structures attributed to D₆ include a set of south-southwesterly trending, east-side-down normal faults (e.g. MGA 807000E 7590700N), southeasterly trending faults (MGA 808220E 7589200N), and flexures of F₅ folds in the Fortescue Group (e.g. near MGA 806000E 7591000N). These structures are younger than the Tumbiana Formation, which is dated at c. 2719 Ma (Nelson, 2001), and are indicative of east-southeasterly directed extension.

Unassigned rocks of uncertain Precambrian age

Dolerite (*d*), quartz (*q*), mylonite (*mmg*)

Two swarms of dolerite dykes post-date the Fortescue Group on SPLIT ROCK. One dolerite dyke trends east-northeast across the northwestern part of the sheet area and cuts the Black Range Dolerite dyke (*AFdb*; MGA 759500E 7619100N) and is assigned to the Neoproterozoic Mundine Well dyke swarm (*Edw*; Hickman and Lipple, 1978; Wingate and Giddings, 2000; see **Mundine Well dyke swarm** below). A younger swarm of thin, east-southeasterly trending dolerite dykes (*d*, Round Hummock Suite of Hickman and Lipple, 1978) cuts across the Shaw Granitoid Complex (MGA 768500E 7583700N) and the Corunna Downs Granitoid Complex (MGA 794600E 7591100N), extending to the eastern boundary of the map sheet. One of these dykes intrudes rocks of the Hardey Formation (Fortescue Group) and follows an easterly trending fault (e.g. MGA 705000E 7589200N). Some dykes of uncertain age are also ascribed to this set, but may be older.

The dolerite dykes of this younger swarm (*d*) are commonly fine grained rocks that weather dark green to black with a fine ophitic texture of plagioclase laths and interstitial augite. Some of the dykes contain a hydrous mafic mineral assemblage of actinolite and epidote

intergrown with plagioclase. In these dykes, relicts of pyroxenes have been completely altered to fine-grained green chlorite, sericite, and ?feldspar, probably as a result of intense deuteric alteration. These dykes were emplaced into fractures that are filled along strike by quartz (*q*), and quartz veins commonly fill parallel fractures to some of the dykes.

The western part of the Corunna Downs Granitoid Complex is cut by narrow, northerly trending ridges of mylonite (*mmg*) formed by extreme shearing of granitic rocks. The mylonite is a fine-grained siliceous rock composed of quartzofeldspathic material, and resembles chert or silcrete in appearance. It contains millimetre-scale zones of granitic rocks composed of plagioclase, microcline, and quartz, and locally contains unsorted fragments of granite containing plagioclase, microcline, and quartz, and aggregates of chlorite and epidote derived largely from biotite. The plagioclase is commonly altered to albite and epidote, and biotite is altered to chlorite and epidote.

Quartz veins (*q*) occupy faults, shear zones, tension gashes, and joints in the Warrawoona Group, and in the Shaw and Corunna Downs Granitoid Complexes. Because no quartz veins cut the Fortescue Group, it is most likely that the veins are older than c. 2772 Ma.

Proterozoic dykes

Kimberlite (*Bk*)

Several thin (up to 3 m), but locally up to 1.5 km-long, ultramafic dykes of undeformed to weakly schistose carbonate and carbonate–chlorite–serpentine–talc rock intrude the Mount Ada Basalt and Duffer Formation along the central part of the Coongan greenstone belt (MGA 773000E 7595000N, 772000E 7596000N, and 769500E 7596000N). These rocks typically have a poorly preserved olivine macrocrystic texture, are quite heavily calcretized, and are interpreted as kimberlite (*Bk*). In thin section, the rocks contain 60–90% fine- to medium-grained carbonate, 5–30% chlorite and serpentine, minor talc, and a few flakes of mica, probably phlogopite. The dykes strike east to southeast across the greenstone belt and are several kilometres south of the along-strike projection of the hypabyssal-facies Brockman Creek Kimberlite on the adjacent MARBLE BAR and MOUNT EDGAR sheet areas (Wyatt et al., 2001; Williams, in prep.).

Mundine Well dyke swarm (*Bdw*)

Dykes of the Mundine Well dyke swarm (*Bdw*) intrude the southwestern part of SPLIT ROCK (MGA 761000E 7579500N). Tyler (1991) stated that this suite extends across the Pilbara Craton, is younger than the Bangemall Supergroup in the Bangemall Superbasin, and thus is probably younger than Mesoproterozoic. A date of 755 ± 3 Ma was obtained for two dykes of the Mundine Well dyke swarm from the Bangemall Superbasin.

The dolerite (*Bdw*) of the Mundine Well dyke swarm on SPLIT ROCK is distinctive from other dolerites because

it is flanked on one or both sides by a ridge, up to 5 m high and 5 m wide, of undeformed, dark-pink-weathering syenite and potassic alteration of wall rocks. Locally, the dolerite is a normal medium- to coarse-grained dolerite. In some places along strike, however, the dolerite contains numerous granitic xenoliths that have a distinctive, coarse-grained texture defined by spherical to ovoid patches of grey quartz surrounded by pink feldspar. In thin section, the granitic xenoliths are composed of linked, elliptical to elongate aggregates of quartz, 1–10 mm across, in a red matrix of feldspar. The quartz forms coarse, unstrained crystals with commonly sutured boundaries and sharp curved boundaries with adjacent myrmekite or feldspar. A dark-pink rind of myrmekite, typically 0.5 mm wide, surrounds the quartz. Feldspars consist of relict cores of coarse-grained plagioclase and K-feldspar rimmed by fine-grained, recrystallized feldspar and myrmekite.

Late structures (*D₇*)

A set of easterly to east-southeasterly striking faults (*D₇*) and quartz veins cuts across the map area, parallel to the late dolerite dykes of the Round Hummock Suite (*d*), with which they are associated. These faults offset the eastern contact of the Shaw Granitoid Complex, with flanking greenstones with an apparent dextral sense of displacement (labelled 7 on Fig. 3; e.g. MGA 772150E, 7580750N). Another fault of this suite cuts the Fortescue Group in the east-central part of the sheet area, along strike to the east from a thin dolerite dyke (*d*; MGA 805500E, 7589250N).

Cainozoic deposits

Cainozoic deposits are widespread on the granitic complexes of SPLIT ROCK and sparsely distributed in areas of greenstones. Older deposits include consolidated alluvial, colluvial, and residual material. More-recent unconsolidated Quaternary deposits include alluvial, colluvial, eluvial, and eolian material.

Gently undulating duricrust surfaces, including ferricrete or ironstone deposits (*Czrf*) and silcrete deposits (*Czrz*) expose underlying bedrock where dissected. The ferricrete grades downward into leached and kaolinized deeply weathered rock. The duricrust represents remnants of Cainozoic or older weathering profiles in which the original rock structures or textures are poorly preserved. Ferricrete deposits are several metres thick, include massive, pisolitic, and nodular ironstone, and consolidated ferruginous alluvium in places. The ferricrete is typically developed on ferruginous shale and banded iron-formation of the Gorge Creek Group in the eastern part of SPLIT ROCK. Silcrete (*Czrz*) is probably Tertiary or older in age, may represent a Tertiary continent-wide weathering event (Idnurm and Senior, 1978), and consists of angular quartz grains and chert clasts set in siliceous cement. Residual calcrete (*Czrk*) overlies and is derived from altered carbonate-rich ultramafic rocks, and covers large areas bordering rivers or creeks over granitic rocks. The calcrete forms sheets, encrustations, and joint-fills, and is either massive or nodular. Consolidated and dissected mixed

eluvium and colluvium (*Czrg*) is composed of quartz–feldspar clay, silt, sand, and gravel derived from granitic rocks.

Consolidated, dissected colluvium (*Czc*) and relict colluvial sand, silt, and gravel (*Czcs*) are derived from adjacent rock outcrops through erosion of topographically high points. Composed of clay, silt, sand, and pebbly sand and gravel with clay or silica cement, dissected colluvium (*Czc*) is most widely distributed on flat granitic complexes and on low slopes or flat plains throughout SPLIT ROCK. Consolidated and dissected colluvium (*Czcg*) is composed of quartz–feldspar clay, silt, sand, and gravel derived from granitic rocks. Consolidated and dissected colluvium composed of quartz sand, silt, and gravel derived from quartz veins (*Czcg*) is exposed along the sides of ridges containing quartz veins.

Coarse-grained, consolidated, and dissected alluvial deposits consisting of clay-cemented, poorly stratified gravel composed of chert, basalt, and dolerite, with sand, silt, and clay (*Czagd*) were deposited on granitic rocks near active rivers. This unit is a surface lag deposit, and probably includes older outwash fan deposits.

Dissected pisolitic, ferruginous (limonitic, goethitic, and hematitic) channel deposits along palaeodrainage lines (*Czaf*) are between 10 and 30 m thick, and contain traces of fossil wood in places. The unit forms elevated terraces and mesas, and has been correlated by Hickman and Lipple (1978) with the Poondano Formation and the Robe Pisolite (de la Hunty, 1965; MacLeod, 1966) that forms part of a peneplain surface known as the Hamersley Surface.

Consolidated and dissected, poorly stratified, alluvial gravel, sand, and silt (*Czaa*, *Czaag* in granitic areas) are along the banks of creeks and rivers.

Quaternary deposits

Quaternary deposits consist of residual, alluvial, and colluvial deposits, together with sheetwash and lacustrine deposits, and minor eolian deposits.

The creek and river system on SPLIT ROCK contains a wide range of alluvial deposits. Unconsolidated alluvial gravel, sand, and silt (*Qaa*) occupy major drainage channels and smaller channels on floodplain. The surface of the major channels is incised below the top of adjacent floodplain and overbank deposits of alluvial sand, silt, with minor clay, and gravel (*Qao*). Large claypans of alluvial silt, clay, and minor sand (*Qaoc*) are developed on floodplains, and are commonly fed by alluvial fans. Minor drainage channels commonly have a clay surface, although some have a scattered quartz-pebble or rock-fragment veneer.

Recent colluvium consisting of sand, silt, and gravel (*Qc*) forms outwash fans, scree, and talus, and is common in hilly areas and on the granitic complex land surface. Other colluvial units consist of quartzofeldspathic eluvial gravel, sand with quartz and rock fragments (*Qcg*) in outwash fans derived from granitic rocks as in areas with

low slopes, and ferricrete sand and pebbles developed over ferricrete or iron-rich rocks (*Qcf*).

Medium- to coarse-grained, residual quartz and feldspar sand with scattered quartz pebbles and granite fragments (*Qrg*) overlies or is adjacent to the main granite exposures. Although the unit is mainly residual, there is some reworking of the finer components by wind action.

Sheetwash deposits of sand and quartz pebble derived from granitic rocks (*Qwg*) directly overlie areas of granitic rock. Fine- to medium-grained eolian sand (*Qs*) forms undulating sheets in the southeastern part of SPLIT ROCK. The variable grain size and coarser grained components of these sands suggest that they constitute a mixture of eolian and eluvial sand.

Economic geology

Early mineral exploration in the SPLIT ROCK area in the late 1880s followed the discovery of gold and base metals in the Marble Bar area. The first recorded production was of copper in the Copper Hills and Kellys mining areas during the 1950s and early 1960s.

Gold

Vein and hydrothermal gold has been found along the length of the Coongan greenstone belt, but is absent from the eastern limb of the Coongan Syncline. The GSWA's Western Australian mineral occurrence database (WAMIN; Ferguson and Ruddock, 2001) records 18 sites, ranging from grab sample localities to alluvial workings and mines, which were worked over periods from 1911 to 1981. The sites are described below from north to south with WAMIN reference numbers in brackets.

A series of gold prospects between about 500 m and 1.3 km west of the Coongan fault system is in metamorphosed basalt units of the Euro Basalt (e.g. Edelweiss; 2798)). Drilling in layered gabbro at Edelweiss returned an assay of 12.28 g/t Au over 5.2 m and this orebody of gold, pyrite, and chalcopyrite was exploited from a large opencut mine near Corboy Cairn (MGA 776500E 7593900N). A small pit was developed in gabbro at Corboy (5813), about 1 km along strike to the north of Edelweiss, and two shallow shafts were dug at Corboy Southeast (5917) where a grab sample contained 33.7 g/t Au. The host rocks to these gold deposits form part of a thick, high-Mg basalt sequence of the Euro Basalt and are in an area of north-northeasterly striking quartz veins.

About 3–4 km south along strike from Edelweiss is the Victory (Coongan; 5815) mine, the largest gold mine on SPLIT ROCK. The deposit was mined from 1911 to 1938 with a recorded production of 1814.4 t of ore at 31.6 g/t Au for a total of 57.4 kg Au. Another 2655 t of ore at 58.5 g/t Au produced 155.3 kg Au. In 1981, 80 t of ore was mined at Stirling (7633), from which 0.588 kg Au was recovered at a grade of 7.35 g/t Au. Another smaller mine was developed at Victory Northwest (5815), although no production figures are available. An extensive drilling

program and costean operation was undertaken about 1.5 km along strike south of the Victory mine at Table Top (2947) and Table Top South (2948), where gossan samples from quartz–tourmaline with pyrite–chalcopyrite–stibnite mineralization contained up to 111 g/t Au. Up to 4.22 g/t Au over 3 m was obtained from drilling and a costean returned 20.75 g/t Au over 3.4 m at Table Top (2947). All of these sites are in carbonate-altered and locally silicified high-Mg metabasalt of the Euro Basalt, whereas at the Victory deposits the ore was extracted from felsic ash flows.

About 3 km west of this line of gold deposits is a series of other gold prospects within sheared rocks near the base of the Euro Basalt and in the Panorama Formation. Grab samples with values up to 74 g/t Au were recorded from quartz veins in sheared chlorite–carbonate schist of the basal, komatiitic Euro Basalt at Triberton Creek C (5918) and in felsic schist of the Panorama Formation at Triberton Creek D (2946). Rotary air blast (RAB) drilling results of 5 m at 2.8 g/t Au and 15.5 g/t Ag were obtained at Triberton Creek D.

A cluster of three hardrock and one alluvial gold prospect 3 km south along strike of Triberton Creek D is at a point where a 1 km-thick stratigraphic section becomes tectonically transposed between two major D₂ shear zones. Coongan North (3231) and P45/244 1 and 2 (4970, 4971) are sites of high gold values in gossan samples and quartz veins from sheared Panorama Formation felsic volcanic rocks; values up to 28 ppm Au, 45 ppm As, and 105 ppm Cu were recorded (Ferguson and Ruddock, 2001). Alluvial workings at Corboy Alluvial 2 (5817) are downstream from the sites of these high assay results. The Corboy Alluvial 1 (5816) and Opaline Well Alluvial 1 and 2 (5818, 5819) workings are farther southeast along strike at the same structural level.

Significant gold workings were developed at Triberton (3056), about 2 km structurally and stratigraphically below and west of the mineralization described above. A shaft at least 11 m deep was sunk on a north–south line of quartz veins in sheared mafic schist; samples from the shaft contained 44.6 g/t Au. Old workings were also developed at Triberton North 1 (3230) on the basis of a high gold result from a grab sample.

Copper

East of the Corunna Downs Granitoid Complex, the Kelly greenstone belt contains various fracture- and fault-hosted quartz veins bearing sulfides. These veins are commonly associated with alteration zones, such as around the Copper Hills (2896) and Kellys (2953) copper deposits, and are commonly supergene enriched in places, such as at the Copper Hills mining area.

Mineralization in the Copper Hills mining area was discovered in 1952 and mining ceased in 1963 after producing about 15 730 t of cupreous ore with a grade of 13% Cu (Ferguson and Ruddock, 2001), and 14.5 kg of silver as a byproduct (Hickman, 1983). Anomalous gold, silver, and copper values within shears zones and gossan from the Emu Creek 2 (4602) and Coongan (2918)

prospects have also been reported from the Copper Hills mining area (Ferguson and Ruddock, 2001). The ore mined from the area contains veined malachite, azurite, chrysocolla, chalcocite, bornite, and rare cuprite in fractured rhyolitic lava of the Wyman Formation, which is locally intruded by the Boobina Porphyry. The mineralization lacks quartz veining and is most probably related to supergene enrichment by groundwater from veined or disseminated pyrite, chalcopyrite, and rare sphalerite sources at depth (Marston, 1979). Extensive wall-rock alteration, in the form of kaolinization, sericitization, chloritization, and epidotization, is common at the mine (Ferguson and Ruddock, 2001), and in the Wyman Formation and Boobina Porphyry near and south of the Copper Hills area. Sericitization is commonly indicated by the replacement of feldspar with fine-grained sericite, quartz, and minor amounts of carbonate, erosion of quartz phenocrysts, alteration of rare biotite phenocrysts to chlorite and sericite, and with the groundmass recrystallized to very fine grained quartz, sericite, carbonate, chlorite, and rutile. This is suggestive of an epithermal alteration system such as found in porphyry copper deposits (Pirajno, 1994), and is probably associated with the Boobina Porphyry.

Mineralization in the Kellys mining area is in or near faulted and quartz-veined contacts between the Boobina Porphyry, Euro Basalt, and porphyry intruding the Euro Basalt. The host rocks are typically chloritized and highly fractured, containing vein quartz and veins rich in malachite, chrysocolla, azurite, bornite, cuprite, and chalcocite. About 610 t of cupreous ore averaging about 19.5% Cu was produced from the area between 1955 and 1970 (Marston, 1979). Anomalous gold (Kellys Ridge) and silver (Sandy Creek) has also been reported from the Kellys mining area (Ferguson and Ruddock, 2001).

Three copper occurrences are recorded from the Coongan greenstone belt. The Marble Bar 1 (5014) prospect is on a 10 mm × 6 m quartz–calcite vein in rhyolite, with malachite and goethite. The Coongan (5995) deposit is an abandoned pit or mine for which no production records are available. The Coongan River prospect (4685) contained copper and lead in chip samples from mixed lithology in the Warrawoona and Gorge Creek Groups with up to 21.7% Cu and more than 1% Pb (Ferguson and Ruddock, 2001).

Tin, tantalum, tungsten, and lithium

The eleven deposits of alluvial and (minor) hardrock tin (Sn as cassiterite), tantalum (Ta as tantalite), lithium (Li) and tungsten (W from wolframite) on SPLIT ROCK, are all related to the Cooglegong Monzogranite in the Shaw Granitoid Complex. Blockley (1980) discussed in detail the tin–tantalum–lithium–tungsten mining in this area during the 1950s and 1960s. Alluvial mining of recent drainage occurred at the Coomba Creek Alluvial (7286), Eleys Creek Alluvial (3012), Hartigans Alluvial (7301), Marshall Creek Alluvial (6361), Split Rock Alluvial 1 and 2 (4880, 4881), Strawberry Creek Alluvial (6178), and Wood Creek Alluvial (8258) mines. Of these, Coomba

Creek (34.95 t of cassiterite concentrate) and Eleys Creek (3.5 km-long workings with a production of 10 000 – 15 000 m³ with a cassiterite grade of 1.3 kg/m³) were the largest. An opencut mine was developed at Hartigans Alluvial (7301) and the Breens deposit (2783) from which 0.255 Mt of material with a grade of 0.78 kg/t SnO was mined with a production of 198.9 kg SnO. Hardrock mining of pegmatite for tin and tungsten occurred at Twin Rocks (4879), and for tungsten at Burrows Well (4978; with a recorded production of 0.62 t of concentrate for 412.9 kg WO₃).

A recorded production of 0.85 t of alluvial and eluvial tin concentrate in 1965 was obtained from a now unknown area on SPLIT ROCK. The limited information suggests that this came either from the southern part of the Corunna Downs Granitoid Complex or from near SPLIT ROCK in the northwestern part of the sheet area (Blockley, 1980).

Chrysotile asbestos

Asbestos (chrysotile) occurrences have been recorded at Split Rock 1 and 2 (6008, 6009) on the MARBLE BAR 1:250 000 map (Hickman and Lipple, 1978). These are hosted by unassigned layered ultramafic intrusive rocks (*Aupd, Aus*) within the Coongan fault system that were emplaced into the top of the Euro Basalt and the Wyman Formation. Serpentinized peridotite and dunite outcrop over a large area in the core of the Coongan Syncline, particularly in the northern (for 10 km north and south of MGA 777000E 7601000N) and south-central (MGA 781300E 7583300N) parts of the map area, and contain widespread asbestos in small veins.

Barite

Barite veining is present in the c. 3308 Ma Budjan Creek Formation 2.5 km south-southeast of the Copper Hills mine. The barite veins reach up to 0.15 m across and are commonly silicified in silica-filled fractures. This indicates that the barite may be related to hydraulic fracturing linked to the c. 3308 Ma igneous activity associated with the Corunna Downs Granitoid Complex, synchronous with volcanism in the Budjan Creek Formation.

References

- ARNDT, N. T., BRUZAK, G., and REISCHMANN, T., 2001, The oldest continental and oceanic plateaus: Geochemistry of basalts and komatiites of the Pilbara Craton, Australia, *in* Mantle plumes: their identification through time *edited by* R. E. ERNST and K. L. BUCHAN: Geological Society of America, Special Paper 352, p. 359–387.
- ARNDT, N. T., NELSON, D. R., COMPSTON, W., TRENDALL, A. F., and THORNE, A. M., 1991, The age of the Fortescue Group, Hamersley Basin, Western Australia, from ion microprobe zircon U–Pb results: *Australian Journal of Earth Sciences*, v. 38, p. 261–281.
- BAGAS, L., in prep., Geology of the Nullagine 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.
- BAGAS, L., SMITHIES, R. H., and CHAMPION, D. C., 2003, Geochemistry of the Corunna Downs Granitoid Complex, East Pilbara Granite–Greenstone Terrane: Western Australia Geological Survey, Annual Review 2001–02, p. 61–69.
- BAGAS, L., VAN KRANENDONK, M. J., and PAWLEY, M., 2003, Split Rock, W.A. Sheet 2854 (version 2, May 2003), Western Australia Geological Survey, 1:100 000 Geological Series.
- BARLEY, M. E., and PICKARD, A. L., 1999, An extensive, crustally-derived, 3325 to 3310 Ma silicic volcanoplutonic suite in the eastern Pilbara Craton: evidence from the Kelly Belt, McPhee Dome and Corunna Downs Batholith: *Precambrian Research*, v. 96, p. 41–62.
- BETTENAY, L. F., BICKLE, M. J., BOULTER, C. A., GROVES, D. I., MORANT, P., BLAKE, T. S., and JAMES, B. A., 1981, Evolution of the Shaw Batholith — an Archaean granitoid–gneiss dome in the eastern Pilbara, Western Australia: *Geological Society of Australia*, Special Publication, v. 7, p. 361–372.
- BICKLE, M. J., BETTENAY, L. F., BARLEY, M. E., CHAPMAN, H. J., GROVES, D. J., CAMPBELL, I. H., and de LAETER, J. R., 1983, A 3500 Ma plutonic and volcanic calc-alkaline province in the Archaean east Pilbara Block: *Contributions to Mineralogy and Petrology*, v. 84, p. 25–35.
- BICKLE, M. J., BETTENAY, L. F., CHAPMAN, H. J., GROVES, D. J., McNAUGHTON, N. J., CHAPMAN, I. H., and de LAETER, J. R., 1989, The age and origin of younger granitic plutons of the Shaw batholith in the Archaean Pilbara Block, Western Australia: *Contributions to Mineralogy and Petrology*, v. 101, p. 361–376.
- BICKLE, M. J., BETTENAY, L. F., CHAPMAN, H. J., GROVES, D. J., McNAUGHTON, N. J., CHAPMAN, I. H., and de LAETER, J. R., 1993, Origin of the 3500–3300 Ma calc-alkaline rocks in the Pilbara Archaean: isotopic and geochemical constraints from the Shaw Batholith: *Precambrian Research*, v. 60, p. 117–149.
- BICKLE, M. J., MORANT, P., BETTENAY, L. F., BOULTER, C. A., BLAKE, T. S., and GROVES, D. I., 1985, Archaean tectonics of the Shaw Batholith, Pilbara Block, Western Australia — structural and metamorphic tests of the batholith concept, *in* Evolution of Archean supracrustal sequences *edited by* L. D. AYERS, P. C. THURSTON, K. D. CARD, and W. WEBER: Geological Association of Canada, Special Paper 28, p. 325–341.
- BLAKE, T. S., 1984, The lower Fortescue Group of the northern Pilbara Craton — stratigraphy and palaeogeography, *in* Archaean and Proterozoic basins of the Pilbara — Evolution and mineralization potential *edited by* J. R. MUHLING, D. I. GROVES, and T. S. BLAKE: University of Western Australia, Geology Department and University Extension, Publication, no. 9, p. 123–143.
- BLAKE, T. S., 1993, Late Archaean crustal extension, sedimentary basin formation, flood basalt volcanism and continental rifting. The Nullagine and Mount Jope Supersequences, Western Australia: *Precambrian Research*, v. 60, p. 185–241.
- BLAKE, T. S., 2001, Cyclic continental mafic tuff and flood basalt volcanism in the Late Archaean Nullagine and Mount Jope Supersequences in the eastern Pilbara, Western Australia: *Precambrian Research*, v. 107, p. 139–177.
- BLEWETT, R., 2002, Archaean tectonic processes: a case for horizontal shortening in the North Pilbara Granite–Greenstone Terrane, Western Australia: *Precambrian Research*, v. 113, p. 87–120.
- BLOCKLEY, J. G., 1980, Tin deposits of Western Australia with special reference to the associated granites: Western Australia Geological Survey, Mineral Resources Bulletin 12, 184p.
- BUICK, R., THORNETT, J. R., McNAUGHTON, N. J., SMITH, J. B., BARLEY, M. E., and SAVAGE, M., 1995, Record of emergent continental crust ~3.5 billion years ago in the Pilbara Craton of Australia: *Nature*, v. 375, p. 574–577.
- BUICK, R., BRAUHART, C. W., MORANT, P., THORNETT, J. R., MANIW, J. G., ARCHIBALD, N. J., DOEPEL, M. G., FLETCHER, I. R., PICKARD, A. L., SMITH, J. B., BARLEY, M. E., McNAUGHTON, N. J., and GROVES, D. I., 2002, Geochronology and stratigraphic relationships of the Sulphur Springs Group and Strelley Granite: a temporally distinct igneous province in the Archaean Pilbara Craton, Australia: *Precambrian Research*, v. 114, p. 87–120.
- CAMPANA, B., HUGHES, F. E., BURNS, W. G., WHITCHER, I. G., and MUCENIEKAS, E., 1964, Discovery of the Hamersley iron deposits (Duck Creek – Mt Pyrron – Mt Turner area): *Australasian Institute of Mining and Metallurgy*, Proceedings 210, p. 1–30.
- COLLINS, W. J., 1989, Polydiapirism of the Archaean Mt Edgar batholith, Pilbara Block, Western Australia: *Precambrian Research*, v. 43, p. 41–62.
- COLLINS, W. J., 1993, Melting of Archaean sialic crust under high a_{H_2O} conditions: genesis of 3300 Ma Na-rich granitoids in the Mount Edgar Batholith, Pilbara Block, Western Australia: *Precambrian Research*, v. 60, p. 151–174.
- COLLINS, W. J., VAN KRANENDONK, M. J., and TEYSSIER, C., 1998, Partial convective overturn of Archaean crust in the east Pilbara Craton, Western Australia — driving mechanisms and tectonic implications: *Journal of Structural Geology*, v. 20, p. 1405–1424.
- COLLINS, W. J., and VAN KRANENDONK, M. J., 1999, Model for the development of kyanite during partial convective overturn of Archaean granite–greenstone terranes: the Pilbara Craton, Australia: *Journal of Metamorphic Geology*, v. 17, no. 2, p. 145–156.
- COOPER, J. A., JAMES, P. R., and RUTLAND, R. W. R., 1982, Isotopic dating and structural relationships of granitoids and greenstones in the eastern Pilbara, Western Australia: *Precambrian Research*, v. 18, p. 199–236.

- DAVIDS, C., WIJBRANS, J. R., and WHITE, S. H., 1997, $^{40}\text{Ar}/^{39}\text{Ar}$ laserprobe ages of metamorphic hornblendes from the Coongan Belt, Pilbara, Western Australia: *Precambrian Research*, v. 83, p. 221–242.
- DAVY, R., 1988, Geochemical patterns in granitoids of the Corunna Downs Batholith, Western Australia: Western Australia Geological Survey, Report 23, p. 51–84.
- de la HUNTY, L. E., 1965, Mount Bruce, Western Australia: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 28p.
- FERGUSON, K. M., and RUDDOCK, I., 2001, Mineral occurrences and exploration potential of the east Pilbara: Western Australia Geological Survey, Report 81, 114p.
- GLIKSON, A. Y., DAVY, R., and HICKMAN, A. H., 1986, Geochemical data files of Archaean volcanic rocks, Pilbara Block, Western Australia: Australia BMR, Record 1986/14, 85p.
- GLIKSON, A. Y., DAVY, R., HICKMAN, A. H., PRIDE, C., and JAHN, B., 1987, Trace elements geochemistry and petrogenesis of Archaean felsic igneous units, Pilbara Block, Western Australia: Australia BMR, Record 1987/30, 63p.
- GLIKSON, A. Y., and HICKMAN, A. H., 1981, Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia: Australia BMR, Record 1981/36, 41p.
- GRIFFIN, T. J., 1990, North Pilbara granite–greenstone terrane, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 128–158.
- HANMER, S., and PASSCHIER, C., 1991, Shear sense indicators: a review: Geological Survey of Canada, Paper 90-17, 72p.
- HICKMAN, A. H., 1975, Precambrian structural geology of part of the Pilbara region: Western Australia Geological Survey, Annual Report 1974, p. 68–73.
- HICKMAN, A. H., 1977, New and revised definitions of rock units in the Warrawoona Group, Pilbara Block: Western Australia Geological Survey, Annual Review 1976, p. 53.
- HICKMAN, A. H., 1980, Archaean geology of the Pilbara Block, Geological Society of Australia, Second International Archaean Symposium, Perth, W.A., 1980, Excursion Guide, 55p.
- HICKMAN, A. H., 1983, Geology of the Pilbara Block and its environs: Western Australia Geological Survey, Bulletin 127, 268p.
- HICKMAN, A. H., 1984, Archaean diapirism in the Pilbara Block, Western Australia, in *Precambrian tectonics illustrated* edited by A. KRÖNER, and R. GREILING: Stuttgart, Germany, Schweizerbarts'che Verlagsbuchhandlung, p. 113–127.
- HICKMAN, A. H., 1990, Geology of the Pilbara Craton, in *Third International Archaean Symposium, Excursion Guidebook* edited by S. E. HO, J. E. GLOVER, J. S. MYERS, and J. R. MUHLING: University of Western Australia, Geology Department and University Extension, Publication no. 21, p. 1–13.
- HICKMAN, A. H., 1997, A revision of the stratigraphy of Archaean greenstone successions in the Roebourne–Whundo area, west Pilbara: Western Australia Geological Survey, Annual Review 1996–97, p. 76–82.
- HICKMAN, A. H., 2001a, Geology of the Dampier 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 39p.
- HICKMAN, A. H., 2001b, East Pilbara diapirism: new evidence from mapping: Western Australia Geological Survey, Record 2001/5, p. 23–25.
- HICKMAN, A. H., and LIPPLE, S. L., 1978, Marble Bar, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 24p.
- IDNURM, M., and SENIOR, B. R., 1978, Palaeomagnetic ages of late Cretaceous and Tertiary weathering profiles in the Eromanga Basin, Queensland: *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 24, p. 263–277.
- KOJAN, C. J., and HICKMAN, A. H., 1998, Late Archaean volcanism in the Kylena and Maddina Formations, Fortescue Group, west Pilbara: Western Australia Geological Survey, Annual Review 1997–98, p. 43–53.
- KRIEWALDT, M., 1964, The Fortescue Group of the Roebourne region, North-West Division: Western Australia Geological Survey, Annual Report 1963, p. 30–34.
- KRIEWALDT, M., and RYAN, G. R., 1967, Pyramid, W.A. (1st edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 39p.
- Le MAÎTRE, R. W., 1989, A classification of igneous rocks and glossary of terms (Recommendations of the International Union of Geological Subcommission on the systematics of igneous rocks): Oxford, U.K., Blackwell Press, 193p.
- LEWIS, J. D., ROSMAN, K. R. J., and de LAETER, J. R., 1975, The age and metamorphic effects of the Black Range dolerite dyke: Western Australia Geological Survey, Annual Report 1974, p. 80–88.
- LIPPLE, S. L., 1975, Definitions of new and revised stratigraphic units of the eastern Pilbara Region: Western Australia Geological Survey, Annual Report 1974, p. 58–63.
- LOWE, D. R., 1983, Restricted shallow-water sedimentation of Early Archaean stromatolitic and evaporitic strata of the Strelley Pool Chert, Pilbara Block, Western Australia: *Precambrian Research*, v. 19, p. 239–283.
- MacLEOD, W. N., 1966, The geology and iron deposits of the Hamersley Range area, Western Australia: Western Australia Geological Survey, Bulletin 117, 170p.
- MacLEOD, W. N., de la HUNTY, L. E., JONES, W. R., and HALLIGAN, R., 1963, A preliminary report on the Hamersley Iron province, North-West Division: Western Australia Geological Survey, Annual Report 1962, p. 44–54.
- McNAUGHTON, N. J., GREEN, M. D., COMPSTON, W., and WILLIAMS, I. S., 1988, Are anorthositic rocks basement to the Pilbara Craton?: Geological Society of Australia, Abstracts v. 21, p. 272–273.
- McNAUGHTON, N. J., COMPSTON, W., and BARLEY, M. E., 1993, Constraints on the age of the Warrawoona Group, eastern Pilbara Craton, Western Australia: *Precambrian Research*, v. 60, p. 69–98.
- McPHIE, J., DOYLE, M., and ALLEN, R., 1993, Volcanic textures: a guide to the interpretation of textures in volcanic rocks: University of Tasmania, Centre for Ore Deposit and Exploration Studies, 198p.
- MARSTON, R. J., 1979, Copper mineralization in Western Australia: Western Australia Geological Survey, Mineral Resources Bulletin 13, 208p.
- MEHNERT, K. R., 1968, Migmatites and the origin of granitic rocks: Amsterdam, The Netherlands, Elsevier Press, 393p.
- MILORD, I., SAWYER, E. W., and BROWN, M., 2001, Formation of diatexite migmatite and granite magma during anatexis of semi-pelitic metasedimentary rocks: an example from St Malo, France: *Journal of Petrology*, v. 42(3), p. 487–505.
- MORANT, P., 1995, The Panorama Zn–Cu VMS deposits, Western Australia: Australian Institute of Geoscientists, Bulletin 16, p. 75–84.
- NELSON, D. R., 1998, Compilation of SHRIMP U–Pb zircon geochronology data, 1997: Western Australia Geological Survey, Record 1998/2, 242p.
- NELSON, D. R., 1999, Compilation of geochronology data, 1998: Western Australia Geological Survey, Record 1999/2, 222p.
- NELSON, D. R., 2000, Compilation of geochronology data, 1999: Western Australia Geological Survey, Record 2000/2, 251p.

- NELSON, D. R., 2001, Compilation of geochronology data, 2000: Western Australia Geological Survey, Record 2001/2, 205p.
- NELSON, D. R., 2002, Compilation of geochronology data, 2001: Western Australia Geological Survey, Record 2002/2.
- NELSON, D. R., in prep., Compilation of geochronology data, 2002: Western Australia Geological Survey, Record 2003/2.
- NOLDART, A. J., and WYATT, J. D., 1962, The geology of portion of the Pilbara Goldfield: Western Australia Geological Survey, Bulletin 115, 199p.
- PAWLEY, M. J., VAN KRANENDONK, M. J., and COLLINS, W. J., in prep., Interplay between magmatism and deformation during the evolution of the domical Archaean Shaw Granitoid Complex, Pilbara Craton, Western Australia: Precambrian Research.
- PIDGEON, R. T., 1984, Geochronological constraints on early volcanic evolution of the Pilbara Block, Western Australia: Australian Journal of Earth Sciences, v. 31, p. 237–242.
- PINK, B. N., 1992, Western Australia Year Book, no. 29: Australian Bureau of Statistics, Perth Office, p. 3.1–3.15.
- PIRAJNO, F., 1994, Hydrothermal mineral deposits: principles and fundamental concepts for the exploration geologist: New York, U.S.A., Springer-Verlag, 709p.
- PITCHER, W. S., 1993, The nature and origin of granite: London, U.K., Blackie Academic and Professional Press, 321p.
- RYAN, G. R., and KRIEVALDT, M. J. B., 1964, Facies changes in the Archaean of the West Pilbara Goldfield: Western Australia Geological Survey, Annual Report 1963, p. 28–30.
- SMITHIES, R. H., 2000, The Archaean tonalite–trondhjemite–granodiorite (TTG) series is not an analogue of Cenozoic adakite: Earth and Planetary Science Letters, v. 182, p. 115–125.
- THORNE, A. M., and TRENDALL, A. F., 2001, Geology of the Fortescue Group, Pilbara Craton, Western Australia: Western Australia Geological Survey, Bulletin 144, 249p.
- THORNE, A. M., TYLER, I. M., and HUNTER, W. M., 1991, Turee Creek, W.A. (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 29p.
- THORPE, R. A., HICKMAN, A. H., DAVIS, D. W., MORTENSEN, J. K., and TRENDALL, A. F. 1992a, U–Pb zircon geochronology of Archaean felsic units in the Marble Bar region, Pilbara Craton, Western Australia: Precambrian Research, v. 56, p. 169–189.
- THORPE, R. A., HICKMAN, A. H., DAVIS, D. W., MORTENSEN, J. K., and TRENDALL, A. F., 1992b, Constraints to models for Archaean lead evolution from precise U–Pb geochronology from the Marble Bar region, Pilbara Craton, Western Australia, in *The Archaean: terrains, processes and metallogeny* edited by J. E. GLOVER, and S. HO: University of Western Australia, Geology Department and University Extension, Publication no. 22, p. 395–408.
- TRENDALL, A. F., 1990a, Hamersley Basin, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 163–191.
- TRENDALL, A. F., 1990b, Pilbara Craton — introduction, in *Geology and mineral resources of Western Australia*: Western Australia Geological Survey, Memoir 3, p. 128.
- TRENDALL, A. F., 1995, Paradigms for the Pilbara, in *Early Precambrian processes* edited by M. P. COWARD, and A. C. RIES: London, U.K., Geological Society, Special Publication 95, p. 127–142.
- TRENDALL, A. F., NELSON, D. R., de LAETER, J. R., and HASSER, S. W., 1998, Precise zircon U–Pb ages from the Marra Mamba Iron Formation and Wittenoom Formation, Hamersley Group, Western Australia: Australian Journal of Earth Sciences, v. 45, no. 1, p. 137–142.
- TURNER, F. J., 1981, Metamorphic petrology: New York, U.S.A., McGraw-Hill, 524p.
- TYLER, I. M., 1991, The geology of the Sylvania Inlier and southeast Hamersley Basin: Western Australia Geological Survey, Bulletin 138, 108p.
- VAN HAAFTEN, W. M., and WHITE, S. H., 1998, Evidence for multiphase deformation in the Archaean basal Warrawoona Group in the Marble Bar area, East Pilbara, Western Australia: Precambrian Research, v. 88, p. 53–66.
- VAN KRANENDONK, M. J., 2000, Geology of the North Shaw 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 86p.
- VAN KRANENDONK, M. J., 2003., Geology of the Tambourah 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes, 57p.
- VAN KRANENDONK, M. J., and MORANT, P., 1998, Revised Archaean stratigraphy of the North Shaw 1:100 000 sheet, Pilbara Craton: Western Australia Geological Survey, Annual Review 1997–98, p. 55–62.
- VAN KRANENDONK, M. J., HICKMAN, A. H., and COLLINS, W. C., 2001a, Comment on ‘Evidence for multiphase deformation in the Archaean basal Warrawoona Group in the Marble Bar area, East Pilbara, Western Australia’: Precambrian Research, v. 105, p. 73–78.
- VAN KRANENDONK, M. J., HICKMAN, A. H., WILLIAMS, I. R., and NIJMAN, W., 2001b, Archaean geology of the East Pilbara Granite–Greenstone Terrane, Western Australia — a field guide: Geological Survey of Western Australia, Record 2001/9, 134p.
- VAN KRANENDONK, M. J., HICKMAN, A. H., SMITHIES, R. H., NELSON, D., and PIKE, G., 2002, Geology and tectonic evolution of the Archaean North Pilbara Terrain, Pilbara Craton, Western Australia: Economic Geology, v. 97, p. 695–732.
- VEARNCOMBE, S., BARLEY, M. E., GROVES, D. I., McNAUGHTON, N. J., MIKUCKI, E. J., and VEARNCOMBE, J. R., 1995, 3.26 Ga black smoker-type mineralization in the Strelley Belt, Pilbara Craton, Western Australia: Journal of the Geological Society of London, v. 152, p. 587–590.
- WILLIAMS, I. R., 1999, Geology of the Muccan 1:100 000 sheet: Geological Survey of Western Australia, 1:100 000 Geological Series Explanatory Notes, 39p.
- WILLIAMS, I. R., in prep., Geology of the MOUNT EDGAR 1:100 000 sheet: Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes.
- WILLIAMS, I. S., PAGE, R. W., FROUDE, D., FOSTER, J. J., and COMPSTON, W., 1983, Early crustal components in the Western Australian Archaean: zircon U–Pb ages by ion microprobe analysis from the Shaw Batholith and Narryer metamorphic belt: in *Sixth Australian Geological Convention*, Geological Society of Australia, Abstracts Series 9, p. 169–171.
- WILLIAMS, I. S., and COLLINS, W. J., 1990, Granite–greenstone terranes in the Pilbara Block, Australia, as coeval volcano–plutonic complexes; evidence from U–Pb zircon dating of the Mount Edgar batholith: Earth and Planetary Science Letters, v. 97, p. 41–53.
- WINGATE, M. T. D., 1997, Testing Precambrian continental reconstructions using ion microprobe U–Pb baddeleyite geochronology and palaeomagnetism of mafic igneous rocks: Canberra, Australian National University, PhD thesis (unpublished).
- WINGATE, M. T. D. and GIDDINGS, J. W., 2000, Age and paleomagnetism of the Mundine Well dyke swarm, Western Australia: implications for an Australia–Laurentia connection at 755 Ma: Precambrian Research, v. 100, p. 335–357.
- WYATT, B. A., MITCHELL, M., WHITE, B., SHEE, S. R., GRIFFIN, W. L., and TOMLINSON, N., 2001, The Brockman Creek Kimberlite, East Pilbara, Western Australia, in *4th International*

- Archaean Symposium, Extended Abstracts *edited by* K. F. CASSIDY, J. M. DUNPHY, and M. J. VAN KRANENDONK: AGSO – Geoscience Australia, Record 2001/37, p. 208–210.
- ZEGERS, T. E., 1996, Structural, kinematic and metallogenic evolution of selected domains of the Pilbara granitoid–greenstone terrain: Netherlands, Faculteit Aardwetenschappen, Universiteit Utrecht, Geologica Ultraiectina 146.
- ZEGERS, T. E., NELSON, D. R., WIJBRANS, J. R., and WHITE, S. H., 2001, SHRIMP U–Pb zircon dating of Archean core complex formation and pancratonic strike-slip deformation in the East Pilbara Granite–Greenstone Terrain: *Tectonics*, v. 20(6), p. 883–908.
- ZEGERS, T. E., WHITE, S. H., de KEIJZER, M., and DIRKS, P., 1996, Extensional structures during deposition of the 3460 Ma Warrawoona Group in the eastern Pilbara Craton, Western Australia: *Precambrian Research*, v. 80, p. 89–105.
- ZEGERS, T. E., WIJBRANS, J. R., and WHITE, S. H., 1999, $^{40}\text{Ar}/^{39}\text{Ar}$ age constraints on tectonothermal events in the Shaw area of the eastern Pilbara granite–greenstone terrain (W Australia): 700 Ma of Archean tectonic evolution: *Tectonophysics*, v. 311, p. 45–81.

Appendix 1

Gazetteer of localities

<i>Locality</i>	<i>MGA coordinates</i>	
	<i>Easting</i>	<i>Northing</i>
Bamboo Springs Homestead (on WARRIE, 2854)	772510	7559031
Breens Sn, Ta deposit (abd)	763831	7607642
Burrows Well tungsten mine (abd)	761703	7613150
Cookindina Pool	790400	7573600
Coomba Creek Alluvial mine (abd)	765126	7607015
Coongan (2918) gold–silver–copper prospect	806464	7598539
Coongan (5995) copper mine (abd)	775037	7599856
Coongan North alluvial gold prospect	773913	7583826
Coongan River copper–lead prospect	782550	7575866
Copper Hills mines (abd)	808217	7601926
Corboy gold mine (abd)	776445	7594622
Corboy Alluvial 1 prospect	773857	7580956
Corboy Alluvial 2 prospect	774137	7584156
Corboy Cairn	776500	7593900
Corboy Southeast gold prospect	777087	7593426
Edelweiss gold prospect	776487	7593936
Eleys Creek Alluvial mine (abd)	758841	7604546
Emu Creek 2 gold–copper–silver prospect	806905	7600360
GSWA 168008	773760	7600840
GSWA 168908	808680	7600840
GSWA 168909	806710	7602440
GSWA 168915	783070	7612460
Kellys copper mine (abd)	797087	7587736
Kellys Ridge gold prospect	797635	7587100
Hartigans alluvial tin–tantalum–lithium mine (abd)	763933	7618287
Hillside	748022	7596103
Marble Bar 1 copper prospect	779546	7619938
Marshall Creek Alluvial mine (abd)	760737	7619856
Norman Cairn	778550	7588650
Opaline Well Alluvial 1 prospect	775837	7573556
Opaline Well Alluvial 2 prospect	775137	7576056
P45/244 1 alluvial gold prospect	774066	7583686
P45/244 2 alluvial gold prospect	773850	7583781
Pinnacle Well	760129	7593289
Sandy Creek silver prospect	792886	7582925
Split Rock 1 asbestos occurrence	776337	7606056
Split Rock 2 asbestos occurrence	776787	7618356
Split Rock Alluvial 1 mine (abd)	769686	7615810
Split Rock Alluvial 2 mine (abd)	769418	7614629
Split Rock Homestead (abd)	768450	7617650
Strawberry Creek Alluvial mine (abd)	763436	7617856
Stirling gold mine (abd)	777400	7589840
Table Top prospect	777737	7588476
Table Top South prospect	777637	7588106
Triberton gold prospect	771977	7582486
Triberton Creek C gold prospect	774537	7589406
Triberton Creek D gold prospect	773787	7586986
Triberton North 1 gold prospect	772099	7582235
Twin Rocks tin–tungsten mine (abd)	770656	7615517
Victory (Coongan) gold mine (abd)	777397	7589856
Victory Northwest gold mine (abd)	777237	7590236
Warranty Gap	784150	7612300
Withnell Creek	777000	7599500
Wood Creek Alluvial mine (abd)	765141	7608646

Appendix 2

Definition of stratigraphic names on SPLIT ROCK

Nandingarra Granodiorite (*AgOna*)

Derivation of name: Nandingarra Pool (MGA 783489E 7612518N) in the northern part of SPLIT ROCK.

Distribution: Core of the Warrery Gap Anticline in the northwestern part of the Corunna Downs Granitoid Complex to the north of Nandingarra Pool on SPLIT ROCK.

Type area: 7 km north of Nandingarra Pool (around MGA 785000E 7618000N).

Lithology: Fine- to coarse-grained, biotite–hornblende granodiorite to tonalite. Monzogranite is rare.

Relationships: Intrudes Panorama Formation in the Warrawoona Group, and is intruded by the Carvana Monzogranite.

Age: Between 3313 ± 4 Ma (GSWA 160212; Nelson, 2002) and 3300 ± 3 Ma (GSWA 160208; Nelson, in prep.), but a date of 3424 ± 4 Ma (GSWA 160211; Nelson, 2002) indicates that the unit includes older granitic rocks, which are probably inclusions within the c. 3313–3300 Ma intrusion.

Triberton Granodiorite (*AgOtr*)

Derivation of name: Triberton Creek in the central part of SPLIT ROCK.

Distribution: Southwestern part of the Corunna Downs Granitoid Complex.

Type area: Southwestern part of the Corunna Downs Granitoid Complex, southwest of Budjan Creek (around MGA 784500E 7595200N).

Lithology: Medium- to coarse-grained, porphyritic biotite–hornblende granodiorite to tonalite with common mafic xenoliths. Minor porphyritic monzogranite.

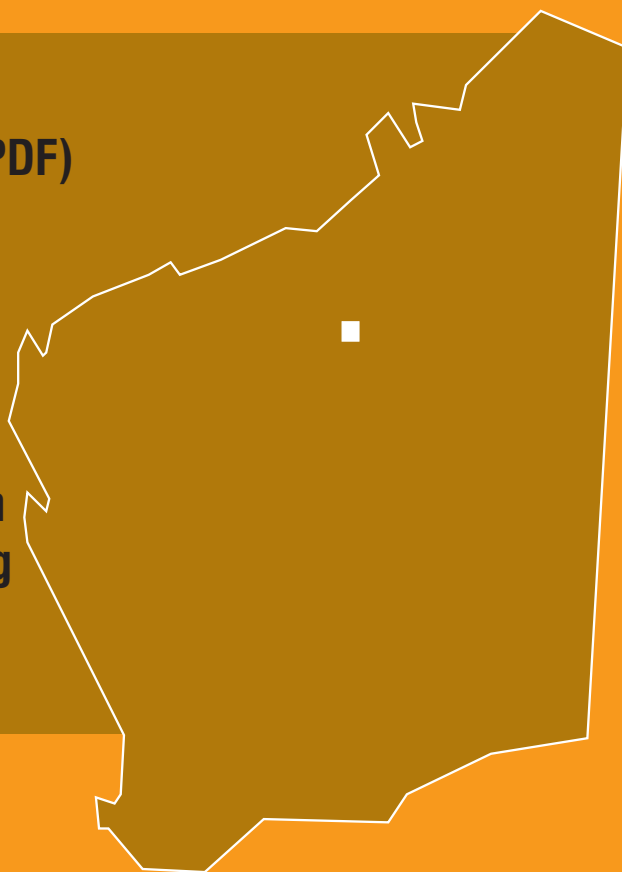
Relationships: Intrudes the c. 3317 ± 2 Ma (Barley and Pickard, 1999) Carvana Monzogranite and is intruded by the c. 3300 Ma (Nelson, in prep.) Mondana Monzogranite. An Ar–Ar age of c. 3400 Ma obtained on hornblende from amphibolite within the immediate contact-metamorphic aureole of the Triberton Granodiorite (sample CC18 at MGA 780800E 7594900N; Davids et al., 1997) suggests that the western part of the Triberton Granodiorite may include older components.

Age: Predominantly between 3317 ± 2 and 3300 Ma, based on relationships described above.

References

- BARLEY, M. E., and PICKARD, A. L., 1999, An extensive, crustally-derived, 3325 to 3310 Ma silicic volcanoplutonic suite in the eastern Pilbara Craton: evidence from the Kelly Belt, McPhee Dome and Corunna Downs Batholith: *Precambrian Research*, v. 96, p. 41–62.
- DAVIDS, C., WIJBRANS, J. R., and WHITE, S. H., 1997, $^{40}\text{Ar}/^{39}\text{Ar}$ laserprobe ages of metamorphic hornblendes from the Coongan Belt, Pilbara, Western Australia: *Precambrian Research*, v. 83, p. 221–242.
- NELSON, D. R., 2002, Compilation of geochronology data, 2001: Western Australia Geological Survey, Record 2002/2, 282p.
- NELSON, D. R., in prep., Compilation of geochronology data, 2002: Western Australia Geological Survey, Record 2003/2.

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