EXPLANATORY NOTES

GOVERNMENT OF WESTERN AUSTRALIA

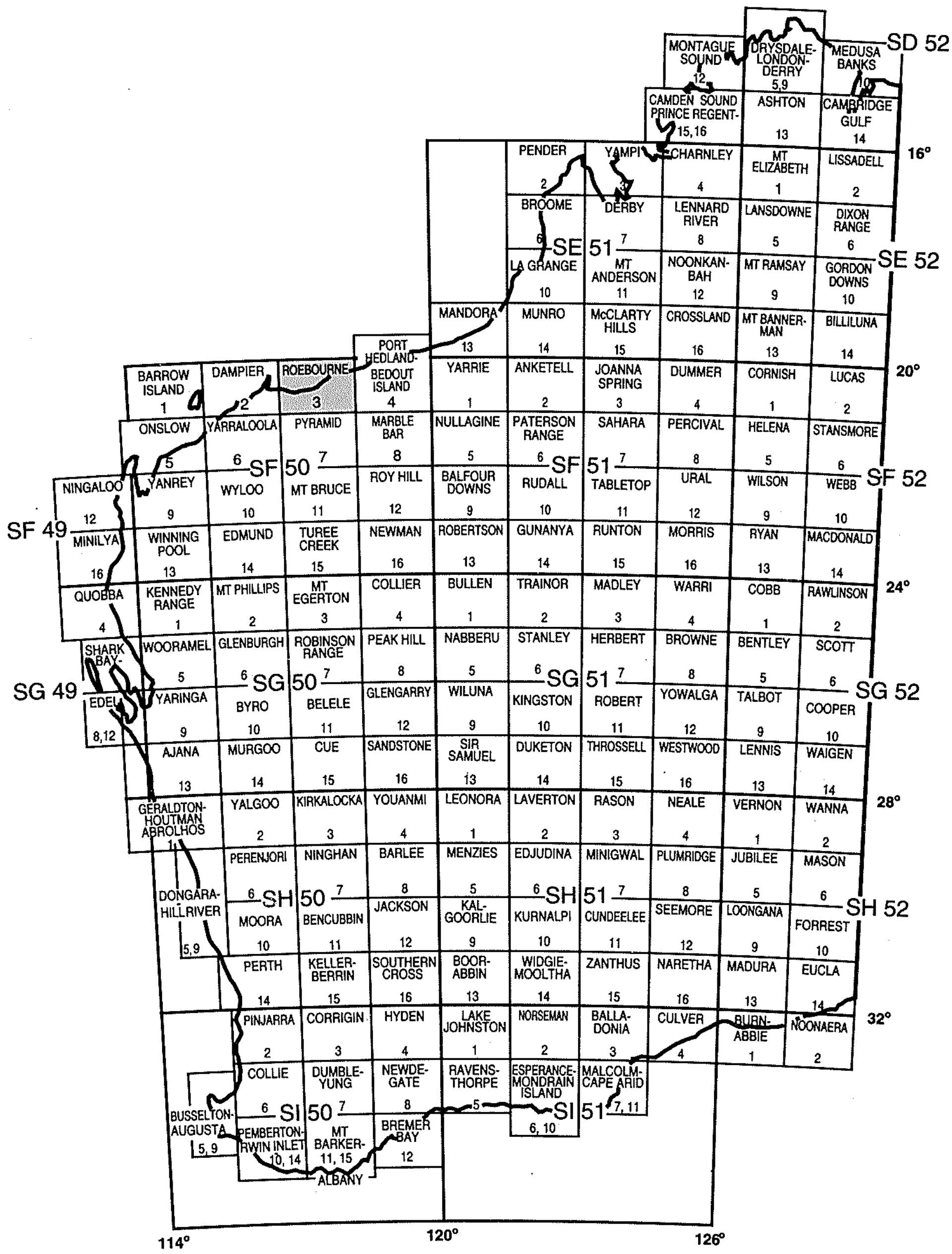
# GEOLOGY OF THE YULE 1:100 000 SHEET

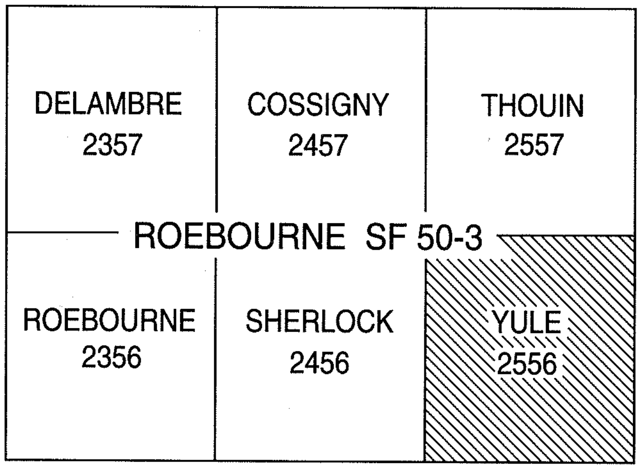
by R. H. Smithies

1:100 000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

DEPARTMENT OF MINERALS AND ENERGY

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# GEOLOGY OF THE YULE 1:100 000 SHEET

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**Cover photograph:**

**Leucocratic phase of the Peawah Granodiorite, south of Palyarra Rock, in the far southwestern corner of the YULE 1:100 000 map sheet.**

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# Geology of the Yule 1:100 000 sheet

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## Abstract

The YULE 1:100 000 sheet lies in the northwestern part of the Archaean Pilbara Craton, and contains rocks belonging to the Pilbara granite–greenstone terrain. Rocks of the Whim Creek Group outcrop immediately west of the sheet area, and were previously thought to comprise the youngest units of the Pilbara Supergroup. However, recent geochronological data have shown that clastic sedimentary rocks of the De Grey Group, which dominate outcrops of the supergroup on YULE, were deposited at the same time (about 3000 Ma) as the Whim Creek Group. Locally, the De Grey Group includes coarse- to fine-grained subarkose, wacke, and shale.

The Mallina Shear Zone trends eastward across the southern half of the sheet. Most rocks of the De Grey Group north of the shear zone are wacke and shale of the Mallina Formation. The De Grey Group south of the shear zone includes rocks that can be confidently assigned to the Constantine Sandstone, which underlies the Mallina Formation, but most rocks cannot be confidently assigned to either formation.

Peridotite and other ultramafic rocks belonging to the Millindinna Intrusion intrude the De Grey Group in the southern half of the sheet. Nested plutons of alkali granite form the c. 2945 Ma Portree Granitoid Complex, which intrudes the De Grey Group in the northern part of the sheet, whereas the c. 2950 Ma Peawah Granodiorite intrudes this group in the southwestern part.

The major north-northeasterly trending folds that characterize the areas to the west (SHERLOCK and MOUNT WOHLER) are poorly developed on YULE, with the main structures of the area being tight, upright, east-northeasterly trending folds.

Gold and antimony have been mined from vein deposits within rocks of the De Grey Group in the southern part of YULE.


**KEYWORDS:** Archaean, Pilbara Craton, regional geology, De Grey Group, Mallina Formation, Mallina Shear Zone

## Introduction

The YULE[1] 1:100 000 geological sheet (SF 50-3, 2556) covers the southeastern part of the ROEBOURNE 1:250 000 sheet in the central Pilbara region, between latitudes 20°30' and 21°00'S and longitudes 118°00' and 118°30'E (Fig. 1). The sheet area overlaps both the West Pilbara Mineral Field and the western edge of the Pilbara Mineral Field.

The northern half of YULE is virtually devoid of outcrop, with only scattered exposures of shale and wacke in the east, and rare outcrops of felsic volcanic rocks and granite in the west. The regional Sholl Shear Zone trends northeasterly across the northwestern corner of the sheet area, but is recognized only as a magnetic feature.

Outcrop in the southern half of YULE is poor, except in the southwestern corner and in the east, around Mount Berghaus (AMG 510028[2]). The easterly trending Mallina Shear Zone is immediately south of Mallina Homestead, near the western edge of the sheet. The shear zone outcrops as a ridge of extensively calcretized and locally silicified shale and wacke, with minor amounts of mafic to ultramafic intrusive and extrusive rocks, and rare ferruginous shale and ironstone. The sedimentary rocks belong to the c. 3000 Ma De Grey Group of the Pilbara Supergroup, and comprise much of the outcrop on YULE. Immediately west of the Yule River, the Mallina Shear Zone is intersected by later faults and is possibly deflected northeastward towards Mount Berghaus.

Most outcrops on YULE belong to the granite–greenstone succession of the Archaean Pilbara Craton.

[1] Capitalized names refer to standard 1:100 000 map sheets, unless otherwise specified.

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

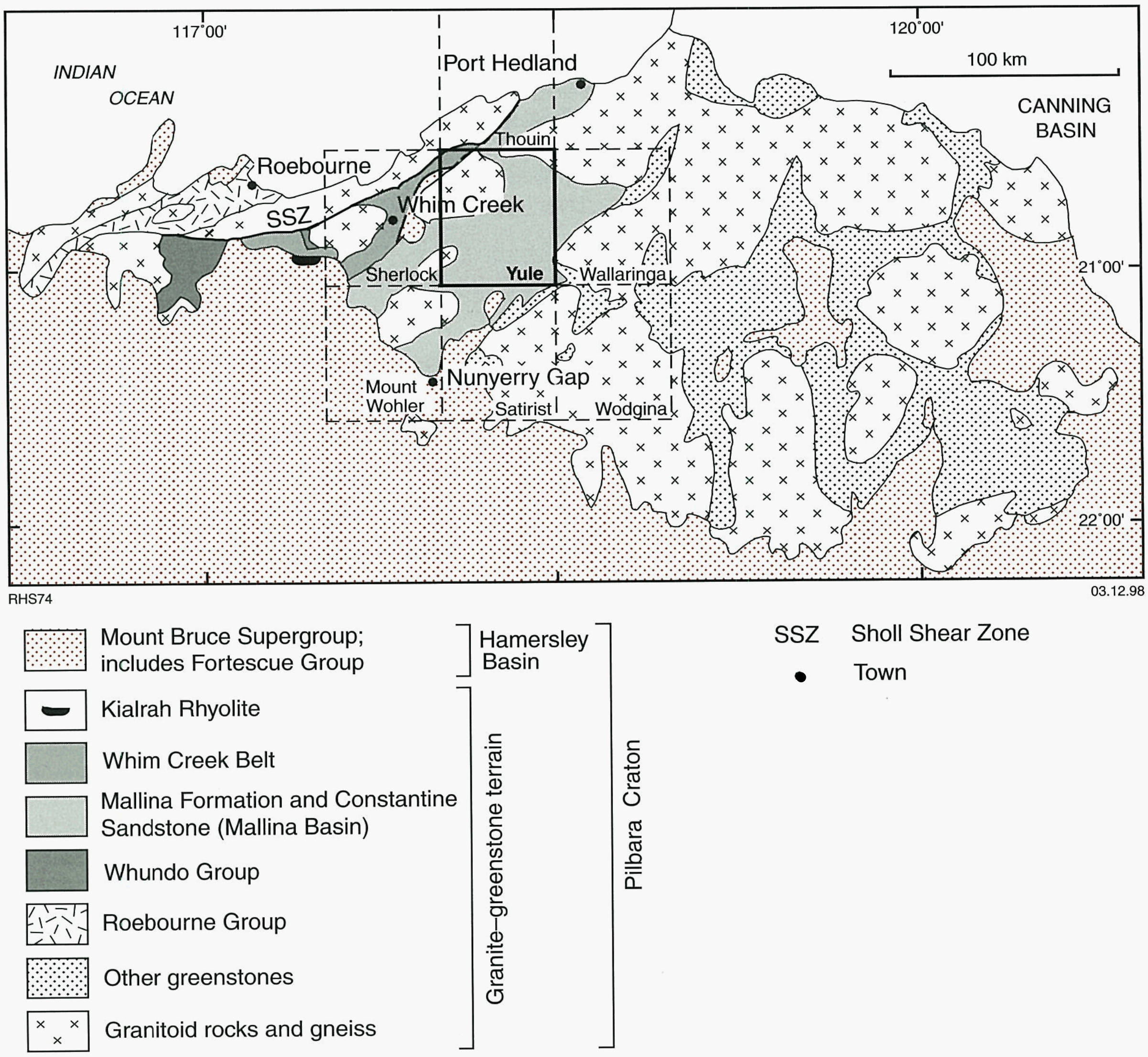



**Figure 1. Regional geological setting of YULE within the western part of the Pilbara Craton**

Two bodies of granitoid rocks outcrop: the Portree Granitoid Complex, which predominantly lies under Quaternary cover north of Mallina Homestead; and the Peawah Granodiorite, in the southwestern part of YULE. Both units intruded rocks of the De Grey Group at c. 2950 Ma (Nelson, 1997, 1998) and locally represent the youngest components of the granite–greenstone succession. Dolerite and gabbro intrusions of late Archaean to early Proterozoic age form a very minor component of YULE, and rocks of the Mount Bruce Supergroup have been removed by erosion.

## Access and landuse

The North West Coastal Highway passes through YULE (Fig. 2), linking the towns of Roebourne and Port Hedland. The Great Northern Highway passes through the northeastern part of the sheet, linking the town of Newman, to the south, with the North West Coastal Highway. The only permanent settlements are Mallina Homestead and Mundabullangana Homestead (Fig. 2). The Whim Creek Hotel is on the North West Coastal Highway at the site of the Whim Creek copper mine, about 20 km west of the sheet area on SHERLOCK (Smithies, 1998a). Mallina Station covers most of the southwestern part of YULE, whereas the northern part is within Mundabullangana Station, and the central and southeastern parts form part of Indee Station. The northernmost portion of the Yandeearra Aboriginal Reserve is in the central southern part of YULE (Fig. 2), on the western side of the Yule River. Farm tracks are well maintained and provide access to most of the area.

Grazing is the primary agricultural activity on YULE. Although there are no operating mines at present, gold and antimony have been extracted from the area, and in particular from extensive workings at Mallina (the Mallina mining centre) and the old Peawah prospect.

# Physiography

The Yule and Turner rivers are major northwesterly flowing river systems on YULE. The main period of flow is during the summer wet season. The northwestern corner of the sheet area consists of tidal flats. Most of the non-tidal land surface comprises low-lying spinifex plains. East-southeasterly trending longitudinal dunes, up to about 15 m in height, are found in the southern half of the sheet area and in the central western region, around Mount Spinifex (AMG 165010). Apart from small isolated scree-covered hills thinly scattered throughout the southern third of YULE, the only elevated land surfaces are the low hills around and south of Mount Berghaus (AMG 510028), the northeasterly trending ridges within the Yandeearra Aboriginal Reserve (referred to here as the Coorungcoorana range) and Mount Dove, and a low, easterly trending ridge south of Mallina Homestead (Fig. 2).

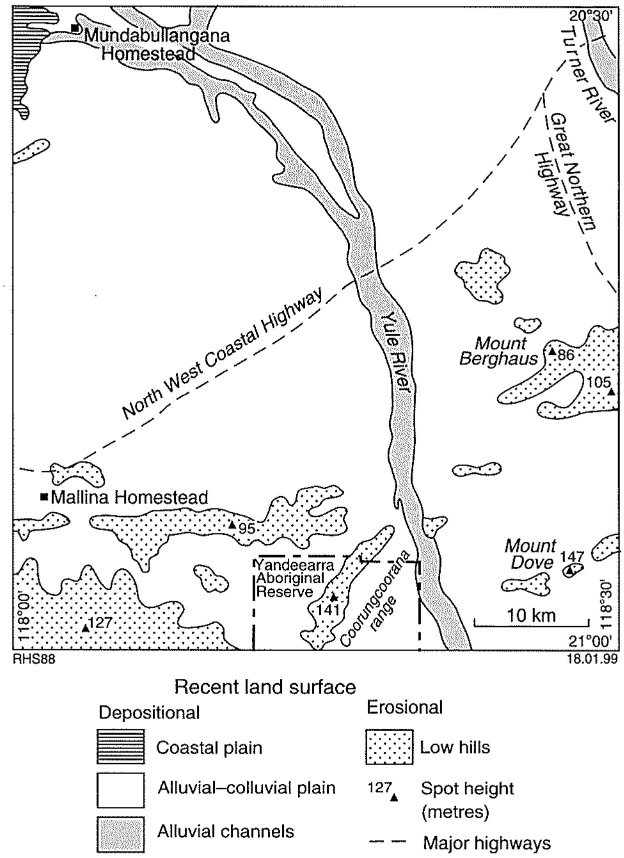



**Figure 2. Physiographical features of YULE**

# Previous investigations

Ryan and Kriewaldt (1964) suggested that the volcano-sedimentary stratigraphy of the western part of the Pilbara Craton developed as a single subsiding trough in which clastic material was derived from essentially contemporaneous stable volcanic margins. The northwestern margin lay in the Mons Cupri – Roebourne region (on SHERLOCK and ROEBOURNE) while the Teichmans region (on SATIRIST) represented the southeastern margin. The entire volcano-sedimentary succession was defined as the Roebourne Group, and appears as such on the PYRAMID 1:250 000 map sheet (Kriewaldt and Ryan, 1963). The group was correlated with the 'Warrawoona succession' of the east Pilbara region.

Further mapping in the west Pilbara region by Fitton et al. (1975) led to a major revision of the stratigraphy. The felsic to intermediate volcano-sedimentary rocks on SHERLOCK were shown to lie unconformably on the 'Warrawoona succession', and redefined as the Whim Creek Group. An unconformity was also recognized between that group and overlying voluminous basalts and high-Mg basalts of the Mount Negri and Louden Volcanics of Hickman (1990).

A thick, poorly outcropping succession of slate and fine- to coarse-grained wacke immediately south of the Whim Creek Belt was named the Mallina Formation, and the underlying sandstone was named the Constantine Sandstone (Fitton et al., 1975). Both units were correlated with the Whim Creek Group.

Hickman (1977, 1983) remapped the Whim Creek area. He suggested that the Mallina Formation and the Constantine Sandstone were older than the Whim Creek Group, and placed them in the Gorge Creek Group, which lies between the redefined Whim Creek Group and the Warrawoona Group. Subsequent studies (Krapez, 1984; Horwitz and Guj, 1986) confirmed earlier suggestions (Fitton et al., 1975) of a regional unconformity within the Gorge Creek Group, leading Hickman (1990) to relocate the Mallina Formation and the Constantine Sandstone into the newly defined De Grey Group. However, it has recently been suggested that in the western part of the Pilbara Craton, rocks of the De Grey and Whim Creek Groups are time-equivalent facies of the same depositional basin (Smithies, 1997a; Smithies et al., 1999), supporting earlier stratigraphic correlations by Fitton et al. (1975) and Horwitz (1990).

Fitton et al. (1975) grouped the mafic and layered mafic–ultramafic sills of the western part of the Pilbara Craton into the Millindinna Complex, the type area for these rocks being around Millindinna Well, 4 km south of the boundary between YULE and SATIRIST. However, at least two generations of mafic and layered mafic–ultramafic intrusions are now identified in the western part of the Pilbara Craton. The Munni Munni Intrusion and associated intrusions in the far west of the craton on DAMPIER and the Sherlock Intrusion on SHERLOCK were emplaced at c. 2925 Ma (Hickman, 1997; Smithies, 1997b). Mafic sills on MOUNT WOHLER and SATIRIST are intruded by the Peawah Granodiorite and must be at least as old as c. 2950 Ma. It is unclear if intrusion of layered mafic–ultramafic sills (which are locally spatially associated with the mafic sills on MOUNT WOHLER, SHERLOCK, and YULE) also pre-dates the intrusion of the Peawah Granodiorite, although both the mafic and layered mafic–ultramafic intrusions are collectively grouped within the redefined Millindinna Intrusion (Smithies, 1998b).

# Regional geological setting

The Pilbara Craton represents the oldest exposed major crustal element of Australia. The Archaean rocks can be divided into two components (Fig. 1): a granite–greenstone terrain, which formed between c. 3600 and c. 2800 Ma (Hickman, 1983, 1990; Barley, 1997); and the unconformably overlying volcano-sedimentary successions (Mount Bruce Supergroup) of the c. 2770 to 2300 Ma Hamersley Basin (Arndt et al., 1991).

The granite–greenstone terrain of the Pilbara Craton consists of large granitoid–gneiss complexes partially surrounded by belts of tightly folded and near-vertically dipping volcanic and sedimentary rocks typically metamorphosed to greenschist facies (i.e. greenstones). The greenstones are exposed mainly in the northern and northeastern parts of the craton, where erosion has removed all but local remnants of the Mount Bruce Supergroup. Based on correlations between well-exposed rock successions in the eastern part of the craton and lithologically similar successions in the western part (Fitton et al., 1975; Hickman, 1983), the greenstones were collectively assigned to the Pilbara Supergroup by Hickman (1983). Four lithostratigraphic groups were defined, recording about 600 million years of greenstone evolution. From oldest to youngest, these include the predominantly mafic and ultramafic volcanic rocks of the Warrawoona Group, and the predominantly sedimentary and felsic volcanic rocks of the Gorge Creek, De Grey, and Whim Creek Groups. Recent mapping and U–Pb dating using the Sensitive High-Resolution Ion Microprobe (SHRIMP) have led to major revisions of the stratigraphy of the Pilbara Craton. Two new groups (Roebourne and Whundo) have been defined in the western part of the craton for rocks that were formerly included in the Warrawoona Group (Hickman, 1997), whereas early correlations between rocks of the De Grey Group and Whim Creek Group (Fitton et al., 1975) have been substantiated (Smithies, 1997a; Smithies et al., 1999)

# Archaean geology

The Archaean geology of YULE is summarized in Figure 3. Virtually all supracrustal rocks exposed on YULE belong to the c. 3000 Ma De Grey Group, which can locally be subdivided into the Mallina Formation and the underlying Constantine Sandstone. Ferruginous chert and banded iron-formation in the southeastern corner of YULE are interpreted to underlie the De Grey Group, but no stratigraphic contacts are exposed. Feldspar–quartz porphyry of the Mons Cupri Volcanics outcrops over a very small area in the northwestern part of YULE, and is assigned to the c. 3000 Ma Whim Creek Group.

The supracrustal succession on YULE was intruded by mafic and ultramafic sills of the Millindinna Intrusion and by the Peawah Granodiorite and Portree Granitoid Complex before the entire sequence was folded. Fold hinges commonly trend northeastward.

During the Cainozoic, rocks of the De Grey Group were extensively replaced by calcrete (Fig. 4) or opaline silica, or both, within and adjacent to numerous shear zones. Where original textures are preserved, the rocks are mapped according to the pre-Cainozoic protolith. Mafic and ultramafic rocks on YULE belong either to the Millindinna Intrusion or are rare volcanic layers within the De Grey Group. However, some mafic and ultramafic rocks are locally affected by shearing to the extent that they cannot be confidently assigned to any particular stratigraphic unit.

Although all rocks of the Pilbara granite–greenstone terrain on YULE have been metamorphosed, most retain primary textures. The rocks are thus described according to their inferred protolith, and for brevity the prefix 'meta' is omitted. Where primary textures have been destroyed, metamorphic rock names are used.

# Unassigned units stratigraphically below the De Grey Group

## Ferruginous chert and banded iron-formation (*Acf*)

The unassigned ferruginous chert and banded iron-formation unit (*Acf*) outcrops at and around Mount Dove (AMG 517841), in the southeastern part of YULE, and is in faulted contact with ultramafic intrusive rocks about 3 km northeast of Mount Dove. Magnetic data indicate that the trend of the ferruginous chert and banded iron-formation unit and of the ultramafic rock swings to the south-southeast at Mount Dove, and outcrop of both units is again encountered in the northeastern corner of SATIRIST.

The rocks consist either of 1–2 cm-thick alternating bands of magnetite-bearing and magnetite-free chert or more distinct bands, up to 1 cm in thickness, of aggregated euhedral magnetite alternating with magnetite-poor chert bands. A layer-parallel spaced cleavage is developed, along which magnetite is replaced by goethite.

# Whim Creek Group

## Mons Cupri Volcanics (*Acf*)

Rare outcrops of feldspar–quartz porphyry in the northwestern part of the sheet can be traced westward onto SHERLOCK, where this rock was assigned to undivided felsic volcanic rocks within the Mons Cupri Volcanics of the Whim Creek Group (*Acf;* Smithies, 1997b). The volcanic rocks underlie rocks of the Cistern Formation, which has been dated at c. 3010 Ma (Nelson, 1997), and unconformably overlie rocks of the Cleaverville Formation, dated at between c. 3015 and 3020 Ma (Hickman, 1997).

The feldspar–quartz porphyry contains about 15% phenocrysts, predominantly of plagioclase, with subordinate quartz and rare microcline. Flow banding is locally well developed and planar, shallow-dipping concentrations of vesicles possibly represent the tops of individual flows.

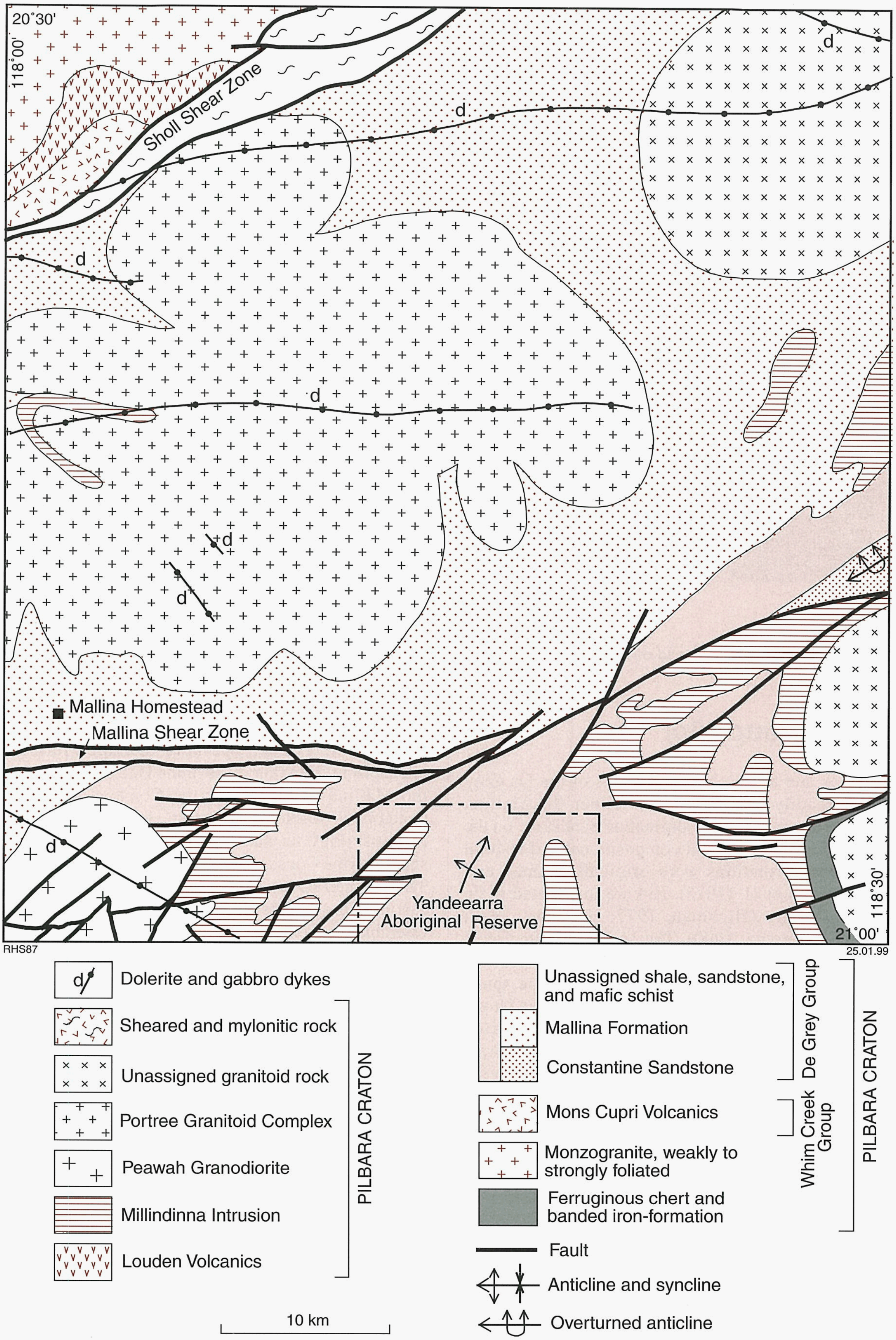



**Figure 3. Solid geology interpretation of YULE**

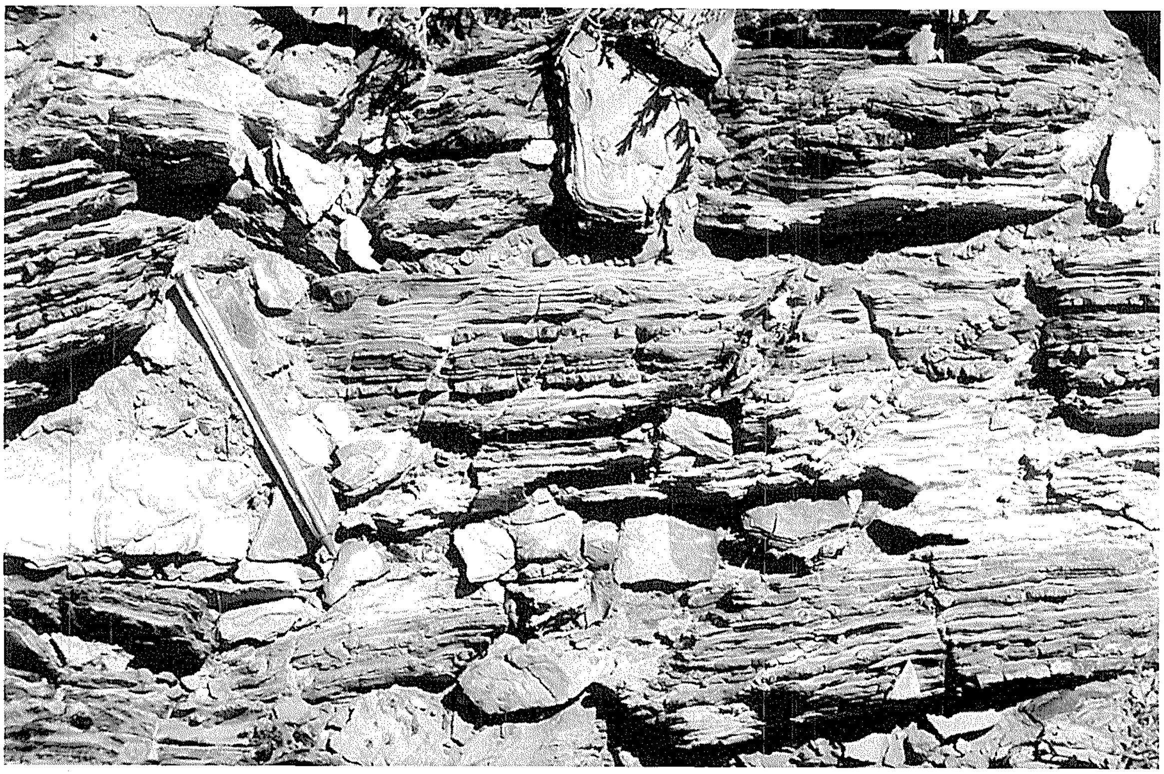



**Figure 4. Calcretized outcrop of wacke of the De Grey Group from within the Mallina Shear Zone**

## De Grey Group (*AD*)

On SHERLOCK and MOUNT WOHLER, rocks of the De Grey Group are readily subdivided into either the Mallina Formation or the underlying Constantine Sandstone on the basis of distinct and persistent compositional and textural features. Both formations were originally named and defined by Fitton et al. (1975), and are interpreted to be of turbiditic origin (Hickman, 1977; Eriksson, 1982; Barley, 1987; Horwitz, 1990). The Mallina Formation is primarily a succession of interbedded, well-graded, medium- to fine-grained wacke and shale, with rare, thick, massive units. In contrast, the Constantine Sandstone comprises medium- to coarse-grained, poorly sorted subarkose to wacke, including common conglomerate layers, and is considerably more thickly bedded than the Mallina Formation. The distinctions between these formations are probably a combined result of differing environments of deposition and source regions. The Constantine Sandstone on MOUNT WOHLER shows features consistent with deposition on the upper-fan region of a submarine fan (Eriksson, 1982; Smithies, 1998c), whereas the Mallina Formation shows features more typical of deposition on a proximal–lobe environment of a submarine fan, with transition to a basin-plain environment (Smithies et al., 1999).

Nevertheless, it has been recognized on MOUNT WOHLER (Smithies, 1998b) that rocks closely resembling those of the Mallina Formation locally formed a volumetrically significant, but never dominant, component of some successions assigned to the Constantine Sandstone. Mapping on SATIRIST and YULE identified further complications in assigning rocks of the De Grey Group to either the Mallina Formation or the Constantine Sandstone. Outcrops of wacke on both map sheets are locally similar in mineralogy to wacke of the Mallina Formation, but similar to the Constantine Sandstone in terms of grain size. These outcrops also include rare pebble beds and lack associated shale interbeds, and on that basis further resemble the Constantine Sandstone. Similarly, quartz-rich wacke and subarkose in the southwestern part of YULE are compositionally similar to the Constantine Sandstone, but are thinly bedded, well-graded, and show a range in grain size more characteristic of the Mallina Formation. Consequently, it is clear that the distinction between the Mallina Formation and the Constantine Sandstone is not always simple or even significant, and it is likely that the two formations are locally gradational. As a result, many rocks of the De Grey Group on YULE are not assigned to either formation. Only where outcrops closely resemble rocks of the Mallina Formation or Constantine Sandstone, as characterized on SHERLOCK and MOUNT WOHLER, are they mapped as either on YULE.

The thickness of units belonging to the De Grey Group cannot be established from exposures on YULE. However, estimates of the maximum thickness of the Mallina Formation east of YULE vary from 2.5 km (Fitton et al., 1975) to 10 km (Miller, 1975), whereas the maximum thickness of the Constantine Sandstone on MOUNT WOHLER is estimated to be about 3.5 km (Smithies, 1998c).

The maximum age of the De Grey Group in the western part of the Pilbara Craton is constrained by an age of c. 3015 Ma from a felsic volcanic sandstone that unconformably underlies the group on MOUNT WOHLER (Smithies, 1998b). A maximum depositional age of c. 3000 Ma for the Mallina Formation was obtained from detrital zircons in a sample of wacke from SHERLOCK (Nelson, 1997). Smithies and Champion (1998) suggested that feldspar(–hornblende) porphyry forming sills, dykes, and rare layers of fragmental rock within the upper part of the De Grey Group was co-magmatic with the Peawah Granodiorite, which was dated by Nelson (1997) at c. 2950 Ma. Some of the layers of fragmental rock are interpreted here to be of either volcanic or volcaniclastic origin, and therefore the intrusive age of the Peawah Granodiorite may also represent the maximum depositional age of the upper part of the De Grey Group.

## Constantine Sandstone (*ADc, ADcs*)

Poorly sorted subarkose and wacke (*ADcs*) that is assigned confidently to the Constantine Sandstone forms small scattered outcrops at three localities: at Mount Berghaus (AMG 510028) in the eastern part of the sheet; on the northwestern side of the Coorungcoorana range in the southern part of the sheet; and along the southern side of the Mallina Shear Zone about 13 km west of the Yule River. The outcrops along the southern side of the Mallina Shear Zone also include numerous lenses of conglomerate that are up to 3 m thick and contain abundant rounded clasts of up to cobble-sized chert.

Medium- to coarse-grained subarkose forms the major component of the poorly sorted subarkose and wacke unit (*ADcs*). Grains of quartz and rare plagioclase are angular to subrounded, and supported by a matrix of quartz, sericite, chlorite, plagioclase, and clay minerals. Green (fuchsitic) and black chert fragments are locally common and, in rare cases, carbonate–serpentine–magnetite clasts are also found. The wacke contains angular to subrounded grains of quartz, plagioclase, and chert fragments and rare perthitic K-feldspar, in a sericite- and chlorite-rich matrix that also contains clay minerals and minor amounts of tourmaline.

Undivided Constantine Sandstone (*ADc*) does not outcrop on YULE, but is interpreted to be present at depth.

## Mallina Formation (*ADm*)

The interbedded shale, siltstone, and medium- to fine-grained wacke (*ADm*) unit, confidently assigned to the Mallina Formation, forms most outcrops of the De Grey Group north of the Mallina Shear Zone. However, no rocks south of the shear zone can be confidently assigned to this formation. Rocks of the Mallina Formation recrystallized close to the Portree Granitoid Complex. Biotite replaces chlorite at lower grades of contact metamorphism, but adjacent to the Portree Granitoid Complex, the shale is converted to hornfels containing porphyroblasts of andalusite or cordierite, or both.

Shale within the Mallina Formation is commonly laminated and ferruginous. Angular silt-sized grains of chert and quartz are common, and plagioclase (pseudomorphed by calcite) is rare. Clay minerals comprise the bulk of the groundmass and are accompanied by abundant chlorite, sericite, quartz, and rare zoisite. There is a prominent slaty cleavage defined by the alignment of mica. Carbonate minerals locally overprint the slaty cleavage and may comprise up to 50% of some rocks.

The wacke component of the Mallina Formation has a grain size range from sand to silt, and individual beds commonly fine upward. The rocks are commonly poorly sorted, and grains range from angular to subrounded. The abundance of quartz commonly exceeds that of feldspar. Lithic fragments are abundant, particularly in the coarser grained rocks. The dominant lithic component is grey chert, but fragments of shale and basalt are also found. The matrix is rich in clay minerals and chlorite with lesser amounts of quartz, plagioclase, biotite, epidote, zoisite, and pyrite. The rocks are commonly iron stained, and some are strongly carbonated.

## Unassigned units (*AD, ADh, ADhil, ADt, ADtq, ADtf, ADbm, ADbx*)

Laminated shale with rare layers of poorly sorted subarkose (*ADh*) forms small outcrops south of the Mallina Shear Zone (e.g. AMG 244865). The shale consists of quartz, chlorite, sericite, and rare epidote and goethite (after pyrite). Individual laminations reach a maximum thickness of 3 mm and are defined by variations in the abundance of chlorite. Poorly sorted, fine- to medium-grained subarkose forms layers up to 1 m thick, and locally shows well-developed grading.

Metamorphosed laminated shale and siltstone (*ADhil*) is locally ferruginous or highly chloritic, or both, and includes layers of metamorphosed ironstone, chlorite–quartz schist, chert, and wacke. This unit is a combination of two distinct rock types that are almost invariably interbedded in various proportions; neither independently forms outcrops large enough to show at map scale. The two rock types are chlorite-rich laminated siltstone and shale, and ferruginous shale, locally with layers of ironstone. The combined unit outcrops south of the Mallina Shear Zone, predominantly on the western side of the Coorungcoorana range (e.g. AMG 322830). The chlorite-rich siltstone and shale consists of quartz and chlorite, with lesser amounts of sericite and rare epidote, goethite, and biotite. Biotite, where present, forms ragged porphyroblasts that overprint primary layering and locally define a late foliation. Chlorite is either randomly distributed throughout the rock, concentrated in cleavage domains that separate microlithons of quartz and chlorite, or defines the primary bedding-parallel lamination, with near-monomineralic layers of chlorite, up to 2 mm in thickness, passing either gradationally or abruptly into quartz–chlorite layers. Layers of chlorite and chlorite–quartz schist outcrop locally, and are up to 30 cm in thickness. Chlorite-rich siltstone locally resembles light-green chert. It is possible that many of the finely laminated white chert layers

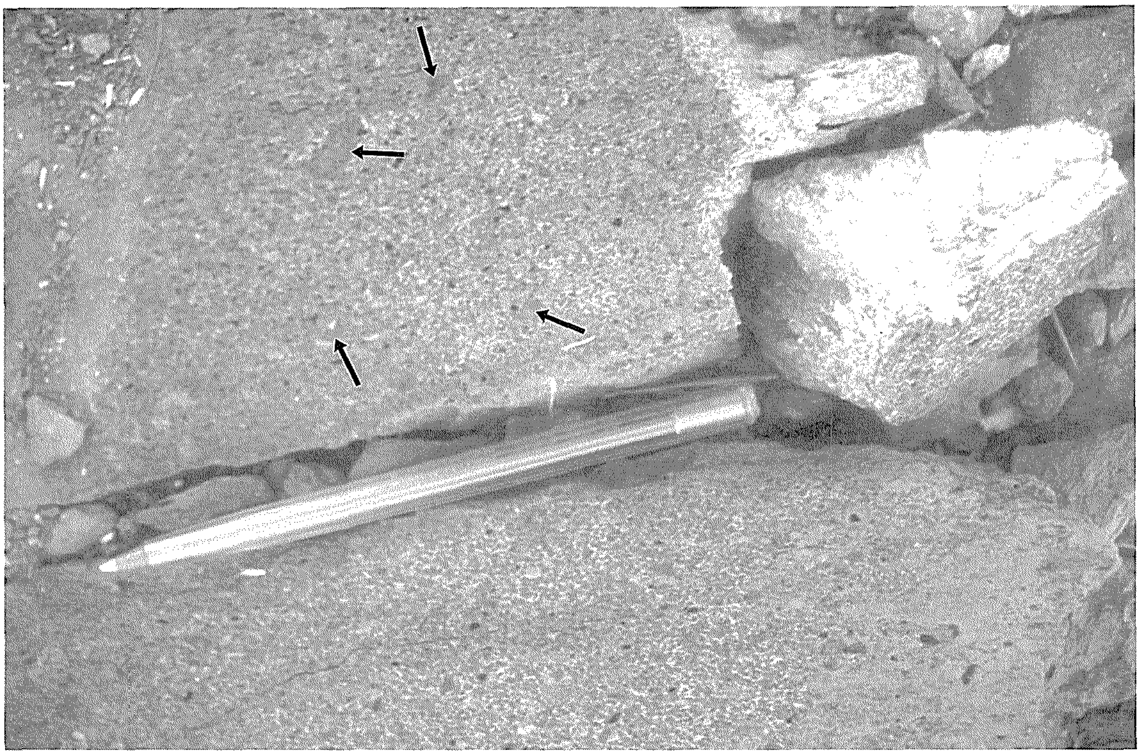



**Figure 5. Medium-grained wacke from the De Grey Group containing abundant angular lithic clasts of mafic material (arrowed), now dominantly chlorite schist. The mafic clasts possibly indicate syn-sedimentary reworking of basalt or high-Mg basalt**

locally forming interbeds up to 10 cm thick are silicified chlorite-rich siltstone.

Many samples of chlorite-rich siltstone and shale contain randomly distributed clasts of subangular to subrounded quartz up to 1 mm in diameter. Rarely, the siltstone and shale unit grades into wacke, as the abundance of quartz clasts increases and lithic fragments become common. The lithic fragments include shale, arkose, and chert, but ragged fragments of chlorite schist, up to 3 mm in diameter, are most abundant (Fig. 5).

On YULE and SATIRIST layers of metamorphosed high-Mg basalt (*ADbm*) form an unassigned component of the De Grey Group (*AD*) and are locally extensively recrystallized to chlorite(–serpentine) schist. On SATIRIST thin flow units of high-Mg basalt are locally interlayered with units of laminated shale and siltstone (*ADhil*). It is likely that the abundance of chlorite and the presence of fragments of chlorite schist in laminated shale and siltstone (*ADhil*) from both SATIRIST and YULE can be at least partly attributed to the sedimentary reworking of syn-depositional high-Mg basalt.

Metamorphosed high-Mg basalt (*ADbm*) is present within and south of the Mallina Shear Zone, either as isolated outcrops (AMG 305887) or outcrops close to, or in contact with, fine-grained metasedimentary units of the De Grey Group (*ADh*, *ADhil;* AMG 328835). All samples are extensively to totally replaced by combinations of chlorite, serpentine, talc, carbonate, and quartz. Most samples are also sheared, but locally preserve spinifex textures diagnostic of an extrusive origin. Preserved primary textures include euhedral phenocrysts of olivine and pyroxene (pseudomorphed by calcite, talc, and serpentine), up to 2 mm in diameter, and distinct, fine-grained pyroxene spinifex textures.

High-Mg basalt is locally interbedded with ironstone, shale, and rare wacke (*ADbx*) on a scale too fine for individual components to be represented at map scale.

Medium- to coarse-grained wacke (*ADt*) is confined to the area south of the Mallina Shear Zone and resembles, in many respects, the wacke component of the Mallina Formation, except that it is locally coarser grained and contains pebble beds and only rare interbeds of shale. It is possible that the medium- to coarse-grained wacke (*ADt*) was deposited in a slightly higher energy environment than the bulk of the Mallina Formation. However, the unit is locally associated with outcrops that can confidently be assigned to the Constantine Sandstone (e.g. AMG 313817), and on that basis, may lie at a slightly lower stratigraphic level than the rocks of the Mallina Formation. The fact that rocks of the Mallina Formation and the medium- to coarse-grained wacke (*ADt*) appear to be confined to opposite sides of the Mallina Shear Zone, which shows a south-side-up displacement, is consistent with the latter proposition.

The medium- to coarse-grained wacke (*ADt*) is commonly poorly sorted, with angular to subrounded grains. Grading is locally well developed. The abundance of quartz commonly exceeds that of feldspar. Lithic fragments are abundant and predominantly of chert and well-laminated shale. The matrix is rich in clay minerals and chlorite with lesser amounts of quartz, plagioclase, biotite, epidote, zoisite, and pyrite. The rocks are commonly iron stained, and some are strongly carbonated. Lenses containing abundant rounded clasts of chert, up to 1 cm in diameter, are locally common and reach a maximum thickness of 1 m.

Fine- to coarse-grained wacke (*ADtq*) contains abundant chert clasts, shows well-developed graded units, and locally includes shale, subarkose, conglomerate, and pebble beds. This unit is also confined to the area south of the Mallina Shear Zone, predominantly in the southwestern corner of YULE. The unit differs from the Mallina Formation in that it includes coarse-grained wacke and, unlike the medium- to coarse-grained wacke (*ADt*), it locally contains a higher proportion of shale interbeds and well-developed graded bedding. The fine- to coarse-grained wacke (*ADtq*) is also commonly more quartz-rich, sericite-rich, and chlorite-poor than both the Mallina Formation and the medium- to coarse-grained wacke (*ADt*). In the southwestern corner of YULE, the rocks in contact with the Peawah Granodiorite have undergone various degrees of contact metamorphism. The resulting hornfels typically contains garnet and biotite, but may also contain andalusite and pinitized cordierite.

Interbedded shale, siltstone, and wacke with layers of feldspar(–hornblende) porphyry of andesitic composition (*ADtf*) only outcrop in the southwestern part of YULE (AMG 169867). Phenocrysts of hornblende and plagioclase (up to 3 and 5 mm in diameter respectively) are either euhedral or broken in a fine-grained groundmass of quartz and plagioclase. Hornblende is partially altered to chlorite and actinolite, and plagioclase and groundmass phases are partially altered to sericite, carbonate, chlorite, and epidote. The porphyry also contains abundant angular fragments of shale and chert up to 3 cm in diameter. Based on the abundance of both broken phenocrysts and angular lithic fragments, the porphyry is interpreted to be either volcanic or volcaniclastic in origin. Petrographically similar rocks from SHERLOCK and MOUNT WOHLER were interpreted to include volcanic, volcaniclastic, and intrusive varieties of the porphyry (Smithies, 1997b, 1998c).

## Mafic intrusions

### Millindinna Intrusion (*AaMoe, AaMu, AaMus*)

Metamorphosed melanogabbro and pyroxenite (*AaMoe*), ultramafic schist (after peridotite; *AaMu*), and serpentinite and serpentinite–actinolite schist after dunite and lherzolite (*AaMus*) outcrop south of the Mallina Shear Zone as sills, up to 400 m thick, within unassigned sedimentary rocks of the De Grey Group. Together they form part of what was formerly named the 'Millindinna Complex' (Fitton et al., 1975), but later renamed the Millindinna Intrusion (Smithies, 1997b). Although no contacts are observed, some of the sills appear to have been intruded by the Peawah Granodiorite. On the basis of geochemical similarities, Smithies and Champion (1998) suggested that the Peawah Granodirite and at least some units of the Millindinna Intrusion were co-magmatic. Therefore, the age of at least some components of the Millindinna Intrusion cannot be significantly older than c. 2950 Ma (Nelson, 1997), the crystallization age of the Peawah Granodiorite.

Alteration and greenschist-facies metamorphism have resulted in partial to complete replacement of plagioclase by epidote and sericite, of pyroxene by actinolite, chlorite, and epidote, and of olivine by talc, serpentine, tremolite, and carbonate. Contact metamorphism near the Peawah Granodiorite has produced cummingtonite in ultramafic rock and hornblende in mafic rock.

Melanogabbro and pyroxenite typically consist of up to 60 and 85% pyroxene (now actinolite) respectively. Some samples contain serpentine and talc, suggesting an olivine-bearing protolith. The melanogabbro and pyroxenite are either discrete sills or constitute the tops of layered sills. In the former situation, the rocks may contain rounded xenoliths of peridotite and lherzolite, up to 1 m in diameter.

Ultramafic schist is dominated by medium-grained tremolite- and serpentine-rich rock (*AaMu*). Samples showing no contact metamorphism range from serpentinite (serpentine–talc–chlorite schist) through chlorite–serpentine–tremolite schist to rare tremolite–chlorite–epidote–plagioclase schist, and reflect a corresponding variation in protolith composition from ultramafic (peridotite) to mafic. The schist is derived predominantly from ultramafic components of the Millindinna Intrusion.

Massive to weakly foliated serpentinite or serpentine–tremolite(–talc–carbonate–chlorite) rock (*AaMus*) is either metamorphosed dunite, consisting almost entirely of cumulate-textured olivine, or lherzolite. The lherzolite contains crystals of pyroxene (now tremolite and chlorite), up to 1 cm in diameter, that poikiolitically enclose olivine. The abundance of pyroxene increases towards contacts with pyroxenite.

## Unassigned rocks younger than the De Grey Group

### Talc–carbonate schist (*Aut*)

Talc–carbonate(–serpentine) schist (*Aut*) forms small outcrops (e.g. AMG 228882 and 133867) within and south of the Mallina Shear Zone. The rock is deformed and recrystallized to the extent that the protolith cannot be confidently distinguished, although rocks of the Millindinna Intrusion and high-Mg basalt of the De Grey Group are obvious possibilities.

## Metamorphosed grey chert (*Acc*)

A single outcrop of metamorphosed grey chert (*Acc*) about 1.5 km north of Langenbeck Well (AMG 212827) lies along the extension of an east-northeasterly trending shear, and is the result of silicification of sheared rocks belonging to the De Grey Group. The grey chert chiefly replaces sheared clastic sedimentary rocks.

# Felsic intrusions

## Peawah Granodiorite and related diorite (*Agpe, Agpes, Agpee*)

The Peawah Granodiorite (*Agpe*) intruded rocks of the De Grey Group at c. 2950 Ma and is exposed in the southwestern corner of YULE. The rock consists of medium- to coarse-grained, equigranular, hornblende–biotite granodiorite and subordinate tonalite. The rock contains up to 15% mafic minerals with subhedral hornblende crystallized either interstitially to plagioclase or as aggregates with biotite, magnetite, and titanite. Biotite forms subhedral to anhedral crystals, in places partially surrounding hornblende. Microcline microperthite forms a late, rare to accessory phase. Accessory minerals include titanite, apatite, zircon, rutile, and magnetite. Sharp contacts between rocks of slightly different mineral proportions, or between xenolith-rich and xenolith-poor rocks (Fig. 6), show the Peawah Granodiorite to be a composite body.

Seriate to porphyrytic diorite (*Agpes*) and equigranular diorite (*Agpee*), are found in the Millindinna Well area, in the southwestern part of YULE. They form sills and dykes within the De Grey Group, and at the contact between the De Grey Group and the Peawah Granodiorite. The diorite is also present as subrounded to rounded xenoliths within the Peawah Granodiorite.

The seriate to porphyrytic diorite (*Agpes*) is fine to medium grained and contains phenocrysts of plagioclase and hornblende, as well as rounded clots of hornblende and biotite. Fine-grained examples contain skeletal phenocrysts of plagioclase in a very fine grained (in places aphyric) groundmass of plagioclase, actinolite (after hornblende and clinopyroxene), quartz, and biotite. The seriate to porphyritic diorite is mineralogically and texturally transitional between the granodiorite (*Agpe*) and the feldspar(–hornblende) porphyry (*ADtf*).

The equigranular diorite (*Agpee*) is medium to coarse grained. Subhedral grains of plagioclase and hornblende are the main components. Clinopyroxene is an early crystallizing phase, forming subhedral to rounded cores to hornblende. Quartz and perthite are late interstitial phases, and biotite rims and partially replaces hornblende.

## Portree Granitoid Complex (*AgP, AgPam, AgPac*)

Magnetic data indicate that the Portree Granitoid Complex (*AgP*) forms a series of discrete, nested plutons in the

RHS 84 5.02.99

**Figure 6. Sharp contact between xenolith-rich and xenolith-poor phases of the Peawah Granodiorite, showing the complex nature of the granodiorite intrusion**

central western part of YULE. Outcrop is very poor and exposes only the northern and southern extremes of the nested pluton complex. Zircons extracted from the rock have been dated (using U–Pb SHRIMP) at c. 2945 Ma, which Nelson (1998) considered to be the crystallization age of the granite. Rocks of the Mallina Formation in contact with the southern exposed part of the granite have been contact metamorphosed.

The rock is commonly massive, but locally contains northerly and northwesterly trending zones of sheared rock. Outcrop in the southern part of the Portree Granitoid Complex is of medium-grained, leucocratic alkali granite (*AgPam*) consisting of quartz, microcline or microcline–microperthite, sodic plagioclase, sodic clinopyroxene, and rare biotite. Blue alkali amphibole is a late-magmatic to sub-solidus replacement of clinopyroxene, whereas chlorite and epidote are either deuteric or metamorphic (or both) replacements of clinopyroxene and biotite.

Outcrop in the northern part of the Portree Granitoid Complex is of coarse-grained alkali granite (*AgPac*) containing tabular perthite, up to 1 cm across, locally crowded with inclusions of sodic plagioclase. Quartz is a major, but interstitial, phase. Large grains of muscovite are also interstitial to perthite, and may be of primary origin. Chlorite and rare epidote are the only mafic phases, and are deuteric or metamorphic (or both) replacements of clinopyroxene and biotite, commonly forming ragged clots that also contain fluorite.

## Quartz veins (*q*) and quartz–tourmaline veins and replacement tourmalinite (*Aqt*)

Quartz veins (*q*) commonly trend northwesterly and lie along and parallel to late faults in the southeastern corner of YULE (AMG 115785 and 215832).

Rocks of the De Grey Group have been affected by intense boron metasomatism (Fig. 7), either along zones parallel to bedding or within and adjacent to fault planes. The metasomatic assemblage essentially consists of quartz and tourmaline, and may preserve all original sedimentary structures where replacement is controlled by bedding planes. The formation of quartz–tourmaline veins and replacement tormalinite (*Aqt*) pre-date formation of the major northwesterly trending quartz veins.

## Dolerite and gabbro dykes (*d*)

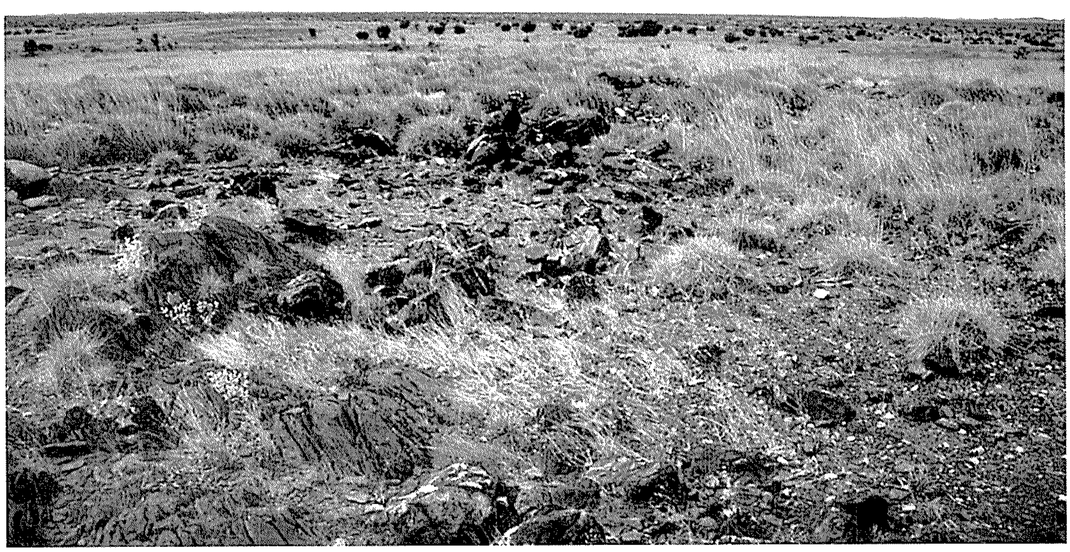
Dolerite and gabbro (*d*) of variable, but probably mainly late Archaean, age form north-northeasterly and north-westerly trending dykes within the Peawah Granodiorite, and north-northeasterly to north-northwesterly trending dykes in the Portree Granitoid Complex.

# Cainozoic deposits

Silcrete and opaline silica (*Czrz*) locally replace quartz-rich sedimentary rocks of the De Grey Group within the Mallina Shear Zone. Siliceous caprock over ultramafic rock (*Czru*) east of the Yule River, in the southern part of YULE, is associated with altered rocks of the Millindinna Intrusion.

Calcrete (*Czrk*) of residual origin locally replaces all rock types on YULE, particularly along faults and shear zones, and is extensively developed over rocks of the De Grey Group within the Mallina Shear Zone. Where original sedimentary structures are preserved, the calcretized rock has been mapped according to the inferred protolith.

Ferricrete (*Czrf*) is locally developed north of the Mallina Shear Zone in the southern part of YULE, where



RHS 85 26.11.98

**Figure 7. Rocks of the De Grey Group totally replaced by an assemblage of quartz and tourmaline**

it develops over rocks of the De Grey Group along inferred contacts with the Portree Granitoid Complex.

# Quaternary deposits

Present-day drainage channels contain alluvial clay, silt, and sand in channels in floodplains, and sand and gravel in rivers and creeks (*Qaa*). Alluvial clay, silt, and sand form overbank deposits on floodplains (*Qao*) between the Yule and Turner rivers, and locally include gilgai (*Qab*). Gilgai is a clay-rich silt or sand deposit characterized by the development of numerous cracks and sinkholes. The clay expands and contracts according to water content, and in dry conditions produces an irregular 'crabhole' surface.

The channel of the Yule River, in the southern part of YULE, is locally flanked by alluvial deposits of sand and gravel in levees and sandbanks (*Qal*). In areas immediately adjacent to rivers, alluvial floodplains contain sand, silt, and clay deposits (*Qaoc*), and claypan deposits (*Qac*).

Colluvium consisting of sand, silt, and gravel (*Qc*) is locally derived from elevated outcrops and deposited as sheetwash and talus.

Sheetwash, including sand, silt, and clay (*Qw*), is deposited on distal outwash fans. Yellow to red quartzo-feldspathic sand (*Qws*) has been deposited as fine outwash in distal outwash fans. Locally reworked by wind action, the sand deposits have been stabilized by extensive grass and shrub cover.

Eolian sand (*Qs*) forms east-southeasterly trending unstable dunes in the southern and western parts of YULE.

Supratidal shelly sand deposits (*Qhms*) comprise partially vegetated calcareous clay, silt, and shelly sand and form supratidal flats on the landward fringe of the intertidal zone (tidal flats) and elevated relicts within that zone.

Supratidal to intertidal mud and silt deposits (*Qhmu*) in the northwestern part of YULE locally include small areas of mangroves adjacent to tidal creeks.

# Structure

Four phases of deformation are recognized on MOUNT WOHLER and designated $D_1$ to $D_4$ (Smithies, 1998c). There is no evidence on YULE for the earliest phase ($D_1$) of easterly trending folds. The second phase ($D_2$) of northerly trending folds is represented only by the faulted western limb of the north-northeasterly trending anticline forming the Coorungcoorana range in the Yandeearra Aboriginal Reserve (Fig. 3). The anticline is an upright fold with an axis that plunges steeply to the north-northeast, and is intersected by a late ($D_4$) fault plane that parallels the axial plane of $D_2$ folds, and has an east-side-down sense of displacement.

In the southwestern corner of YULE, rocks of the De Grey Group and the Millindinna Intrusion have been tightly folded around upright, east-northeasterly trending axial planes. These folds trend in the same direction as $D_3$ folds identified on MOUNT WOHLER (Smithies, 1998b, 1998c) and relate to the same deformation period that produced the Sherlock Anticline on SHERLOCK (Smithies, 1998a). The $D_3$ folds are particularly tight adjacent to the southeastern margin of the Peawah Granodiorite, which is a pre-$D_3$ intrusion (Smithies, 1998c) that presumably acted as a competent block during deformation. Magnetic data suggest the presence of numerous faults that sub-parallel the axial plane of the $D_3$ folds, in the southwestern corner of YULE. The largest of these inferred faults may correlate with the Wohler Shear Zone on MOUNT WOHLER.

Interpretation of magnetic imagery identifies complex, east-northeasterly trending folding and faulting relationships within rocks of the Millindinna Intrusion and ferruginous chert and banded iron-formation (*Acf*) in the southwestern corner of YULE. The rocks partially wrap around a late granitoid pluton.

The Sholl Shear Zone (Fig. 3) forms a well-defined magnetic feature, up to 4 km wide, that trends in a northeasterly direction across the northwestern corner of YULE. Felsic volcanic rocks of the Mons Cupri Volcanics (*Acf*) form isolated outcrops on either side of the zone. Early movement along the Sholl Shear Zone was sinistral (Barley, 1987) and occurred before deposition of the c. 3000 Ma Whim Creek Group (prior to the $D_2$ event). Later dextral displacement of about 30 km displaced the Whim Creek Group (Smithies, 1997b, 1998a) and rocks related to the c. 2925 Ma Munni Munni Complex in the western part of the Pilbara Craton (Hickman, A. H., 1996, pers. comm.), and may be $D_3$ in age.

The Mallina Shear Zone (Fig. 3) forms part of the southwestern margin of the Whim Creek Belt on SHERLOCK (Smithies, 1997b) and MOUNT WOHLER (Smithies, 1998b), and trends in an easterly direction across SHERLOCK and YULE. The zone is defined on YULE as a network of anastomosing faults forming a low ridge of calcretized and silicified rocks of the De Grey Group. In the abundant low-strain areas within the shear zone, the replaced rocks show well-preserved sedimentary structures. Kinematic indicators tentatively show that the last movement along the shear zone was sinistral, but a dip-slip, south-side-up movement dominates. About 8 km west of the Yule River, the Mallina Shear Zone is intersected by a northeasterly trending fault zone, possibly representing part of the Wohler Shear Zone. The Mallina Shear Zone is possibly displaced in a sinistral sense or is deflected to the northeast, and may lie south of Mount Berghaus. The relationships between the easterly to east-northeasterly trending Mallina Shear Zone and the northeasterly trending fault zones (e.g. the Wohler Shear Zone) is not clear. The Mallina Shear Zone is interpreted here as the reactivation of an early growth fault related to the development of the sedimentary basin in which the rocks of De Grey Group formed. On YULE, the latest movement along the northeasterly trending faults appears to post-date the latest movement along the Mallina Shear Zone; however, the Mallina Shear Zone is itself locally northeasterly trending (e.g. on SHERLOCK). It is possible that the northeasterly trending faults are synthetic (riedel) shears associated with major easterly trending shears.

North-northeasterly and north-northwesterly trending quartz veins and magnetic lineaments mark late faults that correspond to the $D_4$ deformation event recognized on MOUNT WOHLER. This faulting post-dates deposition of the lower parts of the c. 2770 Ma Fortescue Group (Smithies, 1998c). A late northwesterly trending fracture cleavage is also developed. Northerly trending magnetic lineaments in the area underlain by the Portree Granitoid Complex correspond in outcrop to thin zones of brittle deformation; however, no significant offset is observed. Numerous creeks near the Mallina Shear Zone trend to the north and may also mark these northerly trending faults.

# Economic geology

Gold and antimony were discovered around Mallina Homestead in 1888. Further discoveries of antimony mineralization included the Peawah prospect, about 7.5 km east-southeast of Mallina Homestead. The Peawah prospect lies within the Mallina Shear Zone, whereas mineralization around Mallina Homestead is within minor shears and quartz veins that trend parallel to the Mallina Shear Zone. All deposits are hosted by rocks of the Mallina Formation.

The main gold-bearing quartz reef, referred to as the Stray Shot, is immediately north of the Mallina Homestead, and yielded a total of 4.0 kg of gold (Hickman, 1983). Gold was not recovered from the antimony-rich lodes at Mallina Homestead and the Peawah prospect. However, Resolute Limited commenced exploration in the area in 1997 and identified significant zones of gold mineralization within, and south of, the Mallina Shear Zone (Phaceas, 1997). Resolute's 'Camel' prospect is within the Mallina Shear Zone, about 5 km east of the Peawah prospect, and includes a zone of mineralization that is continuous over 200 m and locally reaches grades of 6.8 g/t over 22 m (Phaceas, 1997).

The main antimony-bearing deposit at Mallina, Martins lode, is about 500 m east-northeast of the homestead. Here, stringers of stibnite disseminated throughout a fractured quartz reef have yielded over 2.5 t of antimony (Finucane and Telford, 1939). The Peawah prospect has yielded 11.8 t of antimony (Finucane and Telford, 1939).

Greenstone around Quarry Well (AMG 119226) in the northern part of YULE, identified through magnetic imagery, has been explored for base metals and nickel. While no significant mineralization was found, drilling in the region intersected a greenstone succession lithologically and stratigraphically very similar to that of the Whim Creek Group, which outcrops to the west on SHERLOCK.

Rocks of the Millindinna Intrusion in the southern part of YULE and near Mount Dove, east of the Yule River, have been investigated for nickel, copper, and platinum-group element mineralization. No significant mineralization was found, although O'Shea and Davies (1987) quoted maximum values of 70 ppb Pt, 10 ppb Pd, 1600 ppm Cu, and 950 ppm Ni in composite samples of rocks from around Mount Dove.

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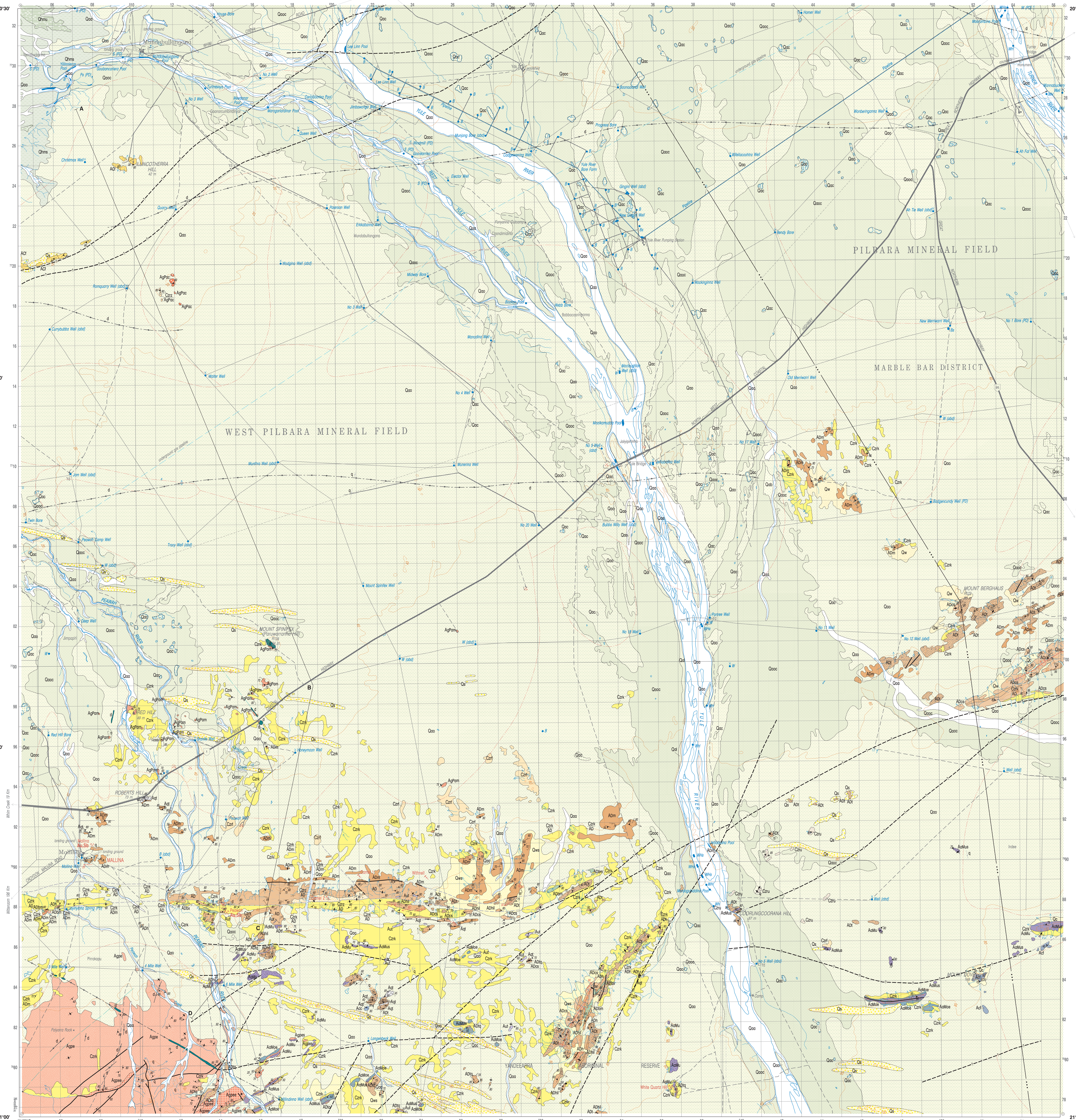
## Appendix

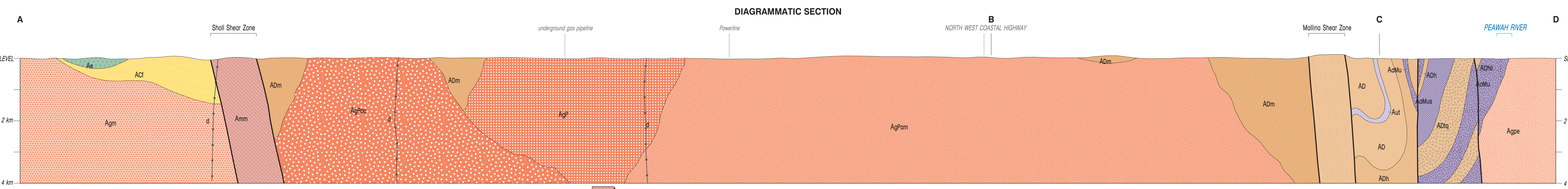
# Gazetteer of localities

| *Place name* | *AMG coordinates* | |
|---|---|---|
| | *Easting* | *Northing* |
| Mallina Homestead | 607000 | 7790400 |
| Mundabullangana Homestead | 610300 | 7730600 |
| Mount Berghaus | 651000 | 7702800 |
| Peawah prospect | 614000 | 7687500 |
| Mount Spinifex | 616500 | 7701000 |
| Coorungcoorana range | 631700 | 7682000 |
| Mount Dove | 651700 | 7684100 |
| Langenbeck Well | 621200 | 7681000 |
| Millindinna Well | 616700 | 7678200 |
| Quarry Well | 612000 | 7722600 |

# YULE




## DIAGRAMMATIC SECTION




## Reference

### PHANEROZOIC — CAINOZOIC — QUATERNARY

- Qhms — Shelly sand in coastal dunes and old beach deposits; contains *Anadara granosa*
- Qhmu — Silt and mud in supratidal to intertidal flats and lagoons
- Qaa — Alluvium—sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains
- Qal — Alluvial sand and gravel in levees and sandbanks
- Qac — Claypan deposits on floodplains
- Qao — Alluvial sand, silt, and clay in floodplains; overbank deposits
- Qaoc — Alluvial sand, silt, and clay; mixed floodplain deposits (Qao) characterized by numerous small claypans
- Qab — Alluvial sand, silt, and clay in floodplain, with gilgai surface in areas of expansive clay
- Qw — Sheetwash—sand, silt, and clay in distal outwash fans
- Qwa — Quartzofeldspathic sand
- Qc — Colluvium—sand, silt, and gravel in outwash fans and scree
- Qe — Eolian sand—red-yellow, wind-blown sand; local ridges

### CAINOZOIC

- Czk — Calcrete—massive, nodular, and cavernous limestone, variably silicified; residual origin
- Czf — Ferricrete—includes ferruginous and pisolitic ironstone on lateritic surfaces
- Czu — Siliceous caprock over ultramafic rock
- Czz — Silcrete and massive nodular silica

### ARCHAEAN — PILBARA CRATON

- d — Dolerite and gabbro dykes; interpreted from aeromagnetic data where dashed
- q — Quartz vein
- Aqt — Quartz-tourmaline vein or replacement tourmalinite
- c 2945 Ma — AgP — PORTREE GRANITOID COMPLEX: alkali granite; metamorphosed (not shown on map)
  - AgPoc — Alkali granite, coarse-grained; massive
  - AgPom — Alkali granite, medium-grained; pyroxene-bearing; foliated to massive
- Contact metamorphic rock; abundant porphyroblasts of andalusite, cordierite, and/or garnet; related to intrusions of PORTREE GRANITOID COMPLEX and PEAWAH GRANODIORITE
- c 2950 Ma — Agpe — PEAWAH GRANODIORITE: metamorphosed medium- to coarse-grained, hornblende-biotite bearing granodiorite and tonalite; metamafic
  - Agpes — Seriate to porphyritic (plagioclase) diorite
  - Agpee — Medium- to coarse-grained equigranular diorite
- Aci — Massive, grey chert; metamorphosed
- Aut — Talc-carbonate schist, after peridotite

**Millindinna Intrusion**

- AoMog — Metamorphosed gabbro and pyroxenite; metamorphosed
- AoMu — Ultramafic schist; tremolite- and serpentine-rich schist, and serpentinite after peridotite; includes minor metachert, metasedimentary rock, and serpentinised high-Mg basalt
- AoMus — Serpentine and serpentine-actinolite schist, after peridotite
- Ab — LOUDEN VOLCANICS: undifferentiated metamorphosed basalt and high-Mg basalt; contemporaneous with part of the De Grey Group (not shown on map)

**Pilbara Supergroup — De Grey Group**

- > 2970 Ma — AD — Unassigned; fine- to coarse-grained clastic rocks; minor high-Mg basalt flows; metamorphosed; appears to be stratigraphically transitional between the CONSTANTINE SANDSTONE and MALLINA FORMATION
  - ADh — Laminated shale; includes minor beds of poorly sorted subarkose
  - ADhl — Laminated shale and siltstone, locally ferruginous and/or chlorite-rich; includes layers of chlorite-quartz schist, chert, and wacke
  - ADt — Turbiditic wacke; medium- to coarse-grained; abundant chert clasts; local graded units; minor pebble beds and shale
  - ADtq — Turbiditic wacke, locally subarkosic; fine- to coarse-grained; abundant chert clasts; well developed graded units; minor conglomerate and pebble beds
  - ADtf — Shale, siltstone, and wacke, with layers of feldspar(-hornblende) porphyry
  - ADbm — High-Mg basalt; locally with pyroxene spinifex texture
  - ADbx — High-Mg basalt interleaved with ironstone, shale, and wacke
- < 3000 Ma — ADm — MALLINA FORMATION: interbedded shale, siltstone, and medium- to fine-grained wacke; minor layers of chert; metamorphosed
- > 2950 Ma — ADc — CONSTANTINE SANDSTONE: undifferentiated coarse- to fine-grained clastic rocks, metamorphosed (not shown on map)
  - ADcs — Poorly sorted subarkose and wacke; metamorphosed

**Whim Creek Group**

- ACf — MONS CUPRI VOLCANICS: metamorphosed felsic volcanic and volcaniclastic rocks; rhyolite, dacite, and minor andesite
- Agm — Monzogranite, weakly to strongly foliated (not shown on map)
- Acf — Ferruginous chert and banded iron-formation

## Symbols

Geological boundary
- exposed
- concealed, interpreted from aeromagnetic data

Fault
- exposed
- concealed
- concealed, interpreted from aeromagnetic data

Strongly foliated rock

Fold, showing axial trace and generalized plunge direction
- anticline
- overturned anticline

Small-scale fold axis, showing trend and plunge
- Z-vergence
- S-vergence

Bedding, showing strike and dip
- inclined
- vertical
- overturned
- trend of bedding

Way-up indicator
- sedimentary structure

Metamorphic foliation, showing strike and dip
- inclined
- vertical

Cleavage, showing strike and dip
- inclined
- vertical

Aeromagnetic lineament

Isotopic age determination site with identification number

Highway with national route marker; bridge

Formed road

Track

Fence, generally with track

Powerline

Gas pipeline — underground gas pipeline

Homestead — Mundabullangana

Locality — Sponamundabun

Building

Yard

Microwave repeater station

Reserve boundary

Horizontal control, major

Sand dune

Contour line, 20 metre interval

Watercourse, with pool

Pool, waterhole, spring

Pipeline

Bore, well

Windpump

Dam, tank

Abandoned — (abd)

Position doubtful — (PD)

Mineral field boundary

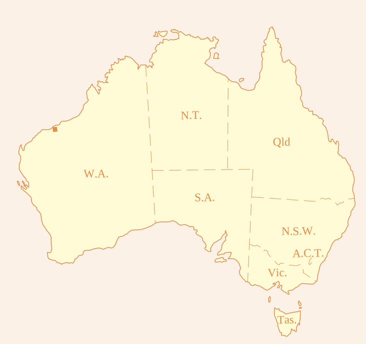
Mining centre — MALLINA

Mine (gold, unless otherwise indicated) — Peewah

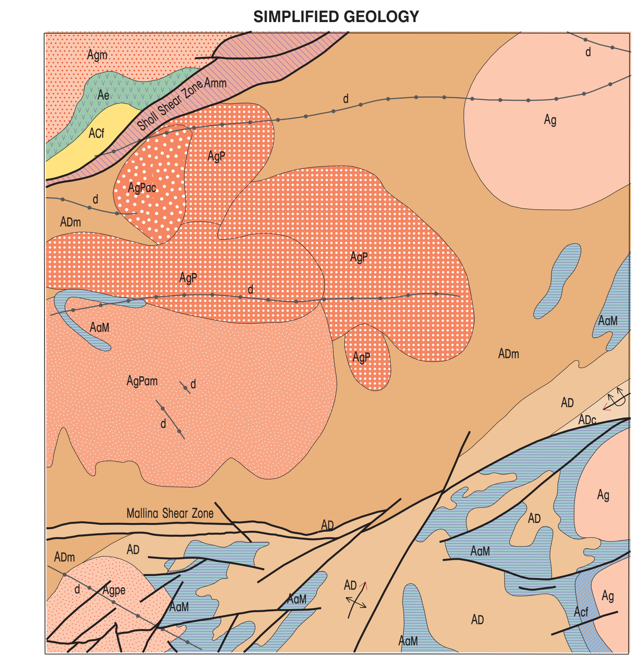
Quarry or pit

Prospect

Mineral occurrence
- Antimony — Sb
- Gold — Au



## SIMPLIFIED GEOLOGY

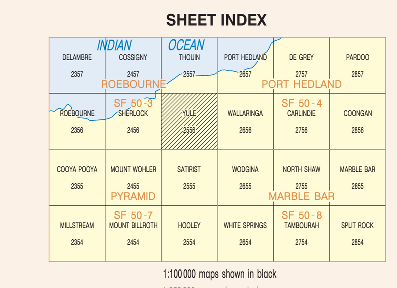


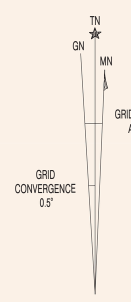

- d — Dolerite and gabbro dykes
- Amm — Sheared and mylonitic rock
- Ag — Unassigned granitoid rock
- AgP, AgPoc, AgPom — Portree Granitoid Complex; AgPoc Coarse-grained phase; AgPom Medium-grained phase
- Agpe — Peawah Granodiorite
- AoM — Millindinna Intrusion
- Ab — Louden Volcanics
- AD — Unassigned shale, sandstone, and mafic schist
- ADm — Mallina Formation
- ADc — Constantine Sandstone
- ACf — Mons Cupri Volcanics
- Agm — Monzogranite, weakly to strongly foliated
- Acf — Ferruginous chert and banded iron-formation

PILBARA CRATON — De Grey Group — Whim Creek Group

SCALE 1:500 000
0 5 10 15 20
Kilometres

## SHEET INDEX




True north, grid north and magnetic north are shown diagrammatically for the centre of the map. Magnetic north is correct for 1998 and moves easterly by about 0.1° in 2 years

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

DEPARTMENT OF MINERALS AND ENERGY
L.C. RANFORD, DIRECTOR GENERAL

NGMA
PRODUCT OF THE NATIONAL GEOSCIENCE MAPPING ACCORD

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
DAVID BLIGHT, DIRECTOR

SCALE 1:100 000
1000 0 1 2 3 4 5 6 7 8 9 10
Metres — Kilometres

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

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

**Geology by R. H. Smithies 1998**
Edited by N. Tetlaw, C. Brien, and G. Loan
Cartography by S. Collopy and B. Williams
Topography from the Department of Land Administration Sheet SF 50-3, 2556, with modifications from geological field survey
Published by the Geological Survey of Western Australia. Copies available from the Information Centre, Department of Minerals and Energy, 100 Plain Street, East Perth, WA, 6004. Phone (08) 9222 3459, Fax (08) 9222 3444
This map is also available in digital form
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SMITHIES, R. H., 1998, Yule, W.A. Sheet 2556:
Western Australia Geological Survey, 1:100 000 Geological Series

# YULE

**SHEET 2556** **FIRST EDITION 1998**

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