Department of
Industry and Resources

EXPLANATORY NOTES

DAMPIER – BARROW ISLAND
1:250 000 SHEET
WESTERN AUSTRALIA

SECOND EDITION

1:250 000 GEOLOGICAL SERIES

SHEET SF 50-2 AND PART OF SHEET SF 50-1 INTERNATIONAL INDEX

Geological Survey of Western Australia

WESTERN AUSTRALIA
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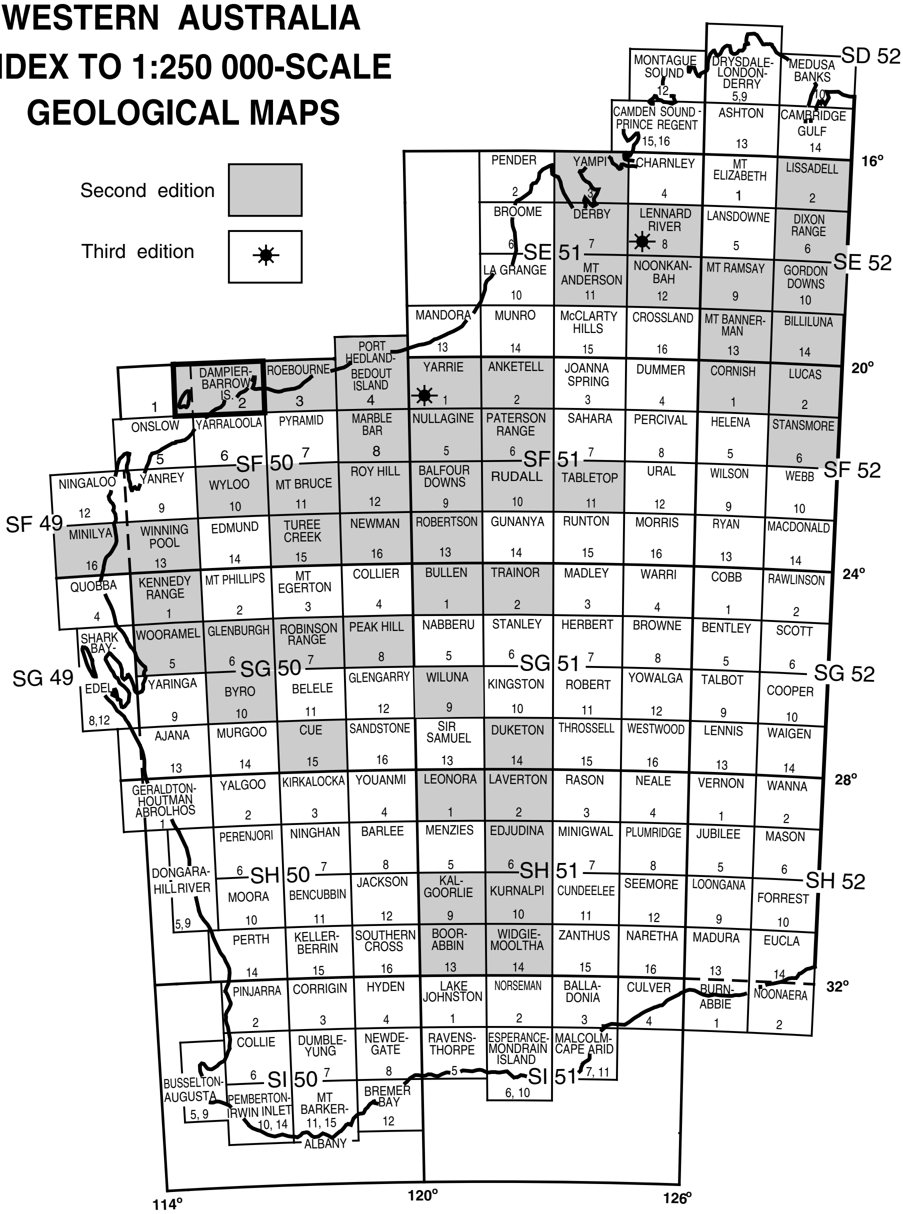

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250 000 GEOLOGICAL SERIES — EXPLANATORY NOTES

DAMPIER – BARROW ISLAND

WESTERN AUSTRALIA

SECOND EDITION

SHEET SF 50-2 AND PART OF SHEET SF 50-1 INTERNATIONAL INDEX

by

A. H. HICKMAN and C. A. STRONG

Perth, Western Australia 2003

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REFERENCE
The recommended reference for this publication is:
HICKMAN, A. H., and STRONG, C. A., 2003, Dampier – Barrow Island, W.A. (2nd Edition): Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 75p.

ISSN 0729-3720

National Library of Australia Card Number and
ISBN 0 7309 4415 8e

Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid Australia (MGA) coordinates, Zone 50. All locations are quoted to at least the nearest 100 m.

Copy editor: M. Apthorpe
Cartography: L. Fogarty
Desktop Publishing: K. S. Noonan

Published 2003 by Geological Survey of Western Australia

Copies available from:
Information Centre
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100 Plain Street
EAST PERTH, WESTERN AUSTRALIA 6004
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by A. H. Hickman and C. A. Strong

ABSTRACT

The Dampier – Barrow Island 1:250 000 sheet includes parts of the Archaean West Pilbara Granite–Greenstone Terrane (WPGGT) and Hamersley Basin, both in the northwest of the Pilbara Craton, and part of the Phanerozoic Northern Carnarvon Basin.

The WPGGT comprises greenstone successions of metamorphosed volcanic, sedimentary, and mafic–ultramafic intrusive rocks, and Archaean granitoids ranging in composition from tonalite to syenogranite. Formation of the WPGGT commenced at about 3280–3240 Ma with rifting of older continental crust, part of which is now preserved as the East Pilbara Granite–Greenstone Terrane (EPGGT). The oldest rocks exposed in the WPGGT are c. 3270–3250 Ma volcanic and sedimentary rocks of the Roebourne Group, and the c. 3270 Ma Karratha Granodiorite, but isotopic data indicate previous crustal material as old as c. 3500 Ma.

After 3240 Ma, the EPGGT and WPGGT were separated by a northeasterly trending rift zone containing no pre-3280 Ma crust. This rift developed into the Central Pilbara Tectonic Zone (CPTZ), that was the focus of volcanism, sedimentation, and granitoid intrusion during tectonothermal episodes at 3160–3090 Ma, 3015–2990 Ma, and 2970–2920 Ma. At 3130–3115 Ma, mafic to felsic volcanic rocks of the Whundo Group were deposited in the northwestern part of the CPTZ, possibly in a volcanic arc. The Roebourne Group and the Karratha Granodiorite are separated from the Whundo Group by the Sholl Shear Zone, a major fault zone that involved sinistral strike-slip movement of at least 200 km. Unconformably overlying the Roebourne and the Whundo Groups is the c. 3020 Ma Cleaverville Formation which consists of banded iron-formation, chert, and fine-grained clastic sedimentary rocks. The Dampier and Cherratta Granitoid Complexes on Dampier – Barrow Island are two of the four granitoid complexes in the WPGGT. The oldest components of the Cherratta Granitoid Complex include 3236 to 3060 Ma tonalite and granodiorite, but most of the granitoids of the WPGGT intruded the area between 3015 and 2990 Ma, possibly during southerly or southeasterly subduction.

WPGGT evolution was dominated by phases of extension and compression, interpreted to include subduction-related processes. The tectonic evolution of the WPGGT involved thrusting, strike-slip faulting, and folding during north–south and northwest–southeast compressive events. The first major tectonic event was at c. 3160 Ma, when basaltic crust of the Regal Formation (possibly oceanic) was thrust southwards across the Roebourne Group and Karratha Granodiorite over an area of at least 1750 km^2. Subsequent deformation included development of the Sholl Shear Zone, c. 3015 Ma thrusting of the Whundo Group onto older sections of the Cherratta Granitoid Complex, and regional upright folding at 2945–2930 Ma. The Cleaverville Formation is present on both sides of the Sholl Shear Zone, indicating that most sinistral strike-slip movement took place before 3020 Ma. However, a later phase of dextral movement occurred at about 2920 Ma.

The c. 2770–2630 Ma Fortescue Group of the Mount Bruce Supergroup (Hamersley Basin) unconformably overlies all units of the WPGGT. Deposition of basaltic rocks of the c. 2770 Ma Mount Roe Basalt and clastic sedimentary rocks of the overlying Hardey Formation was controlled by a northeasterly striking rift system. Following clastic sedimentation and andesitic to dacitic volcanism (Hardey Formation) at c. 2760 Ma, the basaltic to dacitic Kylena Formation was deposited at c. 2750–2730 Ma. The overlying c. 2719 Ma Tumbiana Formation is a succession of basaltic and andesitic pyroclastic and reworked pyroclastic rocks containing thin units of siltstone, quartzite, and stromatolitic carbonate rocks. The Tumbiana Formation is conformably overlain by dominantly basaltic and andesitic rocks of the c. 2717 Ma Maddina Formation and clastic sedimentary rocks of the c. 2690–2630 Ma Jeerinah Formation. The Hamersley Group conformably or disconformably overlies the Fortescue Group, and on

DAMPIER – BARROW ISLAND is represented by the c. 2490 Ma Brockman Iron Formation and the overlying Weeli Wolli Formation.

On DAMPIER – BARROW ISLAND the lower Fortescue Group was deformed by syn-depositional northeasterly trending rifting and open folding, and by later events of uncertain age that include easterly-directed thrusting in the Cape Preston – James Point area, and southeast-directed reverse faulting and related folding on the Burrup Peninsula.

Mesozoic and Cainozoic sedimentary successions of the southeastern margin of the Northern Carnarvon Basin unconformably overlie the northwestern margin of the Pilbara Craton. These Mesozoic and Cainozoic rocks occupy about 70% of DAMPIER – BARROW ISLAND, but are concealed by the Indian Ocean, and were not investigated during the mapping program.

The economic geology of DAMPIER – BARROW ISLAND includes oil and gas production on part of the North West Shelf, small-scale gold mining, nickel and copper mining at Radio Hill, and salt production near Dampier. Geological mapping of DAMPIER – BARROW ISLAND and ROEBOURNE indicates that most gold mineralization is structurally and stratigraphically controlled.

KEYWORDS: Archaean, Pilbara Craton, West Pilbara Granite–Greenstone Terrane, Hamersley Basin, Northern Carnarvon Basin, Roebourne Group, Whundo Group, Cleaverville Formation, Fortescue Group, Hamersley Group, tectonic evolution, oil, gas, gold, nickel, salt.

INTRODUCTION

The DAMPIER – BARROW ISLAND* 1:250 000 map sheet (SF 50-2, and part of SF 50-1) is bounded by latitudes 20°00'S and 21°00'S and longitudes 115°15'E and 117°00'E (Fig. 1). These Explanatory Notes describe the Precambrian and Cainozoic geology of the mainland and island areas of the sheet based on geological mapping between 1995 and 1998. That part of DAMPIER – BARROW ISLAND which is concealed by the Indian Ocean is mainly underlain by Phanerozoic rocks that were not investigated during the mapping project.

DAMPIER – BARROW ISLAND derives part of its name from the port of Dampier, which was built in the 1960s by Hamersley Iron Pty Ltd, and named after the English explorer William Dampier who visited the area in 1688. Although there are no iron ore mines within the sheet area, ore from large mines at Tom Price, Paraburdoo, and Channar, between 150 and 250 km south of DAMPIER – BARROW ISLAND, is transported by rail to port facilities at Dampier. Additional iron ore mines are planned for the George Palmer and Bilanoo deposits, 10 km south of James Point (FORTESCUE), and a conveyor will link these to a proposed loading facility at Cape Preston.

DAMPIER – BARROW ISLAND also includes port facilities and onshore infrastructure for oil and gas production on the North West Shelf. In 2001, the combined value of sales of oil and gas from the North West Shelf Gas Project (NWSGP) immediately to the north of the sheet was approximately $8 billion (Department of Mineral and Petroleum Resources, 2002b). Gas and condensate from the NWSGP are piped to the onshore treatment plant at Withnell Bay, 10 km northeast of Dampier.

The largest town on DAMPIER – BARROW ISLAND is Karratha, which in 2001 had a population of 10 776. Karratha was established in 1968 as a major regional administrative, commercial,

* Names of 1:100 000 and 1:250 000 scale map sheets are printed in capitals. Where 1:100 000 and 1:250 000 scale sheets have the same name, the 1:250 000 sheet is implied.

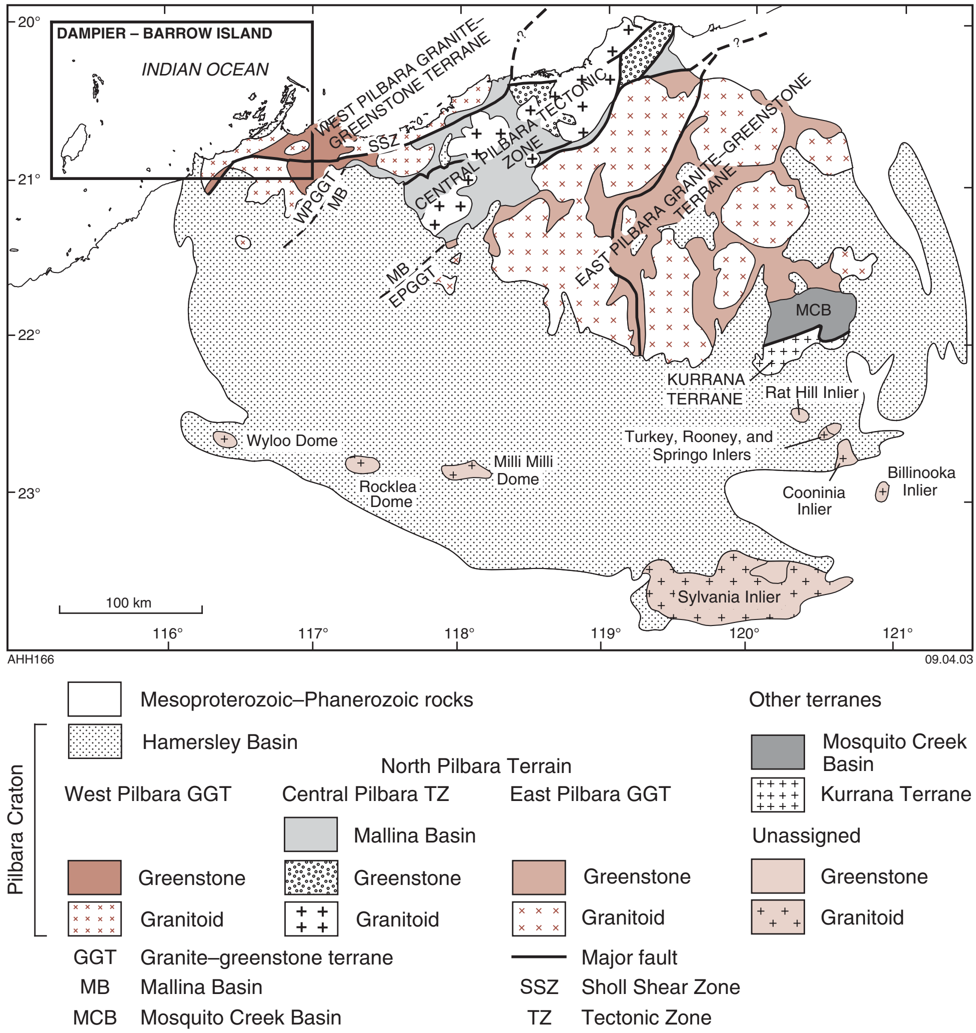

Figure 1. Regional geological setting of DAMPIER – BARROW ISLAND

industrial, and residential centre. In 2001, Dampier had a population of 1490, and Barrow Island had a small population involved in the production of oil and gas from the North West Shelf. Pastoral stations within DAMPIER – BARROW ISLAND are Karratha, Mardie, and Mount Welcome. Karratha Airport provides daily jet services to and from Perth. The North West Coastal Highway connects Karratha to Carnarvon, Geraldton and Perth to the south and, via the Great Northern Highway, to Port Hedland and Broome to the northeast, and Newman to the southeast.

The largest onshore mining operation involves salt extraction from seawater evaporation ponds (Dampier Salt Limited) on the southern side of the Burrup Peninsula. Intermittent mining of nickel and copper has taken place at Radio Hill, 25 km south of Karratha, and there have been relatively small-scale mining operations for gold, copper, semiprecious stones, and industrial minerals. The area has an active pastoral industry (cattle and sheep), in addition to fishing, and tourism. Boating and game fishing around the Dampier Archipelago are extremely popular, both for local residents and tourists.

CLIMATE AND VEGETATION

DAMPIER – BARROW ISLAND has a semi-arid climate with an average rainfall of between 250 and 400 mm. However, total precipitation is extremely variable from year to year, being largely dependent on the passage of tropical cyclones through the area between December and April. Such cyclones generally develop off the northwest Kimberley coast and move southwestward parallel to the Pilbara coastline. Some continue westward into the Indian Ocean, and have no effect on the Pilbara, but others swing southward and southeastward, crossing the coast and bringing rapid, heavy rainfall and strong winds to country along their paths. Rainfall in excess of 100 mm in 24 hours is common during the passage of a cyclone. Outside the cyclone season, longer periods of low to moderate rainfall commonly occur during May and June. This precipitation is associated with southeasterly moving low-pressure systems or to the trailing southern edges of strong equatorial systems. Summer daily maximum temperatures are generally about 35–40°C in coastal regions, and 40–45°C inland. Daily maximum temperatures during winter months are typically about 25°C, with night temperatures about 10–15°C.

DAMPIER – BARROW ISLAND occupies part of the Fortescue Botanical District (Beard, 1975). Flora is closely related to topography, soil types, and proximity to the coast. Much of the coastal belt consists of tidal mud flats with lagoons, samphire flats, and mangroves. Hypersaline conditions on the mud flats, combined with erosion and sediment reworking, preclude vegetation, but intertidal zones are fringed by low, shrubby mangrove of *Avicennia marina* and *Rhizophora mucronata*. Storm beaches and dunes of shelly sand support vines and rhizomatous grasses, whereas farther inland, dwarf shrubs (*Acacia* species) and grasses (e.g. *Triodia pungens*) populate these sandy units.

The extensive plains of the Maitland, Yanyare, and Nickol rivers contain poorly drained red earthy sands, red earths, and expansive silty clay (gilgai). Beard (1975) described this country as short-grass savanna mixed with spinifex. Fine-grained soils support grasses such as *Eragrostis setifolia* and *Triodia wiseana* (buck spinifex), whereas colluvial slopes near hills also contain *Acacia pyrifolia* (kanji), and creeks and rivers are lined with eucalypts.

In the southern part of DAMPIER – BARROW ISLAND the northern foothills of the Chichester Range consist of a rocky dissected plateau that has large areas without soil cover. The basaltic rocks of this area have resulted in the development of hard alkaline soils and shallow loams. This country consists of plain with sparse trees that include *Eucalyptus brevifolia* (snappy gum) and *Triodia wiseana*, and scattered shrubs such as *Acacia xiphophylla* (snakewood).

Low hills and ridges, corresponding to outcrops of metamorphosed volcanic and sedimentary rocks ('greenstones'), for example between Mount Regal and Devil Creek, around Ruth Well, and in the southeastern part of DAMPIER – BARROW ISLAND, are dominated by spinifex and scattered shrubs. In these areas, trees and other grasses are concentrated along the banks of rivers and creeks.

Rocky terrain of the Burrup Peninsula and the islands of the Dampier Archipelago is sparsely vegetated with spinifex and coastal flora.

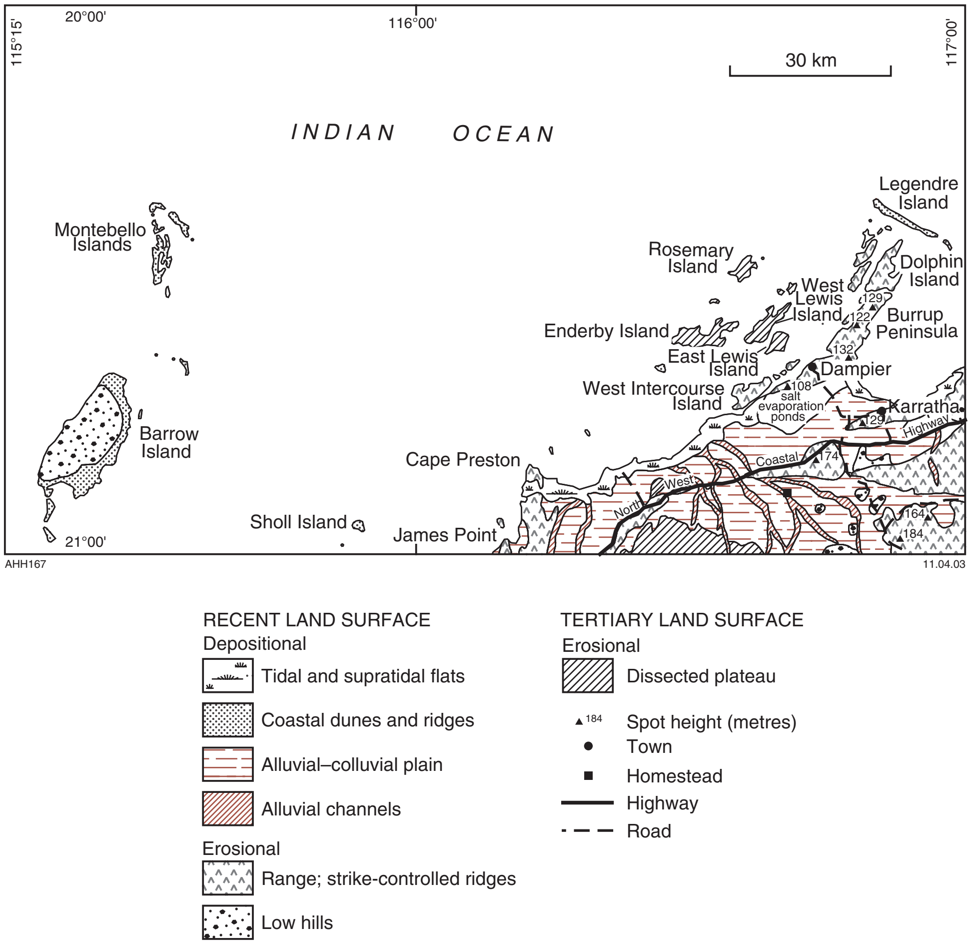

Figure 2. Physiography and access on DAMPIER – BARROW ISLAND

PHYSIOGRAPHY

The physiography of DAMPIER – BARROW ISLAND is the product of erosional and depositional processes acting on the area's bedrock geology. Thus, areas of active erosion, such as the hilly terrain of the southeastern part of the area, and the islands of the Dampier Archipelago, contain different landforms from those in areas of current and recent deposition, for example, on the coastal plain and the floodplains of the major drainages. Figure 2 shows the physiographic divisions of DAMPIER – BARROW ISLAND, based on criteria used across the northern part of the Pilbara region (Hickman, 1983). The same criteria and classification system have also been applied to other 1:100 000 and 1:250 000 sheets in the northwestern Pilbara.

The tidal–supratidal flats physiographic division contains marine, eolian, and alluvial–colluvial material. Along the coast, a belt of dominantly marine sediments forms tidal mud flats and mangrove swamps, flanked by supratidal deposits of shelly sand, silt, and clay. This division includes low dunes of shelly and calcareous sand, which rise up to 20 m above high-tide level. Up to 10 km inland similar low dunes parallel the coastline, but are commonly dissected by marine or fluvial erosion. Saline tidal mud flats, dominated by clay and silt, but also with some calcareous sand, form large lagoons along the coast. Inland from this coastal environment is a gently sloping tract of sand, silt, and clay deposited from creeks and minor channels. Many of these drainages are short and originate from hilly areas close to the coast, but others are distributary channels of deltas. The largest example of a deltaic coastal plain is inland from Regnard Bay, between the Maitland and Yanyare rivers. On larger islands of the Dampier Archipelago, and on Barrow Island, older limestone ridges, locally forming tidal reefs, form a separate division of coastal dunes and ridges (Fig. 2).

The alluvial–colluvial plain division occupies about 40% of the land surface on DAMPIER – BARROW ISLAND (Fig. 2). This includes the Maitland River floodplain and adjacent low-slope pediment plains that abut the dissected plateau, range, and low granite-hills divisions. The alluvial–colluvial plain division is almost entirely underlain by rocks of the granitoid complexes.

On the mainland, the low hills division comprises areas of low rocky hills and scattered inselbergs that are mainly underlain by granitoid rocks. A similar topography exists across much of Barrow Island, but the low hilly country of this area is underlain by relatively flat-lying sedimentary rocks.

The range division consists of strike-controlled ridges separated by narrow, locally steep-sided valleys. In most areas steeply inclined greenstone belts form the ranges. Preferential weathering of the less resistant rock types has locally produced a trellised drainage pattern in these areas. Figure 3 shows the view from the top of a greenstone ridge in the range division to the alluvial–colluvial plain division between Devil Creek and Cape Preston.

On DAMPIER – BARROW ISLAND the dissected plateau division coincides with outcrop of the Fortescue Group in the southern part of the sheet area, and on islands of the Dampier Archipelago. The division includes remnants of the Hamersley Surface (Campana et al., 1964), which on the mainland rises abruptly from the alluvial–colluvial plain division. Here, the boundary of the dissected plateau division is marked by prominent escarpments up to 100 m high and by cliffs up to 50 m high. Topographically high sections of the division contains steep V-shaped valleys, gorges, nick-points, and dendritic drainage patterns. However, on the islands the relief of the division is more subdued, and the land surface is dominated by undulating plateau remnants flanked by low escarpments.

PREVIOUS INVESTIGATIONS

Geological interest in the west Pilbara dates back to 1872, when copper and lead were discovered near the then recently established township of Roebourne. In 1877, auriferous quartz veins were also discovered near Roebourne (Maitland, 1909). Early geological investigations of the area between Roebourne and Dampier were summarized by Kriewaldt (1964a) and Ryan (1966). More recent accounts are reviewed by Hickman (2001, 2002), Hickman et al. (2001), Strong et al. (in prep.), and Hickman et al. (in prep.).

The first edition of DAMPIER – BARROW ISLAND (Kriewaldt et al., 1964) was published following GSWA mapping of the west Pilbara between 1962 and 1964. Between 1979 and 1981, the area around Dampier and Roebourne was mapped at 1:50 000 scale as part of the GSWA urban geology mapping program (Archer, 1979a,b; Biggs, 1979a,b,c, 1980). Two 1:1 000 000-scale geological maps of the northern part of the Pilbara Craton were compiled by Hickman (1983): one showed outcrop lithology, and the other was a solid geology lithostratigraphic interpretation. On the latter map, the major lithological units of the west Pilbara, including those on DAMPIER – BARROW ISLAND, were correlated with sections

Figure 3. View from a ridge of greenstones near Devil Creek westwards towards Cape Preston. This shows contrasting physiographic features between the range division (Sunday Peak in the foreground) and the alluvial–colluvial plain division (middle distance). Hills on the skyline, located south of Cape Preston (15 km away), form part of the range division composed of outcrops of Fortescue Group (MGA 436500E 7684500N)

of the east Pilbara stratigraphic succession (named the Pilbara Supergroup by Hickman, 1981). This correlation supported earlier suggestions (Ryan, 1965; Fitton et al., 1975) that much of the Archaean greenstone succession in the west Pilbara belonged to the c. 3500–3400 Ma Warrawoona Group. Hickman (1990) subsequently recognized, in agreement with Fitton et al. (1975), the existence of a stratigraphic break in the Gorge Creek Group of the west Pilbara, and assigned the upper, coarse clastic sedimentary units to the newly defined De Grey Group.

Krapez (1993) divided the north Pilbara granite–greenstones into five tectono-stratigraphic domains, separated by northeasterly trending lineaments along major strike-slip faults, and proposed a new stratigraphic subdivision of the greenstone succession based on sequence stratigraphy. In the west Pilbara, a domain boundary was interpreted east of DAMPIER – BARROW ISLAND along the western boundary of the Mallina Basin (Fig. 1). West of this boundary the 'Roebourne Megasequence' was thought to be overlain by the 'Mount Negri Megasequence', whereas to the east the 'Roebourne Megasequence' was underlain by the 'Gorge Creek Megasequence'.

The National Geoscience Mapping Accord (NGMA) project between the GSWA and the Australian Geological Survey Organisation (AGSO, now renamed Geoscience Australia) commenced in 1995. In that year, GSWA mapped the DAMPIER and SHERLOCK 1:100 000 sheets, supported by data from NGMA aeromagnetic and radiometric surveys of the west Pilbara (Geological Survey of Western Australia, 1995a, 1995b). Other west Pilbara 1:100 000-scale sheets were mapped between 1996 and 1999. Hickman (1997a) revised the lithostratigraphy of the Roebourne–Whundo area based on the mapping of DAMPIER, PINDERI HILLS, and ROEBOURNE.

Krapez and Eisenlohr (1998) and Smith et al. (1998) modified the sequence stratigraphy and domain interpretation of Krapez (1993) in order to subdivide the west Pilbara succession using the Sholl Shear Zone. Using available geochronology data (Horwitz and Pidgeon, 1993; Nelson, 1996, 1997; Hickman, 1997a; Smith et al., 1998), Krapez and Eisenlohr (1998) interpreted the Sholl Shear Zone as being a major sinistral fault zone that juxtaposed a >c. 3260 Ma island arc succession with a c. 3120 Ma back-arc succession.

Sun and Hickman (1998) reported Neodymium-isotope depleted mantle model ages (Nd T_{DM}) of 3430–3480 Ma for the Roebourne Group and the Karratha Granodiorite. These ages are approximately 200 Ma older than the emplacement ages of these rocks, suggesting that magma generation involved either older basement rocks, enriched lithospheric mantle, or sedimentary rocks derived from older terrains through subduction, or a combination of these sources. This contrasts with Nd isotopic data from the Whundo Group, which indicate that the Group formed from juvenile crust consistent with a subduction zone environment, as suggested by Smith et al. (1998). Kato et al. (1998) presented lithological and geochemical data as evidence that rocks of the Cleaverville area in eastern DAMPIER – BARROW ISLAND were formed in environments ranging from mid-oceanic spreading centres to convergent plate-boundary settings.

Hickman (1999) recognized three major tectono-stratigraphic terranes in the 'north Pilbara granite–greenstone terrane' (Griffin, 1990). Hickman et al. (2000) replaced the informal name 'western terrane' (Hickman, 1999) with the name 'West Pilbara Granite–Greenstone Terrane', and this was defined by Hickman (2001). Hickman (2001) subdivided the West Pilbara Granite–Greenstone Terrane (WPGGT) into tectono-stratigraphic domains (Fig. 4).

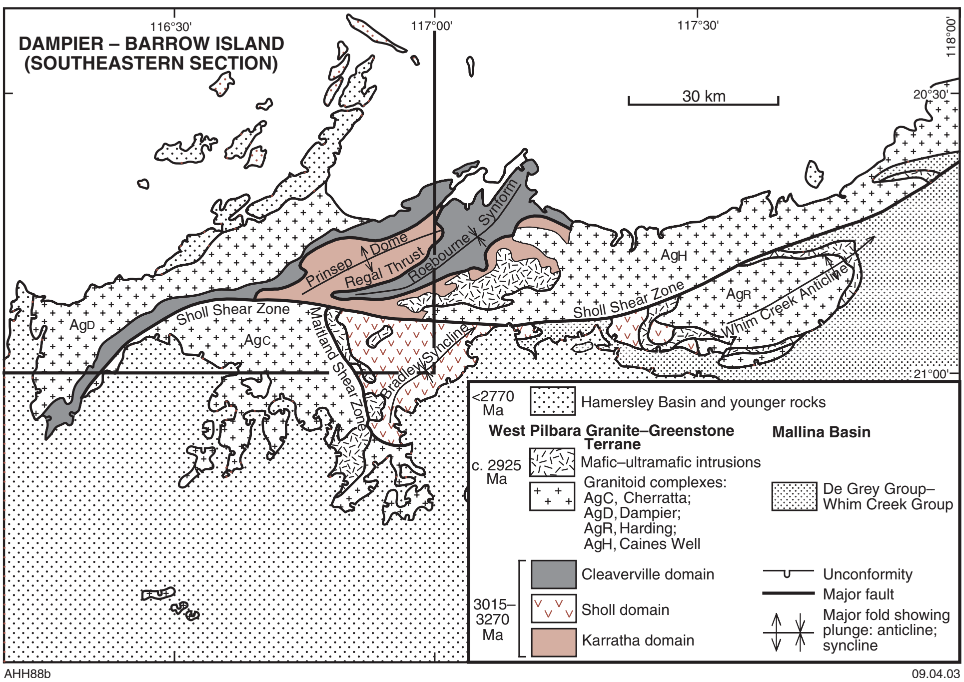

Figure 4. Tectono-stratigraphic domains of the West Pilbara Granite–Greenstone Terrane

Van Kranendonk et al. (2002) reviewed the geology and evolution of the five tectonic subdivisions that are exposed across the area of the north Pilbara granite–greenstone terrain. Hickman (in prep.a) summarized the geological evolution of the WPGGT, concluding that this was consistent with Phanerozoic-style plate-tectonic environments.

The second edition DAMPIER – BARROW ISLAND map is based on geological mapping of DAMPIER in 1995 (Hickman, 1997b) and PRESTON in 1997–98 (Strong et al., 2000), with air photo interpretation of Barrow Island, the Monte Bello Islands, and most of the Dampier Archipelago. No new investigations of the Northern Carnarvon Basin were undertaken, and descriptions and interpretations of this tectonic unit in these Explanatory Notes are based entirely on published information. Field mapping and photo-interpretation of the Precambrian sections of DAMPIER – BARROW ISLAND were assisted by access to multispectral Landsat Thematic Mapper images (AGSO) and high-resolution magnetic and radiometric images (Geological Survey of Western Australia, 1995a,b).

REGIONAL GEOLOGICAL SETTING

DAMPIER – BARROW ISLAND is located in the northwestern part of the Pilbara Craton (Fig. 1). Archaean rocks of the craton can be divided into two components — a granite–greenstone terrain, which formed between c. 3600 and c. 2800 Ma (Hickman, 1983, 1990; Barley, 1997; Van Kranendonk et al., 2002), and unconformably overlying volcano-sedimentary sequences (Mount Bruce Supergroup) of the c. 2770 to 2400 Ma Hamersley Basin (Trendall, 1990, 1995). The granite–greenstone terrain ('Pilbara Block', Hickman, 1983) contains five lithotectonic elements (Van Kranendonk et al., 2002), the most northwesterly of which, the c. 3280–2920 Ma WPGGT, is exposed on DAMPIER – BARROW ISLAND (Fig. 1). Southern DAMPIER – BARROW ISLAND includes lower formations of the Mount Bruce Supergroup, and the northern and western parts of the sheet area are underlain by Phanerozoic rocks of the Northern Carnarvon Basin, but these are almost entirely concealed by the Indian Ocean.

The WPGGT comprises greenstone successions of metamorphosed volcanic, sedimentary, and mafic–ultramafic intrusive rocks, and Archaean granitoids ranging in composition from tonalite to syenogranite. The geological history of DAMPIER – BARROW ISLAND is summarized in Table 1, and the Archaean lithostratigraphy of DAMPIER – BARROW ISLAND is summarized in Table 2. Greenstones of the WPGGT were deposited over 250 Ma in three unconformity-bounded groups. The oldest rocks exposed in the WPGGT are c. 3270–3250 Ma volcanic and sedimentary rocks of the Roebourne Group. Deposition of the Roebourne Group, which comprises two volcanic formations separated by a dominantly sedimentary formation, was partly synchronous with intrusion of the c. 3270 Ma Karratha Granodiorite. Rhyolite and dacite within the central part of the Roebourne Group are interpreted to be genetically related to the granodiorite. Isotopic data indicate that derivation of these c. 3270 Ma rocks involved previous crust or lithospheric mantle as old as c. 3500 Ma (Sun and Hickman, 1998; Hickman, 2001; Van Kranendonk et al., 2002). All these units are restricted to the area north of the Sholl Shear Zone (SSZ).

The Whundo Group (Hickman, 1997a) is an approximately 10 km-thick succession of mafic and felsic metavolcanic rocks (Table 2). The present distribution of the group is restricted to the area south of the SSZ and east of the Cherratta Granitoid Complex, and it has no preserved stratigraphic contacts with the Roebourne Group. Geochronology on felsic volcanic rocks in the central and upper formations of the group gives a range of dates from 3125 to 3115 Ma (Horwitz and Pidgeon, 1993; Hickman, 1997a; Nelson, 1997, 1998). However, the base of the group is intruded by c. 3130 Ma granodiorite of the Cherratta Granitoid Complex (Hickman and Kojan, 2003), establishing that the lowermost sections of the Whundo Group must have been deposited before 3130 Ma. The stratigraphically

Table 1. Summary of the geological history of the DAMPIER – BARROW ISLAND 1:250 000 sheet area

Age (Ma)	*Geological event*
3724–3310	Formation of early sialic crust (not exposed in WPGGT) as part of the EPGGT
3280–3240	Plume-related rifting of the EPGGT to initiate development of the northeasterly trending Central Pilbara Tectonic Zone (CPTZ). Deposition of the Roebourne Group and intrusion of Karratha Granodiorite
3236–3160	Inferred progressive widening of the rift, accompanied by early granitoid intrusion of the Cherratta Granitoid Complex
3160–3130	D_1: Thrusting, recumbent folding, and c. 3160 Ma granitoid intrusion; tectono-metamorphic event, possibly related to plate collision
3160–3060	Intrusion of tonalite and trondhjemite in the Cherratta Granitoid Complex
3130–3115	Deposition of the Whundo Group on juvenile (oceanic-type) crust
3050–3020	D_2: Culmination of sinistral strike-slip movement along the Sholl Shear Zone; upright tight to isoclinal transpressional folding and felsic magmatism; erosion
3020–3015	Deposition of the Cleaverville Formation (Gorge Creek Group)
3015–3010	D_3: Strike-slip movement, felsic magmatism (granitoids, and minor felsic intrusions), and transpressional folding of the Whundo Group and the Cleaverville Formation; north–south thrusting of Whundo Group on YARRALOOLA; intrusion of the Andover, Bullock Hide, and Dingo Intrusions; erosion
3010–2990	Extensive intrusion of granitoids throughout the WPGGT, including the Dampier and Cherratta Granitoid Complexes, and volcanism of the Whim Creek Group (not preserved on DAMPIER – BARROW ISLAND); possibly related to a northeasterly trending volcanic arc
2970–2930	Felsic magmatism in the Cherratta Granitoid Complex; D_4 (2950–2930 Ma): transpressional, northeasterly trending tight to open folding, and commencement of dextral movement along the Sholl Shear Zone; late- to post-tectonic felsic magmatism
c. 2930	D_5: westerly to northwesterly striking strike-slip faulting along the Maitland Shear Zone
c. 2925	Emplacement of main suite of mafic–ultramafic intrusions, followed by intrusion of syenogranite, monzogranite, and granodiorite
c. 2920	D_6: Dextral strike-slip movement along the Sholl Shear Zone, and other east–west and northeasterly striking faults
<2920	D_7: Conjugate faulting produced by north-northwest – south-southeast compression
2920–2770	Erosion
2770–2720	D_h: North-northeasterly trending rifting of the WPGGT, and deposition of the Mount Roe Basalt and Hardey Formation (2770–2760 Ma), lower Fortescue Group; intrusion of northeasterly trending dolerite dykes. Deposition of the Kylena Formation (post-2750 Ma). Deposition of Fortescue Group volcanics and sedimentary rocks in the Dampier Archipelago; intrusion of the Gidley Granophyre (2725 Ma), and the Cooya Pooya Dolerite
c. 2720–2700	Deposition of the Tumbiana and Maddina Formations
c. 2690–2630	Deposition of the Jeerinah Formation (upper Fortescue Group)
c. 2600–2450	Deposition of the lower Hamersley Group, including the Brockman Iron Formation, and the Weeli Wolli Formation
? 1830–1000	Orogenic event on the northwestern margin of the Pilbara Craton, possibly related to the Pinjarra Orogeny: west to east thrusting of the Hamersley and Fortescue Groups at Cape Preston and James Point
755	Intrusion of northeasterly trending dolerite dykes (Mundine Well suite)
>325	Erosion
c. 325–15	Deposition of sedimentary rocks in the Northern Carnarvon Basin
55–present	Cainozoic deposition on the Pilbara Craton

Table 2. Archaean and Palaeoproterozoic lithostratigraphy of the DAMPIER – BARROW ISLAND 1:250 000 sheet area

Group	*Formation*	*Thickness (m)*	*Lithology and relationships*
Hamersley Group	Weeli Wolli Formation (*ⱣHj*)	0–600	Thinly laminated jaspilite, locally brecciated
	Brockman Iron Formation (*ⱣHb*)	200–600	BIF and minor siltstone. Age c. 2490 Ma
		concealed succession	
Fortescue Group	Jeerinah Formation (*AFj*)	150–200	Sandstone, siltstone, shale, chert, BIF, and felsic tuff. Age c. 2680–2630 Ma
	Maddina Formation (*AFm*)	600–700	Basalt and basaltic andesite; minor andesite, dacite, and rhyolite. Age c. 2717 Ma
	Tumbiana Formation (*AFt*)	100–200	Volcaniclastic sandstone, and siltstone, argillite, tuff, and stromatolitic carbonate rocks; local basalt, and minor chert. Age c. 2719 Ma
	Kylena Formation (*AFk*)	300–500	Basalt, basaltic andesite, and dacite; local high-Mg basalt and rhyolite; local basal sandstone
	Hardey Formation (*AFh*)	0–80	Sandstone, conglomerate, siltstone, shale and tuff; thin basal conglomerate; includes Lyre Creek Member (*AFhy*), containing felsic volcaniclastic sandstone and tuff. Age c. 2760 Ma
	Mount Roe Basalt (*AFr*)	0–200	Massive and vesicular basalt; local volcaniclastic sandstone, conglomerate, shale, basaltic agglomerate, high-Mg basalt, basaltic breccia, and tuff. Age c. 2770 Ma
		~ ~ ~ *high-angle unconformity* ~ ~ ~	
Gorge Creek Group	Cleaverville Formation (*AGl*)	1 500	BIF, chert, and fine-grained clastic sedimentary rocks. Age c. 3020 Ma
		~ ~ ~ *possible low-angle unconformity* ~ ~ ~	
Whundo Group	Bradley Basalt (*AUb*)	>4 000	Pillow basalt, massive basalt, and minor units of felsic tuff and chert. Age 3115 ± 5 Ma
	Tozer Formation (*AUt*)	2 500	Tholeiitic to calc-alkaline volcanic rocks, including felsic pyroclastic units. Minor chert and thin BIF. Age c. 3120 Ma
	Nallana Formation (*AUn*)	2 000	Dominantly basalt, but includes minor ultramafic and felsic units. Felsic tuff dated at 3125 ± 4 Ma. Base of formation intruded by 3130 Ma granitoids and truncated by Maitland Shear Zone
		~ ~ ~ *tectonic contact along Sholl Shear Zone* ~ ~ ~	
	Regal Formation (*ARr*)	2 000	Basal peridotitic komatiite overlain by pillow basalt and local chert units. Intruded by microgranite and c. 3015 Ma felsic porphyry (*Apf*)
		~ ~ ~ *tectonized contact along Regal Thrust* ~ ~ ~	

Table 2. (continued)

Group	*Formation*	*Thickness (m)*	*Lithology and relationships*
Roebourne Group	Nickol River Formation (*ARn*)	100–500	Banded chert, iron formation, ferruginous clastic sedimentary rocks, quartz–sericite schist, felsic volcanic rocks, carbonate rocks, and volcanogenic sedimentary rocks and local conglomerate. Quartz–sericite schist protolith less than 3269 ± 2 Ma, and rhyolite dated at 3251 ± 6 Ma
	Ruth Well Formation (*ARw*)	1 000–2 000	Basalt and extrusive peridotite with thin chert units. Intruded by granodiorite and tonalite (*Agka*) dated at 3270 ± 2Ma

highest formation of the Whundo Group, the Woodbrook Formation, is not exposed on DAMPIER – BARROW ISLAND.

The c. 3020 Ma Cleaverville Formation outcrops north and south of the SSZ, and unconformably overlies the Roebourne Group and the Whundo Group. A lithostratigraphic correlation with the Gorge Creek Group of the East Pilbara Granite–Greenstone Terrane (EPGGT) is based on apparent continuity of the formation across the western margin of the EPGGT (Smithies and Farrell, 2000). The Cleaverville Formation is composed of banded iron-formation (BIF), ferruginous chert, grey-white banded chert, and black chert, and metamorphosed shale, siltstone, and minor volcanogenic sedimentary rocks. The depositional age of the formation is closely constrained by clastic zircons in three samples dated at 3018 ± 3 Ma, 3015 ± 5 Ma, and 3022 ± 12 Ma (Nelson, 1998), and by an intrusive granophyre dated at 3014 ± 6 Ma (Nelson, 1997).

Granitoid rocks of the WPGGT include four age components: the c. 3270–3260 Ma Karratha Granodiorite, granitoid rocks in the range 3160–3070 Ma, c. 3015–2990 Ma granitoids, and 2970–2920 Ma granitoids. On DAMPIER – BARROW ISLAND the 3270–3260 Ma Karratha Granodiorite ranges from allotriomorphic granular tonalite to granodiorite (Nelson, 1998; Smith et al., 1998). Much older Nd T_{DM} model ages of 3480–3430 Ma from this body (Sun and Hickman, 1998) indicate that magma generation involved older crust or enriched lithospheric mantle. One of the samples (JS17) dated by Smith et al. (1998) contained near-concordant zircon cores with $^{207}Pb/^{206}Pb$ ages up to c. 3311 Ma, which is consistent with the recycling of older crust.

The SSZ bounds the Cherratta Granitoid Complex to the north, and to the southwest it is unconformably overlain by the Fortescue Group. To the east, the Maitland Shear Zone (MSZ) separates the complex from the Whundo Group, although small stocks of monzogranite and syenogranite assigned to the complex locally intrude the greenstones. The oldest part of the complex is located on PINDERI HILLS to the south, where small inliers of tonalite were dated at c. 3236 Ma (Nelson, 1999). Elsewhere, the oldest components of the complex are c. 3150–3060 Ma banded grey granite–tonalite gneiss with xenoliths of amphibolite-facies mafic gneiss and sheets of leucocratic gneiss. Other components range from syenogranite to granodiorite, including hornblende-rich and porphyritic granitoids.

The Dampier Granitoid Complex intrudes the Roebourne Group, and is intruded by the c. 2725 Ma Gidley Granophyre. Most of the complex consists of porphyritic monzogranite to granodiorite, and a mixed assemblage including banded gneissic granitoids, syenogranite, and pegmatite. Two dated samples indicate that a substantial part of the Dampier Granitoid Complex is c. 2990 Ma in age (Nelson, 1998, 1999).

The Mount Bruce Supergroup (Hamersley Basin) is a succession of volcanic and sedimentary rocks, up to 10 km thick, that on DAMPIER – BARROW ISLAND unconformably overlies the WPGGT. Published geochronology (Arndt et al., 1991; Wingate, 1999) indicates that deposition of the lowest group, the Fortescue Group (Table 2), commenced at c. 2770 Ma, and continued to c. 2630 Ma (Nelson et al., 1999). The Fortescue Group is a continental succession of volcanic and sedimentary rocks, and the regional extent and angular nature of the basal unconformity provides testimony to major erosion of the WPGGT between 2940 and 2770 Ma. Units of sandstone or polymictic conglomerate, containing subrounded clasts derived from the underlying granite–greenstones, locally lie at the base of the Fortescue Group, but are generally too thin and irregular to be represented at map scale. On the Burrup Peninsula, the unconformity between the Dampier Granitoid Complex and the Fortescue Group was intruded by a thick sill of gabbro and granophyre, collectively named the Gidley Granophyre. Gabbro of this intrusion was dated at 2725 ± 3 Ma (Wingate, M. T. D., 1997, writt. comm.). On DAMPIER – BARROW ISLAND, all rocks in the Fortescue Group are metamorphosed to prehnite–pumpellyite facies (Smith et al., 1982).

The Fortescue Group is conformably overlain by the Hamersley Group. On DAMPIER – BARROW ISLAND, the Hamersley Group is poorly preserved in the area between James Point and Cape Preston, where only the c. 2490 Ma Brockman Iron Formation is well exposed.

A large section of the DAMPIER – BARROW ISLAND sheet area covers part of the Northern Carnarvon Basin (Fig. 1). This major sedimentary basin contains Palaeozoic, Mesozoic, and Cainozoic sequences that unconformably overlie the northwestern margin of the Pilbara Craton. Exposures of the Northern Carnarvon Basin on DAMPIER – BARROW ISLAND are limited to Barrow Island, where two Cainozoic formations conceal underlying Cretaceous sedimentary rocks and older sequences. The Northern Carnarvon Basin is of major economic importance as a source of gas and oil (see **Economic geology**).

TECTONIC EVOLUTION

The Archaean and Proterozoic structural geology of DAMPIER – BARROW ISLAND is closely related to the area's location on the northwestern margin of the Pilbara Craton. By c. 3280 Ma the EPGGT had evolved into a relatively rigid craton. Between 3280 and 3240 Ma plume-related magmatism and rifting of the northwestern EPGGT led to deposition of the Roebourne Group and intrusion of the Karratha Granodiorite, and separation of the EPGGT and WPGGT across a northeasterly trending rift (Hickman, 2001; Van Kranendonk et al., 2002; Hickman, in prep.a). This rift evolved into the Central Pilbara Tectonic Zone (CPTZ), which for 290 Ma experienced episodes of compression, extension, volcanism, sedimentation, and granitoid intrusion. Major structures such as thrusts, strike-slip faults, and folds in the WPGGT have northeast–southwest trends. The first recognized thermotectonic event, at 3160 Ma, is interpreted to have coincided with plate collision between the WPGGT and an unknown plate to the north (Hickman, in prep.a). This is interpreted to be the time that the Regal Formation was thrust southwards across the Nickol River Formation, Ruth Well Formation, and Karratha Granodiorite, over an area of at least 1750 km^2. Subsequent deformation included major strike-slip movement along the Sholl Shear Zone (SSZ), c. 3015 Ma thrusting of the Whundo Group onto older sections of the Cherratta Granitoid Complex, and regional upright folding at 2945–2930 Ma.

Granitoid complexes of the WPGGT are elongated in a northeasterly direction. Isotopic data indicate that the main tectono-magmatic episodes occurred at 3160–3060 Ma, and

3016–2970 Ma. Most granitoids in the WPGGT were intruded between 3016 and 2970 Ma, a period that coincided with felsic volcanism in the Whim Creek Group on the southeastern margin of the WPGGT.

The geological evolution of the WPGGT has been reviewed by Van Kranendonk et al. (2002) and Hickman (in prep.a). The geology of the terrane is consistent with Phanerozoic-style plate tectonic processes (Krapez, 1993; Smith et al., 1998; Krapez and Eisenlohr, 1998; Van Kranendonk et al., 2002). Superimposed thrusts, strike-slip faults, and folds indicate successive periods of north–south or northwesterly–southeasterly extension and compression. Krapez and Eisenlohr (1998) and Smith et al. (1998) suggested an intra-arc setting for the Roebourne Group, and a back-arc setting for the Whundo Group, both being adjacent to a subduction zone that, on present geography, was positioned to the northwest. However, geochronology indicates that the Roebourne and Whundo Groups differ in age by about 150 Ma, and therefore cannot be genetically related. Other problems include the lack of any arc granitoids related to the Whundo Group, the only known granitoids of c. 3130 Ma age being on the continental side of the inferred back-arc basin. The present interpretation is that the Whundo Group was deposited in an extensional basin floored by oceanic crust, and that the Roebourne Group was deposited during earlier continental rifting associated with a mantle plume (Van Kranendonk et al., 2002; Hickman, in prep.a).

The Hamersley Basin is a Neoarchaean to early Palaeoproterozoic tectonic unit that unconformably overlies the WPGGT and other terranes of the Pilbara Craton. The lithostratigraphy of the Hamersley Basin consists of three groups that together make up the Mount Bruce Supergroup. Only the lower half of this succession, comprising the Fortescue Group and the lower part of the Hamersley Group, is preserved on DAMPIER – BARROW ISLAND (Table 2).

Blake (1993) and Thorne and Trendall (2001) described the regional stratigraphy and tectonic evolution of the Fortescue Group. Thorne and Trendall (2001, p. 220) stated that in the northern Pilbara the volcanic formations of the group are principally composed of subaerial to shallow marine mafic lavas analogous to those of Phanerozoic flood basalt provinces. However, on PINDERI HILLS, volcanic formations of the Fortescue Group include basalt, high-Mg basalt, andesite, dacite, and minor rhyolite (Kojan and Hickman, 1998).

Blake (1993) emphasized the extent to which regional faults controlled the locations of depositional basins by pointing out that deposition of the lower part of the Fortescue Group took place in several north-northeasterly trending rifts formed by west-northwest–east-southeast extension. Thorne and Trendall (2001) concluded that the Hamersley Basin formed by lithospheric stretching, and evolved from rift-related volcanism and sedimentation to deposition on a subsiding, passive continental margin. The tectonic model preferred by Thorne and Trendall (2001) involved protracted north–south or north-northeast – south-southwest crustal extension related to a major rift along the present-day southern Pilbara margin. In this model, north-northeasterly trending rifts in the northern Pilbara were interpreted to have formed at a high angle to the principal east-southeasterly trending rift of the southern Pilbara, probably analogous to a failed rift arm.

The Hamersley Basin succession on DAMPIER – BARROW ISLAND is deformed by structures related to c. 2770–2700 Ma northeasterly trending rifting and open folding, and by thrusting of uncertain age in the area between James Point and Cape Preston (Hickman and Strong, 1998). These authors suggested that these structures formed during either the c. 1800 Ma Capricorn Orogeny or during the c. 1300–1100 Ma Proto-Pinjarra Orogeny (Myers et al., 1996).

GEOCHRONOLOGY

Precise U–Pb geochronology from DAMPIER – BARROW ISLAND is summarized in Table 3, and Table 4 lists geochronological data indicating the existence of pre-3300 Ma crustal components in the area. These data are referred to throughout these Notes, and are used in the map legend.

ARCHAEAN ROCKS

PILBARA SUPERGROUP

The West Pilbara Granite–Greenstone Terrane (WPGGT) comprises greenstone successions of metamorphosed volcanic, sedimentary, and mafic–ultramafic intrusive rocks, and Archaean granitoids ranging in composition from tonalite to syenogranite. Following Hickman (1983), the greenstones are collectively assigned to the Pilbara Supergroup, and the revised Archaean lithostratigraphy of the WPGGT, modified from Hickman (1997a), is shown in Table 2.

Roebourne Group (*AR*)

The lithostratigraphy of the Roebourne Group is summarized in Table 2. Field relations and geochronological data have established that basal mafic and ultramafic metavolcanic rocks of the Ruth Well Formation (*ARw*) are the oldest preserved components (Hickman, 1997a). These rocks are undated, but must be older than c. 3270–3250 Ma, the age of conformably overlying felsic metavolcanic and metasedimentary rocks of the Nickol River Formation (*ARn*) and coeval, intrusive granitoid rocks of the Karratha Granodiorite (*Agka*; Nelson, 1998; Smith et al., 1998; Hickman, 1999). The Ruth Well Formation includes metabasalt, serpentinized peridotitic komatiite, talc–chlorite schist, grey- and white-banded chert, and black chert. The overlying Nickol River Formation contains grey- and white-banded chert, ferruginous chert, BIF, fine-grained clastic sedimentary rocks, quartzite, felsic volcanic rocks, metamorphosed carbonate sedimentary rocks, and conglomerate.

The Regal Formation structurally overlies the Nickol River Formation, and was previously assigned to the Roebourne Group (Hickman, 1997a). This stratigraphic assignment, which is shown on the DAMPIER – BARROW ISLAND map, was based on the lithological similarity of the Regal Formation (peridotitic komatiite, metabasalt, and chert) to the Ruth Well Formation. However, the contact between the Regal Formation and the Nickol River Formation is invariably tectonized. Hickman et al. (2000) named the regional tectonic contact the Regal Thrust, and noted that it can be traced over a large area, extending eastwards onto ROEBOURNE (Hickman and Smithies, 2001). Sun and Hickman (1998) interpreted the chemistry of the Regal Formation to be similar to that of mid-oceanic-ridge basalt (MORB), which would be inconsistent with a normal stratigraphic position above metamorphosed clastic sedimentary rocks of the Nickol River Formation. This chemical classification, if correct, would imply that either the Regal Formation was obducted onto the Nickol River and Ruth Well Formations, or that the Regal Formation is not part of the Roebourne Group. Hickman (in prep.a) consequently redefined the Roebourne Group to exclude the Regal Formation.

Ruth Well Formation (ARw, ARwb, ARwc, ARwg, ARwu)

The Ruth Well Formation (*ARw*) includes metabasalt, serpentinized peridotitic komatiite, talc–chlorite schist, grey- and white-banded chert, and black chert. On DAMPIER – BARROW

Table 3. Precise U–Pb zircon geochronology (SHRIMP*, unless otherwise indicated) on DAMPIER – BARROW ISLAND, and adjacent areas

Age (Ma)	*Lithology/formation*	*Location (MGA)* *Easting*	*Northing*	*Sample*	*Reference*
3270 ± 2	tonalite, Karratha Granodiorite	477100	7696100	142433	Nelson (1998, p. 102–104)
3269 ± 2	quartz–sericite schist, Nickol River Formation	501000	7705700	136819	Nelson (1998, p. 99–101)
3267 ± 4	granodiorite, Karratha Granodiorite	485500	7702000	N4438	Smith (1997)
3267 ± 17(c)	rhyolite, Nickol River formation	474900	7697700	118975	Nelson (1997, p. 154–157)
3265 ± 4	granodiorite	497400	7691000	JS43	Smith et al. (1998)
3261 ± 4	granodiorite, Karratha Granodiorite	484700	7696700	JS17	Smith et al. (1998)
3258 ± 12	granodiorite	487200	7690600	N3214	Smith (1997)
3251 ± 6	rhyolite, Nickol River formation	474900	7697700	118975	Nelson (1997, p. 154–157)
3236 ± 3	tonalite, Cherratta Granitoid Complex	448490	7634670	142535	Nelson (1998, p. 93–95)
3221 ± 28(c)	monzogranite, Cherratta Granitoid Complex	519190	7664990	168932	Nelson (2001, p. 167–170)
3149 ± 15(c)	tonalite, Cherratta Granitoid Complex	492500	7664000	142835	Nelson (1999, p. 119–121)
3130 ± 4	tonalite, Cherratta Granitoid Complex	492500	7664000	142835	Nelson (1999, p. 119–121)
3128 ± 6	rhyolite, Tozer Formation	492900	7678900	N4325	Smith (1997)
3127 ± 8(c)	monzogranite, Cherratta Granitoid Complex	519190	7664990	168932	Nelson (2001, p. 167–170)
3125 ± 4	dacite tuff, Nallana Formation	491500	7685000	114350	Nelson (1996, p. 164–167)
3122 ± 7	rhyolite, Tozer Formation	491700	7678200	114358	Nelson (1997, p. 134–137)
3121 ± 2	rhyolite dyke	483600	7698400	N4413	Smith (1997)
3118 ± 3	rhyolite, Tozer Formation	492500	7683200	114356	Nelson (1996, p. 156–159)
3118 ± 2	rhyolite tuff, Woodbrook Formation	535100	7688200	144256	Nelson (1998, p. 114–116)
3117 ± 3	welded tuff, Woodbrook Formation	508800	7686900	127378	Nelson (1998, p. 111–113)
3116 ± 3	dacite, Whundo Group	548400	7686100	144210	Nelson (1998, p. 117–119)
3115 ± 5	felsic tuff, Bradley Basalt	501500	7686300	114305	Nelson (1996, p. 160–163)
3114 ± 5	granodiorite, Cherratta Granitoid Complex	489490	7665670	JS33	Smith et al. (1998)
3112 ± 6(a)	felsic tuff, Tozer Formation	497300	7685900	W197	Horwitz and Pidgeon (1993)
3095 ± 11(c)	tonalite, Cherratta Granitoid Complex	486460	7661750	142661	Nelson (1998, p. 96–98)
3068 ± 6	tonalite, Cherratta Granitoid Complex	486460	7661750	142661	Nelson (1998, p. 96–98)
3050 ± 8(c)	monzogranite, Cherratta Granitoid Complex	507500	7654430	168934	Nelson (2001, p. 171–172)
3024 ± 4	mylonite, Sholl Shear Zone	494800	7689300	JS25	Smith et al. (1998)
3023 ± 9	dacite, north of Sholl Shear Zone	495500	7690200	118976	Nelson (1997, p. 175–178)
3022 ± 12	sandstone, Cleaverville Formation	502100	7714300	127330	Nelson (1998, p. 52–55)
3021 ± 3	porphyry sill, Ruth Well Formation	519800	7709100	144224	Nelson (1999, p. 157–159)
3018 ± 3*	sandstone, Cleaverville Formation	516900	7686700	142830	Nelson (1998, p. 63–65)
3018 ± 2	porphyry sill, Regal Formation	501600	7711200	127327	Nelson (1998, p. 136–138)
3016 ± 4	Harding Granitoid Complex	511700	7693700	168936	Nelson (2001, p. 178–180)
3015 ± 5*	sandstone, Cleaverville Formation	509000	7712500	136899	Nelson (1998, p. 120–122)
3014 ± 2	quartz–feldspar porphyry	496900	7693000	118979	Nelson (1997, p. 179–182)
3014 ± 6	granophyre sill, Cleaverville Formation	517000	7687200	127320	Nelson (1997, p. 183–186)
3013 ± 4	monzogranite, Cherratta Granitoid Complex	491930	7667280	JS35	Smith et al. (1998)
3006 ± 12	monzogranite, Cherratta Granitoid Complex	519190	7664990	168932	Nelson (2001, p. 167–170)
2997 ± 3	syenogranite, Dampier Granitoid Complex	470800	7704600	136844	Nelson (1998, p. 105–107)
2995 ± 11	tonalite, Cherratta Granitoid Complex	475500	7680100	136826	Nelson (1997, p. 158–162)
2994 ± 2	granodiorite, Cherratta Granitoid Complex	465400	7690300	118974	Nelson (1997, p. 150–153)
2990 ± 3	granodiorite, Cherratta Granitoid Complex	478950	7664550	142657	Nelson (1999, p. 115–118)
2988 ± 4	granodiorite, Cherratta Granitoid Complex	486100	7668350	142438	Nelson (1999, p. 112–114)
2988 ± 7	monzogranite, Cherratta Granitoid Complex	507500	7654430	168934	Nelson (2001, p. 171–172)
2982 ± 5	monzogranite, Dampier Granitoid Complex	421270	7672550	142893	Nelson (1999, p. 152–156)
2970 ± 5	Harding Granitoid Complex	507900	7691500	142430	Nelson (1999, p. 108–111)
2952 ± 6	pegmatite phase, Dampier Granitoid Complex	421270	7672550	142893	Nelson (1999, p. 152–156)
2944 ± 5	leucocratic phase, Cherratta Granitoid Complex	475500	7680100	136826	Nelson (1997, p. 158–162)
2925 ± 16	pegmatite, Munni Munni Intrusion	484560	7665080	103227	Arndt et al. (1991)
2924 ± 5	microgranite, Munni Munni Intrusion	485450	7664750	142436	Nelson (1998, p. 90–92)
2725 ± 3(b)	gabbro, Gidley Granophyre	479000	7719000	na	Wingate (1997, written comm.)
2719 ± 6	tuffaceous siltstone, Tumbiana Formation	506870	7635510	168935	Nelson (2001, p. 175–177)
2717 ± 2	dacite, Maddina Formation.	475400	7624100	144993	Nelson (1998, p. 133–135)
2715 ± 6	tuffaceous siltstone, Tumbiana Formation	521140	7641450	94775	Arndt et al. (1991)
2684 ± 6	ignimbrite, Jeerinah Formation	425040	7640650	94776	Arndt et al. (1991)

NOTES: * Sensitive high-resolution ion microprobe
(a) Conventional U–Pb zircon date
(b) SHRIMP U–Pb–Th baddeleyite date
(c) Interpreted as xenocrystic population

Table 4. Geochronological data supporting the existence of pre-3270 Ma source rocks in the evolution of the West Pilbara Granite–Greenstone Terrane on DAMPIER – BARROW ISLAND and immediately adjacent parts of ROEBOURNE

Age (Ma)	*Method*	*Material*	*Rock unit/age*	*Sample no.*	*Reference*
3494 ± 15	Sm–Nd	rock	Karratha Granodiorite, 3261 Ma	JS17	Smith et al. (1998)
3479 ± 13	Sm–Nd	rock	Karratha Granodiorite[(a)], 3265 Ma	JS43	Smith et al. (1998)
3461 ± 8	$^{207}Pb/^{206}Pb$	zircon	Cleaverville Formation, 3022 Ma	127330	Nelson (1998)
3449 ± 5	$^{207}Pb/^{206}Pb$	zircon	Nallana Formation, 3125 Ma	114350	Nelson (1996)
c. 3430	Sm–Nd	rock	Nickol River Formation, 3251 Ma	118975	Sun and Hickman (1998)
3391 ± 15	Sm–Nd	rock	mylonite, 3050–2920 Ma	JS25	Smith et al. (1998)
3311 ± 8	$^{207}Pb/^{206}Pb$	zircon	Karratha Granodiorite, 3261 Ma	JS17	Smith et al. (1998)
3309	Sm–Nd	rock	Harding Granitoid Complex, 2970 Ma	JS25	Smith et al. (1998)
c. 3298	Sm–Nd	rock	dacite intrusion, 3023 Ma	118976	Sun and Hickman (1998)
3287 ± 17	$^{207}Pb/^{206}Pb$	zircon	Cleaverville Formation, 3022 Ma	127330	Nelson (1998)

NOTES: (a) Smith et al. (1998) assigned this unit to the Harding Granitoid Complex

ISLAND, the formation outcrops around the margins of the Karratha Granodiorite (*Agka*), and forms most of the greenstone succession immediately north of the Sholl Shear Zone (SSZ) between the Maitland River and the eastern boundary of the sheet area. Undivided Ruth Well Formation (*ARw*) 4 km south of Karratha includes intercalated ultramafic and mafic rocks and thin chert units. The cherts, which are less than 2 m thick, are interpreted as metamorphosed interflow sediments separating tholeiitic and ultramafic lava flows. Individual mafic and ultramafic units are commonly 10–20 m thick, and comprise alternating flow packages. Shearing along the margin of the Karratha Granodiorite has attenuated the succession. Here, and in other areas, the Ruth Well Formation is extensively intruded by the c. 3270–3260 Ma Karratha Granodiorite (*Agka*). East of the Nickol River, the formation is intruded by c. 3015 Ma monzogranite and granodiorite (*Agm*), and by <3016 Ma gabbro of the Andover Intrusion (*AaAo*).

The stratigraphy of the formation is most completely preserved 5 km south of Mount Regal and between Ruth Well and the Nickol River. In these areas, the Ruth Well Formation is composed of a lower unit of serpentinized peridotite and spinifex-textured peridotitic komatiite (*ARwu*), and an overlying metabasalt containing minor chert (*ARwb*). About 5 km southeast of Mount Regal, and near Mount Prinsep, the formation includes units of grey- and white-banded chert, ferruginous chert, and minor quartzite (*ARwc*). Local lenticular units of black chert too small to show at 1:250 000 scale are located 3 km west, and 3 km northeast, of Mount Prinsep (Hickman, 1997b).

Serpentinized peridotite and peridotitic komatiite with olivine spinifex texture (*ARwu*) form thick units south of Ruth Well and 3 km southeast of White Quartz Hill. A volcanic origin for these rocks is indicated by a number of features: local spinifex texture (Tomich, 1974); associated metabasalt and thin chert units; and an absence of any visible intrusive relationships with adjacent volcanic and sedimentary rocks. However, some of the thicker and more massive serpentinized peridotites (e.g. 3 km southeast of White Quartz Hill) may be metamorphosed sills.

Metabasalt containing minor chert (*ARwb*) outcrops south of the Karratha Granodiorite (*Agka*) between Mount Regal and the Nickol River. Metamorphic grade ranges from greenschist to lower amphibolite facies, and the metabasalt is typically massive, lacking pillow structures, and contains widespread alteration including pervasive quartz veinlets, and carbonate alteration. Flow tops are typically difficult to recognize, except where there are interflow sedimentary rocks or altered flow-top breccias. Alteration in the upper sections of flows has mainly involved silicification and epidotization. Depending on the metamorphic grade, most metabasalt consists of a fine-grained assemblage of amphibole (actinolite, tremolite, or hornblende), quartz (chiefly secondary), albite, epidote, chlorite, and minor sericite, sphene, clinozoisite, carbonate minerals, and opaque minerals. Relict clinopyroxene phenocrysts are locally preserved, but replacement by amphibole is normally complete. Plagioclase is extensively saussuritized, original labradorite or andesine having been replaced by albite.

Foliated and sheared metabasalt with sheared veins and sheets of microgranite and pegmatite (*ARwg*) outcrops along the southern contact of the Karratha Granodiorite (*Agka*). This unit is interpreted to have formed at c. 3270 Ma, when the Karratha Granodiorite intruded the lower part of the Roebourne Group.

Nickol River Formation (ARn, ARns, ARnc, ARncf, ARnu)

The Nickol River Formation contains grey- and white-banded chert, ferruginous chert, BIF, fine-grained clastic sedimentary rocks, quartzite, felsic volcanic rocks, metamorphosed carbonate sedimentary rocks, conglomerate, and serpentinized peridotite. On DAMPIER – BARROW ISLAND, the formation is exposed on the limbs of the Prinsep Dome, and between Mount Regal and Devil Creek. Stratigraphic correlation between the greenstone succession of the Devil Creek area (PRESTON) and greenstones east of the Maitland River (DAMPIER) is based on aeromagnetic data that indicate continuity of the Cleaverville Formation (chiefly BIF), which is the highest stratigraphic unit of both greenstone successions. In both areas, the Cleaverville Formation stratigraphically overlies a 1000–2000 m-thick metabasalt unit (Regal Formation), which in turn overlies metamorphosed clastic sedimentary rocks and chert (Nickol River Formation). The Nickol River Formation is also preserved on the southeastern limb of the Roebourne Synform (Figs 4 and 5), where it is extensively deformed adjacent to the Regal Thrust (see **Structure**, p. 37). Samples of the formation collected during the mapping of DAMPIER (Hickman, 1997b) were dated at 3269 ± 2 Ma and 3251 ± 6 Ma (Nelson, 1997, 1998; Table 3). The formation's composition indicates that it was deposited as a shallow-water succession, including material derived by erosion of underlying units. Layers of serpentinized peridotite within the formation are interpreted as ultramafic lavas.

Metaconglomerate 2 km north of the Lower Nickol mining centre consists of angular to subrounded pebbles and boulders (up to 15 cm in diameter) of chert and fuchsitic schist in a poorly sorted sandstone matrix. Beds of conglomerate also form part of a thick sequence of metamorphosed sandstone and siltstone north and northeast of Lower Nickol mining centre. Quartzite overlies metamorphosed felsic volcanic rocks close to the southeastern margin of the Karratha Granodiorite, and also outcrops 3 km southeast of Mount Regal. Its lithological associations suggest that it is a metamorphosed volcanogenic sandstone.

Within the undivided Nickol River Formation (*ARn*), metamorphosed volcaniclastic sandstone and siltstone underlie the Regal Thrust around the northeastern closure of the Prinsep Dome, 8 km south of Cleaverville. The unit is chiefly composed of quartz–sericite schist, phyllite, ferruginous chert, and boudinaged quartz veins. Below this unit is a thicker succession of metasandstone containing minor conglomerate and metasiltstone that outcrops about 8 km south of Cleaverville. These rocks include silicified (cherty) breccia, grey- and white-banded chert (derived by silicification of fine-grained clastic sedimentary rock), and some mylonitic zones. Black chert, interpreted to represent silicified carbonaceous shale, also outcrops in this area. The chert is typically weakly banded as alternating black and dark-grey layers, but can also be homogeneous apart from quartz veinlets.

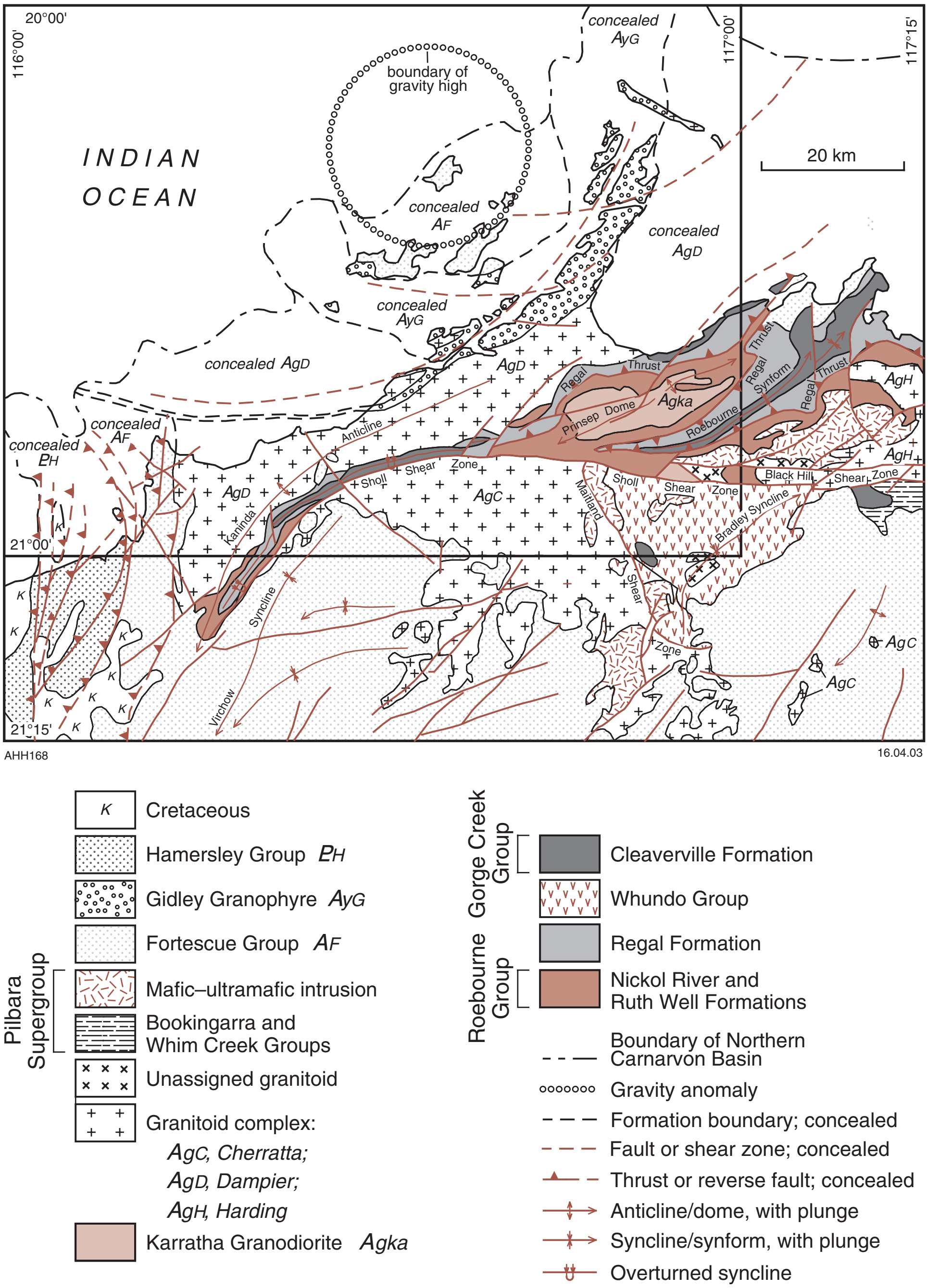

Figure 5. Simplified geological map showing major structures on DAMPIER – BARROW ISLAND and adjacent areas

Chert, and metamorphosed BIF, carbonate and ferruginous clastic sedimentary rocks, with local quartzite and conglomerate (*ARns*) outcrop north and south of Mount Regal, and 3 km south of Karratha. Much of the unit is pelitic, and the protolith is interpreted to have been sulfidic shale. Near-surface silicification of sulfidic shale may have formed the ferruginous chert and BIF (*ARncf*) that outcrops in easterly striking ridges south, east and southwest of Karratha; alternatively, the chert and BIF may be primary.

Chert (*ARnc*) units mapped east and southwest of Karratha, south of Mount Regal, and between Devil Creek and Slopers Well, consist predominantly of grey- and white-banded chert, and ferruginous chert, with minor pale grey, or grey-green chert. Quartz–sericite schist interlayered with green chert, grey chert, and grey- and white-banded chert 3 km south of Karratha is interpreted to be a sheared sedimentary or felsic volcanic rock.

Grey- and white-banded chert, locally associated with beds of quartzite too thin to map separately, includes silicified fine-grained clastic sedimentary rocks or tuff, but some units may have originated as primary silica deposits. Alternating white and grey layers, typically 1–10 mm thick, are mostly sharply defined but some colour grading is locally present. This may represent graded bedding in the fine-grained clastic protoliths; consistent way-up evidence is rarely visible. Green and grey-green chert outcrops 2 km east-southeast of Mount Regal, 4 km northeast of Tobacco Well, and 1.5 km southwest of Nickol Well. The rock is generally banded with alternating dark- and pale-green layering, but may also have pale-grey or white layers. The distinctive colour of the rock is attributed to finely disseminated chromium muscovite (fuchsite). Green chert commonly outcrops close to chromium-rich ultramafic rocks. In places (e.g. near Mount Regal), the rock has been quarried for the production of ornamental and semiprecious stone.

Serpentinized peridotite, and local komatiitic peridotite with olivine spinifex texture (*ARnu*), outcrops 3 km south of Karratha. Excellent exposures of olivine spinifex texture outcrop on a ridge (Fig. 6) approximately 1.5 km west of the Karratha access road. Here, spinifex-textured flows of ultramafic lava are preserved within a tectonized lens of serpentinized peridotite. Individual ultramafic lava flows are 1–2 m thick, and dip northwestwards at 10–30º. The most visually striking feature of the flows is the excellent development of sheaf-spinifex texture, in which blades of serpentinized olivine are up to 0.5 m in length. The sheaf-spinifex zones of each flow are overlain by zones of random-spinifex texture, and these underlie fractured, aphanitic, and vesicular flow tops. The basal parts of the flows are poorly exposed due to rubble from overlying flow components, but consist of massive serpentinite with locally visible olivine cumulate texture. Thin sections from similar rocks at nearby localities suggest that the olivine plates of the sheaf-spinifex zone are likely to have been completely replaced by serpentine and tremolite. Serpentinized peridotite lacking spinifex texture is typically massive, and may include metamorphosed sills.

Regal Formation (ARr, ARrg, ARrc, ARru)

Undivided Regal Formation (*ARr*), which forms most of the formation, comprises massive and pillowed basalt that in most areas has been metamorphosed to amphibolite facies. Extensive exposures of metabasalt are located southeast of the Karratha Granodiorite, south of Cleaverville, south of Karratha, southwest of Mount Regal, and in the Devil Creek area. Metamorphosed gabbro and dolerite sills are most common in the outcrops south of Cleaverville. Following an early stratigraphic interpretation (Hickman, 1997a), the formation was included in the Roebourne Group on the DAMPIER – BARROW ISLAND map, but it has subsequently been removed because later mapping has shown that its contact with the Nickol River Formation regionally is a tectonic contact (Hickman, in prep.a).

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Figure 6. Platy spinifex texture in peridotite flows within the Nickol River Formation south of Karratha (MGA 482500E 7704900N)

South and east of Lower Nickol mining centre, and 1 km northwest of Mount Regal, the lower part of the Regal Formation is composed of serpentinized peridotite and komatiite (*ARru*). This unit is thinner and more poorly preserved than the lower ultramafic section of the Ruth Well Formation, but the general mineralogy of the rocks is similar. Within the Roebourne Synform, the Regal Formation contains sheared metabasalt with sheared veins and sheets of microgranite and pegmatite (*ARrg*). This unit lies in a zone of intense shearing and granitic intrusion, flanked to the southeast by narrow belts of mylonite. A foliated sill of quartz–feldspar porphyry, which represents a northeastern extension of the granitic sheets, has been dated at 3018 ± 2 Ma (Nelson, 1998). This is interpreted as the age of formation of this mixed unit (*ARrg*), although shearing (which affects both the metabasalt and the granitic components) occurred later. These data also provide a minimum age (3018 Ma) for the Regal Formation, but a better constraint for the depositional age of the formation is interpreted to be the inferred age of c. 3160 Ma for D_1 (see **Deformation events**).

Chert (*ARrc*) is rare in most outcrops of the formation on DAMPIER – BARROW ISLAND, and is mapped separately only in the Devil Creek area, where it is predominantly ferruginous chert.

Whundo Group (*AU*)

The Whundo Group (Hickman, 1997a) is an approximately 10 km-thick succession of mafic and felsic metavolcanic rocks that outcrops south of the SSZ between the Cherratta and Caines Well Granitoid Complexes. Geochronology on felsic volcanic rocks in the central and upper formations of the group gives a range of ages from 3125 to 3115 Ma (Horwitz and Pidgeon, 1993; Hickman, 1997a; Nelson, 1997, 1998). However, the base of the Nallana Formation is intruded by c. 3130 Ma granodiorite of the Cherratta Granitoid Complex (Hickman and Kojan, 2003), establishing that the lowermost sections of the Whundo Group must have been deposited before 3130 Ma. On southeastern DAMPIER – BARROW ISLAND, the Nallana Formation is 2000 m thick and comprises metabasalt, ultramafic rocks, intermediate pyroclastic rocks, and sills of dolerite. The Tozer Formation, which conformably overlies the Nallana Formation and is 2500 m thick, consists of alternations of metamorphosed basalt, andesite, dacite, rhyolite, and thin metasedimentary units including chert and BIF. Dates from the Tozer Formation are close to 3120 Ma. The most homogeneous formation of the Whundo Group is the Bradley Basalt (*AUb*), which is more than 4000 m thick and conformably overlies the Tozer Formation. The bulk of the Bradley Basalt consists of metamorphosed, massive and pillowed basalt, but on ROEBOURNE (Hickman and Smithies, 2001) spinifex-textured high-Mg basalt is present near its base, and units of felsic tuff are intercalated with basalt and dolerite sills in the upper part of the formation. A felsic tuff 1000 m above the base of the Bradley Basalt was dated at 3115 ± 5 Ma (Nelson, 1996). On ROEBOURNE, the Bradley Basalt is conformably overlain by felsic volcanic rocks of the Woodbrook Formation (Hickman, 1997a), which is the uppermost formation of the Whundo Group.

Nallana Formation (AUnb, AUnf)

The Nallana Formation outcrops on southeastern DAMPIER – BARROW ISLAND, where it is almost entirely composed of metabasalt with local mafic schist (*AUnb*). The metabasalt consists mainly of either massive or pillowed basalt that has been metamorphosed to greenschist facies. Varying degrees of strain are indicated by local flattening or shearing of pillow structures. Vesicles in the pillows are filled with quartz, carbonate minerals, or chlorite. Interstitial material between the pillows is composed of cryptocrystalline chloritic rock, palagonite, chert, or altered tuff. Flow tops within the basaltic units are generally difficult to recognize, except where there are interflow sedimentary rocks or altered flow-top breccias. Alteration in the upper sections of flows has mainly involved silicification and epidotization. Most metabasalt is a fine-grained assemblage of amphibole (actinolite, tremolite, or hornblende), quartz (largely secondary), albite, epidote, chlorite, and minor sericite, sphene, clinozoisite, carbonate minerals, and opaques.

Metamorphosed plagioclase-phyric basalt 800 m southwest of Radio Hill mine contains numerous small euhedral plagioclase phenocrysts. In thin section, saussuritized phenocrysts of plagioclase up to 5 mm across make up about 30% of the rock. The matrix is a fine-grained assemblage of actinolite, epidote, and quartz. Mafic schist within a unit of strongly deformed mafic tuff, 3 km northeast of Radio Hill mine, has a greenschist assemblage of actinolite, chlorite, and minor quartz.

On DAMPIER – BARROW ISLAND, metamorphosed felsic volcanic rock (*AUnf*) forms the top of the Nallana Formation 500 m north of Mount Sholl. The rock is a schistose dacite or rhyolite with sericite–carbonate alteration. In thin section, scattered phenocrysts of quartz and plagioclase are set in a sericitized and carbonated quartz–feldspar groundmass. The margins of the euhedral plagioclase (albite) phenocrysts are partly replaced by carbonate, chlorite, and sericite, but internally the phenocrysts are relatively unaltered. Zircon forms prismatic, partly zoned microphenocrysts up to 0.25 mm in length. The rock (GSWA 114350) was dated at 3125 ± 4 Ma (Nelson, 1996). A rounded, dark brown, xenocrystic zircon from the same sample returned a $^{207}Pb/^{206}Pb$ model age of 3449 Ma (Nelson, 1996).

Tozer Formation (AUtb, AUtf)

The Tozer Formation conformably overlies the Nallana Formation, and is a 2500 m-thick succession of metamorphosed volcanic rocks, comprising basalt, dacite, rhyolite, and rhyolitic pyroclastic units, with local beds of chert and BIF. The succession is extensively carbonated, epidotized, and silicified over a large area east of Mount Sholl, and mapping protoliths is more difficult than in other areas. Field observations indicate that the Tozer Formation may include andesite, but limited geochemical data (Glikson et al., 1986) indicate interlayering of tholeiite and rhyolite. Data in Glikson et al. (1986) indicate significant geochemical differences between the basaltic rocks of the Tozer Formation and the overlying Bradley Basalt. Tholeiites of the upper Tozer Formation (4 analyses) are enriched in SiO_2 (50.00–51.50%) and MgO (7.20–8.70%), and depleted in Fe (FeO_2 + Fe_2O_3: 8.66–10.36%), TiO_2 (0.36–0.98%), V (130–255 ppm), Y (11–26 ppm), and Zr (46–86 ppm), compared to the overlying Bradley Basalt. The Bradley Basalt (4 analyses) contains higher Fe (FeO_2 + Fe_2O_3: 11.82–13.56%), TiO_2 (1.42–1.61%), V (317–381 ppm), Y (33–40 ppm), Zr (101–127 ppm), but lower SiO_2 (46.70–49.50%) and MgO (4.30–6.05%) than tholeiite of the Tozer Formation. Data for the high-field-strength elements, Y, Ti, and Zr, are consistent with progressive crystal fractionation with increasing stratigraphic height.

Metamorphosed basalt and andesite (*AUtb*) includes massive and pillow basalt. Pillows are common over a large area east of Mount Sholl, where varying degrees of strain are indicated by local flattening or shearing of pillow structures. Vesicles in the pillows are filled with quartz, carbonate minerals, or chlorite. Interstitial material between the pillows is composed of cryptocrystalline chloritic rock, palagonite, chert, or altered tuff.

Felsic volcanic rock (*AUtf*) includes metamorphosed rhyolitic lava, tuff and agglomerate. Metamorphosed rhyolite outcrops 2 km southeast of Gaffs Well and 2 km southeast of Mount Sholl. The rhyolite at Gaffs Well forms the top of a small hill, and is fine grained to glassy. In thin section it is porphyritic, glomerocrystic, and spherulitic. Phenocrysts are composed of sodic plagioclase, epidote, quartz, or chlorite (replacing ferromagnesian minerals). The aphanitic groundmass consists of ovoid intergrowths of radiating feldspar and quartz, feldspar microlites, anhedral interstitial quartz and chlorite, subhedral granular epidote, sericite, titanite, and accessory minerals. The unit near Mount Sholl is a rhyolite lava with sparse feldspar and quartz phenocrysts, overlain by felsic tuff and a volcanogenic sedimentary rock. Its mineralogy is similar to the Gaffs Well rock, except that some phenocrysts are composed of biotite, and minor carbonate is present in the groundmass.

Metamorphosed rhyolitic tuff and agglomerate forms large outcrops about 2.5 km south-southeast of Gaffs Well. The well-preserved coarse pyroclastic texture and wedge-shaped nature of the unit indicate a locally developed explosive felsic volcanic centre — a rare occurrence in the greenstones of the west Pilbara.

Metamorphosed volcaniclastic rocks of rhyolite and dacite composition, interbedded with local volcanogenic sedimentary rocks, form thin stratigraphic units in the greenstone succession southeast of Mount Sholl. Thickly bedded units show variations in the size of angular clasts of felsic lava within felsic tuff matrix. Secondary silicification has given the finer grained beds a cherty appearance. Graded bedding and small-scale cross-bedding confirm that the succession in this area becomes younger towards the southeast.

Bradley Basalt (AUb, AUbs)

Undivided Bradley Basalt (*AUb*) is composed of metamorphosed pillow basalt, massive basalt, dolerite sills, and minor units of metamorphosed komatiitic basalt, andesite, dacitic tuff, and chert. The formation is exposed in the Bradley Syncline on southeastern DAMPIER – BARROW ISLAND. About 4 km east-southeast of Tozers Well, the Bradley Basalt contains a 1–5 m-thick unit of metamorphosed sandstone, shale and chert (*AUbs*). This is interpreted to be a silicified interflow unit, and it is veined by gossanous quartz that contains approximately 1.2% combined Cu and Zn (GSWA 114339; Hickman, 2001).

Gorge Creek Group (*AG*)

In the east Pilbara, the Gorge Creek Group (*AG*) comprises a thick metamorphosed succession of clastic sedimentary rocks, chert, BIF, and basaltic volcanic rocks. On DAMPIER – BARROW ISLAND, only one formation of the group, the Cleaverville Formation (*AGl*; Ryan and Kriewaldt, 1964), is preserved.

Cleaverville Formation (AGl)

The Cleaverville Formation is composed of BIF, ferruginous chert, jaspilite, grey-white and black chert, and metamorphosed shale, siltstone, and minor felsic volcaniclastic rocks (*AGl*). Excellent exposures of the formation are provided by wave-cut platforms at Cleaverville (Fig. 7). BIF with minor ferruginous chert outcrops mainly between Cleaverville Beach and Karratha, but is also exposed at Miaree Pool on the Maitland River, in the core of the Roebourne Syncline. In the Devil Creek area, the formation is composed of ferruginous chert and grey-and-white chert. Iron minerals, predominantly magnetite, hematite, and goethite, make up about 50% of BIF, and are interlayered with quartz at 1–10 mm intervals. The rock is typically black or dark grey, and forms

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Figure 7. Beach exposures of the Cleaverville Formation east of Cleaverville Beach (MGA 503300E 7716700N)

units up to 50 m thick in which BIF is interbedded with red jasper, shale, or mudstone. At depth, the shale and mudstone are black or dark grey, but surface exposures are commonly pale grey, brown, or cream to off-white due to bleaching. Jaspilite, a variety of iron formation containing alternating layers of magnetite and red jasper, forms a large unit 3 km south of Gwen Creek, and in other areas minor jaspilite is present within BIF.

On ROEBOURNE (Hickman and Smithies, 2001), metamorphosed clastic sedimentary rocks at the base of the Cleaverville Formation suggest an erosional contact on pillow basalt of the underlying Regal Formation, but an angular unconformity has not been recognized. The depositional age of the Cleaverville Formation is closely constrained by detrital zircons dated at 3018 ± 3 Ma (Nelson, 1998), and by intrusive granophyre dated at 3014 ± 6 Ma (Nelson, 1997). Samples of the Cleaverville Formation also contain detrital zircons with near concordant ages of c. 3287–3236 Ma, and one zircon dated at 3461 ± 8 Ma (Nelson, 1998). The former population was probably derived by erosion of the Karratha Granodiorite, but the 3461 ± 8 Ma age coincides with the age of crust in the EPGGT. This suggests that EPGGT crust, or similar crust, was exposed in the west Pilbara at 3020 Ma.

Ohta et al. (1996) and Kiyokawa and Taira (1998) interpreted the chert and BIF of the Cleaverville Formation as having been deposited in deep-water oceanic environments remote from any influx of continental material. However, this interpretation is not supported by evidence provided by sedimentary structures and mineralogy (Sugitani et al., 1998) that the Cleaverville Formation in the adjacent Roebourne area is a shallow-water deposit. Also significant, as noted above, is the fact that the Cleaverville Formation contains clastic zircons dated at 3461 ± 8 Ma and 3287 ± 17 Ma (Nelson, 1998). These ages suggest deposition on or adjacent to older continental crust. Archaean BIF of the northern EPGGT rests directly on a major erosional unconformity above deformed granitoids (Dawes et al., 1995; Williams, 1999), and was deposited directly on continental crust.

Mafic–ultramafic intrusions

The six layered mafic–ultramafic intrusions on DAMPIER – BARROW ISLAND are compositionally similar, and occur within a northerly to northeasterly trending zone that extends eastward onto ROEBOURNE and southward onto PINDERI HILLS. Intrusive relationships with dated granitoids and greenstones, and available geochronology on the intrusions (Arndt et al., 1991; Frick et al., 2001) indicate that most of the intrusions were emplaced at about 2925 Ma. The Andover Intrusion is intruded by c. 3016 Ma monzodiorite (Nelson, 2001), and is therefore older than the other intrusions (Hickman, 2002).

The intrusions are discordant to the greenstones and to the granitoids that they intrude, and are generally lopoliths or funnel-shaped bodies (Hoatson et al., 1992). Most comprise a lower section of ultramafic layers overlain by a layered unit of gabbro, leucogabbro, norite, and rare anorthosite and granophyre. The largest intrusions are several kilometres thick (e.g. the Munni Munni Intrusion on PINDERI HILLS is about 5500 m thick) and outcrop over 100 to 150 km^2. The intrusions have been actively explored by mineral exploration companies (Ruddock, 1999). On DAMPIER – BARROW ISLAND, the Radio Hill Intrusion is mined for nickel and copper at the Radio Hill mine. Also on DAMPIER – BARROW ISLAND, the Sholl Intrusion contains nickel–copper deposits that have yet to be commercially exploited, although trial mining and extracting nickel and copper using a bioleach method commenced at the Sholl B1 deposit in late 1999. On PINDERI HILLS, about 15 km south of Radio Hill, large, low-grade deposits containing PGE, nickel, and copper, have been discovered in the Munni Munni Intrusion (Williams et al., 1990).

Andover Intrusion (AaAo, AaAu)

The Andover Intrusion is the largest layered intrusion of the WPGGT, and it occupies an area of about 200 km^2, southeast and southwest of Roebourne. Only the western part of the intrusion is exposed on DAMPIER – BARROW ISLAND. Mapping on ROEBOURNE (Hickman, 2002) indicates that the main part of the intrusion is a lopolith, or a funnel-shaped body, that intruded the Ruth Well Formation, and was subsequently intruded by a c. 3016 ± 4 Ma monzodiorite (Nelson, 2001) of the Harding Granitoid Complex. On DAMPIER – BARROW ISLAND, the Andover Intrusion intrudes the Ruth Well Formation, and also intrudes the Karratha Granodiorite where this is exposed on the southern limb of the Roebourne Synform. Its intrusive relationships to undated monzogranite and granodiorite (*Agm*) and c. 3015 Ma quartz–feldspar porphyry (*Apf*) are unclear.

Metamorphosed gabbro, leucogabbro, dolerite, and minor anorthosite (*AaAo*) outcrop in dark grey to black, bouldery hills and ridges, and are all massive rocks jointed at 0.5 to 2 m intervals. A rare, weakly developed mineral layering is generally defined by plagioclase-rich layers 1–10 cm thick. In thin section, gabbro has a hypidiomorphic assemblage of saussuritized plagioclase, pyroxene (variably replaced by actinolite and chlorite), and brown hornblende. Accessory minerals include sphene and carbonate, and some gabbro contains minor quartz. Metamorphosed leucogabbro differs from metagabbro in containing more plagioclase. Microscopic examination reveals saussuritized plagioclase, tremolite, clinopyroxene, chlorite, traces of brown hornblende, and variable amounts of calcite.

About 1 km south of No 6 Well, and close to the northern margin of the Andover Intrusion, the metamorphosed gabbro and dolerite contains angular blocks of metabasalt. This injection breccia probably formed by fragmentation of basaltic wallrocks followed by gabbro intrusion. The observation that only basalt forms clasts within the breccia indicates formation more or less in situ.

Metapyroxenite, with minor undivided ultramafic rocks (*AaAu*), is a minor component of the Andover Intrusion on eastern DAMPIER – BARROW ISLAND, where it outcrops along the northern margin of the intrusion, and 2 km southeast of No 6 Well. Unlike metagabbro and massive serpentinite, metapyroxenite is generally extensively altered, and forms low, weathered outcrops. The rock is fine to medium grained, with an allotriomorphic granular texture, and is mainly composed of secondary amphibole (actinolite or tremolite) and minor chlorite, talc, and epidote. Opaque minerals form disseminated anhedral grains and discontinuous layers along grain boundaries and cleavage traces.

Bullock Hide Intrusion (AaBo, AaBu)

The Bullock Hide Intrusion outcrops intermittently over an area of approximately 20 km^2 north and southeast of Bullock Hide Well, about 10 km west of Mount Sholl. The intrusion is elongated in a north-northwesterly direction, and is 10 km long and up to 3 km wide. On its eastern side, it intrudes the Nallana Formation (Whundo Group), to the north it is truncated by the Sholl Shear Zone (SSZ), and to the west it is separated from the Cherratta Granitoid Complex by the Maitland Shear Zone (MSZ).

The Bullock Hide Intrusion is composed of steeply inclined layers of serpentinized peridotite, talc–chlorite schist, and metamorphosed gabbro, leucogabbro, and dolerite. At its northern end, it includes large outcrops of gabbro–basalt injection breccia similar to breccia in the Andover and Dingo Intrusions. Along most of its length, the intrusion contains a steeply inclined, north-northwesterly striking tectonic foliation (S_5, see **Deformation**

events) parallel to the MSZ. The intrusion is also deformed by several faults parallel to the MSZ, and most of these faults are veined by quartz. Shear lineations within the faults plunge at low angles to the north-northwest, as do similar lineations in mylonite of the MSZ. At the northern end of the Bullock Hide Intrusion this foliation is rotated to strike east–west adjacent to the SSZ. Additional evidence of deformation close to the SSZ is provided by outcrops of metagabbro 5 km east-northeast of Bullock Hide Well; these outcrops are interpreted as part of the Bullock Hide Intrusion, which has been displaced eastwards by dextral drag folding adjacent to the SSZ. As noted by Hickman (2001), the Bullock Hide Intrusion may be a tectonically displaced western section of the Andover Intrusion, which outcrops on the northern side of the SSZ, 15 km east of Bullock Hide Well.

Although the Bullock Hide Intrusion is one of the larger west Pilbara mafic–ultramafic intrusions, it is not marked by a correspondingly large positive anomaly on regional aeromagnetic images (Geological Survey of Western Australia, 1995b). The intrusion is intruded by monzogranite of the Cherratta Granitoid Complex, and the aeromagnetic data indicate that this granitoid intrusion is very extensive, particularly beneath areas of no outcrop. This conclusion raises the possibility that the Dingo Intrusion, which on the present interpretation (see above) is effectively a large xenolith within the Cherratta Granitoid Complex, may originally have been part of the Bullock Hide Intrusion, as suggested by Hoatson and Sun (2002). The interpretation that the Andover, Bullock Hide, and Dingo Intrusions were originally all part of one major mafic–ultramafic intrusion is supported by their compositional difference from the other west Pilbara mafic–ultramafic intrusions. The Andover, Bullock Hide, and Dingo Intrusions contain multiple layers or zones of peridotite (pyroxenite is minor), gabbro, and dolerite; and ultramafic and mafic rocks are present in approximately equal proportions. In contrast, all other west Pilbara mafic–ultramafic intrusions are dominated by gabbro, or gabbro and dolerite, with peridotite and pyroxenite being restricted to the lowermost zones. Additionally, the Andover, Bullock Hide, and Dingo Intrusions include substantial volumes of gabbro–basalt injection breccia, that is very rare or absent in the other intrusions.

Metamorphosed gabbro, leucogabbro, and minor anorthosite (*AaBo*) are interlayered with serpentinized peridotite (*AaBu*) over most of the outcrop area of the Bullock Hide Intrusion. Talc–chlorite schist, 1.5 km north-northeast of Bullock Hide Well, is associated with serpentinite, and may represent altered pyroxenite. However, pyroxenite has not been identified in the intrusion. Serpentinized peridotite is typically massive, and forms dark-grey or black hills and ridges. Metagabbro outcrops in lower hills and ridges, and northwest of Bullock Hide Well includes large amounts of gabbro–basalt injection breccia.

Dingo Intrusion (AaDo, AaDu)

The Dingo Intrusion is situated in the Cherratta Granitoid Complex 8 km west-northwest of Radio Hill mine, and its outcrop is restricted to a 3 km^2 area immediately west of Cockatoo Creek. The intrusion is composed of moderately to steeply dipping layers of serpentinized peridotite, metapyroxenite, and metamorphosed gabbro and dolerite, with local amphibolite (metabasalt). Its contacts with the surrounding granitoids are concealed, but aeromagnetic data suggest that its north–south strike length is about 5 km, and that its width is little more than the exposed width of 1.5 km. Metagabbro and amphibolite in the northern and western parts of the intrusion contain intrusive veins of fine-grained monzogranite and felsite. Monzogranite of the Cherratta Granitoid Complex on the eastern bank of Cockatoo Creek, near Cockatoo Bore (abandoned), contains xenoliths of leucogabbro and metabasalt. These relationships support an interpretation that the Dingo Intrusion is intruded by granitoids of the Cherratta Granitoid Complex.

Geochronology on the northern part of the Cherratta Granitoid Complex indicates that most of the granitoids in this area are c. 2990 Ma in age (Table 3). Unless the granitoids in the immediate vicinity of the Dingo Intrusion are less than c. 2925 Ma (the approximate age of the Radio Hill and Munni Munni Intrusions), the evidence outlined above suggests that the Dingo Intrusion may be of similar age to the Andover Intrusion (c. 3016–2990 Ma).

Metamorphosed gabbro and minor anorthosite (*AaDo*) forms the eastern third of the Dingo Intrusion, and includes injection breccia consisting of gabbro and microgabbro containing angular blocks of metabasalt. This rock is lithologically similar to injection breccia in the Andover and Bullock Hide Intrusions. The central part of the Dingo Intrusion is composed of a 500 m-thick layer of serpentinized peridotite which, together with metapyroxenite in the southwestern part of the intrusion, is mapped on DAMPIER – BARROW ISLAND as serpentinized peridotite and metapyroxenite (*AaDu*). Further subdivision of the Dingo Intrusion is shown on DAMPIER (Hickman, 1997b), and additional description is provided by Hoatson et al. (1992).

Mount Sholl Intrusion (AaHo, AaHu)

The Mount Sholl Intrusion is a shallow-dipping, predominantly gabbroic intrusion within the Nallana Formation (Whundo Group), 3 km northwest of Mount Sholl. The intrusion is discordant to the Nallana Formation, and its structure at depth is uncertain. Mineral exploration along the northwestern and northern margins of the intrusion has located several bodies of disseminated and massive nickel–copper sulfide mineralization within an irregular, lenticular, steeply dipping zone of serpentinized peridotite, pyroxenite, and minor metagabbro. This predominantly ultramafic assemblage is mapped as serpentinized peridotite, talc–chlorite schist, and metapyroxenite (*AaHu*) on DAMPIER – BARROW ISLAND.

Metamorphosed gabbro and minor anorthosite (*AaHo*) outcrop over a 15 km^2 area of low rocky hills northwest of Mount Sholl. Hoatson and Sun (2002) described this gabbroic assemblage as consisting of fine- to medium-grained recrystallized gabbro, gabbronorite, ferrogabbro, plagioclase clinopyroxenite, and anorthositic gabbro, and noted that the metagabbros differ from those in other west Pilbara mafic–ultramafic intrusions by containing cumulate pyroxene, with late crystallization of plagioclase.

North Whundo Intrusion (AaNo)

The North Whundo Intrusion is exposed in southeastern DAMPIER – BARROW ISLAND and northeastern PINDERI HILLS, and comprises metamorphosed gabbro, dolerite, and minor anorthosite (*AaNo*). The North Whundo Intrusion intrudes the Bradley Basalt of the Whundo Group, and is inclined moderately southwards. On PINDERI HILLS it is overlain by the Yannery Granite, and the two bodies may be genetically related (Hickman and Kojan, 2003). Minor copper mineralization is present in the Bradley Basalt close to the northern, basal contact of the intrusion (Ruddock, 1999).

Radio Hill Intrusion (AaRo, AaRu)

The Radio Hill Intrusion outcrops in southeastern DAMPIER – BARROW ISLAND, but the southern margin of the intrusion is exposed on PINDERI HILLS. The geology of the intrusion has been described by Hoatson et al. (1992), Frick et al. (2001), and Hoatson and Sun (2002), and mineralization in the intrusion was summarized by De Angelis et al. (1987), and Ruddock (1999). Drilling has revealed that the intrusion forms a basin-like structure, with massive Ni–Cu sulfide zones in gabbro, gabbronorite, and plagioclase websterite in the basal part of the intrusion (Frick et al., 2001). This basal zone passes upwards into interlayered dunite, lherzolite, olivine websterite, clinopyroxenite, and plagioclase websterite. The DAMPIER – BARROW ISLAND map shows this ultramafic part of the intrusion as ultramafic rocks (*AaRu*). An overlying zone of olivine gabbro is overlain by an upper zone of quartz gabbro (Frick et al., 2001; Hoatson and Sun, 2002). The total thickness of the intrusion exceeds 1200 m. Frick et al. (2001) used the Re–Os method to date massive sulfides of the intrusion at 2892 ± 34 Ma, which is within analytical error of the 2925 ± 16 Ma U–Pb zircon date on the Munni Munni Intrusion (Arndt et al., 1991), approximately 12 km to the south on PINDERI HILLS.

Metamorphosed gabbro, dolerite, and minor anorthosite (*AaRo*) make up the greater part of the Radio Hill Intrusion, and outcrop most prominently on Radio Hill, 2 km south of Radio Hill mine. As in other mafic–ultramafic intrusions of the west Pilbara, these rocks outcrop as dark-grey to black bouldery hills and ridges. The rocks are massive, jointed at 0.5 to 2 m intervals, and are petrographically indistinguishable from similar rocks in the Andover Intrusion (see above).

GRANITOID ROCKS

DAMPIER – BARROW ISLAND contains parts of two granitoid complexes (Cherratta and Dampier Granitoid Complexes) and one large pluton (Karratha Granodiorite). Additionally, there are various smaller granitoid outcrops that have not been assigned to larger bodies. The granitoids have intrusive contacts with adjacent greenstones, and have locally detached and enveloped parts of the greenstone succession. Many of the granite–greenstone contacts are faulted and sheared. Available geochemical data indicate a wide range of granitoid compositions, ranging from tonalite–trondhjemite–granodiorite (TTG) to monzogranite and syenogranite. TTG magmatism was episodic at c. 3270–3260 Ma, c. 3160–3070 Ma, and c. 3015–2990 Ma, whereas monzogranite and syenogranite intruded the area between c. 2990 and 2925 Ma.

Karratha Granodiorite (*Agka*)

The Karratha Granodiorite (*Agka*) is the oldest identified granitoid unit of the West Pilbara Granite–Greenstone Terrane. U–Pb zircon geochronology (Nelson, 1998; Smith et al., 1998) has established that its components crystallized at 3270–3260 Ma, and Sm–Nd isotopic analyses have given Nd T_{DM} model ages of 3480–3430 Ma (Sun and Hickman, 1998). The c. 200 Ma difference between the emplacement age and the Nd T_{DM} model ages indicates that magma generation involved older crust or enriched lithospheric mantle. A sample (JS17) dated by Smith et al. (1998) contained near-concordant zircon cores with $^{207}Pb/^{206}Pb$ ages up to 3311 Ma, thereby supporting the involvement of older crust in magma generation.

The Karratha Granodiorite intruded and locally enveloped the greenstones of the Roebourne Group (Hickman, 1997b). U–Pb zircon ages from felsic and sedimentary rocks of the Nickol River Formation (Table 3) indicate that these are approximately the same age as the granodiorite, and are therefore interpreted to be genetically related. The main body of the Karratha Granodiorite occupies the core of the Prinsep Dome (Fig. 5), and extends across a poorly exposed 250 km^2 area. Subsequent to the mapping of DAMPIER, geochronology by Smith et al. (1998) indicates that the intrusion also outcrops on the southern limb of the Roebourne Synform, immediately north of the Sholl Shear Zone (Fig. 5).

Microscopic examination shows that the Karratha Granodiorite ranges from allotriomorphic granular tonalite to granodiorite. The main constituents are anhedral to subhedral sutured plagioclase, interstitial quartz, and minor K-feldspar, hornblende (variably replaced by actinolite), biotite (commonly replaced by chlorite), epidote, and sericite. Minor minerals include sphene, apatite, leucoxene, opaques, and zircon.

Cherratta Granitoid Complex (*AgC*, *AgCg*, *AgCm*, *AgCmh*, *AgCmx*, *AgCn*, *AgCp*)

The Cherratta Granitoid Complex is bounded to the north by the Sholl Shear Zone, whereas to the southwest it is unconformably overlain by the Fortescue Group. To the east, the Maitland Shear Zone separates it from the greenstones of the Whundo Domain (Figs 4 and 5), although small stocks of monzogranite and syenogranite assigned to the complex locally intrude the greenstones. The complex is poorly exposed on DAMPIER – BARROW ISLAND, but available geochronology indicates that most of the granitoids in this area are c. 2990 Ma in age (Table 3). Older granitoids are included in the Cherratta Granitoid Complex south of DAMPIER – BARROW ISLAND, with c. 3150–3070 Ma TTG granitoids outcropping east of the Munni Munni Intrusion, and a c. 3236 Ma tonalite (Nelson, 1998) on southwestern PINDERI HILLS (Hickman and Kojan, 2003).

The internal structure of the Cherratta Granitoid Complex can be interpreted using a combination of aeromagnetic data and observations at isolated outcrops. East of the Maitland River, tectonic foliations have a northerly to northeasterly strike and dip steeply eastwards. In the northeast of the Cherratta Granitoid Complex, the Sholl Shear Zone abruptly truncates this structural fabric. West of the Maitland River, aeromagnetic lineaments indicate east-northeasterly striking lithological zones, apparently including concealed large greenstone enclaves. Smaller greenstone enclaves (amphibolite facies metabasalt, *Aba*) are exposed north of Toorare Pool, and south of Marcia Bore.

Undivided granitoid rock (*AgC*) outcrops along the northern contact of the Sholl Shear Zone 2 km west of Mornong Well. This unit chiefly consists of hornblende- and biotite-granodiorite containing scattered xenoliths of amphibolite. It has intruded the Sholl Shear Zone, but a weak gneissic foliation indicates emplacement between the earliest and latest strike-slip movements. For this reason, it is assumed to be of similar age to the mylonite (*Amm*) in the shear zone. In thin section, the rock is a coarse-grained assemblage of quartz, plagioclase, and hornblende.

Seriate syenogranite and monzogranite (*AgCg*) is exposed east of Cherratta Pool and 3 km southwest of Possum Bore. The rock is quartz rich, contains no visible biotite or hornblende, and is either weakly foliated or non-foliated. This last feature suggests that it is one of the younger components of the Cherratta Granitoid Complex.

Foliated monzogranite to granodiorite (*AgCm*), locally sparsely porphyritic and weakly banded, outcrops in the eastern part of the complex and intrudes the Whundo Group east of the Maitland Shear Zone. However, the same unit also underlies the Fortescue Group in the northwestern part of the complex, north and south of Mount Wilkie, and 2 km southwest of Marcia Bore. Hornblende- and biotite-rich monzogranite (*AgCmh*) outcrops around Toorare Pool and northwest of Cockatoo Bore. Both rock types typically form massive hilly outcrops, and are foliated and locally weakly banded. In the field, hornblende- and biotite-rich monzogranite (*AgCmh*) is distinguished from other granitoids of the complex by its abnormally high hornblende (variably replaced by actinolite) content, and by magnetism due to disseminated magnetite. The hornblende and actinolite crystals are orientated in the plane of the foliation. The rock is generally medium- to coarse-grained monzogranite, but local granodiorite is also present. In thin section it consists of plagioclase, microcline, quartz, hornblende–actinolite, chloritized biotite, sphene, apatite, epidote, and opaques. Some hornblende crystals have relict cores of pyroxene, but this alteration may have been late magmatic.

Foliated monzogranite containing xenoliths of amphibolite (*AgCmx*) outcrops at Bullock Hide Well. The rock at this locality comprises approximately equal proportions of greenstone material and granitoids, and is interpreted to have formed by granitoid injection and stoping of the Bullock Hide Intrusion. Subsequent shearing produced interlayering of granitoids and greenstones, generally at 0.1 to 1 m intervals. Partial assimilation of mafic material contaminated the granitoid magma to increase the amphibole and chlorite content of the monzogranite.

Banded grey monzogranite–tonalite gneiss (*AgCn*), with xenoliths of amphibolite-facies mafic gneiss and sheets of leucocratic gneiss, outcrops in the southern part of DAMPIER – BARROW ISLAND, near Mount Leopold and Marcia Bore. Here, the gneiss underlies the Fortescue Group unconformity, and exposures too small to show on the map outcrop intermittently along the Maitland River south of Karratha Homestead, where the gneiss is intruded by porphyritic monzogranite–granodiorite (*AgCp*) and hornblende- and biotite-monzogranite (*AgCmh*). Excellent river-bed exposures 2 km east-southeast of Toorare Pool show amphibolite gneiss alternating with leucocratic gneiss (Fig. 8). The amphibolite consists of bright-green hornblende, sericite, quartz, epidote, opaque iron minerals (probably magnetite), and minor sphene. Leucocratic layers are composed of a strongly laminated assemblage of sericitized plagioclase, quartz, hornblende, chlorite, and minor microcline. The rocks have been strongly sheared, metamorphosed to amphibolite facies, and show weak retrogression.

About 2 km west of Toorare Pool, a sample of gneiss contains zircon populations dated at 2995 ± 11 Ma and 2944 ± 5 Ma (Nelson, 1997). This was interpreted to indicate two generations of granitoid in the gneiss. Lithologically similar gneiss on PINDERI HILLS was

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Figure 8. Sheared amphibolite xenolith within gneiss of the Cherratta Granitoid Complex, Maitland River (MGA 478600E 7678950N)

dated at 3130 ± 4 Ma (Table 3), and included c. 3150 Ma zircons (Nelson, 1999). This establishes that several ages of gneiss are present in the Cherratta Granitoid Complex.

Porphyritic monzogranite–granodiorite (*AgCp*) is exceptionally well exposed around Karratha Homestead, and for about 5 km to the southeast along the Maitland River. Granodiorite forms a substantial component of the unit at this locality. The rock is medium grained, foliated to weakly gneissic, and contains megacrysts of microcline up to 10 cm long and 6 cm wide. Plagioclase and quartz are the dominant constituents, and hornblende is present in most exposures. Deformation has caused fragmentation and partial rounding of feldspar crystals, and produced lenticular quartz aggregates. The porphyritic granitoid contains xenoliths and layers of grey gneissic granitoid, and is locally intruded by veins of seriate biotite syenogranite. A sample (GSWA 118974) of porphyritic hornblende granodiorite collected near Karratha Homestead was dated at 2994 ± 2 Ma (Nelson, 1997).

Dampier Granitoid Complex (*AgD, AgDm, AgDp*)

The Dampier Granitoid Complex is the most northwesterly granitoid complex of the Pilbara Craton. It extends for 100 km southwestward from outcrops on the Burrup Peninsula to Eramurra Creek on northern FORTESCUE. On the Burrup Peninsula, the complex is intruded by the c. 2725 Ma Gidley Granophyre, and in the Dampier Archipelago it is unconformably overlain by the c. 2770–2630 Ma Fortescue Group. In southwestern DAMPIER – BARROW ISLAND, and on FORTESCUE, the complex is also unconformably overlain by the Fortescue Group. Two samples of syenogranite and monzogranite from the complex have been dated by U–Pb zircon geochronology at c. 2990 Ma (Table 3), but older gneissic granitoids of the complex have not been dated.

The Dampier Granitoid Complex is very poorly exposed, making conclusions about its overall composition difficult. Aeromagnetic data (Geological Survey of Western Australia, 1995b) suggest that the approximately 1% outcrop may be representative of most of the complex. On this assumption, the complex comprises metamorphosed porphyritic syenogranite to granodiorite (*AgDp*) and a mixed assemblage of metamorphosed even-grained monzogranite to granodiorite that contains banded gneissic granitoids, syenogranite, and pegmatite (*AgDm*). The composition of the complex is thus similar to that of the Cherratta Granitoid Complex, and large parts of the two granitoid complexes were probably formed at the same time (Hickman, 2001). However, whereas Nd T_{DM} model ages from the Cherratta Granitoid Complex fall within the range 3250–3140 Ma (S-S. Sun, Geoscience Australia, writt. and pers. comm., 1997, 2000), similar data from the Dampier Granitoid Complex have provided Nd T_{DM} model ages of 3387–3247 Ma (GSWA, unpublished data). This indicates that the Karratha Granodiorite and/or the lower part of the Roebourne Group contributed old crustal material to the Dampier Granitoid Complex, whereas the Cherratta Granitoid Complex was emplaced into juvenile crust. Analyses on the cores of several zircons from one sample of the Dampier Granitoid Complex gave $^{207}Pb/^{206}Pb$ ages ranging up to 3255 Ma; the latter age being similar to that of the Karratha Granodiorite and the lower part of the Roebourne Group (3270–3260 Ma, Hickman, 1997a). This supports the evidence from Nd T_{DM} model ages that the Karratha Granodiorite or the lower part of the Roebourne Group, or both, contributed material to the complex. The complexes are separated by the SSZ, but post-2990 Ma strike-slip movement on this structure was probably less than 40 km (Smithies, 1998a; Hickman, 2001).

Undivided metamorphosed granitoid rock (*AgD*) is mapped either in areas not visited during the mapping, where deep weathering has obscured original compositions, or where a mixed assemblage of granitoids has been identified. Most outcrops are located either on the Burrup Peninsula, on islands of the Dampier Archipelago, or in poorly exposed areas between Devil

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Figure 9. Strongly foliated compositionally banded granodiorite and monzogranite of the Dampier Granitoid Complex 2km northeast of Gnoorea Soak (MGA 434050E 7691100N)

Creek and Cape Preston. In the latter area, undivided metamorphosed granitoid rock (*AgD*) is well exposed along an old track from Devil Creek to Pelican Point, about 2 km northeast of Gnoorea Soak. Here, in an area where the old track crosses salt-encrusted lagoons, a mixed assemblage of granitoids is exposed in weathered rock platforms and bouldery outcrops at Gnoorea Soak (Fig. 9) and Granites Lagoon (informal name; Fig. 10). Granitoid types include foliated biotite granodiorite and trondhjemite, that contain intrusive sheets of monzogranite and veins of pegmatite. All granitoids are intruded by fine-grained dolerite dykes (*d*) of varying thickness.

Foliated biotite granodiorite at this locality consists of a recrystallized feldspar–quartz mosaic, with a preferred alignment of biotite (replaced by chlorite) and polycrystalline quartz. The feldspar is predominantly sericitized and epidotized plagioclase, but minor microcline is also present. A dark-grey granodiorite at the same locality has a slightly more mafic composition, and contains more chlorite (replacing biotite) than the foliated biotite granodiorite. Another component of the mixed granitoid assemblage is recrystallized trondhjemite containing almost no microcline.

Porphyritic granitoid rock (*AgDp*) is exposed along the eastern shoreline of the Burrup Peninsula, and on islands of the Dampier Archipelago, and consists mainly of syenogranite and monzogranite. Microcline megacrysts up to 5 cm long are set in a medium- to coarse-grained groundmass of plagioclase, microcline, and quartz. The rock is locally non-foliated, but commonly shows a flow alignment of the microcline phenocrysts. All outcrops are within 100 m of basal units of the Gidley Granophyre, and evidence of remelting is common. In thin section, tridymite (a high temperature polymorph of silica) and feldspar form a granophyric matrix to saussuritized plagioclase and quartz. On East Lewis Island, porphyritic monzogranite contains layers of alternating phenocryst-rich

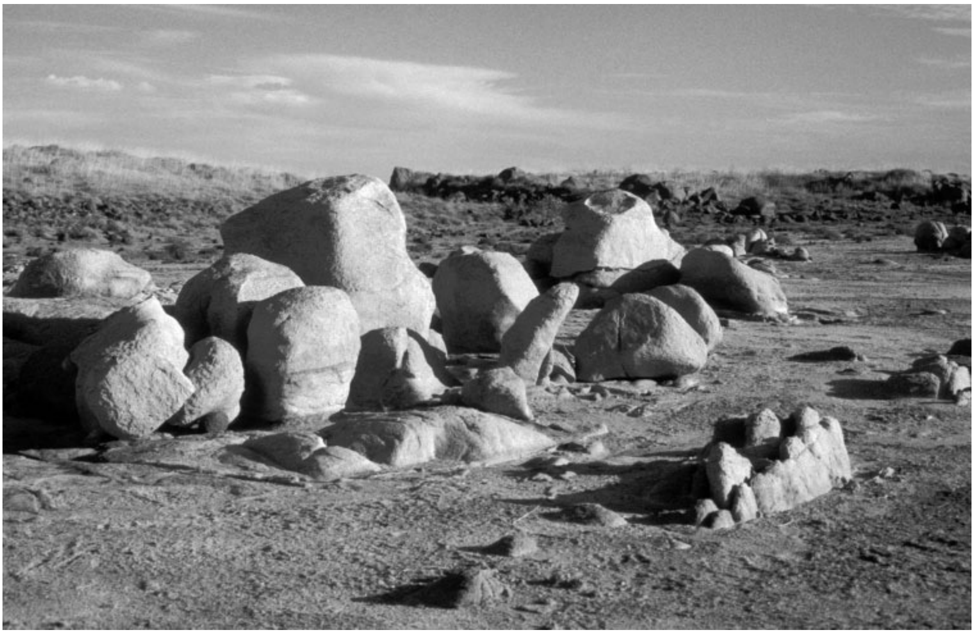

Figure 10. Monzogranite of the Dampier Granitoid Complex at 'Granites Lagoon' (informal name; MGA 435000E 7693250N), 6 km west-northwest of Yerwararron Hill

and phenocryst-poor phases, and a well-developed, parallel flow alignment of the microcline crystals.

Foliated, and commonly banded, monzogranite to granodiorite (*AgDm*), with veins and sheets of syenogranite, aplite, and pegmatite, is exposed along the margins of the salt evaporation ponds south of Dampier, and forms numerous scattered outcrops in the area between Devil Creek and Cape Preston, and near Gnoorea Soak (Fig. 9). To the south of the Dampier evaporation ponds, the oldest components are dark-grey granitoid gneiss containing amphibolite xenoliths, but the dominant constituent is a later, medium- to coarse-grained monzogranite composed of K-feldspar, quartz, and abundant plagioclase. Biotite is pseudomorphed by chlorite. A sample (GSWA 136844) collected from an abandoned quarry 7 km southwest of Karratha Airport was dated at 2997 ± 3 Ma (Nelson, 1998).

Unassigned monzogranite and granodiorite (*Agm*)

Immediately north of the Sholl Shear Zone and east and west of the Nickol River, irregular stocks and sheets of the monzogranite and granodiorite (*Agm*) intrude greenstones of the Roebourne Group. The granitoids are typically equigranular, medium grained, and tectonically foliated. Compositional banding is visible in many outcrops, and minor shear zones are locally present. The unit may include parts of the c. 3270–3260 Ma Karratha Granodiorite, but local intrusive relationships to quartz–feldspar porphyry (*Apf*) indicate that younger granitoids are also present. A sample of mylonitized granitoid (JS25) from the Sholl Shear Zone at the Nickol River was dated at 3024 ± 4 Ma and included a range of zircon $^{207}Pb/^{206}Pb$ ages from 2959 to 3044 Ma (Smith et al., 1998). This mylonitized granitoid was probably derived from adjacent monzogranite and granodiorite (*Agm*).

ROCKS OF MINOR INTRUSIONS AND SHEAR ZONES

Unassigned minor felsic intrusions

Sills, dykes, and irregular stocks of quartz–feldspar porphyry, granophyre, and rhyolitic to dacitic rock intrude the Roebourne Group and the Karratha Granodiorite north of the Sholl Shear Zone (SSZ) east and west of the Nickol River. An isolated body of intrusive rhyolite intrudes the Regal Formation 3 km north of Lower Nickol mining centre.

Quartz–feldspar porphyry (Apf)

Quartz–feldspar porphyry (*Apf*) forms minor intrusions in the area north of the SSZ and east of Ruth Well. It intrudes the greenstones of the Roebourne Group (Hickman, 1997b), and is intruded by late monzogranite of the monzogranite and granodiorite (*Agm*) unit in this area. Contacts between quartz–feldspar porphyry and the Andover Intrusion are obscured by scree. A sample (GSWA 118979) of the quartz–feldspar porphyry was dated at 3014 ± 2 Ma, with evidence of a disturbance event at 2917 ± 14 Ma (Nelson, 1997). Microscopic examination indicates that the porphyry comprises plagioclase, quartz, and K-feldspar, with minor chlorite, and rare epidote, carbonate, sericite, and zircon. Quartz and plagioclase are highly strained, and lamellar twin planes in plagioclase are curved and broken. The porphyry may be a high-level intrusion related to granodiorite of the monzogranite and granodiorite unit (*Agm*) in this area. Smaller bodies of rhyolite, dacite, and granophyre intrude greenstones on both sides of the Sholl Shear Zone between Ruth Well and Mount Ada (ROEBOURNE). On DAMPIER – BARROW ISLAND, dacite 1 km east of the Nickol River (GSWA 118976) was dated at 3023 ± 9 Ma (Nelson, 1997).

Metamorphosed rhyolite (Afr)

Metamorphosed rhyolite (*Afr*) forms a small intrusive stock 3 km north of Lower Nickol mining area. The rhyolite, which intrudes metabasalt and chert of the Regal Formation, is silicified and epidotized. An attempt to date the rock using the SHRIMP U–Pb zircon method was unsuccessful (Nelson, D. R., 1997, written comm.).

Unassigned mafic and ultramafic rocks

Metamorphosed pyroxenite (Aux)

An isolated outcrop of metamorphosed pyroxenite (*Aux*) is located 2.5 km south of Nickol River Hill. The shape of the outcrop suggests that the unit is part of a plug, which could be related to the Mount Sholl Intrusion about 3 km to the west. In thin section, the rock is a fine- to medium-grained metapyroxenite with an allotriomorphic granular texture. Pyroxene crystals are pseudomorphed by actinolite, chlorite, epidote, and minor carbonate. The prismatic cleavage of the pyroxene is well preserved, but is slightly curved, indicating deformation. Interstitial clusters of tabular epidote pseudomorphs, probably after plagioclase, are present throughout. Abundant leucoxene pseudomorphs after ilmenite are disseminated throughout the pyroxenite, and goethite boxworks have replaced pyrite.

Serpentinized ultramafic rock (Aus)

Serpentinized ultramafic rock (*Aus*) is mapped in the Black Hill Shear Zone (Fig. 5), 3 km north of Nickol River Hill. It is uncertain if this mylonitized rock was derived from intrusive peridotite of the Andover Intrusion, or from extrusive peridotite of the Ruth Well Formation.

Serpentinite of this type typically consists of a felted intergrowth of serpentine minerals, with varying amounts of talc, chlorite, carbonate minerals, and finely divided opaque minerals.

Mafic schist (Abs)

Mafic schist (*Abs*) in the SSZ 1 km north of Nickol River Hill is interpreted to be strongly sheared metabasalt of the Whundo Group. The rock consists mainly of felted to granoblastic actinolite or hornblende, with subordinate plagioclase, chlorite and epidote, and minor quartz, opaques, and carbonate minerals.

Strongly foliated metabasalt (Aba)

Strongly foliated metabasalt (*Aba*) in the SSZ 2 km southwest of Mount Prinsep forms a tectonic lens derived from either the Roebourne Group or the Whundo Group. The amphibolite has a mineralogy similar to mafic schist (*Abs*), but is not a schist. Strongly foliated metabasalt (*Aba*) also forms large xenoliths within the Cherratta Granitoid Complex near Toorare Pool and south of Marcia Bore.

Rocks of shear zones

Mylonite (Amm)

Mylonite (*Amm*), representing intensely sheared granitoids and greenstones, occurs along the Sholl Shear Zone (SSZ), which is locally up to 2 km wide. Rock pavements in the Nickol River, 1 km north of Nickol River Hill, provide exposures of the northern section of this major shear zone. Here, the mylonite is dominantly silicic and represents extremely sheared granitoids, but there are also layers of amphibolite. Other good exposures are present 3 km northeast of Karratha Homestead. Here, the mylonite comprises 0.5 – 2.0 mm-wide laminae of very fine-grained siliceous material containing small clasts of quartz, plagioclase, microcline, and crushed garnet. The morphology of rare feldspar porphyroclasts in some of the less intensely deformed laminae indicates a sinistral shear sense. Mylonite, too thin to map at 1:250 000 scale, outcrops along other major strike-slip faults and thrusts (see **Structure**). Within greenstones, the mylonite can be mafic in composition. One such mylonite occurs 3 km south of Bardies Tank where the rock is a finely laminated assemblage of hornblende, quartz, feldspar, and biotite, with porphyroblasts of garnet up to 3 mm across.

Unassigned mafic and ultramafic intrusive rocks

DAMPIER – BARROW ISLAND includes various mafic and ultramafic intrusive rocks of the Pilbara Supergroup that are not assigned to named intrusions. Metamorphosed gabbro, dolerite, pyroxenitic gabbro, and pyroxenite form dykes, sills and other small intrusions in various parts of DAMPIER – BARROW ISLAND. Intrusive relations indicate that most of these intrusions are younger than c. 3000 Ma, and that they predate the earliest volcanic rocks of the Fortescue Group (c. 2770 Ma).

Metamorphosed gabbro and dolerite (Ao)

Metamorphosed gabbro and dolerite (*Ao*) forms two large, east-northeast trending dykes that intrude the c. 3270 Ma Karratha Granodiorite 10 km south of Karratha. The larger, southern dyke is intruded by north-northwesterly trending c. 2725 Ma granophyric dykes (*Ayx*) related to the Gidley Granophyre, and aeromagnetic data indicate that this gabbro–dolerite dyke terminates at the Sholl Shear Zone (last major movement at c. 2920 Ma). Further indirect evidence of the age of these dykes is provided by isotopic data on a large dolerite dyke (*Aod*) of similar alignment 3 km north of Lower Nickol mining area (see below). Other minor intrusions of gabbro and dolerite (*Ao*) include a sill in the Regal Formation 2 km south of Karratha, a lenticular east–west sill in the Sholl Shear Zone at Nickol River Hill, and sills in the Bradley Basalt 3 km east of North Whundo, and in the Nallana Formation 1 km west of Radio Hill mine.

Metamorphosed dolerite (Aod)

Metamorphosed dolerite (*Aod*) forms sills in the Tozer Formation 2 km southeast of Mount Sholl, and forms a large, east-northeasterly trending dyke 3 km north of Lower Nickol mining centre. Rare-earth element (REE) data from this dyke (Sun and Hickman, 1999) is very similar to REE data from c. 2950 Ma mafic volcanic rocks of the Bookingarra Group on ROEBOURNE, suggesting that the age of the dyke may also be c. 2950 Ma.

Metamorphosed pyroxenitic gabbro (Aogx)

A sill of metamorphosed pyroxenitic gabbro (*Aogx*) intrudes the contact between amphibolite of the Regal Formation (*ARr*) and chert of the Cleaverville Formation (*AGl*) 2 km west-southwest of Slopers Well. This gabbro is mainly composed of large fibrous to prismatic tremolite crystals, with lesser amounts of interstitial plagioclase, leucoxene, minor quartz, and rare apatite. The tremolite crystals are interpreted to be pseudomorphs after primary pyroxene. Plagioclase is locally mantled by granophyric intergrowths of plagioclase and quartz. Minor hornblende that forms marginal intergrowths with tremolite may be a product of deuteric alteration of the pyroxene (Strong et al., in prep.).

STRUCTURE OF THE WEST PILBARA GRANITE–GREENSTONE TERRANE

The Archaean greenstones (Pilbara Supergroup) and granitoids of DAMPIER – BARROW ISLAND are part of the West Pilbara Granite–Greenstone Terrane (WPGGT). The tectonic evolution of this terrane occurred between 3270 and c. 2920 Ma (Van Kranendonk et al., 2002), and was separate and distinctly different from that of the unconformably overlying Hamersley Basin (post-2770 Ma). The structural geology of the Hamersley Basin on DAMPIER – BARROW ISLAND is described later in these Explanatory Notes.

Tectono-stratigraphic domains

The WPGGT is divided into four granitoid complexes and three tectono-stratigraphic domains (Fig. 4; Hickman, 2001). Each of the three domains has a different lithostratigraphy and structural history from the other two, but certain later deformation events are common to all the domains.

DAMPIER – BARROW ISLAND covers parts of the Karratha, Sholl, and Cleaverville domains and parts of the Dampier and Cherratta Granitoid Complexes (Fig. 4). North of the Sholl Shear Zone (SSZ), the c. 3270 Ma Karratha domain consists of the Ruth Well and Nickol River Formations of the Roebourne Group, and the intrusive Karratha Granodiorite. The Regal Thrust, an early (D_1) layer–parallel shear zone, separates the Karratha domain from the Cleaverville domain, containing the Regal and Cleaverville Formations. The Regal Thrust is folded by the Prinsep Dome and Roebourne Synform, and both these fold structures are truncated by late-stage (c. 2920 Ma) movement on the Sholl Shear Zone. The mid-oceanic-ridge basalt (MORB)-like geochemistry of the Regal Formation (Sun and Hickman, 1999) raises the possibility that the Regal Thrust is a plane of obduction of oceanic crust across the Karratha domain, implying lateral movement of many tens of kilometres. Alternatively, if the Regal Formation is not Archaean MORB but, as interpreted by Hickman (1997a), is an upward continuation of the Ruth Well – Nickol River Formation succession, lateral movement could be less than 10 km.

Near Cleaverville, the Cleaverville domain is structurally more complex than elsewhere, with repetition of the Regal and Cleaverville Formations due to faulting and tight to isoclinal folding. Ohta et al. (1996) interpreted the Cleaverville area as part of an accretionary complex related to subduction of oceanic crust. However, this interpretation conflicts with evidence that the Cleaverville Formation is a shallow-water deposit (Sugitani et al., 1998). Additionally, the Cleaverville Formation is distributed over a wide area of the WPGGT (Hickman, 1997a), and has recently been identified 200 km to the east, on the western margin of the EPGGT (Smithies and Farrell, 2000). At least part of the faulting within the Cleaverville domain post-dates the Fortescue Group, and is probably related to a northeasterly trending belt of reverse faults (D_{11}) that deforms the c. 2725 Ma Gidley Granophyre.

Granitoids of the Dampier Granitoid Complex intrude the Cleaverville domain, as do c. 3015 Ma minor felsic intrusive rocks such as quartz–feldspar porphyry (*Apf*). Approximately 9 km southwest of Sunday Peak (southern boundary of DAMPIER – BARROW ISLAND) monzogranite and granodiorite (*AgDm*) of the Dampier Granitoid Complex intrude ferruginous chert and BIF (*ARncf*) of the Nickol River Formation. Elsewhere, the Nickol River Formation is part of the Karratha domain, but this may not be the situation in the Sunday Peak area, where the Regal Thrust has not been recognized.

South of the SSZ, the Maitland Shear Zone (Hickman, 1997b) separates the Cherratta Granitoid Complex from the Sholl domain. The Sholl domain mainly comprises the 3125–3115 Ma Whundo Group (not preserved north of the SSZ), but the Cleaverville Formation is also a component on ROEBOURNE. Certain granitoids of the Cherratta Granitoid Complex intrude the Sholl domain.

Regional-scale strike-slip movement along the SSZ has resulted in a complete stratigraphic mismatch between the Karratha and Sholl domains (Fig. 4). Differences in age, lithology, and geochemistry between these domains indicate formation in different tectonic environments, and at different times. Isotopic differences between rocks northwest and southeast of the SSZ include Sm–Nd data (Sun and Hickman, 1998; Hickman et al., in prep.) that indicate reworking of 3500–3300 Ma crustal material in the northwest, but the presence of juvenile crust, younger than c. 3280 Ma, in the southeast. This suggests that EPGGT crust, or crust of similar age, underlies the northwestern area, but this must be thin, or more probably absent, in the CPTZ to the southeast. The CPTZ is interpreted to have developed from 3240 Ma, initially as a continental rift system (Hickman, in prep.a). Prior to 3130 Ma another episode of extension had created a rift basin floored by oceanic-type crust (see **Tectonic evolution**), in which the Whundo Group was deposited. A suggested correlation of the Roebourne Group with the Sulphur Springs Group of the EPGGT implies overall strike-slip movement of at least 200–250 km (Sun and Hickman, 1998; Hickman, in prep.a).

Deformation events

D_1 (3160–3130 Ma)

The earliest recognizable tectonic structures on DAMPIER – BARROW ISLAND and ROEBOURNE are low-angle thrusts and recumbent folds in the Roebourne Group. Limited evidence from

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Figure 11. Laminated chert–carbonate rock in the upper part of the Nickol River Formation (MGA 475050E 7697850N)

minor structures suggests that these large-scale D_1 structures were produced by southerly directed thrusting. Large-scale isoclinal folds in the Nickol River Formation 2 km southeast of Mount Regal were recumbent and southwesterly facing prior to tilting by the D_6 Prinsep Dome. Intrafolial isoclines are relatively common within the Nickol River Formation of the Mount Regal area (Hickman et al., 2000), and are probably minor structures related to the recumbent folds. A bedding–parallel tectonic foliation, S_1, is preserved in metasedmentary rocks of the Nickol River Formation (Fig. 11) and in metabasalt of the Regal Formation. This foliation is parallel to the D_1 thrusts, and is probably the same age. However, it was reactivated by parallel shearing during later tectonic events, and is locally folded by D_4 folds (Fig. 13).

The Regal Thrust is exposed 1.5 km east–southeast of Bardies Tank on the southern limb of the Prinsep Dome. Here, a finely laminated silicic mylonite has been isoclinally folded (Fig. 14). Part of the outcrop (Fig. 15) shows that the isoclinal folds have been progressively refolded by later tight to isoclinal folds. Plunges of the early isoclines are generally low (up to 30°) and towards the east or west, and the prevailing dip of the mylonite is 60–80° south. This indicates thrusting from either the north or the south.

A tectono-metamorphic event at 3160–3150 Ma is indicated by zircon geochronology (Smith et al., 1998) and K–Ar geochronology (Kiyokawa and Taira, 1998), and is interpreted as coinciding with D_1 (Hickman, 2001). Granitoids of this age have been identified southeast of DAMPIER – BARROW ISLAND (Nelson, 1999) and close to the southeastern margin of the CPTZ (Nelson, 2000), confirming a thermal event at this time.

The SSZ may have commenced with sinistral strike-slip movement as early as 3160 Ma (see below), but most movement took place after deposition of the Whundo Group (3125–3115 Ma), and probably culminated between 3050 and 3015 Ma.

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Figure 12. Tight to isoclinal D_3 folding of ferruginous chert of the Cleaverville Formation 2 km northeast of Slopers Well (MGA 446000E 7690800N)

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Figure 13. D_4 open folds that have deformed S_1 in chert–carbonate rock of the Nickol River Formation (MGA 475100E 7697850N)

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Figure 14. Isoclinal folds in mylonite of the Regal Thrust east of Bardies Tank (MGA 492000E 7696800N)

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Figure 15. A refolded D_1 isoclinal fold in the mylonite developed along the Regal Thrust east of Bardies Tank (MGA 492000E 7696800N)

D_2 (mainly c. 3050–3020 Ma)

Measurable strike-slip movement on the SSZ is dextral and approximately 30–40 km. However, the dextral movement is a late-stage feature of this major crustal structure, and was preceded by far greater sinistral movement (see below).

Sinistral strike-slip movement on the northeasterly striking SSZ is consistent with north–south compression similar to that responsible for the D_1 structures. Direct evidence for sinistral movement is provided by porphyroclasts within fine-scale mylonitic lamination (Hickman, 2001). Asymmetry of shear-sense indicators consistently implies sinistral movement along the foliation planes of the mylonite. Rock pavements in the Nickol River (MGA 494800E 7689600N) provide excellent exposures (Figs 16–19) of the northern section of this major shear zone. The mylonite is dominantly silicic, and represents extremely sheared granitoids, but there are also layers of amphibolite. Mylonite lamination is folded by tight, west-plunging Z-folds, which may be related to late dextral movement, and isoclinal folds (Fig. 18). All these structures are displaced by late brittle fractures (Fig. 19), which are locally filled by pseudotachylite. These are probably related to a post-Fortescue Group north–south compressional event which produced a conjugate fault system in the Dampier–Roebourne area (Hickman, 2001). Evidence for major early movement on the SSZ is provided by the stratigraphic mismatch across the fault (see **Tectono-stratigraphic domains**), which cannot be explained by the measurable 30–40 km of dextral displacement (D_6) that took place after deposition of the Whim Creek Group.

The 3020 Ma Cleaverville Formation is present on both sides of the SSZ, indicating that the inferred 200–250 km sinistral movement (see above) took place prior to 3020 Ma. The

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Figure 16. Mylonite of the Sholl Shear Zone exposed in the bed of the Nickol River (MGA 494800E 7689600N)

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Figure 17. Closely laminated siliceous mylonite in the Sholl Shear Zone at the Nickol River (MGA 494800E 7689600N)

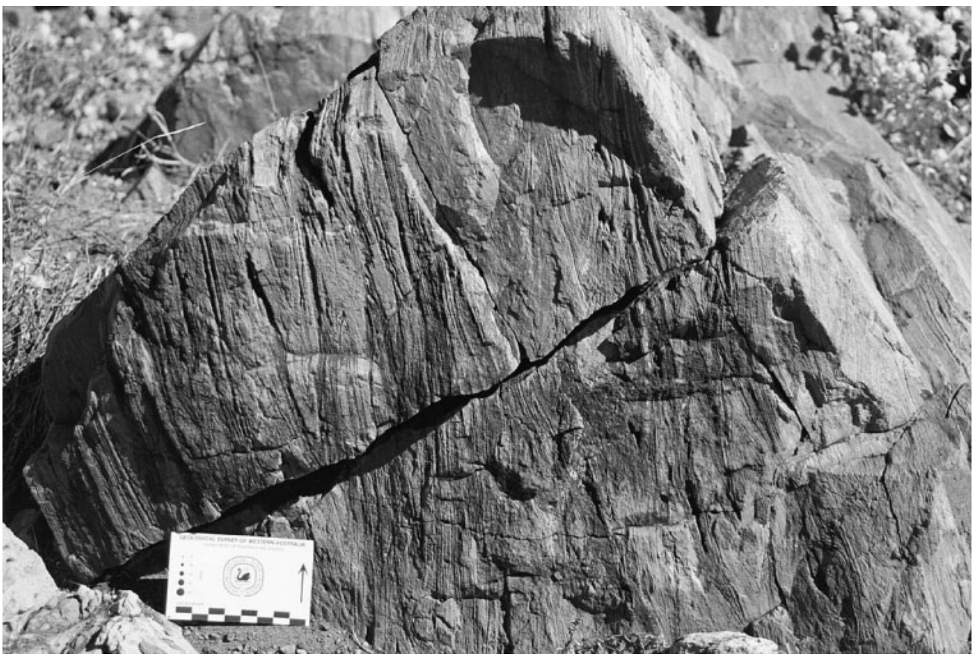

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Figure 18. Isoclinal folding of mylonite foliation in the Sholl Shear Zone at the Nickol River (MGA 494800E 7689600N)

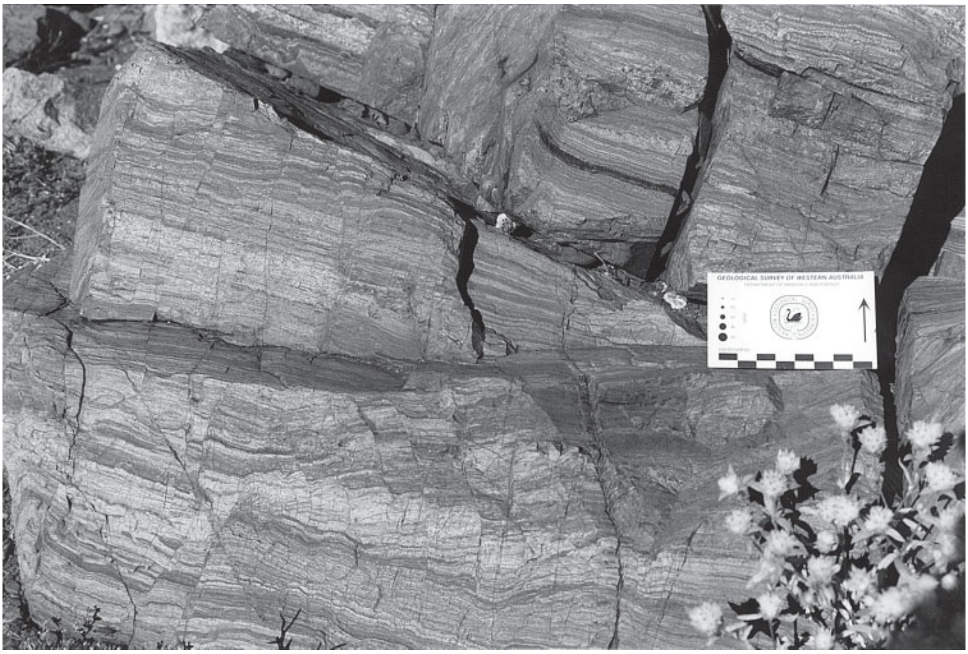

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Figure 19. Compositional banding in mylonite of the Sholl Shear Zone at the Nickol River, showing late-stage brittle fractures (MGA 494800E 7689600N)

movement was later than 3115 Ma because it juxtaposed the Whundo Group with the Roebourne Group. The Cleaverville Formation includes detrital zircons dated at c. 3050 Ma, and c. 3070 Ma granitoids form part of the Cherratta Granitoid Complex (Nelson, 1998). For this reason the main part of D_2 is tentatively placed at 3050–3020 Ma, but movement was probably intermittent from 3115 Ma.

D_3 (3015–3010 Ma)

Tight to isoclinal east-northeasterly trending folds in the c. 3020 Ma Cleaverville Formation between Karratha and Cleaverville are attributed to the D_3 event. D_3 folds in the Regal greenstone belt between Miaree Pool and Mount Regal, and in the Devil Creek area (Fig. 12) are intruded by c. 2997 Ma granitoids (Nelson, 1998, p. 105–107) of the Dampier Granitoid Complex. In the metabasalt of the Regal Formation, S_3 is locally synchronous with intrusive sheets of 3015 Ma quartz–feldspar porphyry (*Afp*) and porphyritic microgranite (*Agp*). On ROEBOURNE, at Mount Ada, easterly trending upright tight to isoclinal D_3 folds in the Cleaverville Formation contain a sill of 3014 Ma granophyre (Nelson, 1997). These fold structures are unconformably overlain by the c. 3010 Ma Warambie Basalt of the Whim Creek Group (Hickman, 2002). On PINDERI HILLS, Hickman and Kojan (2003) noted that the D_3 event included north–south thrusting of the Whundo Group onto the Cherratta Granitoid Complex.

D_4 (c. 2950–2930 Ma)

The D_4 event formed major northeasterly trending tight to open folds such as the Prinsep Dome, Roebourne Synform, and Bradley Syncline (Fig. 5). Both the Bradley Syncline and the Roebourne Synform extend eastwards onto ROEBOURNE (Hickman, 2002). Hickman (2001, 2002) and Hickman and Smithies (2001) assigned these structures to the D_6 event because they formed during the sixth deformation event to affect the sheet areas described. However, Van Kranendonk et al. (2002) separated the north Pilbara deformation events into sequences confined to individual terranes and basins. D_4 and D_5 structures were recognized only in the Whim Creek and Mallina Basins, and do not appear to affect the WPGGT. Subsequent events have also been renumbered.

The D_4 structures of the WPGGT are correlated with major 'D_3' folds in the Mallina Basin on MOUNT WOHLER and SHERLOCK (Smithies, 1998a), and are equivalent to Phase 4 structures described by Krapez and Eisenlohr (1998). Geochronology on MOUNT WOHLER (Smithies, 1998b) established that the age of these structures must be 2950–2930 Ma. D_4 folds are oblique to the SSZ and to other strike-slip faults of the WPGGT and CPTZ. The folds are probably a result of transpression within a post-2950 Ma east–west belt of dextral strike-slip movement.

Minor D_4 structures include a steeply dipping, east-northeasterly striking axial–plane foliation (S_4) in the Prinsep Dome and in an anticline east of Mount Sholl. Minor D_4 folds (Fig. 13) deform S_1 southeast of Mount Regal and 1 km southwest of Nickol Well. The Mount Regal folds plunge southwestward, and the Nickol Well folds plunge to the northeast.

D_5 (c. 2930 Ma)

On DAMPIER – BARROW ISLAND, the north-northwesterly striking Maitland Shear Zone truncates major northeasterly trending D_4 folds of the Sholl domain. A parallel tectonic foliation (S_5) is developed in the adjacent greenstones of the Whundo Group, in the Bullock Hide Intrusion, and in the granitoids of the Cherratta Granitoid Complex. North of Bullock Hide Well, all these structures are truncated by the SSZ. Shear zones are present also within the Cherratta Granitoid Complex. About 2 km east-southeast of Toorare Pool, in the bed of the Maitland River, exposures of granitoid gneiss (*AgCn*) have a strong shear foliation (S_5) that dips 30° eastwards. About 2 km west of Toorare Pool, the same gneiss contains late zircon populations dated at 2944 ± 5 Ma and 2925 ± 2 Ma (Nelson, 1997).

D_6 (c. 2920 Ma)

The latest movement on the SSZ was dextral (D_6), which on SHERLOCK displaced the Whim Creek Group and the Caines Well Granitoid Complex by 30–40 km (Smithies, 1998a). On ROEBOURNE, it displaced slivers of the Cleaverville Formation at least 20 km from Mount Ada to De Witt Hill (Hickman, 2002). As noted above, the Bullock Hide Intrusion might be a tectonically displaced section of the Andover Intrusion (mainly exposed on ROEBOURNE), in which case dextral strike-slip movement exceeded 15 km. On ROEBOURNE and DAMPIER – BARROW ISLAND, the Black Hill Shear Zone is a major dextral strike-slip fault that is subsidiary to the SSZ. The Black Hill Shear Zone displaces the Andover Intrusion by 10 km (Hickman, 2002). As noted by Krapez and Eisenlohr (1998), zircon geochronology on several rock units close to the SSZ has revealed a metamorphic disturbance event at about 2920 Ma that could have coincided with D_6.

Minor D_6 structures in the Sholl Shear Zone include dextral drag folding and isoclinal folding (Fig. 18) of S_2 mylonite lamination, and associated small-scale faulting and brecciation.

D_7 (<2920 Ma)

The Sholl Shear Zone and earlier structures are deformed by a D_7 conjugate system of north-northeasterly striking sinistral faults and west-northwesterly striking dextral faults. Examples of these structures are present in the Roebourne Synform near Ruth Well. The precise age of D_7 faults is unknown, but they predate the 2770 Ma Mount Roe Basalt of the Fortescue Group.

METAMORPHISM OF THE WEST PILBARA GRANITE–GREENSTONE TERRANE

Greenstones of the Roebourne Group north of the Sholl Shear Zone (SSZ) have been metamorphosed to amphibolite facies, whereas south of the shear zone the Whundo Group contains rocks at lower greenschist facies. This difference is attributed to a component of reverse movement on the northerly dipping SSZ. An exception is present in the Cleaverville domain between Karratha and Cleaverville. Here, downward movement on steep faults on the northwestern side of the Prinsep Dome has preserved greenschist facies sections of the Regal Formation.

The granitoid complexes contain greenstone enclaves that are metamorphosed to amphibolite facies, and the granitoids show evidence of retrogression from amphibolite facies.

ARCHAEAN–PROTEROZOIC INTRUSIONS

Dolerite and gabbro dykes (d)

Dolerite and gabbro dykes (*d*) on DAMPIER – BARROW ISLAND are of various ages, and trend northeasterly, northwesterly and east–west across the area. Aeromagnetic lineaments with these trends are also presumed to coincide with mafic dykes. The dominant dyke trend is northeasterly, and intrusions of this type are interpreted to correlate mainly with a northerly to northeasterly trending dyke swarm along the western margin of the Pilbara Craton. Most of the northeasterly trending dykes are interpreted to be Proterozoic, but some may be feeders to volcanic formations in the Fortescue Group. Northwesterly trending dykes have the same trend as Proterozoic dykes on PINDERI HILLS (Hickman and Kojan, 2003), but the east–west gabbro dykes (almost entirely concealed) are parallel to the basal gabbro intrusions (*AyGo*) of the Gidley Granophyre, and may therefore be Archaean.

Gabbro dykes (o)

A northerly trending gabbro dyke (*o*) of uncertain age intrudes the Kylena Formation between Mount Rough and Mount Preston.

Quartz veins (q)

Quartz veins (*q*) of various and uncertain ages outcrop in many parts of DAMPIER – BARROW ISLAND. Quartz veins typically intrude faults, and are up to 20 m thick, but lenticular along strike. The largest quartz veins (*q*) are present along northeasterly striking fractures in the Karratha Granodiorite, and occupy faults that have deformed the Fortescue Group to the northeast on ROEBOURNE.

NEOARCHAEAN–PALAEOPROTEROZOIC ROCKS

HAMERSLEY BASIN

The Hamersley Basin is a Neoarchaean to early Palaeoproterozoic tectonic unit that unconformably overlies the WPGGT and other terranes of the Pilbara Craton. The lithostratigraphy of the Hamersley Basin consists of three groups that together make up the Mount Bruce Supergroup, a succession of volcanic and sedimentary rocks, up to 10 km thick, that covers an area of about 100 000 km^2 (Trendall, 1990). The Mount Bruce Supergroup occupies about 65% of the Pilbara Craton, and unconformably overlies the granite–greenstone terranes. DAMPIER – BARROW ISLAND contains exposures of the lower two groups, the Fortescue and Hamersley Groups.

Fortescue Group

The Fortescue Group is the oldest of three groups that constitute the Mount Bruce Supergroup. The Fortescue Group is dominantly volcanic, and has an age range of c. 2770–2630 Ma (Arndt et al., 1991; Nelson et al., 1992; Wingate, 1999). On DAMPIER – BARROW ISLAND, all rocks in the Fortescue Group are metamorphosed to prehnite–pumpellyite facies (Smith et al., 1982). The contact between the Fortescue Group and the granite–greenstones is an angular unconformity. A polymictic conglomerate, containing subrounded clasts derived from the underlying granite–greenstones, locally marks the base of the Fortescue Group, but is generally too thin and irregular to be represented at map scale.

The Fortescue Group on DAMPIER – BARROW ISLAND comprises a mixed assemblage of mafic to felsic volcanic and sedimentary rocks and is subdivided into the Mount Roe Basalt and the Hardey, Kylena, Tumbiana, Maddina, and Jeerinah Formations. Basalt and andesite on islands of the Dampier Archipelago are assigned to the Fortescue Group, but not to individual formations. Based on contact relationships with the Gidley Granophyre, the volcanic rocks of the Dampier Archipelago are considered to be approximately the same age as the Kylena Formation, but for reasons explained below are described separately in these Explanatory Notes.

The volcanic rocks of the Mount Roe Basalt – Hardey Formation succession, at the base of the Fortescue Group, are bimodal (Arndt et al., 1991). In contrast, Kojan and Hickman (1998) presented evidence that the volcanic rocks within the Kylena, Tumbiana and Maddina Formations represent four separate phases of mafic to felsic volcanism, and have mixed calc-alkaline and tholeiitic affinities.

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

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

Mount Roe Basalt (AFr, AFrb, AFrbm, AFrs)

In southern DAMPIER – BARROW ISLAND, the Mount Roe Basalt (*AFr*) comprises a 200 m-thick succession that includes massive, columnar-jointed, vesicular, and glomeroporphyritic flows of basalt, with local volcaniclastic sandstone, and basaltic agglomerate and tuff. The basal unconformity of this formation with underlying granitoids of the Cherratta Granitoid Complex is exceptionally well exposed at Mount Leopold (Fig. 20), where it outcrops about 50 m above the base of a 100–150 m high, north-facing escarpment. The unconformity is an irregular erosional surface with visible relief up to 50 m. Subaerial lava flows of the Mount Roe Basalt were erupted onto a Neoarchaean granitoid landscape of low hills that was cut by deeply incised gulleys. These palaeodrainages and other low-lying areas contained clastic sediments that are now preserved as lenticular units of sandstone and conglomerate, and minor shale (*AFrs*). Minimal leaching of the granitoids immediately beneath the unconformity indicates rapid erosion.

The basal unconformity of the Mount Roe Basalt is also well exposed north and south of Mount Wilkie (Fig. 21), south of KAP 2, and on the southeastern side of Yerwararron Hill. At Yerwararron Hill an outlier of basaltic volcanic rocks correlated with the Mount Roe Basalt unconformably overlies the Dampier Granitoid Complex. This correlation is based on the lithology of the volcanic rocks, including the presence of glomeroporphyritic basalt that is elsewhere typical of the Mount Roe Basalt. A thin (2–4 m) and lenticular basal unit of pebbly sandstone, conglomerate, and minor shale (*AFrs*) is present at Yerwararron Hill. The conglomerate includes cobbles of grey- and white-banded chert, granite, and quartz, and the sandstone contains graded bedding. Yerwararron Hill and the adjacent KAP 2 provide the only exposures of Mount Roe Basalt north of the Sholl Shear Zone on DAMPIER

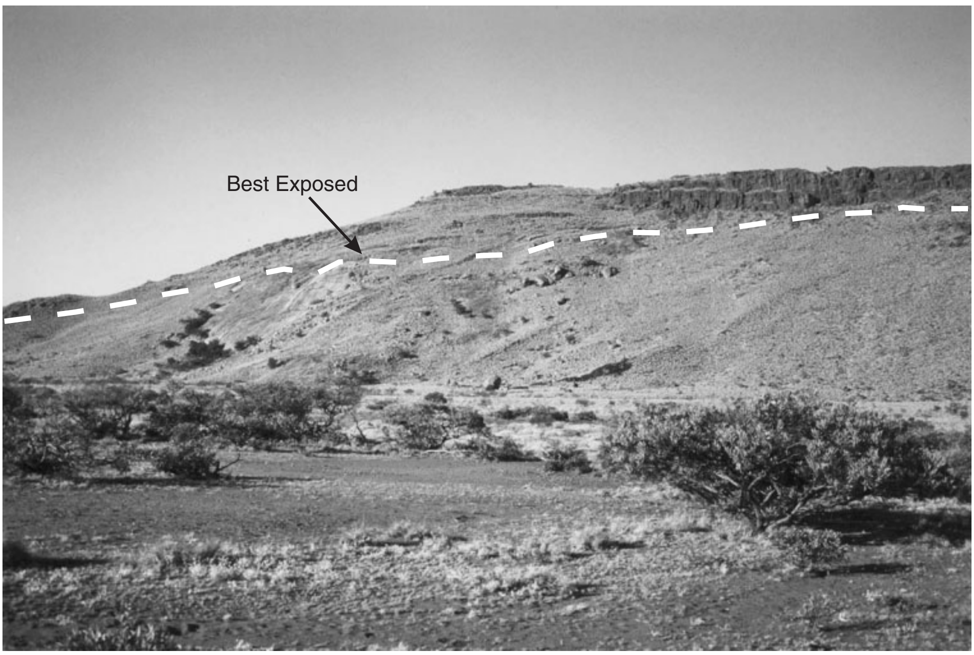

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Figure 20. View westwards of the basal unconformity of the Fortescue Group near Mount Leopold (MGA 461700E 7678450N). Sandstone and basalt of the Mount Roe Basalt (upper part of cliff) overlie granitoid rocks of the Cherratta Granitoid Complex

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Figure 21. Mount Roe Basalt unconformably overlying the Cherratta Granitoid Complex on the east side of Devil Creek, 1.5 km northeast of Tullawar Pool (MGA 438500E 7680800N)

– Barrow Island. However, there are large exposures of the formation north of the SSZ immediately east of the sheet area on Roebourne.

At KAP 2, the Mount Roe Basalt unconformably overlies the contact between the Dampier Granitoid Complex and the Regal Formation, whereas 2 km south of KAP 2 the massive and vesicular flows of the formation form a small outlier that unconformably overlies the Regal Formation and the Cleaverville Formation. Other outcrops assigned to the Mount Roe Basalt in the area south of KAP 2 consist of breccia and conglomerate with clasts of coarse-grained monzogranite and chert in a matrix of basalt. Clasts are subangular to rounded and range from 2 to 30 cm in diameter.

South of the SSZ, the basal unconformity of the Mount Roe Basalt is exposed on the lower slopes of Mount Wilkie. Most exposures show no development of basal sandstone, and basalt of the formation immediately overlies either foliated monzogranite and granodiorite (*AgCm*) or foliated monzogranite containing xenoliths of amphibolite (*AgCmx*). Near the southern boundary of Dampier – Barrow Island, 3 km southwest of Tullawar Pool, the Mount Roe Basalt unconformably overlies mylonitized granitoid rock (*Ammg*) in the SSZ, and mylonitized zones beneath the unconformity are also present 2.5 km south of Mount Wilkie. These observations confirm that deposition of the Mount Roe Basalt post-dated mylonite development along, and adjacent to, the SSZ; although the conglomerate and breccia near KAP 2 suggest some reactivation of the SSZ during syn-depositional rifting.

Outcrops of basaltic breccia (*AFrb*) 2 km west-southwest of Byong Pool consist of variably carbonated, dark grey-green vesicular basalt fragments in a basaltic matrix. There are no exposed contacts between the breccia and surrounding lava flows of the Mount Roe Basalt, and its origins are therefore uncertain.

Flows of high-Mg basalt (*AFrbm*) are present in the centre of the Mount Roe Basalt east of Mount Wilkie. The high-Mg basalt is pale grey, locally columnar jointed, and in places has a fine granular texture. In thin section, a sample (GSWA 148144) collected 4.5 km south of Byong Pool, comprised a plagioclase and clinopyroxene groundmass containing fibrous orthopyroxene altered to chlorite (Radke, 1997). Geochemical analysis of this sample showed the rock to contain 10.75% MgO, 845 ppm Cr, and 226 ppm Ni.

Hardey Formation (AFh, AFhs, AFhy)

The Hardey Formation (*AFh*) conformably overlies the Mount Roe Basalt in southern DAMPIER – BARROW ISLAND, and south of the sheet area it unconformably overlies rocks of the WPGGT. On DAMPIER – BARROW ISLAND, the lower part of the formation is mainly composed of poorly to moderately sorted, medium- to coarse-grained sandstone, conglomerate, siltstone, shale, and tuff (*AFh*). However, sandstone and quartz sandstone (*AFhs*) locally overlie the Mount Roe Basalt. The upper part of the Hardey Formation is composed of felsic volcaniclastic sandstone and tuff of the Lyre Creek Member (*AFhy*), and is conformably overlain by the Kylena Formation (*AFk).*

On DAMPIER – BARROW ISLAND, the maximum thickness of the Hardey Formation is approximately 80 m, and the formation is preserved only south of the Sholl Shear Zone (SSZ), southeast of Tullawar Pool. Southeast of DAMPIER – BARROW ISLAND, on PINDERI HILLS, the formation is generally about 200 m thick, and locally up to 1000 m thick (Hickman and Kojan, 2003), indicating an overall northwesterly stratigraphic thinning. Thorne and Trendall (2001) recorded southerly directed palaeocurrents on PINDERI HILLS, and interpreted southwestern DAMPIER – BARROW ISLAND to have been an upland area with no deposition of the Hardey Formation. The formation is absent in the Cape Preston area, where the Kylena Formation is the lowest unit of the Fortescue Group and directly overlies the Dampier Granitoid Complex.

Normal faulting 2 km southwest of Tullawar Pool coincides with a rapid northwesterly thinning of the formation, and with a marked increase in polymictic conglomerate. These northeasterly striking normal faults, with downthrow to the southeast, may have originated as growth faults, the conglomerate being deposited along the southeastern slopes of a fault scarp, or series of scarps. It is also possible that the SSZ was reactivated at this time, with downthrow on its southeastern side. Such faulting would have resulted in an upland area northwest of the SSZ.

Kylena Formation (AFk, AFkfd)

On DAMPIER – BARROW ISLAND, the Kylena Formation (*AFk*) is composed of fine-grained massive and amygdaloidal basalt, basaltic andesite, and dacite, with local high-Mg basalt and rhyolite. Thorne and Trendall (2001) provided a comprehensive regional description of the Kylena Formation, including its volcanic facies and petrography.

The most extensive exposures of the Kylena Formation on DAMPIER – BARROW ISLAND are in the Cape Preston area, where its original stratigraphic thickness ranges from 300 m to 500 m. Here the formation unconformably overlies the Dampier Granitoid Complex, and includes lenticular basal sandstone and conglomerate units, too thin to show on the 1:250 000 map. The granitoids immediately beneath the unconformity show no evidence of saprolite development, indicating rapid deposition of the Kylena Formation following their erosion. This is consistent with the Cape Preston area being an upland area during deposition of the lower Fortescue Group (see above). Dacite (*AFkfd),* with minor andesite, forms the upper 150 m of the formation in the Cape Preston area. South of the SSZ, the formation conformably overlies the Hardey Formation, which in turn overlies the Mount Roe Basalt, indicating a deeper depositional basin than in the Cape Preston area.

In the Cape Preston area, the Kylena Formation is tectonically thickened by west to east thrusting, but this type of deformation does not extend south of the SSZ. This suggests that movement associated with the thrusting, possibly at c. 1100 to 1000 Ma (Table 1, and see **Proterozoic deformation**), was locally dissipated by contemporaneous dextral strike-slip along the SSZ.

Tumbiana Formation (AFt)

DAMPIER – BARROW ISLAND contains the most westerly exposures of the Tumbiana Formation (*AFt*), which is a distinct lithological component of the Fortescue Group across the northern half of the Pilbara Craton. Regionally, the formation is composed of sandstone, siltstone, shale, stromatolitic limestone and dolomite, basalt and basaltic to andesitic tuff (Thorne and Trendall, 2001). Of particular interest are the stromatolitic carbonate rocks, which rank the formation as one of the oldest (c. 2719 Ma) abundantly fossiliferous units on Earth. Awramik and Buchheim (2001) interpreted the carbonates as lacustrine deposits, and commented that they were deposited in one of Earth's most laterally extensive ancient lakes, or lake systems. However, Thorne and Trendall (2001) interpreted the Tumbiana Formation as originating in coastal, nearshore shelf, and offshore shelf environments.

In the Cape Preston area of DAMPIER – BARROW ISLAND, the Tumbiana Formation is approximately 200 m thick, and consists of a lower 50 m-thick unit of tuff, siltstone, shale, chert, and stromatolitic carbonate rock; a central 100 m-thick unit of vesicular basalt (with minor basaltic andesite); and an upper 50 m-thick unit of accretionary lapilli tuff. On DAMPIER – BARROW ISLAND, the Tumbiana Formation appears to conformably overlie the Kylena Formation, but approximately 120 km to the east-southeast on COOYA POOYA the Kylena Formation was folded (see $\mathbf{D_h}$) and eroded prior to deposition of the Tumbiana Formation, resulting in an angular unconformity (Hickman, in prep.b).

Maddina Formation (AFm, AFmfd)

On DAMPIER – BARROW ISLAND, the Maddina Formation (*AFm*) is restricted to the Cape Preston area, where it conformably overlies the Tumbiana Formation (*AFt*). The formation comprises a succession of basalt and basaltic andesite flows, with minor andesite, dacite, and rhyolite. Thrusting complicates assessment of the formation's primary stratigraphic thickness, estimated at approximately 600–700 m. An earlier estimate by Thorne and Trendall (2001) that the formation is 1100 m thick did not allow for thrust repetition (Hickman and Strong, 1998).

The upper part of the Maddina Formation is composed of dacite (*AFmfd*). On PINDERI HILLS, 50 km to the southeast, Kojan and Hickman (1998) used geochemical and radiometric data to identify dacite in the central and upper parts of the formation. One sample of dacite from PINDERI HILLS was dated at 2717 ± 2 Ma (Nelson, 1998, p. 133–135) using the SHRIMP U–Pb zircon method.

Jeerinah Formation (AFj)

Exposures of the Jeerinah Formation (*AFj*) are restricted to an area 2 km south of James Point on the southern boundary of DAMPIER – BARROW ISLAND. On a regional scale, these outcrops represent some of the most westerly exposures of the formation, which outcrops intermittently throughout the southern half of the Pilbara Craton (Thorne and Trendall, 2001). Composed principally of siltstone, banded chert, and minor black shale, and being extensively faulted, the formation is a recessive unit on DAMPIER – BARROW ISLAND, and is poorly exposed. Previous mapping on YARRALOOLA (Williams, 1968) indicates that concealed lithologies on DAMPIER – BARROW ISLAND probably include sandstone, dolomite, basalt, andesite, and felsic tuff. A sample of andesitic ignimbrite from outcrops of the formation on YARRALOOLA, 40 km south of James Point, was dated at 2684 ± 6 Ma (Arndt et al., 1991).

Unassigned rocks of the Dampier Archipelago (AF(b), AF(s), AF(si), AF(o))

A succession of basalt and andesite (*AF(b)*), with local thin units of sandstone and conglomerate (*AF(s)*) and intermediate volcaniclastic sedimentary rock and tuff (*AF(si)*), is present on many islands of the Dampier Archipelago. The total thickness of the Fortescue Group succession is estimated at 200–500 m, and it includes units that are variously older and younger than the c. 2725 Ma Gidley Granophyre. On East Lewis Island, basaltic andesite of the succession unconformably overlies both the Dampier Granitoid Complex (MGA 465950E 7720950N) (Figs 22 and 23) and the Gidley Granophyre (MGA 464800E 7720100N). Likewise, on Enderby Island basalt of the succession unconformably overlies the Dampier Granitoid Complex that is locally exposed in cliff sections (Fig. 24). However, on Enderby Island (at MGA 483500E 7721100N), basalt of the succession is intruded by leucocratic veins at the margin of the Gidley Granophyre, and elsewhere by microgranitoid dykes (*g*). This suggests that the volcanic succession of the Dampier Archipelago might be genetically related to the Gidley Granophyre intrusive complex.

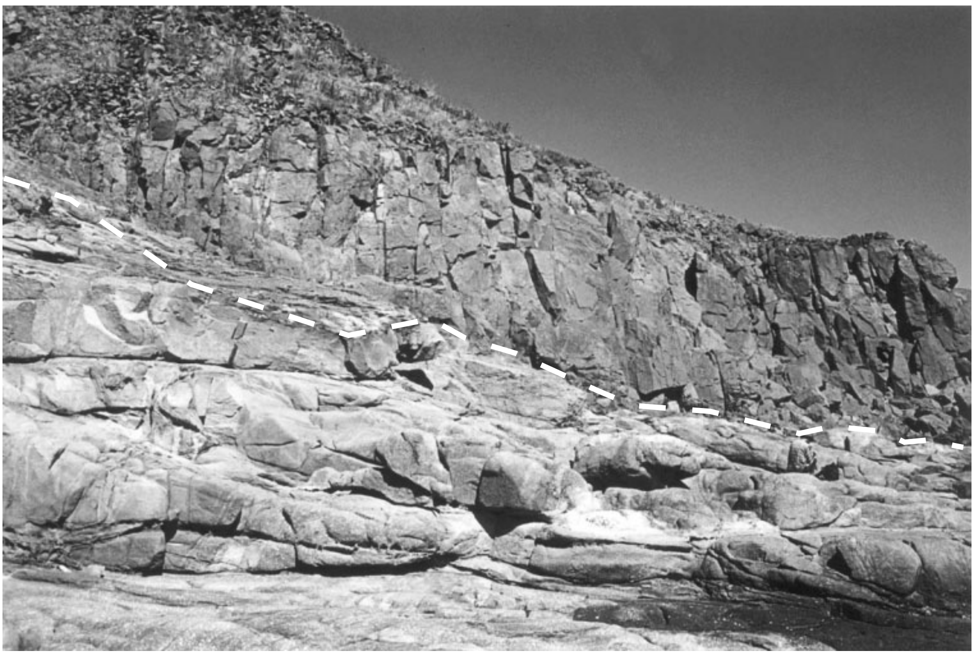

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Figure 22. Unconformity between the Dampier Granitoid Complex and the Fortescue Group, East Lewis Island (MGA 466000E 7720950N)

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Figure 23. Conglomerate immediately above the basal Fortescue Group unconformity, East Lewis Island (MGA 466000E 7720950N)

Aeromagnetic data (GSWA, 1995b) indicate no continuity between the volcanic rocks of the Dampier Archipelago and the Fortescue Group of the mainland, and the two successions, though partly time-equivalent, may have been deposited separately. The Dampier Archipelago succession is similar in age to the Kylena Formation, but it exhibits several lithological differences from that unit. The basalt–andesite succession of the Dampier Archipelago contains several intercalations of sandstone and conglomerate (*AF(s)*), and is intruded by several thick sills of gabbro and dolerite (*AF(o)*). Rosemary Island was not visited during the mapping for the second edition of DAMPIER – BARROW ISLAND, but mapping in the 1960s (Kriewaldt et al., 1964) revealed that the succession there includes a thick unit of intermediate volcaniclastic sedimentary rock and tuff (*AF(si)*). This is not an assemblage present in the Kylena Formation of the mainland.

Gidley Granophyre and related rocks (AyG, AyGo, AyGox, Ayx, Agr, g)

De Laeter and Trendall (1971) described the Gidley Granophyre as an intrusion of granophyre and associated gabbro along the basal unconformity of the Fortescue Group. On the Burrup Peninsula, the Gidley Granophyre is a northwesterly dipping composite sill consisting of a lower unit of gabbro (*AyGo*) and quench-textured gabbro (*AyGox*), and an upper unit of granophyre (*AyG*). The recent mapping has revealed that the Gidley Granophyre is not a simple, sill-like intrusion along the unconformity between the Dampier Granitoid Complex and the volcanic succession of the Dampier Archipelago. Large enclaves of partly melted granitoid rock (*Agr*), up to 3 km in length, indicate that the granophyre intruded the granitoid complex as a number of irregular sheets. In many areas the basal unconformity of the volcanic succession is intruded by granophyre, but the granophyre is locally absent (e.g. East Lewis Island, Fig. 22).

The total thickness of the Gidley Granophyre is at least 2 km, and it outcrops over an area of about 100 km^2. Aeromagnetic data (GSWA, 1995b) indicate that the structure of the Gidley Granophyre is concave towards the northwest, and that the outcropping section of the intrusion is merely the southeastern margin of a circular structure centred about 5 km northwest of Rosemary Island. Rosemary Island contains large outcrops of gabbro that are close to the centre of a circular, 30 km-radius, gravity high (Blewett et al., 2000, p. 22). Thus, the exposed Gidley Granophyre may be merely the southeastern margin of a much larger circular intrusive complex that has a central core of gabbro. The observation that northwesterly dipping sheets of gabbro intrude both the volcanic succession of the Dampier Archipelago and the Dampier Granitoid Complex southeast of the Gidley Granophyre suggests that these intrusions may be cone sheets.

Within the main body of the Gidley Granophyre, contact between the gabbro (*AyGo*) and overlying granophyre (*AyG*) is intrusive, with veinlets of silicic granophyre intruding the gabbro (Fig. 25). However, the consistent spatial association between the gabbro and the granophyre, and their common intrusion between the Dampier Granitoid Complex and the Fortescue Group, suggests that they were intruded at about the same time. The basal gabbro (*AyGo*) has been dated at 2725 ± 3 Ma, using U–Th–Pb ion microprobe analyses of baddeleyite (Wingate, M. T. D., 1997, written comm.). Several attempts to extract zircon from the granophyre have been unsuccessful, and the precise age of the upper section of the intrusion is uncertain.

The 2725 Ma baddeleyite age establishes that the Gidley Granophyre is younger than the Mount Roe Basalt and the c. 2760 Ma Hardey Formation, but older than the upper formations of the Fortescue Group. It may be similar in age to the Cooya Pooya Dolerite, which southeast of DAMPIER – BARROW ISLAND intrudes the Hardey and Kylena Formations, and is overlain by the c. 2719 Ma Tumbiana Formation.

Xenoliths of partly melted granitoid (*Agr*), ranging in size from a few centimetres in diameter to 3 km long, are present in both the gabbro and granophyre sections of the Gidley Granophyre, and indicate extensive fragmentation and massive veining of the granitoid complex. In thin section, the melted granitoid consists of saussuritized plagioclase, quartz, and abundant interstitial tridymite and remelted feldspar. At the base of the Gidley Granophyre, contact metamorphism and local partial melting of the Dampier Granitoid Complex caused fracturing in the basal gabbro and back-injection of leucocratic veins (Hickman, 2000). At the top of the Gidley Granophyre, basalt and andesite of the Dampier Archipelago volcanic succession (*AF(a)*) are locally intruded by marginal leucocratic veins (see above) and dykes of granophyric microgranite (*g*).

The gabbroic section of the Gidley Granophyre is composed dominantly of medium- to coarse-grained gabbro (*AyGo*). De Laeter and Trendall (1971) also described noritic gabbro consisting of hypersthene, augite, and labradorite, with micrographic albite–quartz intergrowth. On the eastern side of the Burrup Peninsula, between Hearson Cove and Sloping Point, and 3 km south of Dampier, the lower section of the gabbro contains layers of spectacular quench-textured acicular pyroxene (*AyGox*). Pyroxene crystals up to 15 cm long are concentrated in vertical branching structures up to 2 m in height. In thin section, fresh augite is present within a coarse matrix of saussuritized plagioclase, chloritized pseudomorphs after clinopyroxene, and interstitial patches of granophyric tridymite and feldspar. These granophyric areas were probably derived from remelted granitoid inclusions. Sheets of melt material locally form sills and dykes in the layered zone, and rare xenoliths of gabbro are present in the marginal zone of the adjacent granitoids of the Dampier Granitoid Complex, suggesting extensive granitoid remelting.

Fine- to medium-grained granophyre (*AyG*) comprises most of the Gidley Granophyre, and is massive, homogeneous (apart from partly remelted granitoid inclusions), and well jointed.

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Figure 24. Cliffs on the southeastern shore of Enderby Island, where basalt of the Fortescue Group unconformably overlies the Dampier Granitoid Complex (MGA 453500E 7719850N)

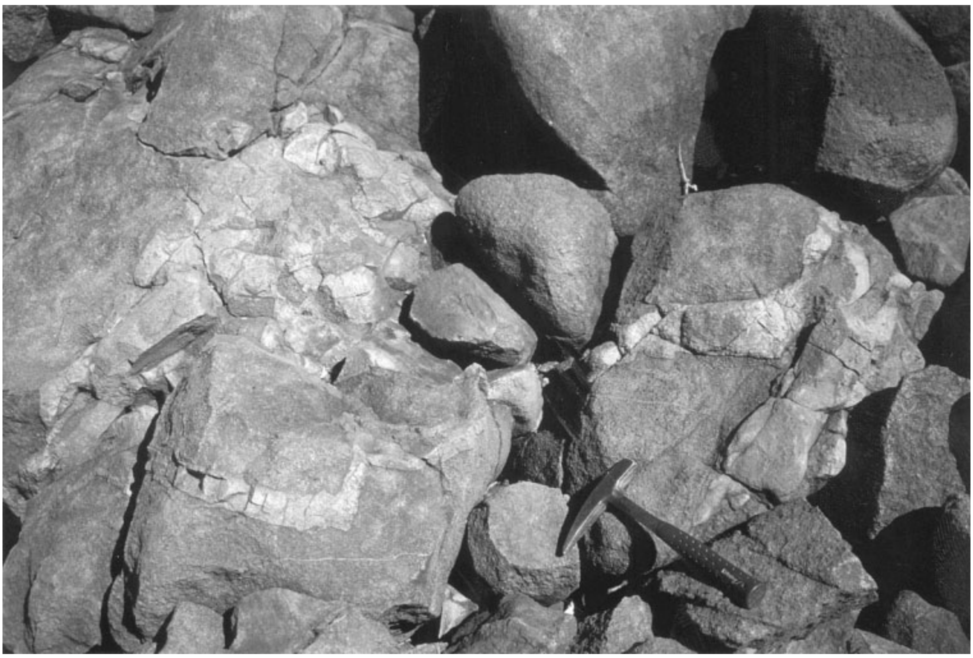

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Figure 25. Gidley Granophyre 6 km west-southwest of Dampier, showing gabbro of the intrusion cut by later veins of granophyre (MGA 464400E 7610450N)

Where layering is visible on 1:25 000-scale colour aerial photographs, or defined by slight colour and grain size variations in outcrop, this layering is orthogonal to the dominantly near-vertical joint system. Outcrops of the rock are typically reddish brown to black, but freshly broken surfaces range from dark reddish green to dark blue-grey or purple-grey. In thin section, the rock consists almost entirely of finely intergrown quartz and alkali feldspar.

North-northwesterly trending, granophyric, xenolith-rich dykes (*Ayx*) on the mainland appear to be related to the Gidley Granophyre complex. These dykes intruded along a narrow zone from 13 Mile Well to North Whundo, and their alignment is consistent with their radiating from the postulated centre of the intrusive complex near Rosemary Island. The dykes cut both the SSZ and the Sholl Intrusion, but no contacts with the Fortescue Group are preserved. One kilometre west of Pat Bore, one of the dykes is cut by a northeasterly trending dolerite dyke (*d*). The xenolith-rich dykes (*Ayx*) contain angular to subrounded fragments of vein quartz, quartzite, and granitoids (Fig. 26). These xenoliths commonly comprise 25–50% by volume of the dykes, and are set in a fine-grained, grey, granophyric matrix. Hickman (2002) suggested that the xenolith-rich dykes might be feeders to the Gidley Granophyre. However, it is possible that the dykes are remnants of a fracture system linking the Gidley Granophyre complex with the Cooya Pooya Dolerite.

Hamersley Group

Outcrops of the Hamersley Group on DAMPIER – BARROW ISLAND are restricted to the James Point area, and consist almost entirely of the Brockman Iron Formation. West to east thrusting of the succession (Hickman and Strong, 1998) is interpreted to have resulted in

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Figure 26. Xenolith-rich granophyre dyke (*Ayx*) near Pat Bore (MGA 481400E 7697650N)

the tectonic removal or extreme attenuation of lower Hamersley Group formations such as the Marra Mamba Iron Formation, Wittenoom Formation, Mount Sylvia Formation, and the Mount McRae Shale. These formations form extensive outcrops on YARRALOOLA, about 40 km south of James Point.

With the exception of the Carawine Dolomite in the Isabella Range of the northeastern Pilbara, the James Point area contains the most northerly exposures of the Hamersley Group. A recent model for the development of the Hamersley Basin during deposition of the Jeerinah Formation (Thorne and Trendall, 2001) involves deepening of the basin from a west-northwesterly trending coastal facies along the Chichester Range to a deeper submarine facies in the Hamersley Range. If this basin morphology continued during deposition of the lower Hamersley Group, the lower formations of the Hamersley Group would be much thinner in the James Point area than farther south (or possibly never deposited). This northerly stratigraphic thinning of formations is consistent with isopach mapping of the Dales Gorge Member of the Brockman Iron Formation (Trendall and Blockley, 1970, Plate 3). Trendall and Blockley (1970) stated that the Mount Sylvia Formation is exposed at James Point, but this formation was not identified during the recent mapping.

Brockman Iron Formation (ⱣHb)

At James Point the Brockman Iron Formation (*ⱣHb*) consists of BIF, chert, and minor siltstone and mudstone. The formation is strongly magnetic, and aeromagnetic data (GSWA, 1995b) indicate that the iron formation extends at least 30 km north and north-northwest of James Point beneath the Indian Ocean. In outcrop, BIF consists of alternating iron-rich and quartz-rich layers at various scales down to less than 1 mm. Mineral constituents include quartz, hematite, magnetite, ferrostilpnomelane, siderite, and ankerite (Trendall and Blockley, 1970). Mudstone and siltstone units are generally less than a few metres thick, and contain complex folding and brecciation, interpreted to be partly related to local thrusting of the succession. However, Trendall and Blockley (1970, p. 64) noted that two of the shale units (S4 and S16) of the Dales Gorge Member contain breccia units over 1 m thick over a wide area of the Hamersley Range, suggesting that these deposits have regional significance.

Weeli Wolli Formation (ⱣHj)

Partly brecciated, thinly laminated jaspilite (*ⱣHj*) outcrops on the foreshore 1 km southwest of James Point. These exposures are interpreted to form a faulted lens of the Weeli Wolli Formation. Elsewhere in the Hamersley Basin, this formation is composed of jaspilite, shale, and dolerite overlying the Brockman Iron Formation, and includes lithologically distinctive red iron formation. This rock is typically evenly laminated at 1–5 mm intervals, but in individual samples these intervals are very uniform. Additional information on the Weeli Wolli Formation is available in Trendall and Blockley (1970).

STRUCTURE OF THE HAMERSLEY BASIN AND PROTEROZOIC UNITS

The structural geology of the Hamersley Basin on DAMPIER – BARROW ISLAND includes open folds, faults, and dykes of various ages and orientations. Some of these structures are probably superimposed on underlying rift structures that were active during deposition of the Mount Roe Basalt and the Hardey Formation (Blake, 1993). These early structures in the Fortescue Group have an age range of 2770–2750 Ma, whereas folds and thrusts in the Cape Preston – James Point area post-date the Brockman Iron Formation, and are therefore Proterozoic or younger.

Deformation events

D_h: Hamersley Basin crustal extension (c. 2770–2720 Ma)

Blake (1993) recognized a period of west-northwesterly–east-southeasterly crustal extension during deposition of the Mount Roe Basalt and the overlying Hardey Formation. The resulting structures were northeasterly trending normal faults and mafic dykes. Extrusion of flood basalts (Mount Roe Basalt) was followed by the development of extensional intracratonic sedimentary basins (Hardey Formation).

East–west thickness variations in the Hardey Formation indicate east–west variations in basin depth, due either to rifting or to differential erosion of underlying units (Hickman and Kojan, 2003). The stratigraphic differences between Cape Preston and areas southeast of the Sholl Shear Zone (as described above) indicate that the SSZ and adjacent faults formed topographic features at 2770–2760 Ma.

Southeast of DAMPIER – BARROW ISLAND, on COOYA POOYA, Hickman (in prep.b) has identified north-northeasterly trending open folds that deform the Kylena Formation but pre-date the Tumbiana Formation, and result in an angular unconformity between these formations. There is no evidence of this unconformity on DAMPIER – BARROW ISLAND, although the unconformity at the base of the Dampier Archipelago succession may be coeval. It is possible that the pre-2719 Ma deformation of the Kylena Formation on COOYA POOYA was related to intrusion of the Cooya Pooya Dolerite, which may have occurred at the same time as intrusion of the 2725 Ma Gidley Granophyre (see **Gidley Granophyre**).

Archaean–Proterozoic deformation events

On the Burrup Peninsula, the 2725 Ma Gidley Granophyre is deformed by northwesterly dipping reverse faults and northeasterly trending open folds, but there are no other useful constraints on the age of these structures. The curvature of these faults along strike indicates a relationship to the circular structure that is centred northwest of Rosemary Island (see **Gidley Granophyre**), in which case they could be late D_h structures.

Proterozoic deformation (1830–1780 Ma or 1100–1000 Ma)

Hickman and Strong (1998) recognized thrust-stacking of the Fortescue Group and the Brockman Iron Formation in the Cape Preston – James Point area. Although all formations dip westwards at low to moderate inclinations, distinct stratigraphic levels (e.g. the basal Fortescue Group – Dampier Granitoid Complex unconformity and the Tumbiana Formation) are repeated across strike. Hickman and Strong (1998) documented several exposures of shear zones and breccia along thrust contacts. East of the zone of thrusting, two major south-southwesterly plunging folds, the Kaninda Anticline and the Virchow Syncline (newly defined names, Fig. 5), probably formed prior to thrusting. This conclusion is based on mapping farther south on YARRALOOLA (Williams, 1968) where northerly striking faults (probably southern extensions of the thrusts) cut the fold structures. The Virchow Syncline post-dates the Hamersley Group, but its precise age is unknown.

Easterly directed thrusting and folding in the Cape Preston area has not been directly dated, but post-dates deposition of the Hamersley Basin, and pre-dates northeasterly trending dolerite dykes interpreted to belong to a 755 Ma suite (Table 1). Hickman and Strong (1998) suggested that the Cape Preston structures could be related to plate convergence on the northwestern margin of the Pilbara Craton. Palaeoproterozoic thrusting is present along the eastern and southern margins of the Pilbara Craton, and might also have occurred against the western margin. In this scenario, the Cape Preston structures would be approximately the same age as structures of the Capricorn Orogeny. In the southwestern part of the Pilbara Craton, the prevailing strike of structures in the Capricorn Orogen is west-northwesterly, whereas the Cape Preston thrust and fold structures strike north–south. However, fold axes and faults formed during the 1830–1780 Ma Capricorn Orogeny (Occhipinti et al., 2001), progressively change orientation around the southwestern margin of the Pilbara Craton, maintaining a general parallelism with the adjacent margin of the craton.

Alternatively, the Cape Preston structures could be related to the c. 1100–1000 Ma Pinjarra Orogeny, and could be Grenvillian structures formed during assembly of the Rodinian supercontinent. In the latter situation, plate collision was probably between the Pilbara Craton and Chinese and Cimmerian plates (Rodinian reconstruction in Baillie et al., 1994).

The northwesterly trending dolerite dykes (*d*) on DAMPIER – BARROW ISLAND are interpreted to be related to the Capricorn Orogeny, based on relationships on southern PINDERI HILLS (Hickman and Kojan, 2003).

Neoproterozoic crustal extension (755 Ma)

Northeasterly and east-northeasterly trending dolerite dykes in the western part of the Pilbara Craton are correlated with the Mundine Well suite dated at 755 Ma, and are related to the breakup of the Rodinia supercontinent (Wingate and Giddings, 2000).

NORTHERN CARNARVON BASIN

The northwestern, offshore section of DAMPIER – BARROW ISLAND is mainly underlain by Mesozoic and Cainozoic sedimentary rocks within the southeastern part of the Northern Carnarvon Basin. This basin is the most southwesterly of four sedimentary basins that collectively form the northeasterly trending Westralian Superbasin (Hocking et al., 1994). The Northern Carnarvon Basin covers an area of more than 250 000 km^2, and the total area of the Westralian Superbasin is approximately 800 000 km^2.

Tectonic development of the Northern Carnarvon Basin, and the three other basins of the Westralian Superbasin, was a response to crustal thinning and rifting along the northwestern coast of Western Australia during the mid-Carboniferous to Early Permian breakup of Gondwana. Deep-level seismic data from a number of lines across the North West Shelf (AGSO North West Shelf Study Group, 1994) indicate a northeasterly trending zone of lower crustal thinning parallel to the Pilbara and Kimberley coastlines. Formation of this zone is attributed to northwest–southeast or north–south extension during the separation and northerly drift of the ‘Sibumasu Terrane’ (Sengor, 1987) away from Western Australia. The Westralian Superbasin formed on the faulted continental margin between Western Australia and the newly formed ocean, ‘Neo-Tethys’ (Veevers, 1988) to the northwest (AGSO North West Shelf Study Group, 1994).

Glaciation limited sedimentation in basins of the Westralian Superbasin until the Late Permian, but in the Triassic and Jurassic, thick sedimentary successions accumulated in depocentres such as the Dampier and Barrow Sub-basins. These depocentres lie within a system of northeasterly and northerly striking faults that AGSO North West Shelf Study Group (1994) attributed to regional north–south compression.

Exposures of the Northern Carnarvon Basin succession on DAMPIER – BARROW ISLAND are limited to outcrops of Cainozoic formations on Barrow Island. Figure 27 is a new

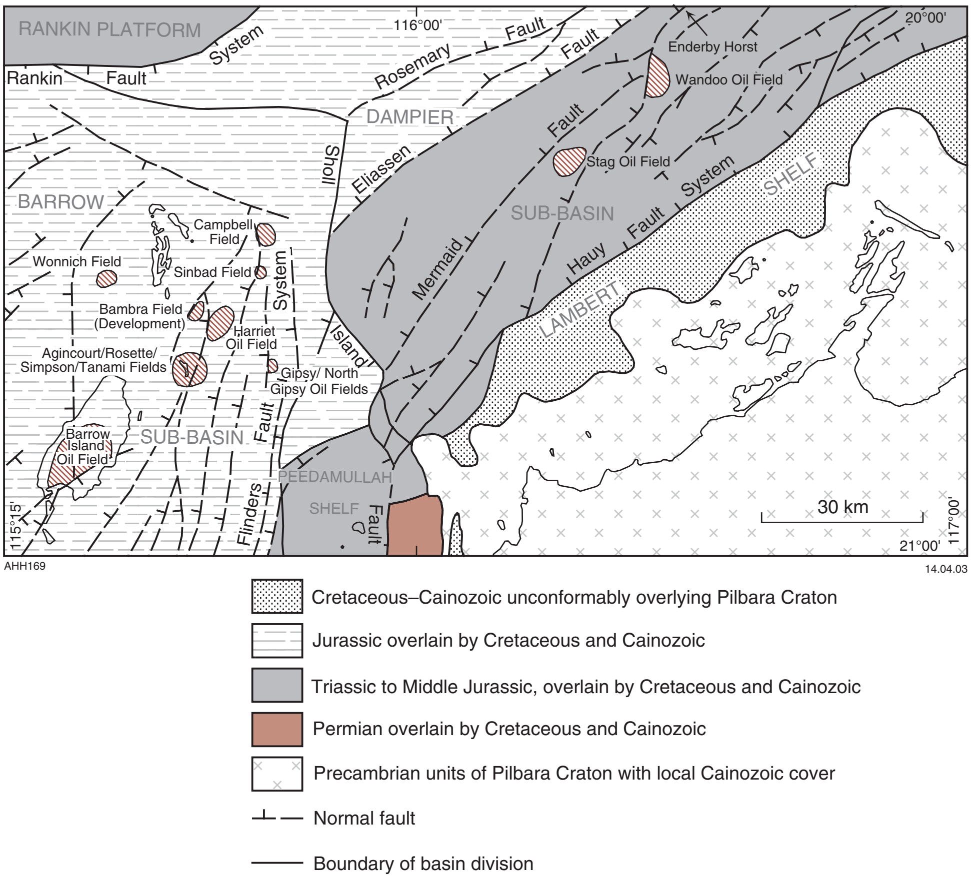

Figure 27. Geological interpretation of the Northern Carnarvon Basin on Dampier – Barrow Island

compilation of the geology of the Northern Carnarvon Basin on Dampier – Barrow Island using data from Hocking (1994), Delfos (1994), Gorter (1994), Polomka and Lemon (1996), Myers and Hocking (1998), and Crostella et al. (2000). The southeastern margin of the basin, which has been placed in various positions by previous workers, is here reinterpreted based on aeromagnetic data (GSWA, 1995b). Major divisions of the basin are those described by Hocking (1994), who provided additional subdivision into terraces, troughs, and trends.

The southeastern margin of the Northern Carnarvon Basin is an unconformity between a thin succession of Cretaceous rocks to Cainozoic and Precambrian rocks of the Pilbara Craton. The Cretaceous succession thickens offshore and, northwest of the Hauy and Sholl Island Fault Systems (Fig. 27), unconformably overlies a rifted and folded Triassic–Jurassic sedimentary succession. Within the depocentres of the Dampier and Barrow Island Sub-basins, this Triassic–Jurassic succession is up to 10 km thick. Figure 27 outlines the structural geology of this succession beneath the Cretaceous–Cainozoic cover. The hydrocarbon geology of the area is briefly outlined later in these Notes (see **Economic geology**).

No single reference provides a comprehensive description of the stratigraphy and structure of the Northern Carnarvon Basin, and a compilation of the available data from individual publications (e.g. AGSO North West Shelf Study Group, 1994; Delfos, 1994; Gorter, 1994; Hocking et al., 1994; Stagg and Colwell, 1994; Polomka and Lemon, 1996; Crostella et al., 2000) is beyond the scope of these Explanatory Notes. Only those formations that are exposed on Barrow Island are described below.

Barrow Island was not visited during mapping for the second edition of DAMPIER – BARROW ISLAND, but a new photointerpretation was undertaken using 1:25 000-scale colour photographs utilizing previously published information (Kriewaldt et al., 1964).

CAINOZOIC ROCKS OF THE NORTHERN CARNARVON BASIN

Giralia Calcarenite (Czg)

The Giralia Calcarenite (*Czg*) is Middle to Late Eocene in age, and consists of yellow to brown, medium- to coarse-grained calcarenitic to calciruditic packstone to grainstone (Hocking et al., 1987). It is locally abundant in foraminifera, and contains terebratulid brachiopods, nautiloids, echinoids, bivalves, gastropods, bryozoans, fish teeth, and crustacean fragments (Condon et al., 1956). The formation is estimated to be about 60m thick (Condon et al., 1956), and is interpreted to be a high-energy, open-marine shelf deposit (Hocking et al., 1987). Exposures on Barrow Island are limited to windows and inliers along deeper valleys within the Trealla Limestone.

Trealla Limestone, Cape Range Group (Czct)

The Trealla Limestone (*Czct*) is exposed over a large part of Barrow Island, and comprises calcarenite, calcirudite, and calcisiltite units. In outcrop, it is a shelly, white to cream packstone to grainstone, containing foraminifera, calcareous algae, bryozoans, and ostracods. The formation is a Middle Miocene component of the Cape Range Group (Hocking et al., 1987), and varies in thickness up to several hundred metres. The depositional environment of the formation ranges from lagoonal to marine shelf, and outer shelf and slope facies are present north of DAMPIER – BARROW ISLAND (Hocking et al., 1987).

CAINOZOIC DEPOSITS

Cainozoic deposits cover about 70% of the land surface of DAMPIER – BARROW ISLAND, and overlie mainly granitoid units. Three main categories of Cainozoic units are present: Eocene to early Pleistocene clastic and chemical deposits that have been eroded by the present drainage system; recent alluvial, colluvial, eluvial, and eolian deposits; and recent marine, estuarine, and coastal eolian deposits.

EOCENE TO EARLY PLEISTOCENE

Clastic and chemical deposits (Czaa, Czaf, Czag, Czak, Czcb, Czrf, Czrk)

Eocene to early Pleistocene clastic and chemical deposits have been eroded by the present drainage system. Cainozoic deposits of alluvial sand, silt, and clay (*Czaa*), dissected by the present-day drainage, are preserved where the Yanyare River discharges into a coastal lagoon. High-level alluvial gravel deposits (*Czag*) are locally exposed as gravel beds up to 5 m thick in the banks of some drainages and between drainages. These old alluvial deposits are a concealed part of the regolith in the coastal plain, and are used as a source of gravel for road construction. Calcrete of alluvial origin (*Czak*) is distributed along drainages, for example 2 km west of Radio Hill Mine and 1.5 km north of Miaree Pool. At the locality near Miaree Pool, the calcrete outcrops in the bed of the Maitland River and includes cemented river gravel. Pisolitic limonite deposits (*Czaf*) preserved on mesas at Twin Table Hills are similar to components of the Robe Pisolite in the western part of the Pilbara Craton. Hocking et al. (1987, p. 173, 175) correlated the Robe Pisolite with the Giralia Calcarenite (*Czg*). Cainozoic colluvium with gilgai surfaces in areas of expansive clay (*Czcb*) outcrops 4 km west of Gnoorea Well, and is interpreted to be a product of the weathering of adjacent mafic rocks including dolerite and gabbro dykes (*d*). Residual calcrete, consisting of variably silicified massive, nodular, and cavernous limestone (*Czrk*), overlies amphibolite (*Aba*) southwest of Toorare Pool, and forms large silicified outcrops 6 km southwest of Karratha Airport. The underlying bedrocks in the latter area are granitoids of the Dampier Granitoid Complex, but Cainozoic colluvium containing clasts of amphibolite is interpreted to underlie the calcrete. Residual ferricrete, locally including pisolitic or nodular ironstone (*Czrf*), outcrops southwest of Karratha Airport, in a large low mound 3 km northwest of Bullock Hide Well, and southeast of James Point. The ferricrete is interpreted to overlie iron-rich lithologies such as iron formation, ferruginous chert, mafic rocks, or Cainozoic sedimentary rocks including mafic clasts.

RECENT DEPOSITS

Alluvial, colluvial, eluvial, and eolian deposits (Qaa, Qal, Qac, Qao, Qaoc, Qab, Qw, Qwb, Qc, Qs, Qrg)

Present-day drainage systems contain alluvial clay, silt, and sand in channels on floodplains, and sand and gravel in rivers and creeks (*Qaa*). Alluvial sand and gravel in levees and sandbanks (*Qal*) outcrops along the lower sections of major drainages such as the Maitland River and Melford Creek. Beyond the levees are floodplain deposits of alluvial sand, silt, and clay (*Qao*), a deposit type that is also widespread farther inland between most of the main drainage lines. These floodplain deposits commonly contain numerous small claypans (*Qac*) where floodwaters have temporarily ponded before evaporating, or where local heavy rain has resulted in small playa systems. Alluvial floodplains containing abundant small claypan deposits (*Qaoc*) are present east and west of the Maitland River. Where floodplain deposits include a substantial amount of clastic material derived from mafic or ultramafic sources, brown soil and expansive clay (*Qab*) are present. In wet weather such areas are generally impassible by vehicle, and in dry weather the surface of the ground is broken by expansion crevices and depressions known as ‘crabholes’.

Sheetwash, including sand, silt, and clay (*Qw*), is deposited on distal outwash fans and includes some gilgai (*Qwb*). Colluvial sand, silt, and gravel (*Qc*) forms proximal sections of outwash fans around most outcrops of Archaean rocks, and is a widespread unit on DAMPIER – BARROW ISLAND. The composition of colluvial units depends on the lithology of source rocks in the adjacent hills. Fine- to medium-grained eolian sand (*Qs*) overlies colluvial and sheetwash deposits on the southeastern side of the Burrup Peninsula, near Karratha Airport, and 4 km south of Gnoorea Well. The sand is red to yellow due to iron staining of quartz grains and contains few or no shell fragments (unlike sand of the coastal dunes). Eluvial sand over granitoid rocks (*Qrg*) is a quartzofeldspathic residual deposit derived from underlying or nearby granitoid bedrock, and forms outcrops east and west of McKay Creek, south of Toorare Pool, and north of Prinsep Well.

Marine, estuarine, and coastal eolian deposits (Qhm, Qhms, Qpmb)

Quaternary deposits of marine, estuarine, and eolian origin occur in the coastal belt of lagoons, mangrove swamps, and sand dunes, and on islands immediately off the coast. The oldest deposit is a siliceous limestone consisting of lime-cemented shelly sand, dune sand, and beach conglomerate (*Qpmb*). This limestone, locally previously referred to as the 'Bossut Formation' (Lindner, *in* Johnstone, 1961), is commonly exposed as rock platforms, reefs, and offshore bars within the tidal zone, but is also preserved inland, where it forms old coastal dunes and strand lines. Unconsolidated shelly sand (*Qhms*) forms coastal dunes and old beach deposits. At Hearson Cove, on the Burrup Peninsula, and at Cleaverville, this unit was mined as a source of limesand (Hickman, 1983). Tidal mudflat deposits (*Qhm*) are composed of supratidal to intertidal silt and mud, and include tidal creeks fringed by stands of mangroves. The lagoonal mudflats are highly saline due to slow evaporation of ponded seawater, whereas the mud and silt deposits of the mangroves are less saline due to better drainage and repeated flushing by tides.

ECONOMIC GEOLOGY

Some of the earliest mineral discoveries in Western Australia were made in the west Pilbara. In 1872, copper and lead were discovered southwest of Roebourne, and on DAMPIER – BARROW ISLAND gold was discovered at Upper Nickol in 1890. Between 1911 and 1913 copper mineralization was found at Whundo and Yannery Hill, about 10 km south of DAMPIER – BARROW ISLAND.

The most important mining activities on DAMPIER – BARROW ISLAND are the production of oil and gas from the North West Shelf, and salt production by the solar evaporation of seawater. Other mineral commodities from DAMPIER – BARROW ISLAND have been gold, copper, nickel (with copper), semiprecious stone, limesand, construction materials, sand, and gravel for road construction. The distribution and geology of metallic mineral deposits in the west Pilbara was summarized by Ruddock (1999).

OIL AND GAS

In 2001, oil and gas production from fields on DAMPIER – BARROW ISLAND (Fig. 27) had an approximate value of $1 billion (based on data in Department of Mineral and Petroleum Resources, 2002b). These fields are not part of the North West Shelf Gas Project (NWSGP) which is a group of fields on RANKIN BANK, immediately north of DAMPIER – BARROW ISLAND. The NWSGP is currently by far the most important producer of oil and gas in Western Australia, with 2001 production valued at approximately $7 billion. By comparison, the total value of all sales of petroleum products from Western Australia during 2001 was $9.985 billion (Department of Mineral and Petroleum Resources, 2002b). The major components by value of this production were crude oil (43%), liquified natural gas (LNG: 29%, all from the NWSGP), condensate (18%), and natural gas (6%). Gas and condensate from the NWSGP are piped to the onshore treatment plant at Withnell Bay on the Burrup Peninsula (DAMPIER – BARROW ISLAND).

The productive fields on DAMPIER – BARROW ISLAND during 2001 were, in alphabetical order, Agincourt, Barrow Island, Campbell, Gipsy, Harriet, North Gipsy, Rosette, Simpson, Sinbad, Stag, Tanami, Wandoo, and Wonnich (Fig. 27). Total production from DAMPIER – BARROW ISLAND fields in 2001 was 20.95 million barrels oil (23% of State total), 0.67 million barrels condensate (1.9% of State total), and 1 163 613 thousand cubic metres gas (4.6% of State total). The largest oil producers on DAMPIER – BARROW ISLAND were Stag, Wandoo, Barrow Island, Gipsy, Simpson, North Gipsy, Agincourt, Harriet, and Tanami, whereas the largest condensate and gas producers were Wonnich, Sinbad, and Campbell. Precise production data for 2001 are provided in Department of Mineral and Petroleum Resources (2002b).

Economic oil and gas accumulations on DAMPIER – BARROW ISLAND are situated in the Dampier and Barrow Sub-basins, whereas those in the adjacent NWSGP are in the Dampier Sub-basin and Rankin Platform. The fields are restricted to areas containing a combination of suitable source rocks, conduits, reservoir rocks, seal lithologies, and structural traps. Bradshaw et al. (1994) commented that source rocks are dominantly Jurassic deep-water marine sedimentary rocks deposited under anoxic conditions, but with input of large volumes of terrestrial organic material. Reservoir rocks are mainly sandstone units below or within the Lower Cretaceous Muderong Shale which forms a top seal. However, within any particular field oil and gas accumulations may be stacked at different stratigraphic levels; for example, Jurassic reservoir rocks are locally important at Barrow Island (Hocking et al., 1987). Zaunbrecher (1994) interpreted the formation of economic concentrations of oil and gas as the result of oil migration along faults from thermally mature, overpressured source rocks to reservoir rocks beneath a thermally immature top seal. Favourable structural traps are, in most fields, open anticlines or domes, but faults locally form traps by juxtaposing seals against reservoirs. Descriptions of individual fields on DAMPIER – BARROW ISLAND are given in Purcell and Purcell (1994), and summaries of exploration and development of the fields are provided in Department of Mineral and Petroleum Resources (2002b).

GOLD

On DAMPIER – BARROW ISLAND, gold was discovered at Upper Nickol in 1890, but much of the early production was not recorded. Between 1900 and 1962, production of 12.13 kg of gold was recorded from mines at Lower Nickol, but prospectors operating in the area during 1995 and 1996 stated that historical production had been far greater, possibly exceeding 100 kg. Only 0.34 kg of alluvial and dollied gold was recorded at Lower Nickol prior to 1962, but the extensive alluvial workings in the area suggest greater production. Likewise, gold production at Upper Nickol also appears to be understated by official production figures (0.357 kg in 1913) because the extent of underground mining is inconsistent with such low production.

All primary gold deposits on DAMPIER – BARROW ISLAND are epigenetic and structurally controlled. North of the Sholl Shear Zone (SSZ), all known deposits are close to the Regal Thrust, and are generally hosted by sheared ultramafic or mafic rocks. To the south of the SSZ, gold deposits are confined to fault zones within the Whundo Group.

Primary gold mineralization at Lower Nickol is mainly in narrow lodes that consist of quartz veinlets in sheared ultramafic schist of the Ruth Well Formation. Inspection of the old workings over an east–west strike length of approximately 4 km, revealed that all the mineralized zones strike east-northeast, and dip south-southeast at 70–85°. The ultramafic schist is a silicified and carbonate-altered actinolite–chlorite–quartz rock with variable amounts of talc and carbonate minerals. At the eastern end of the line of workings, near the Lydia mine, gold mineralization is developed in schistose metasedimentary rocks of the Nickol River Formation. At the Lydia mine, a 15–20 cm-wide quartz vein dips 80° towards 155° through arenaceous schist. According to production records, the chief mines at Lower Nickol are Tozers and Kings. The Lower Nickol gold deposits occur beneath the Regal Thrust, and on the southern side of a later east-northeastward striking shear zone that extends northeast to Dixon Island. Most recent prospecting at Lower Nickol has concentrated on alluvial deposits. Additional information on the workings is available in Finucane et al. (1939).

The principal gold mine at Upper Nickol was Radleys Find, but shafts and test pits extend over a strike length of about 1 km. At Radleys Find, mining has followed a 0.5 m-wide quartz vein that dips 70° towards 020° within chloritized and carbonate-altered mafic schist in the Nallana Formation of the Whundo Group. The workings, now collapsed, appear to have been at least 15–20 m deep. The line of workings follows a curved splay fault related to the SSZ that is present 1 km to the north. Southeast from Radleys Find, this fault appears to dextrally displace the northeastern end of the Sholl Intrusion, suggesting that it is a late structure.

About 3 km south-southwest of Radleys Find, there are old eluvial workings and a shallow pit known as Four Ounce. The collapsed shaft at Four Ounce has exposed a quartz vein dipping 80° towards 160° through silicified metabasalt. Approximately half way between Radleys Find and Four Ounce, on the side of Roebourne–Cherratta Road, a small pit has exposed a 1 m-wide quartz vein striking 100° through chloritized metabasalt of the Nallana Formation.

The Orpheus fault system (D_4) is approximately 20 km long, extending from Radio Hill east-northeastwards to Orpheus and the SSZ. Displacement along the fault is difficult to measure because the fault is generally parallel to the strike of the Whundo Group. Gold mineralization is present east of Mount Sholl where local prospectors state that about 60 kg of alluvial gold was obtained. Old alluvial workings are also present 1 km south of Mount Sholl. Minor gold mineralization is associated with Cu–Zn mineralization at Orpheus and 1 km west-southwest of Orpheus.

Gold mining east-northeast of No 6 Well has focussed on an east-northeastward striking belt of faulting and shearing immediately beneath the Regal Thrust. The faulting continues northeastwards to the Carlow Castle mine on ROEBOURNE. About 1 km west of No 6 Well, recent mining has exposed auriferous quartz veins, up to 0.5 m wide and dipping 50° towards 290°, in carbonate-altered and silicified metabasalt of the Ruth Well Formation. A sample from one of these veins contained 7.02 g/t gold (Hickman, 2001). Workings about 4 km to the east-northeast (extending onto ROEBOURNE) are in talc–carbonate schist of the Ruth Well Formation that is intruded by felsic dykes. Here, gold mineralization is in lodes that consist of ultramafic schist with gossanous quartz veinlets. A sample from one of these lodes contained 60 g/t gold (Hickman, 2001).

Gold prospecting has also been carried out 2 km west-southwest of Bardies Tank where costeans have been cut into metabasalt that is intruded by a porphyritic granitoid dyke too small to show on the map.

BASE METALS (COPPER, LEAD, AND ZINC)

The most prospective area for copper–lead–zinc mineralization on DAMPIER – BARROW ISLAND is along the Orpheus fault system within the Whundo Group. The Orpheus copper–zinc(–silver–gold) mineralization was discovered by Dragon Resources in 1995 (Ruddock, 1999), although old workings already existed along the fault system. Mapping on ROEBOURNE (Hickman, 2002) revealed that the mineralization extends for at least 2.5 km east-northeast from Orpheus to the Bradley Well area. Gossan samples collected from Orpheus contained up to 6.8% Cu, 1.04% Zn, 45 ppm Ag, and 0.45 g/t Au (Hickman, 2001). The poorly outcropping Bradley Well gossanous zone revealed no evidence of previous exploration, but samples of gossan and quartz were found to contain up to 14.5% Zn, 2.2% Pb, 840 ppm Ag, 1.1 g/t Au, and 0.2% Cu (Hickman, 2002). About 1.5 km west-southwest of Orpheus, a gossanous quartz sample from old shallow workings contained 3.15% Cu and 1.2 g/t Au (Hickman, 2001). About 5 km west-southwest of Orpheus, another sample of gossan from the Orpheus fault system contained 0.14% Cu and 0.22% Zn (Hickman, 2001), and had been tested by old prospecting pits. Copper–zinc mineralization along the Orpheus fault system is present as sulfide lenses and sulfidic quartz veins in sheared metabasalt of the Bradley Basalt in the northeast and the Tozer Formation in the southwest. The age of the faulting is about 2950–2920 Ma, but the copper–zinc mineralization may have been tectonically mobilized from concealed volcanic massive sulfide (VMS) deposits in the Whundo Group. Whundo Group VMS deposits have not been identified on DAMPIER – BARROW ISLAND, but are present south of the sheet area at Whundo and Yannery Hill on PINDERI HILLS (Collins and Marshall, 1999; Hickman and Kojan, 2003). Although most of the known copper–zinc mineralization is in narrow shear zones, and is irregularly distributed along strike, the Orpheus fault system probably merits further investigation for its mineral potential.

Other isolated copper occurrences on DAMPIER – BARROW ISLAND are small deposits associated with lenticular quartz veins, and these appear to have limited economic potential. Examples include deposits at Devil Creek, Canhams, and Tom Well, all of which are described in Marston (1979) and Ruddock (1999). During the mapping of PRESTON (Strong et al., in prep.) gossans were discovered 3 km west-southwest of Slopers Well, and 4 km southeast of James Point. The most northerly of the two Slopers Well localities (MGA 441700E 7688950N) includes gossanous quartz within ferruginous chert that contains up to 7% Zn and 0.6% Cu (GSWA 148711). The southern locality (MGA 442200E 7688100N) includes limonitic chert with 0.5% Zn (GSWA 148716). The gossan located southeast of James Point (GSWA 148896, from MGA 415800E 7677800N) is hosted by the Jeerinah Formation, and contains 1125 ppm Zn. All these mineral occurrences justify further examination.

NICKEL AND COPPER IN LAYERED INTRUSIONS

Westfield Minerals discovered nickel–copper mineralization near Radio Hill in 1972, but it was not until 1983 that the present nickel–copper deposit at Radio Hill mine was discovered by AGIP and SAMIM. Mining during the late 1990s produced over 43 000 t of nickel concentrate (Ruddock, 1999). Measured and indicated resources are estimated to be 0.976 Mt at 2.58% Ni, 1.28% Cu, and 0.11% Co (Ruddock, 1999). Massive lenses and stringer networks of pentlandite, pyrrhotite, and chalcopyrite mineralization occur in gabbro, close to the contact with an ultramafic layer of the c. 2925 Ma Radio Hill Intrusion. Descriptions of the Radio Hill mineralization are provided by de Angelis et al. (1987) and Hoatson et al. (1992).

Whim Creek Consolidated NL discovered nickel–copper mineralization in the Mount Sholl Intrusion in 1970. Total resources of the A1, B1, and B2 deposits are currently estimated to be 4.8 Mt at about 0.7% Ni and 0.88% Cu (from data in Ruddock, 1999), with the Sholl B2 deposit containing most of these resources. The mineralization consists of aggregates of pentlandite, pyrrhotite, and chalcopyrite within a thin gabbroic marginal layer along the northwestern margin of the intrusion. This gabbroic layer underlies a thicker ultramafic layer of peridotite and pyroxenite that forms the main basal section of the Mount Sholl Intrusion. Mathison and Marshall (1981) and Marston (1984) provided additional information on the Mount Sholl deposits.

Minor copper mineralization is present in metabasalt at the contact with gabbro of the North Whundo Intrusion, and is assumed to be related to the intrusion (Ruddock, 1999).

NICKEL AND COPPER IN KOMATIITE

The Ruth Well nickel–copper deposits were discovered by Whim Creek Consolidated NL in 1971, and have been described by Tomich (1974) and Marston (1984). Mineralization comprises violaritized pentlandite, pyrrhotite, gersdorffite, niccolite, chalcopyrite, and magnetite, within serpentinized extrusive peridotite of the Ruth Well Formation. This association suggests that the deposits are of a similar type to the extrusive Kambalda nickel deposits of the eastern Yilgarn Craton. However, Ruddock (1999) noted that the mineralization may be within a tectonic slice of the Andover Intrusion that has been faulted into the Ruth Well Formation on the northern side of the Sholl Shear Zone. One diamond drillhole intersected 8.38 m of mineralization averaging about 3.52% Ni and 0.78% Cu (Marston, 1984). Although high grade, the deposits are relatively small, probably containing resources of no more than 70 000 t at about 3% Ni (Marston, 1984).

PLATINUM GROUP ELEMENTS

Platinum group elements (PGE) and minor gold are associated with nickel–copper sulfide deposits in the layered mafic–ultramafic intrusions of the west Pilbara (Hoatson et al., 1992). On DAMPIER – BARROW ISLAND, this type of mineralization has been identified in the Mount Sholl, Radio Hill, and Dingo Intrusions. Additional information is provided by Ruddock (1999).

IRON ORE

Although DAMPIER – BARROW ISLAND contains BIF of the Cleaverville Formation and of the Brockman Iron Formation, no economic concentrations of magnetite iron ore have been identified. Small deposits of pisolitic iron ore (*Czaf*) at Twin Table Hills are probably uneconomic.

On FORTESCUE, about 10 km south of James Point, large deposits of magnetite have recently been discovered in the Brockman Iron Formation, and mining plans (Austeel Pty Ltd.) include construction of a conveyor to carry ore to a proposed loading facility at Cape Preston (Department of Mineral and Petroleum Resources, 2002a).

SEMIPRECIOUS STONE

Bright-green chert has been excavated 3 km north of Edna Well for use as an ornamental stone. The chert is close to an ultramafic unit within the Ruth Well Formation, and its green colour is due to a chromium impurity.

LIMESAND AND LIMESTONE

A review of limestone and limesand resources of Western Australia (Abeysinghe, 1998) includes a summary of deposits in the Dampier Archipelago. Kojan (1994) noted that most of the resources are largely within nature and conservation reserves. About 379 000 t of limesand was quarried at Hearson Cove for use in the Dampier iron-ore pelletizing plant (Kojan, 1994), but since 1980 this area has been closed and rehabilitated. Calcium carbonate content of the deposit was approximately 80%, with the main impurity being silica. Between 1974 and 1992 about 173 000 t of limesand was mined at Cleaverville (Kojan, 1994). Similar deposits are present at numerous places along the coast within dunes of shelly sand (*Qhms*).

Most limestone resources occur in the islands of the Dampier Archipelago, particularly Legendre Island, where siliceous limestone (*Qpmb*) contains potentially mineable deposits (Abeysinghe, 1998). Baxter (1972) reported that $CaCO_3$ content of the limestone units on DAMPIER – BARROW ISLAND ranged up to 87.5%. Because most of the limesand and limestone deposits are along the coast, environmental considerations place serious constraints on their potential for mining.

SAND

Dominantly eolian sand has been obtained from sand and gravel pits east of Karratha and from sand pits on the southern side of the Burrup Peninsula, south of Dampier, mostly for house foundations and fill.

ROAD BUILDING AND CONSTRUCTION MATERIALS

Road building and construction materials include river gravels, mostly obtained from localities along the Maitland River, and colluvium and weathered rock, which are typically available close to wherever gravel roads require maintenance or construction projects exist. The Gidley Granophyre has been quarried for industrial developments on the Burrup Peninsula, and has been investigated for use as 'armour stone' (Brice and Abeysinghe, 1998).

SALT

Salt mining from the solar evaporation of seawater 7 km south of Dampier commenced in 1972. Dampier Salt Limited's operations are currently capable of producing salt at about 4 Mt per annum.

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Appendix 1

Gazetteer of localities

Place name	*MGA coordinates* *Easting*	*Northing*	*Place name*	*MGA coordinates* *Easting*	*Northing*
13 Mile Well	476950	7705250	Miaree Pool	459700	7693900
Bardies Tank	490800	7697450	Mornong Well	471350	7694100
Bradley Well[(a)]	537838	7682455	Mount Ada[(a)]	516838	7686555
Bullock Hide Well	478900	7687900	Mount Leopold	460050	7679400
Byong Pool	447950	7683850	Mount Princep	479000	7693600
Canhams	486282	7683439	Mount Regal	474000	7698000
Cape Preston	417350	7696200	Mount Sholl	491600	7684700
Carlow Castle mine[(a)]	506884	7698925	Mount Wilkie	439550	7683200
Cherratta Pool	473300	7681700	Nickol River	495000	7689400
Cleaverville[(a)]	502900	7716400	Nickol River Hill	495850	7688650
Cleaverville Beach[(a)]	502000	7716500	Nickol Well[(a)]	500050	7703700
Cleaverville Creek	498000	7714500	No 6 Well	497700	7695000
Cockatoo Bore	479750	7683400	North Whundo	495439	7678096
Cockatoo Creek	480000	7685000	Orpheus	499608	7687559
Dampier	470000	7715000	Pelican Point	437500	7697450
De Witt Hill[(a)]	535000	7688200	Possum Bore	469250	7681050
Devil Creek	439800	7687000	Prinsep Well	478500	7696300
Dixon Island[(a)]	506000	7718500	Radio Hill[(a)]	486500	7678000
East Lewis Island	464000	7721000	Radio Hill mine	486430	7679570
Edna Well	474900	7695600	Radleys Find	489482	7688545
Enderby Island	483500	7721100	Roebourne[(a)]	515138	7703155
Eramurra Creek[(a)]	422800	7673500	Rosemary Island	458000	7735000
Four Ounce	487439	7685716	Ruth Well	484900	7694050
Gaffs Well	490200	7679800	Sholl B1 deposit	489609	7687776
Gnoorea Soak	434050	7691100	Sholl B2 deposit	488156	7686189
Gnoorea Well	433600	7689000	Slopers Well	444200	7689900
Gwen Creek	492400	7708000	Sloping Point	486200	7730350
Hearson Cove	479000	7718500	Sunday Peak	434250	7682450
James Point	413250	7681050	Tobacco Well	487800	7702250
KAP2	440700	7689350	Toorare Pool	477000	7679850
Karratha	482600	7706500	Tom Well	482788	7703246
Karratha Airport	476000	7710000	Tozers Well	495050	7681300
Karratha Homestead	465800	7691600	Tullawar Pool	437200	7679800
Legendre Island	492730	7742970	Twin Table Hills	484139	7688446
Lower Nickol (mining centre)	497000	7706000	Upper Nickol (mining centre)	489000	7686500
Lydia mine	499600	7706600	White Quartz Hill[(a)]	529638	7690055
Maitland River	459500	7694300	Whundo[(a)]	492460	7669750
Marcia Bore	453650	7683650	Yannery Hill[(a)]	489000	7674100
McKay Creek	427350	7682000	Yerwararron Hill	441050	7691900
Melford Creek	452200	7692300			

NOTES: (a) Place outside sheet area

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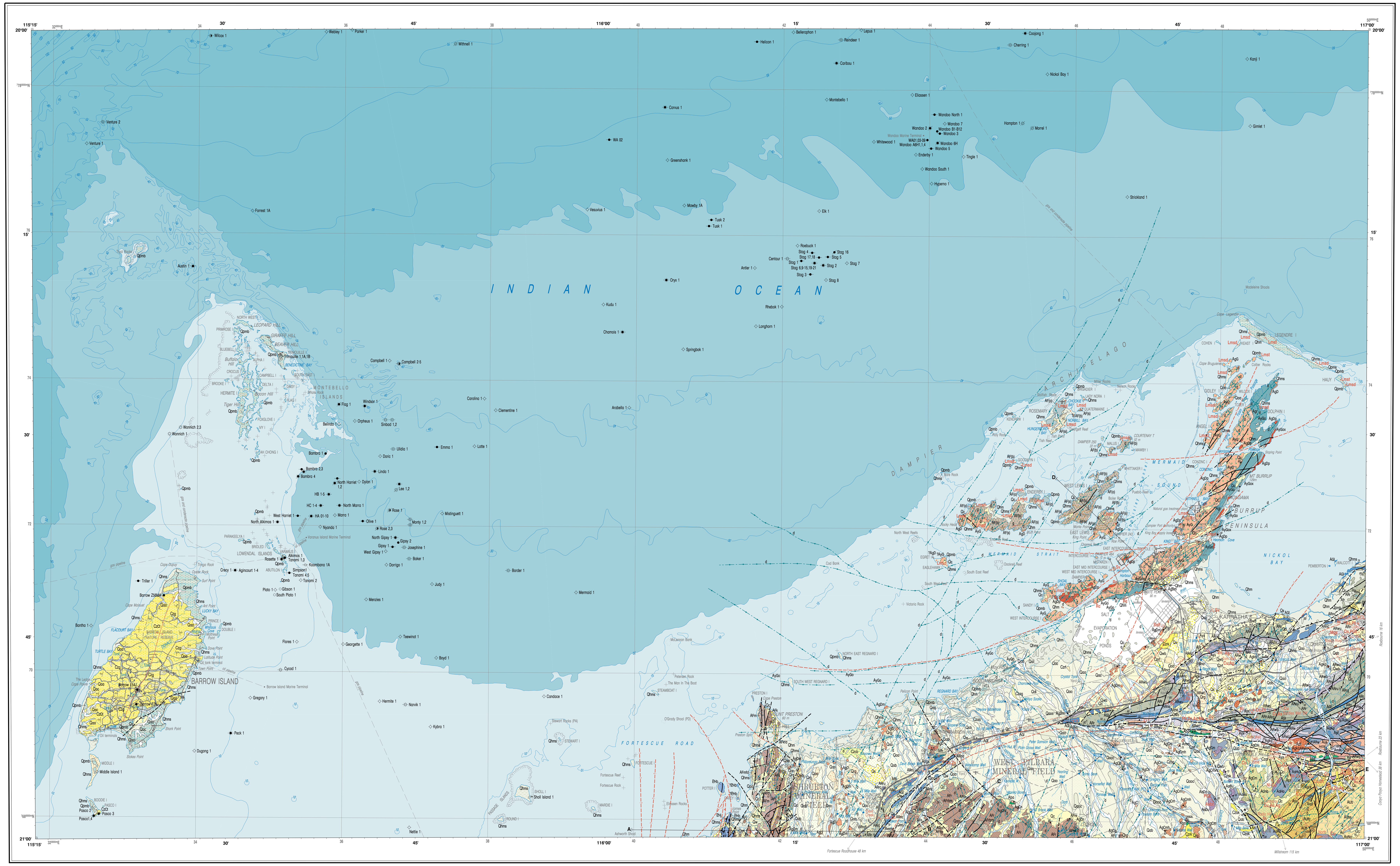
HICKMAN, STRONG   DAMPIER – BARROW ISLAND, W.A., SECOND EDITION   EXPLANATORY NOTES

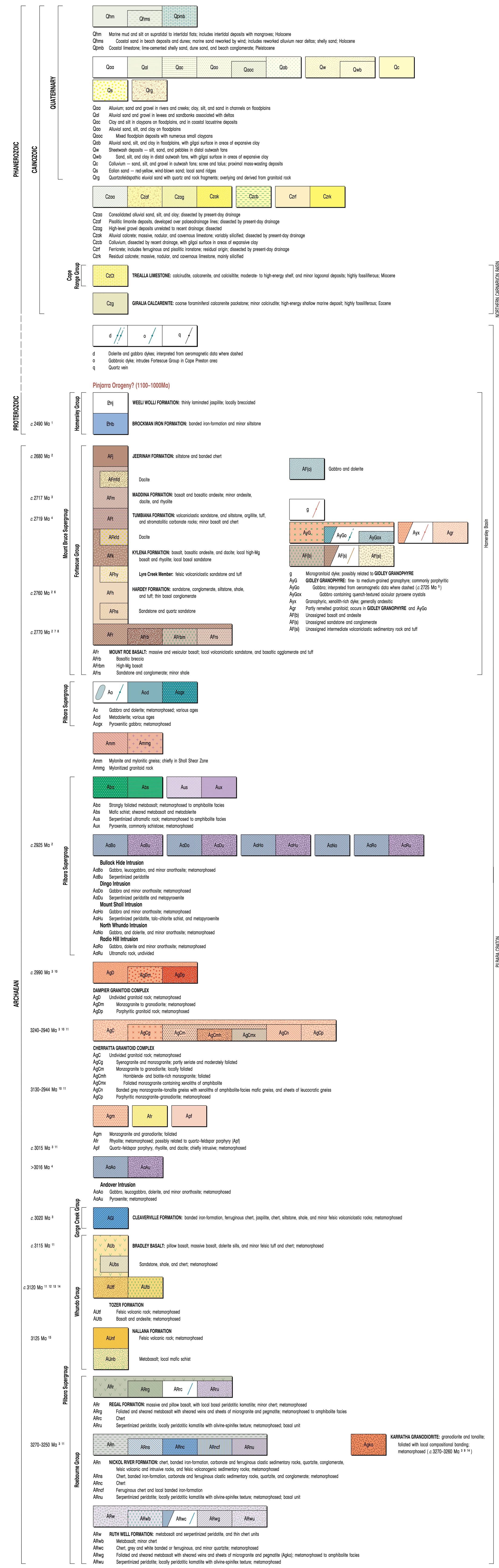
AUSTRALIA 1:250 000 GEOLOGICAL SURVEY

DAMPIER — BARROW ISLAND

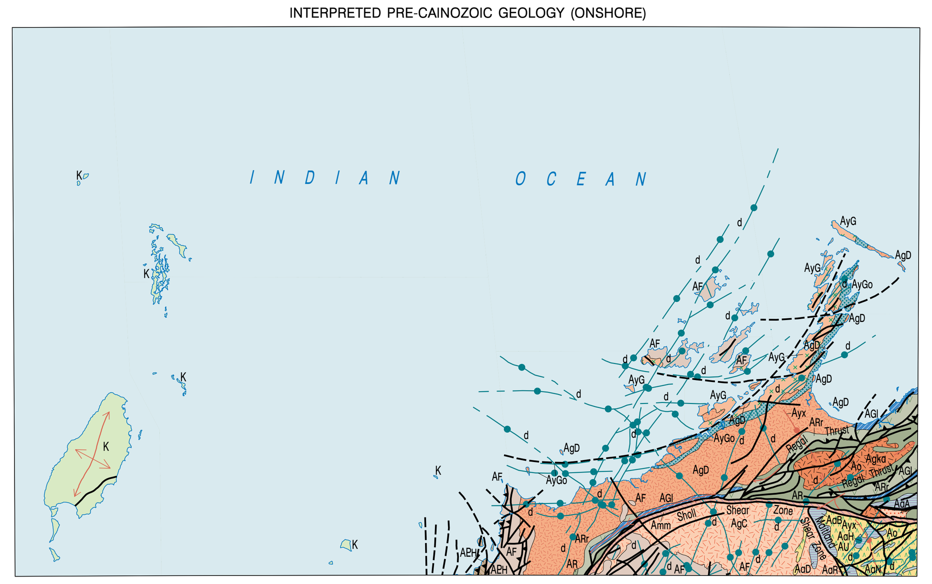
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

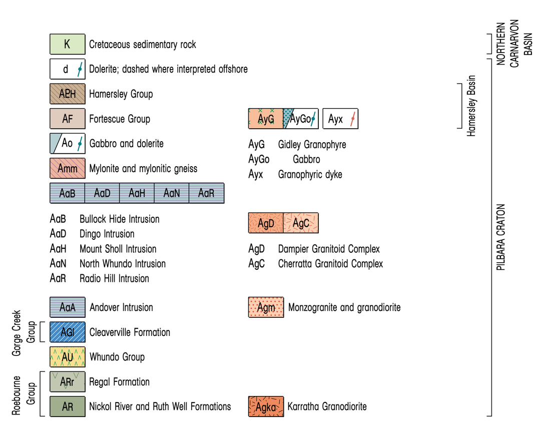
SHEET SF 50-2 AND PART OF SHEET SF 50-1





INTERPRETED PRE-CAINOZOIC GEOLOGY (ONSHORE)





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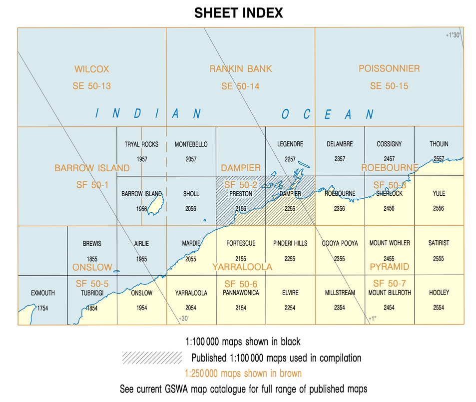
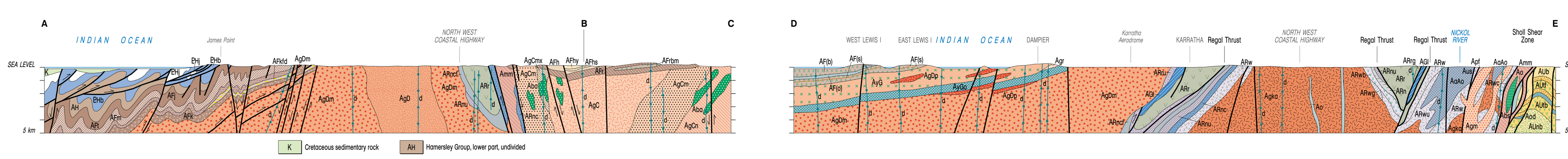
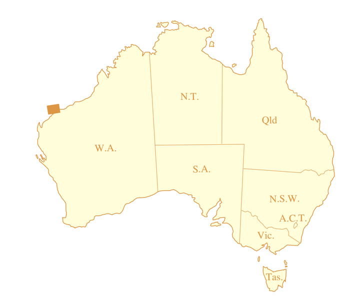
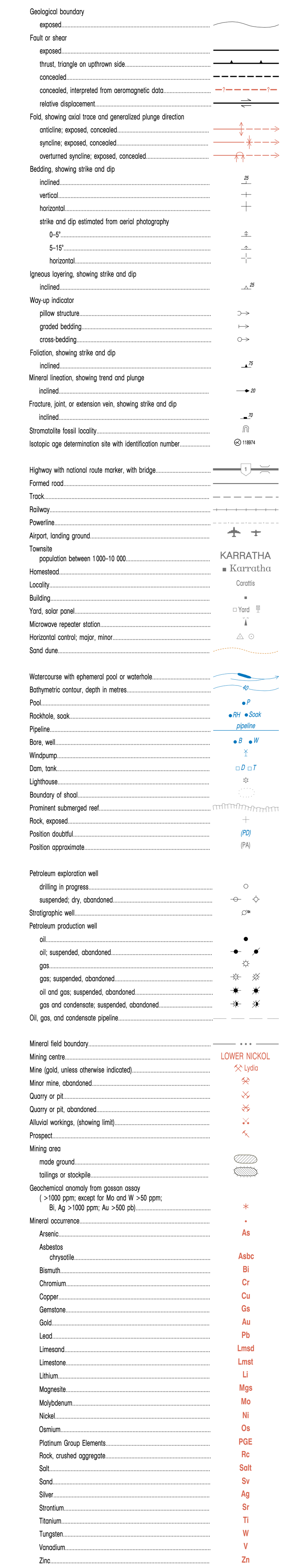


DIAGRAMMATIC SECTIONS

NATURAL SCALE







Geology by A. H. Hickman and C. A. Strong 1997–2000

Geochronology by:

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Edited by N. Tetlaw and C. Brien

Cartography by D. Ladbrook, B. Williams, and K. Greenberg

Topography from the Department of Land Administration Sheet SF 50-2 and part sheet SF 50-1 with modifications from geological field survey

Bathymetric data supplied by the Department of Transport. This map is not intended for marine navigation

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Petroleum wells status accurate as at March, 2001

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The recommended reference for this map is:
HICKMAN, A. H., and STRONG, C. A., 2000, Dampier–Barrow Island, W.A. Sheet SF 50-2 and part sheet SF 50-1 (2nd edition): Western Australia Geological Survey, 1:250 000 Geological Series

Department of Industry and Resources

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PRODUCT OF THE NATIONAL GEOSCIENCE AGREEMENT

SCALE 1:250 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
BATHYMETRIC DATUM: LOWEST LOW SEA LEVEL

Grid lines indicate 20 000 metre interval of the Map Grid Australia Zone 50

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

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

DAMPIER — BARROW ISLAND

SHEET SF 50-2 AND PART OF SHEET SF 50-1

SECOND EDITION 2001

Version 1.1 — July 2003