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GEOLOGY OF THE SATIRIST 1:100 000 SHEET

by R. H. Smithies and T. R Farrell

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by
R. H. Smithies and T. R. Farrell

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Cover photograph:
Gneissic banding in a component of the Cheearra Monzogranite (part of the Yule granitoid Complex)

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Geology of the Satirist 1:100 000 sheet

by

R. H. Smithies and T. R. Farrell

Abstract

The SATIRIST 1:100 000 sheet lies in the central part of the Archaean North Pilbara Terrain, straddling the contact between the Central Pilbara Tectonic Zone and the East Pilbara Granite–Greenstone Terrane. It incorporates the southeastern part of the c. 3000 Ma Mallina Basin and other older greenstone belts. The Pilbara Well greenstone belt is a northeasterly trending sequence within the central part of SATIRIST. The upper stratigraphic portion of this belt is dominated by metasedimentary rocks and is assigned to the Gorge Creek Group. The lower stratigraphic portion, dominated by metamorphosed high-Mg basalt, is unassigned but may form part of either the Warrawoona Group or the Sulphur Springs Group. In the southern part of SATIRIST, the Cheearra greenstone belt comprises a series of roof pendants and xenoliths within the Yule Granitoid Complex. The age of these greenstones is unknown. Monzogranite, dated at c. 2930 to 2935 Ma, forms voluminous intrusions throughout SATIRIST and includes the Satirist Granite, on the western edge of the sheet, and most of the western part of the Yule Granitoid Complex. The Cheearra Monzogranite forms an older component of the Yule Granitoid Complex, and is possibly as old as c. 3200 Ma. Some rocks within the Yallingarrintha Tonalite, which forms xenoliths within the Cheearra Monzogranite, are as old as 3420 Ma. Much of the southwestern corner of SATIRIST is covered by rocks of the Fortescue Group, the oldest unit being the c. 2770 Ma Mount Roe Basalt. The Pilbara Well greenstone belt has had extensive gold mining activity, which combined with mining centres within the Mallina Basin, has accounted for a large proportion of historical gold production in the western and central Pilbara region.

KEYWORDS: Archaean, Pilbara Craton, regional geology, Mallina Basin, East Pilbara Granite–Greenstone Terrane, Central Pilbara Tectonic Zone, Pilbara Well greenstone belt

Introduction

The SATIRIST* 1:100 000 geological sheet (SF 50-7, 2555) covers the northeastern part of the PYRAMID 1:250 000 map sheet, in the northern Pilbara region. It is bounded by latitudes 21°00'S and 21°30'S, and longitudes 118°00'E and 118°30'E, and lies in the West Pilbara Mineral Field (Fig. 1).

Rocks are well exposed throughout much of the sheet area, except in the north between the Yule River and Mount Langenbeck (MGA† 266756) and in some areas underlain by granitoid rocks.

Most outcrop on SATIRIST forms part of the granite–greenstone succession of the Archaean Pilbara Craton, whereas outcrop in the southwestern corner of the sheet area is predominantly lower volcano-sedimentary sequences (Fortescue Group) of the 2770 to 2300 Ma Hamersley Basin (Arndt et al., 1991). The sequences dip gently to the south, exposing the lower two-thirds of the Fortescue Group stratigraphy on SATIRIST.

Granitoid rock and greenstone outcrop in similar proportions. Three distinct granitoid bodies are recognized on SATIRIST and at least two of these — the Satirist Granite and the Peawah Granodiorite — have intruded the exposed greenstones. The third body — the Yule Granitoid Complex — is dominated by granitoid rocks that are younger than the greenstones; however, it also contains xenoliths of the c. 3420 Ma Yallingarrintha Tonalite, which represents the oldest rock identified on SATIRIST.

The greenstones on SATIRIST are assigned to the Pilbara Supergroup (Hickman, 1983) and can be subdivided into the De Grey Group, Gorge Creek Group, and rocks older than the Gorge Creek Group. The older greenstones form

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

† Localities are specified by the Map Grid of Australia (MGA) 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. MGA coordinates of localities mentioned in the text are listed in Appendix 1.

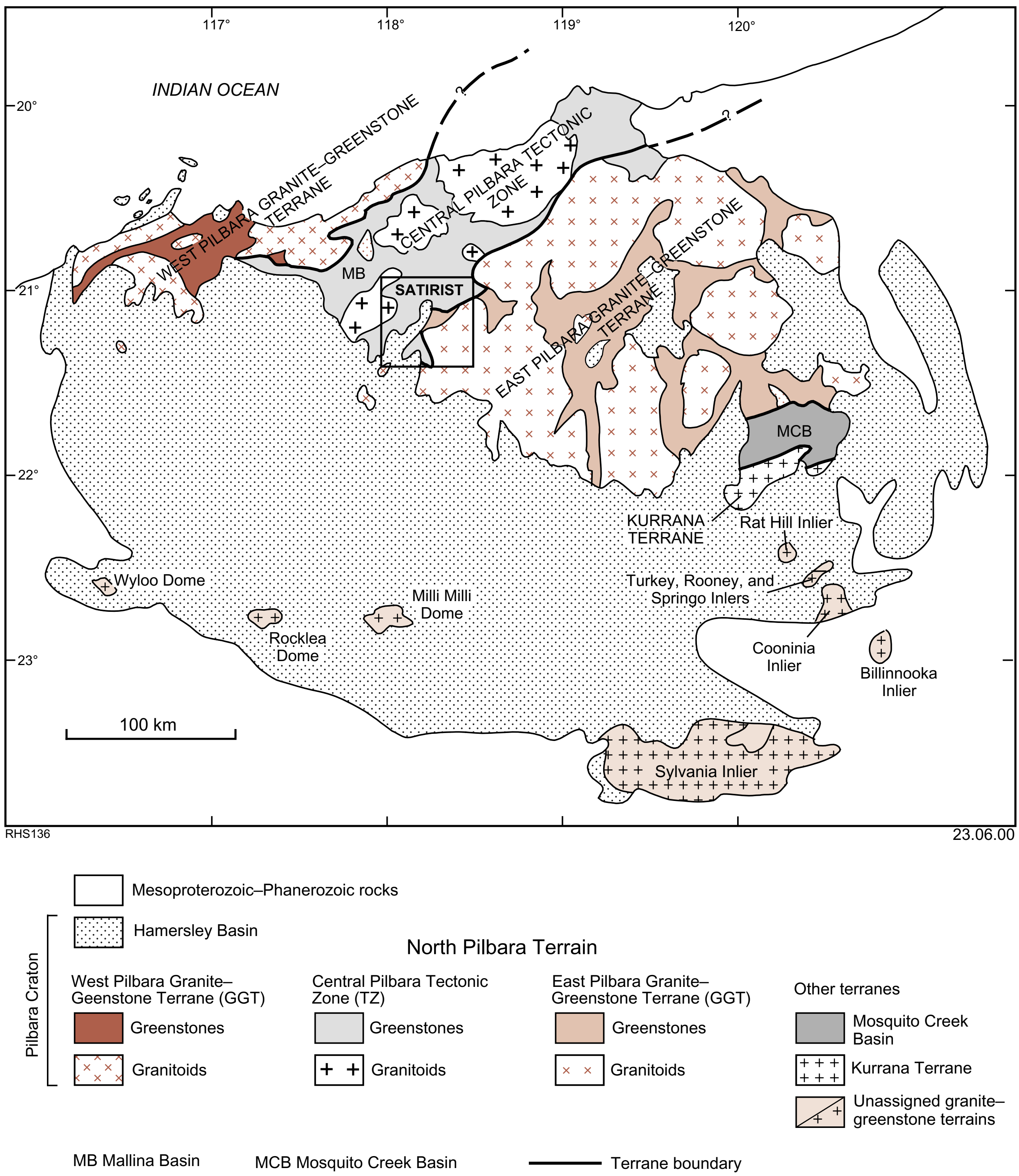


Figure 1. Regional geological setting of SATIRIST within the northern part of the Pilbara Craton

the northeasterly trending Pilbara Well greenstone belt. Rocks of the De Grey Group are the youngest rocks of the Pilbara Supergroup, outcropping in the northern and western parts of SATIRIST and form the southeastern part of the Mallina Basin. Greenstones in the southern part of SATIRIST form the Cheearra greenstone belt and cannot be confidently assigned to any lithostratigraphic group.

Access and land use

The North West Coastal Highway lies to the north of SATIRIST and YULE, and the Great Northern Highway to the east on WODGINA. The closest town to SATIRIST is Port Hedland, which lies approximately 80 km to the north-northeast and can be accessed along both highways. A well-maintained gravel road, approximately 42 km long, links the Great Northern Highway to the Mungarinya Aboriginal Community on Yandeearra Station. The two tracks linking that community to the North West Coastal Highway are poorly maintained; one passes through Mallina Homestead on YULE and the other runs along the west bank of the Yule River.

The Mungarinya Aboriginal Community is the only permanent settlement on SATIRIST. The associated Yandeearra Aboriginal Land encompasses Yandeearra Station and the majority of the sheet area. The western edge of the sheet divides between Mallina Station in the north from Croydon Station in the south. Much of the southwestern part of the sheet area is a rugged dissected plateau that forms the northeastern part of the Mungaroona Range Nature Reserve. The northeastern corner of SATIRIST lies within Indee Station.

Grazing is the primary agricultural activity on Yandeearra Aboriginal Land and on the three stations within SATIRIST. There are no active mines, although the area around Friendly Creek (Friendly Creek mining centre), Station Peak (Station Peak mining centre), Teichman Well, and between Friendly Creek and Annie Gap (MGA 366583), have produced large amounts of gold in the past. The Friendly Creek mining centre has also been a large producer of tin, and copper has been mined at Egina.

Physiography

The northwesterly flowing Yule River is the only large drainage system on SATIRIST, which flows mostly during the summer wet season. Physiographic divisions on SATIRIST closely match major geological divisions. Rocks of the Fortescue Group in the southwestern corner of the sheet area and the older part of the greenstone sequence in the centre of the sheet area, form a prominent plateau (Fig. 2). This surface is up to about 400 m above sea level and is the tertiary peneplain that Campana et al. (1964) called the Hamersley Surface. The area covered by rocks of the Mallina Basin comprises the range, low hills, and sandplain physiographical divisions, whereas areas underlain by granitoid rocks comprise the eolian sandplain and alluvial–colluvial plain divisions (Fig. 2).

Regional geological setting

The Pilbara Craton is the oldest exposed major crustal element of Australia. The Archaean rocks can be divided into two components (Fig. 1) — a granite–greenstone terrain that formed between c. 3600 and 2800 Ma (Hickman, 1983, 1990; Barley, 1997), and the unconformably overlying volcano-sedimentary sequences (Mount Bruce Supergroup) of the c. 2770–2300 Ma Hamersley Basin (Arndt et al., 1991). The geological history of, and around, SATIRIST, is summarized in Table 1.

The granite–greenstone terrain of the Pilbara Craton is exposed mainly in the north and northeastern parts of the craton where erosion has removed most of the Mount Bruce Supergroup. This region has recently been divided into the East Pilbara and West Pilbara Granite–Greenstone Terranes, separated by the northeasterly trending Central Pilbara Tectonic Zone (Fig. 1; Hickman, in prep.; Hickman et al., in prep.).

The East Pilbara Granite–Greenstone Terrane comprises large ovoid granitoid–gneiss complexes partially surrounded by belts of tightly folded and near-vertically dipping volcanic and sedimentary rocks that are typically metamorphosed to greenschist facies (i.e. greenstones). The greenstones accumulated periodically between c. 3600 and 2950 Ma, although the majority of the succession was deposited before c. 3230 Ma. Between c. 3600 and 2850 Ma, felsic magmatism also took place periodically. Although the majority of granitoid rocks in the eastern part of the terrane intruded before c. 3240 Ma, monzogranite dated at c. 2930 to 2945 Ma forms a volumetrically large and locally dominant component of granitoid complexes in the western part of the terrane. Whereas the East Pilbara Granite–Greenstone Terrane has a characteristic ovoid outcrop pattern, the West Pilbara Granite–Greenstone Terrane contains northeasterly trending linear granitoid complexes and greenstone belts. The granitoid and greenstone components of the western terrane are c. 3270 and 2925 Ma.

The northeasterly trending Mallina Basin forms the major component of the Central Pilbara Tectonic Zone and straddles the boundary between the East and West Pilbara Granite–Greenstone Terranes. Mafic to felsic volcanic and volcaniclastic rocks of the Whim Creek Belt form the northwestern margin of the basin. Elsewhere, the basin is dominated by a thick sequence of tightly folded turbidite and mass-flow deposits. The contact between the Whim Creek greenstone belt and the West Pilbara Granite–Greenstone Terrane is a locally faulted unconformity, which separates c. 3010 Ma volcanic rocks at the base of the Whim Creek Group from metabasalts of the c. 3125 Ma Whundo Group (Hickman, 1997) and banded iron-formation (BIF) of the c. 3020 Ma Cleaverville Formation.

The boundary between the East Pilbara Granite–Greenstone Terrane and the Central Pilbara Tectonic Zone is typically the basal contact between the Mallina Basin and the underlying granite–greenstone sequences. This contact is a locally faulted disconformity. The basement to the Mallina Basin includes chert that has been dated at c. 3015 Ma and assigned to the Cleaverville Formation of the Gorge Creek Group (Smithies et al., 1999). Thus, deposition of the Cleaverville Formation is the earliest know greenstone-forming event common to both the East and West Pilbara Granite–Greenstone Terranes.

The maximum age of the Mallina Basin is constrained by the underlying c. 3020–3015 Ma Cleaverville Formation. Maximum depositional ages of c. 3000 Ma for the Mallina Formation and c. 2995 Ma for the Constantine Sandstone were obtained from detrital zircons in samples from SHERLOCK (Nelson, 1997, in prep.). Most of the basinal succession must have been deposited and tightly folded before being intruded by the Peawah Granodiorite and Portree Granite at c. 2950 Ma. However, the age of detrital zircons from a wacke of the Mallina Formation sampled near Egina Well on SATIRIST, show that deposition

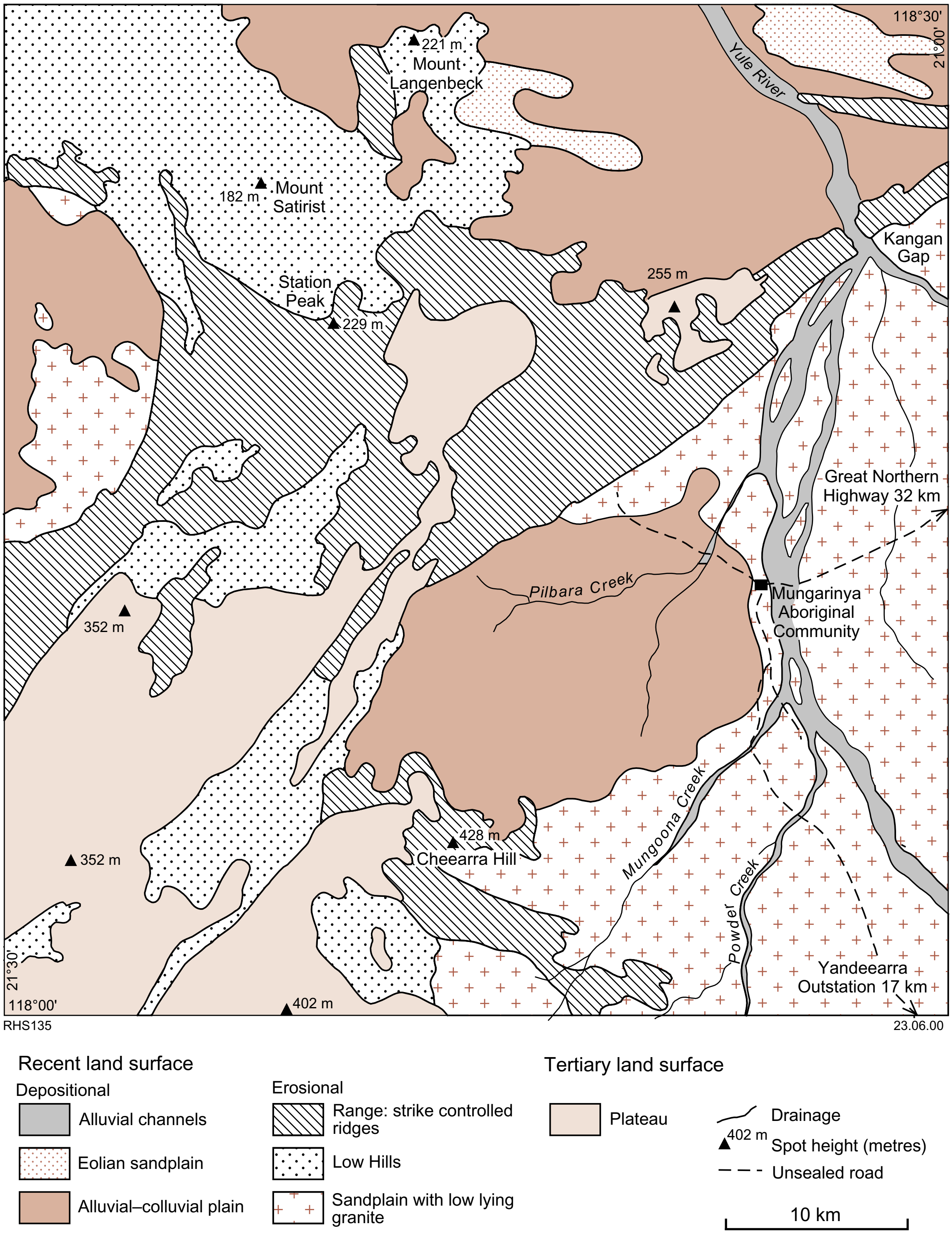


Figure 2. Physiographical features of SATIRIST

continued until at least c. 2940 Ma and indicates an unconformity, as yet unidentified, within the Mallina Basin. Shear zones are present within and along the margins of the Mallina Basin, parallelling the northeasterly trending axis of the basin. These shear zones are interpreted to overlie basement structures related to early basin formation (Smithies, 1999). The basement structures were reactivated, probably during extension at c. 2950 Ma, and intruded by dioritic to granodioritic rocks such as the Peawah Granodiorite (Smithies and Champion, in press). It is likely that this extensional event initiated the second phase of deposition within the Mallina Basin.

Table 1. Summary of the geological history of SATIRIST

Age (Ma)	*Central Pilbara Tectonic Zone*	*East Pilbara Granite–Greenstone Terrane*
c. 3420		Intrusion of components of the Yallingarrintha Tonalite into unidentified country rock of similar age to, or older than, the Warrawoona Group
?		Deposition of Pilbara Well greenstone belt units that lie stratigraphically beneath the Gorge Creek Group
3160–2945		Intrusion of the Cheearra Monzogranite and Yandeearra Granodiorite
3020–3015	------------------------------- Deposition of the Cleaverville Formation (Gorge Creek Group) -------------------------------	
3000–2950	Deposition of the De Grey Group in the Mallina Basin and emplacement of the Millindinna Intrusion	
?	--- Easterly trending folds (D_1) ---	
?	-- Major northerly trending folds (D_2) --	
c. 2950	Intrusion of the Peawah Granodiorite, associated granodiorite, diorite, and gabbro, and contact metamorphism of the De Grey Group	
c. 2945 or older		Medium-grade metamorphism of the Cheearra greenstone belt and the southwestern part of the Yule Granitoid Complex
2945–2940	-- Intrusion of feldspar and quartz porphyries --	
c. 2940 or younger	Further deposition within the Mallina Basin	
2940–2930	Intrusion of the Satirist Granite and contact metamorphism of the De Grey Group	Intrusion of Mungarinya, Powdar, and ?Pilbara Creek Monzogranites
?	----------------------------- East-northeasterly trending folds, including John Bull synform (D_3) -----------------------------	
?		Movement along the contact between the Pilbara Well greenstone belt and the Yule Granitoid Complex
c. 2770	--------------------------- Deposition of volcanic and sedimentary rocks of the Fortescue Group ---------------------------	
2770 and younger	---------------------------------- Dip-slip faulting along major northeasterly trending faults ----------------------------------	

Several new lithostratigraphic units have been recognized in the course of the current mapping; these are defined in Appendix 2.

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 of this trough lies in the Mons Cupri – Roebourne region (SHERLOCK, ROEBOURNE), whereas the Teichmans region (SATIRIST) represents the southeastern trough margin (Ryan and Kriewaldt, 1964). The entire volcano-sedimentary sequence was defined as the Roebourne Group, which appears as such on PYRAMID (Kriewaldt and Ryan, 1963), and was correlated with the 'Warrawoona succession' of the east Pilbara.

Further mapping in the western and central Pilbara region (Fitton et al., 1975) led to a major revision of the stratigraphy. The felsic to intermediate volcano-sedimentary rocks on SHERLOCK were shown to unconformably overlie the 'Warrawoona succession' and were redefined as the Whim Creek Group. A thick and poorly outcropping sequence of slate and fine- to coarse-grained wacke immediately south of the Whim Creek Belt was called the Mallina Formation, and underlying sandstone was called the Constantine Sandstone (Fitton et al., 1975). Both were correlated with the Whim Creek Group.

Regional correlations between similar well-exposed rock successions in the eastern and western parts of the craton (Fitton et al., 1975; Hickman, 1983), indicated that the greenstones could be collectively assigned to a single stratigraphic package, which Hickman (1983) called the Pilbara Supergroup. These correlations incorporated a reinterpretation of the Whim Creek area that suggested that the rocks of the Whim Creek Group were younger than those of the Mallina Formation and Constantine Sandstone, and should therefore be placed within the De Grey Group. Thus, the Pilbara Supergroup comprised four lithostratigraphic groups (from oldest to youngest) — predominantly mafic and ultramafic volcanic rocks of the Warrawoona Group, and predominantly sedimentary and felsic volcanic rocks of the Gorge Creek, De Grey, and Whim Creek Groups.

Recent mapping and SHRIMP U–Pb dating however, have led to major revisions of the Pilbara Supergroup. Rocks that were formerly assigned to the Warrawoona Group (Hickman, 1997) have now been placed in two new groups of the West Pilbara Granite–Greenstone Terrane — the Whundo Group and the redefined Roebourne Group. Also, in the area west of Marble Bar, rocks formally assigned to the Warrawoona Group within the East Pilbara Granite–Greenstone Terrane have been reassigned to the Sulphur Springs Group by Van Kranendonk and Morant (1998). It has also been suggested that in the Central Pilbara Tectonic Zone, the De Grey and Whim Creek Groups are time-equivalent facies of the same depositional basin (Smithies, 1997a; Smithies et al., 1999), thereby supporting the strat-igraphic correlations of Fitton et al. (1975) and Horwitz (1990). More recently, it has been proposed that the rocks of the De Grey Group are slightly younger than much of the Whim Creek Group (Huston et al., 2000).

Greenstone sequences stratigraphically beneath the De Grey and Whim Creek Groups, outcrop in the Teichmans region (SATIRIST) of the East Pilbara Granite–Greenstone Terrane. This region was investigated by Fitton et al. (1975) and Hickman (1983). Fitton et al. (1975) placed an upper chert unit that unconformably underlies the De Grey Group, into the Gorge Creek Group. An underlying sequence of chert and felsic to ultramafic volcanic rocks was placed into the 'Teichmans Group', which included a lower unit termed the 'Friendly Creek Formation' (Fitton et al., 1975). Hickman (1983) later correlated the 'Teichmans Group' with the Warrawoona Group and reassigned the 'Friendly Creek Formation' to the Duffer Formation.

Archaean rocks

All rocks of the Pilbara granite–greenstone terranes on SATIRIST have been metamorphosed. Those that retain primary textures are described according to their inferred protolith, and for brevity the prefix 'meta' is omitted. However, some of the rocks have been extensively recrystallized, particularly the sedimentary rocks of the De Grey Group where they are close to the Satirist Granite and the Peawah Granodiorite. Where the protolith of a contact metamorphic rock is known, the metamorphic rock has been grouped under that protolith and the metamorphic mineral assemblages are described after the primary assemblages.

The Archaean geology of SATIRIST is summarized in Figure 3. Rocks of the c. 2770–2680 Ma Fortescue Group cover the southwestern part of the map sheet. These rocks are mostly shallowly dipping and weakly metamorphosed. An unconformity is well developed between the Mount Roe Basalt, which commonly forms the basal unit of the Fortescue Group, and the underlying granite–greenstone terrain. Topographical variation of the unconformity resulted in the Mount Roe Basalt not being deposited everywhere.

SATIRIST straddles the boundary between the East Pilbara Granite–Greenstone Terrane and the Central Pilbara Tectonic Zone (Fig. 1). The greenstones within the sheet area can locally be divided into the De Grey Group, Gorge Creek Group, and rocks older than the Gorge Creek Group. Rocks confidently assigned to the De Grey Group are restricted to the Central Pilbara Tectonic Zone and form the southwestern part of the Mallina Basin. Here, the contact between the Mallina Basin and the East Pilbara Granite–Greenstone Terrane is a locally faulted disconformity. In the southeastern corner of MOUNT WOHLER (Smithies, 1998a), the base of the Mallina Basin is well defined by a cobble-conglomerate unit that unconformably overlies chert of the Cleaverville Formation (Gorge Creek Group). On SATIRIST, a similar relationship is present north of the Empress mine, that is, a thick chert unit and an underlying felsic volcanic sandstone are also correlated with the Cleaverville Formation. To the southwest of Empress mine, immediately west of Teichman Well, a locally thick conglomerate may be the basal unit of the Mallina Basin. However, this conglomerate is faulted against high-Mg basalt of the pre-Gorge Creek Group greenstone sequence. Between the Empress mine and the Kangan Gap region, the base of the Mallina Basin is a coarse-grained subarkose. The basal contact in this area is an erosional surface that locally truncates the Cleaverville Formation to expose underlying basalts.

The lower part of the De Grey Group also includes siltstone, ferruginous shale, and minor iron formation. In the areas where these rocks outcrop (e.g. MGA 147611, 063461), the base of the Mallina Basin is difficult to identify and the stratigraphic position of isolated prominent exposures of chert and BIF (e.g. Mount Langenbeck) is unclear; however they most probably belong to the Cleaverville Formation. A sequence of siltstone, ferruginous shale, and iron formation outcrops along the eastern margin of the Satirist Granite. It is separated from the granite by a layer of Constantine Sandstone up to 1 km wide, and bounded to the east by another layer of Constantine Sandstone or by a gabbro sill. This sequence contains a distinctive chlorite–actinolite-rich schist unit that represents metamorphosed high-Mg basalt and lesser komatiite. Local lenses of cobble-conglomerate at the base of the Constantine Sandstone (MGA 056454), possibly indicates an erosional hiatus. On SATIRIST, this sequence has been assigned to the De Grey Group because it is similar to rocks east of the Satirist Granite that clearly belong to that group. However, it is possible that the sequence unconformably underlies the De Grey Group, forming an upper unit of fine-grained clastic rocks and mafic-ultramafic lavas within the Cleaverville Formation.

On SATIRIST, outcrop of the Gorge Creek Group is primarily confined to the East Pilbara Granite–Greenstone Terrane; however, minor exposures of the Cleaverville

Formation are present in the cores of tight and upright anticlines within the Central Pilbara Tectonic Zone. On SATIRIST, greenstones older than the Gorge Creek Group are confined to the East Pilbara Granite–Greenstone Terrane and, with rocks of the Gorge Creek Group, form the northeasterly trending Pilbara Well greenstone belt. The minimum age of the older greenstones of the Pilbara Well greenstone belt is constrained by the c. 3015 Ma Cleaverville Formation; the maximum age is not known. The Yallingarrintha Tonalite outcrops between the greenstones of the pre-Gorge Creek Group and younger granitoid rocks of the Yule Granitoid Complex, and on WODGINA has been dated at c. 3420 Ma (Nelson, 1999). However, the nature of the contact between the Yallingarrintha Tonalite and the Pilbara Well greenstone belt cannot be determined and so the relative age of those greenstones is unclear.

The Pilbara Well greenstone belt can broadly be divided into three main, lithologically contrasting units: a lower mafic–ultramafic sequence, a thin felsic unit, and an upper unit of chert and BIF. The lower mafic–ultramafic sequence (Teichmans Group of Fitton et al., 1975) is dominated by high-Mg basalt, peridotite, and thin units of chert and clastic sedimentary rock, with associated zones of intense silica alteration. This sequence shows lithological similarities to rocks of the Warrawoona Group (Hickman, 1983) in the east Pilbara. In contrast, the felsic unit contains a range of felsic clastic sedimentary rocks, and minor rhyolite and trachyte. Silicification of the felsic rocks is widespread and locally intense. The felsic unit is comparable to the felsic rocks at Nunyerry Gap on MOUNT WOHLER (Smithies, 1998a,b), and is thought to be part of the Gorge Creek Group (Hickman, 1983). The upper chert–BIF unit consists of layered chert and silicate-facies BIF, with subordinate, poorly exposed clastic sedimentary rocks, felsic schist, and foliated basalt, and is correlated with the Cleaverville Formation. The greenstone sequences are metamorphosed and folded into a regional-scale, upright, northeasterly plunging fold — the John Bull Syncline of Fitton et al. (1975) — and referred to here as the John Bull synform.

The mafic–ultramafic sequence in the Pilbara Well greenstone belt is dominated by high-Mg basalt, but also contains ultramafic rocks, clastic sedimentary rocks, chert layers, and conformable zones of silicification. Most of the sequence appears to comprise repeated cycles of high-Mg basalt flows (with or without ultramafic rock, and thin gabbro sills), overlain by silicified mafic-fragmental rocks and poorly sorted sedimentary rocks, and an upper conformable silicified zone of one or more chert layers. The age of the sequence is equivocal, as there are no geochronological data and it is not possible to correlate the sequence with formations elsewhere in the East Pilbara Granite–Greenstone Terrane. The change in lithology from the mafic–ultramafic sequence to the overlying Gorge Creek Group is suggestive of a depositional hiatus, but it is not clear if an unconformity exists. In addition, the chert horizons may mark significant time breaks, and it is possible that the sequence contains units of different age. In view of these issues, the Pilbara Well sequence has not formally been assigned to any specific group.

Greenstone xenoliths and roof pendants are present throughout the Yule Granitoid Complex in the southern and southeastern parts of SATIRIST. In the southern part, the Cheearra greenstone belt comprises a nearly continuous linear array of large xenoliths and roof pendants within the complex; however, none can be confidently assigned to a lithostratigraphic group.

The Cheearra greenstone belt contains a high-grade metamorphosed and multiply deformed sequence that consists of interleaved amphibolite, quartzite, tonalite gneiss, ultramafic schist, and minor mafic gneiss, hornblendite, and biotite-rich schist. The sequence is intruded by abundant small pegmatite veins, and is layered from centimetre-scale layering in tonalite gneiss (with individual layers ranging in composition from amphibolite to tonalite), to 5–10 m-scale alternating layers of tonalite gneiss, amphibolite, and ultramafic rock. Individual layers of ultramafic rock are discontinuous (possibly due to boudinage), and larger lenses and pods of less deformed rock are common. Tremolite schist is the most abundant ultramafic rock type. It is typically well foliated and, in places, contains radiating or fan-like aggregates of tremolite, up to 20 mm in diameter. Locally, tremolite schist also contains large porphyroblasts (up to 20 mm) of serpentinized ?olivine.

Unassigned units and units stratigraphically below the Gorge Creek Group

Ultramafic rocks (*Au*, *Aud*, *Auk, Aup, Aur*, *Auxo*)

Unassigned ultramafic rocks include units that cannot be confidently assigned either to the Millindinna Complex or to extrusive units of the Mallina Basin, or those units that are clearly older than rocks of the Gorge Creek Group. Such ultramafic rocks are common in parts of the Pilbara Well and Cheearra greenstone belts. They are also a minor component of the Mallina Basin and are present as xenoliths and roof pendants within the Yule Granitoid Complex.

In the Pilbara Well greenstone belt, ultramafic rocks typically form lenses and layers, mostly less than 200 m thick, within the mafic sequence. Larger bodies of ultramafic rock are present 4 km north-northeast, and 7.2 km west, of Friendly Creek mining centre.

Outcrops of ultramafic rock that are weathered or strongly deformed have mainly been mapped as undivided ultramafic rock (*Au*). In areas of better exposure, the ultramafic rocks have been subdivided into serpentinized dunite (*Aud*), serpentinized peridotite (*Aup*), and tremolite-rich schist (*Aur*). Minor rock types not shown separately on the map include carbonate–altered peridotite and talc–chlorite schist. Olivine spinifex textures are locally present in many ultramafic units in the Pilbara Well greenstone belt (e.g. MGA 341579), but mostly do not outcrop in readily mappable units.

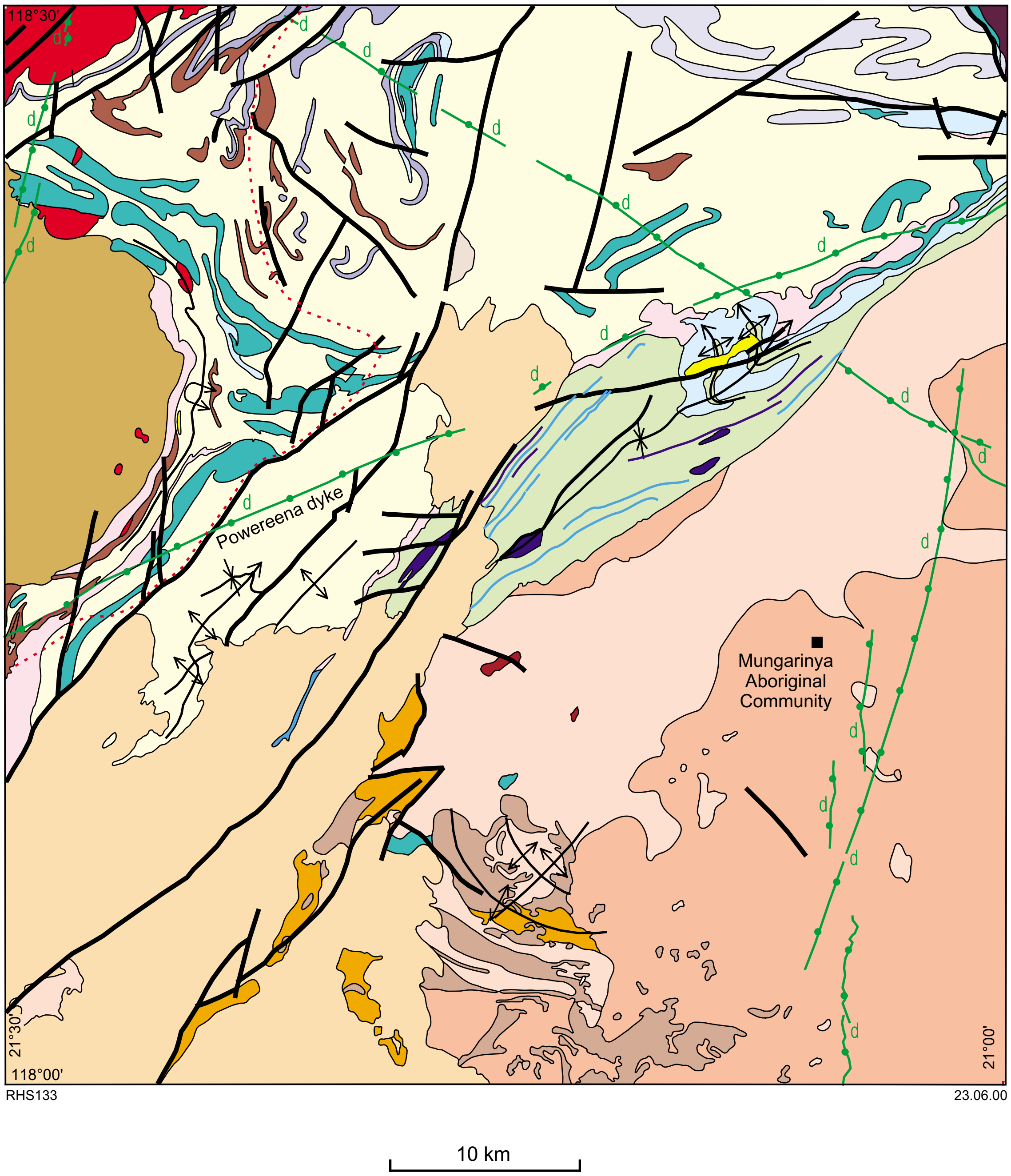
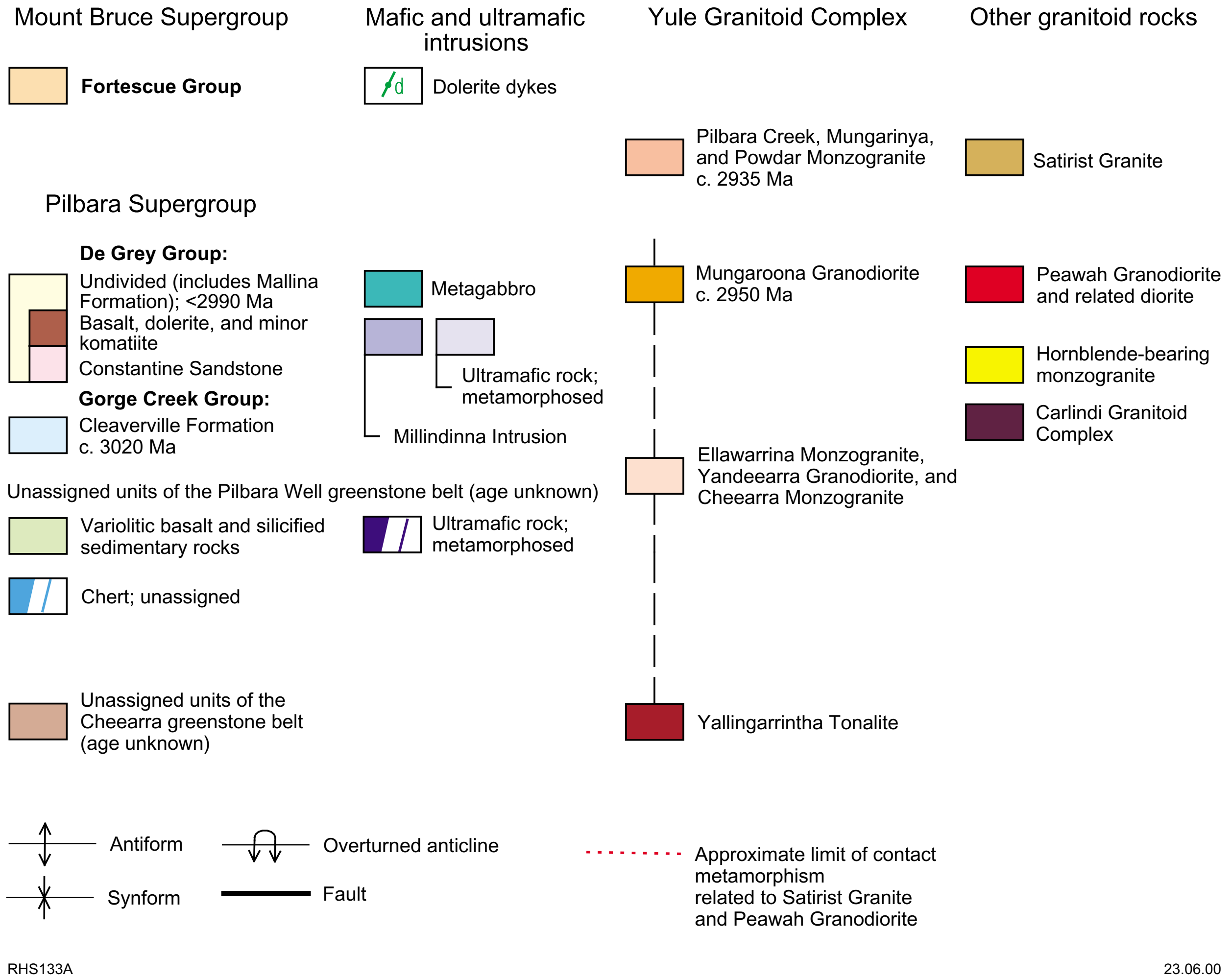


Figure 3. Interpreted bedrock geology of Satirist

Serpentinized peridotite (*Aup*) is the most abundant ultramafic rock type. In larger bodies, the rock is typically fine- to medium-grained and massive, with a relict orthocumulate texture. Phenocrysts of olivine, up to 5 mm in size, and oikocrysts of clinopyroxene, up to 10 mm in size, are present locally. Olivine is largely replaced by serpentine and lesser amounts of talc, magnetite, tremolite, and carbonate, whereas clinopyroxene is replaced by tremolite, talc, and fine-grained magnetite. In a few rocks, commonly in the cores of altered grains, there are relics of fresh olivine and clinopyroxene (Fig. 4). The best exposure of peridotite is in a large ultramafic body near the southwestern end of the Pilbara Well greenstone belt, 7.2 km west of the Friendly Creek mining centre (MGA 309498). Here, the peridotite is fine- to medium-grained, with relict mesocumulate and orthocumulate textures, and local zones that are weakly porphyritic in olivine. The rock is relatively massive and homogeneous in most places, but locally has an anastomosing, spaced foliation. Minor associated rock types are serpentinized dunite (*Aud*), fine-grained sedimentary rock, high-Mg basalt, and fine-grained gabbro. A poorly exposed talc–chlorite schist outcrops along the southeastern margin of the unit.

Serpentinized dunite (*Aud*) is a minor local variant in many bodies of peridotite. The best exposure of dunite is



present 3 km north of the Friendly Creek mining centre. Here, the rock is fine- to medium-grained, massive, and homogeneous, with a well-preserved olivine adcumulate texture.

Tremolite-rich schist (*Aur*) is common on the margins of the larger ultramafic bodies and in ultramafic units less than about 50 m thick. The rock is typically fine-grained and well foliated, and comprises acicular tremolite with subordinate amounts of chlorite and fine-grained opaque minerals.

Olivine pyroxenite (*Auxo*) forms a thin layer within a layered sequence 3.8 km southwest of the Hong Kong mine. It is a weakly deformed rock, rich in clinopyroxene and with minor amounts of olivine. The pyroxene, originally up to 4 mm in diameter, is largely replaced by tremolite. Relict cores of pale-brown clinopyroxene are preserved in some grains. The olivine is present as rounded inclusions and has been replaced by chlorite(–tremolite–sphene – opaque minerals).

Ultramafic rock forms a major component of the Cheearra greenstone belt, particularly to the south of Cheearra Hill where these rocks are interleaved with amphibolite, quartzite, and granitic gneiss on a 5–10 m scale. Here, the ultramafic rock is typically a strongly deformed tremolite–serpentine–talc–chlorite schist and has been mapped as undivided ultramafic rock (*Au*). The schist locally contains radiating or fan-like aggregates of tremolite and porphyroblasts of serpentinized ?olivine, both up to 20 mm in diameter. In the north of the Cheearra greenstone belt, weakly deformed serpentine–tremolite–talc–chlorite rock (*Auk*) locally preserves a well-developed olivine-spinifex texture. These komatiites indicate that at least some of the ultramafic rocks in the Cheearra greenstone belt are probably of extrusive origin.

Most of the ultramafic rocks that form xenoliths and roof pendants within the Yule Granitoid Complex are serpentinized peridotite (*Aup*), but many weakly deformed examples are komatiites (*Auk*), based on preserved olivine-spinifex textures.

Mafic rocks (*Ab*, *Aba, Abaz, Abm*, *Abmf, Abmz*, *Abx, Abi, Aby, Abu, Abz*, *Aogz*)

Mafic rocks are a major component of both the Pilbara Well and Cheearra greenstone belts, and are mostly well exposed.

Where the mafic rocks of the Pilbara Well greenstone belt are fine grained and weathered or altered, they have

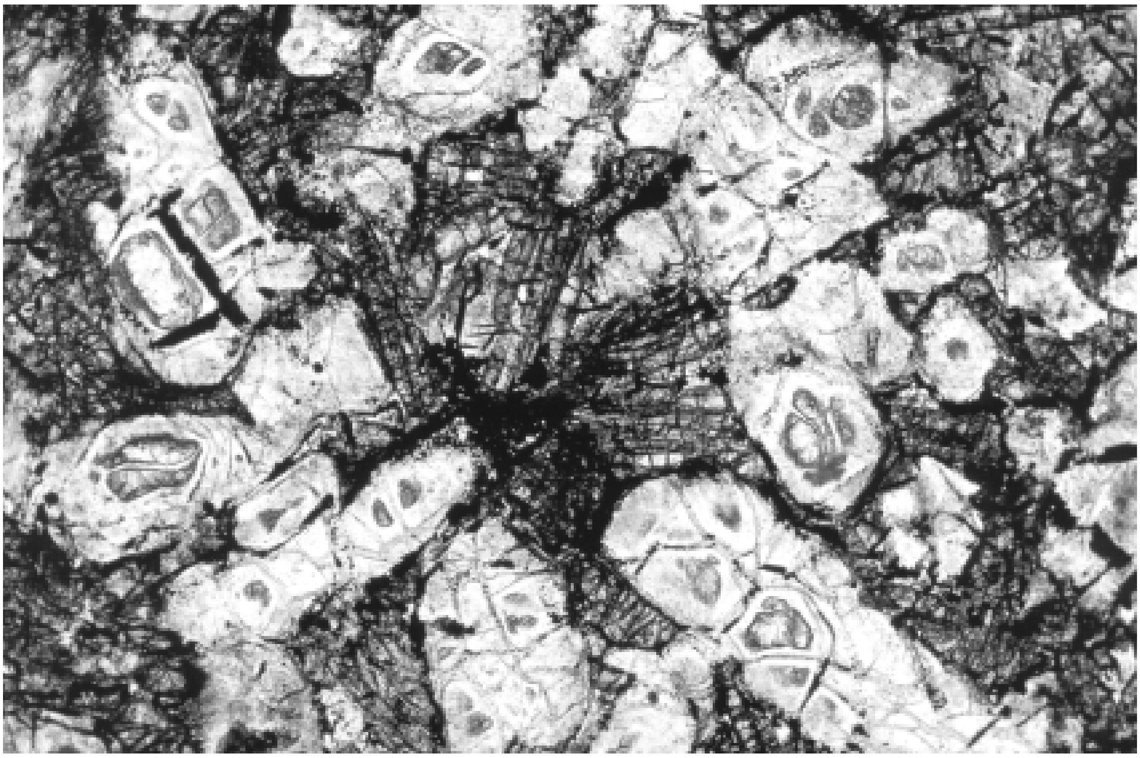


Figure 4. Photomicrograph of serpentinized peridotite from the Pilbara Well greenstone belt showing relict orthocumulate texture. The rock has partly serpentinized, elongate olivine crystals with relict cores of fresh olivine. Interstitial areas are occupied by fresh, elongate crystals of clinopyroxene and abundant fine-grained opaque minerals (mostly ?magnetite). GSWA 161037, MGA 301541. Plane-polarized light, width of field approximately 3 mm

been mapped as undivided (*Ab*). Weakly deformed, variolitic high-Mg basalt (*Abm*), is well exposed in many parts of the belt. The basalt typically contains abundant small varioles up to 6 mm in diameter (Fig. 5), and commonly has a fine, relict pyroxene-spinifex texture. Where the varioles are abundant, they merge into irregularly shaped pale zones and, in places, form distinctive pale stripes. High-Mg basalt with small phenocrysts of olivine and clinopyroxene is a minor variant in some areas, and peridotite and fine-grained gabbro are locally present. In parts of the sequence on the northern limb of the John Bull synform (e.g. MGA 321531), pillow structures are common and indicate a northwesterly younging direction.

In thin section, the varioles in high-Mg basalt (*Abm*) are defined by a small difference in the proportion of tremolite–actinolite, and by concentrations of a brownish material too fine to be identified optically (Fig. 6). Pyroxene crystals have been replaced by tremolite–actinolite or chlorite, or both, and plagioclase has been replaced by albite(–epidote–sphene). Carbonate alteration of high-Mg basalt is common, both as widespread patchy alteration and as amygdale fillings.

Spherulitic structures, ranging up to 25 mm in diameter, are present in some outcrops of high-Mg basalt (Fig. 7). They are similar to the varioles, which are typically also present, but are mostly much larger. The spherulitic structures have a sharp boundary defined by a 0.02 to 0.04 mm-thick albite rim. Surrounding the spherulites is a distinct dark halo, rich in tremolite and actinolite, which grades outwards into the host basalt. Internally, the spherulites have a diffuse concentric zoning, defined by a gradual change in the proportion of tremolite–actinolite, and an ultrafine, unidentified brown mineral phase. Spinifex textures are also common internally.

Strongly foliated, variolitic, high-Mg basalt (*Abmf*) is restricted to narrow zones, mainly along the contact between sequences of high-Mg basalt, chert, and silicified rock. This high-Mg basalt has unusual amphibole-rich patches up to 10 mm in diameter, and is interpreted to be a strongly deformed high-Mg basalt on the basis of relict pyroxene-spinifex textures.

Poorly exposed, weathered, strongly silicified mafic and sedimentary rocks (*Abz*) are interbedded with thin layers of chert (*Ac*) in an east-northeasterly trending zone, about 3 km north of the Friendly Creek mining centre. Rocks in this unit are mainly fine grained and extremely silicified and therefore the protolith is not easily identifiable. The rocks are typically cherty, with vague structures and diffuse layering (?alteration effects), and range from pale creamy brown to pale green-grey. Some rocks have a microscopic relict igneous-texture, similar to that of an intergranular-textured gabbro. Siltstone and fine-grained sandstone are present in parts of the unit, as well as possible silicified ultramafic units. Strongly silicified,

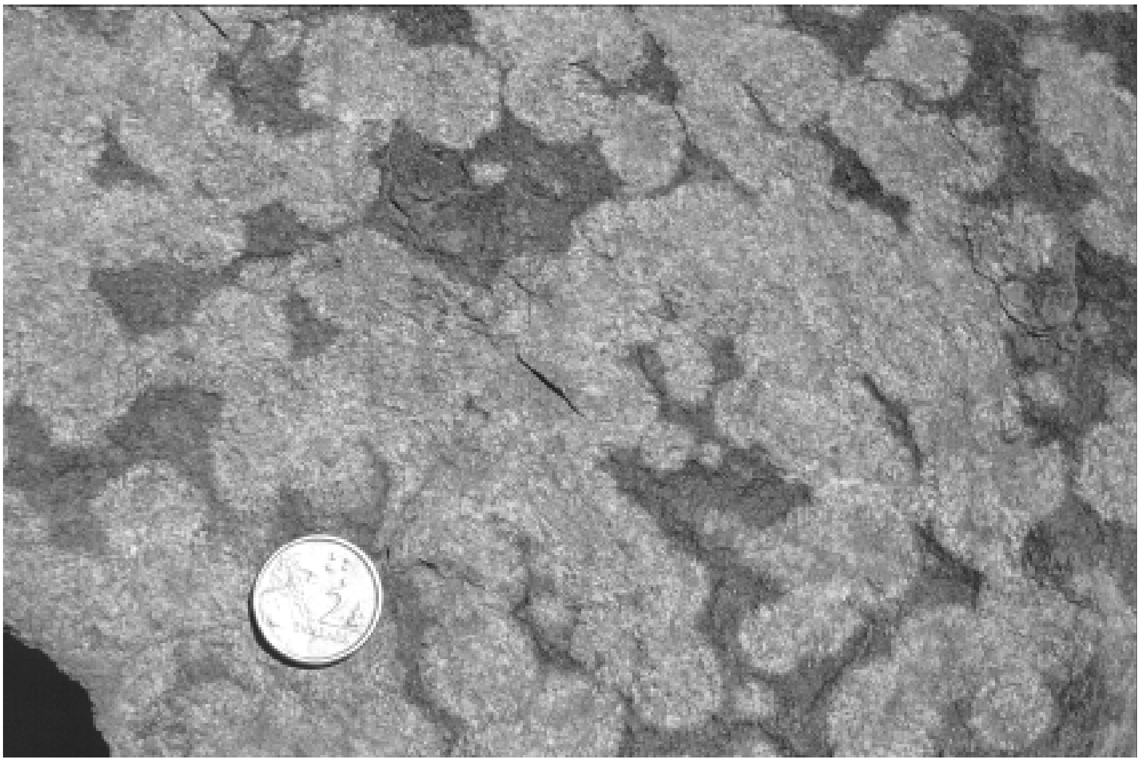


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Figure 5. Varioles in a metamorphosed high-Mg basalt from the Pilbara Well greenstone belt. The varioles have an internal pyroxene-spinifex texture and are up to 15 mm in diameter. MGA 407542

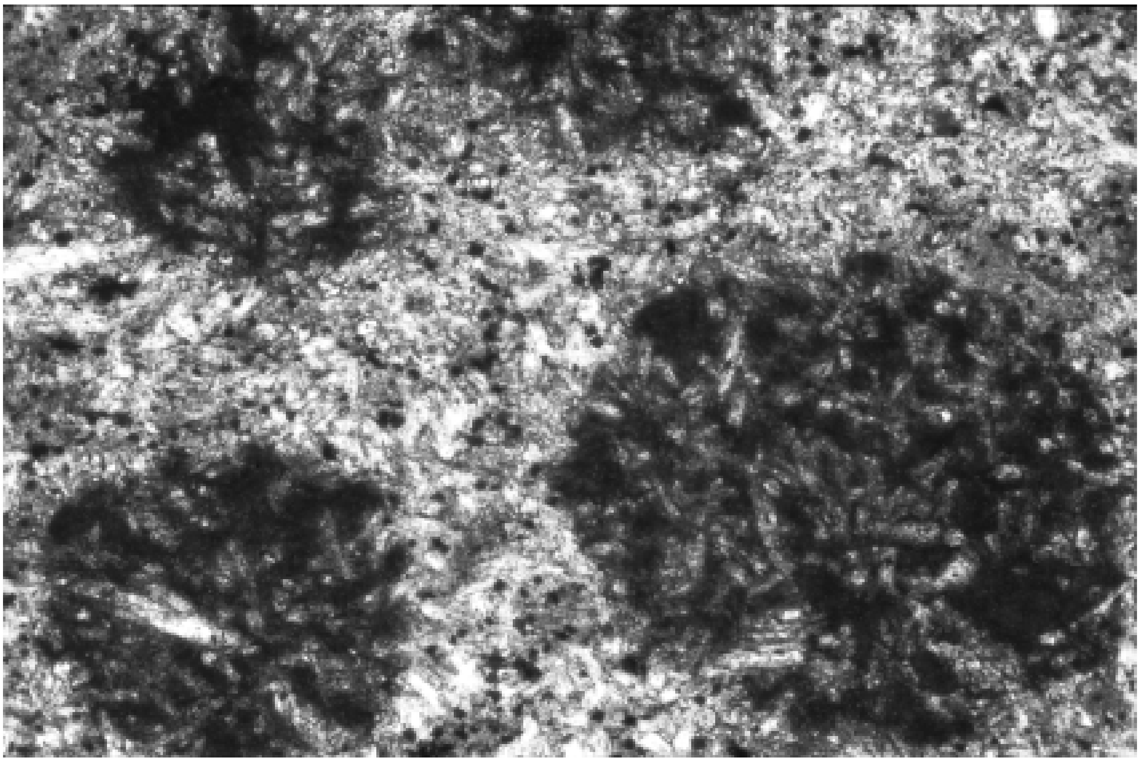

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Figure 6. Photomicrograph of varioles (dark areas) in a metamorphosed high-Mg basalt from the Pilbara Well greenstone belt. The varioles are defined mainly by a greater proportion of fine-grained tremolite–actinolite and dispersed submicroscopic material. GSWA 137588, MGA 380590. Plane-polarized light, width of field approximately 3 mm

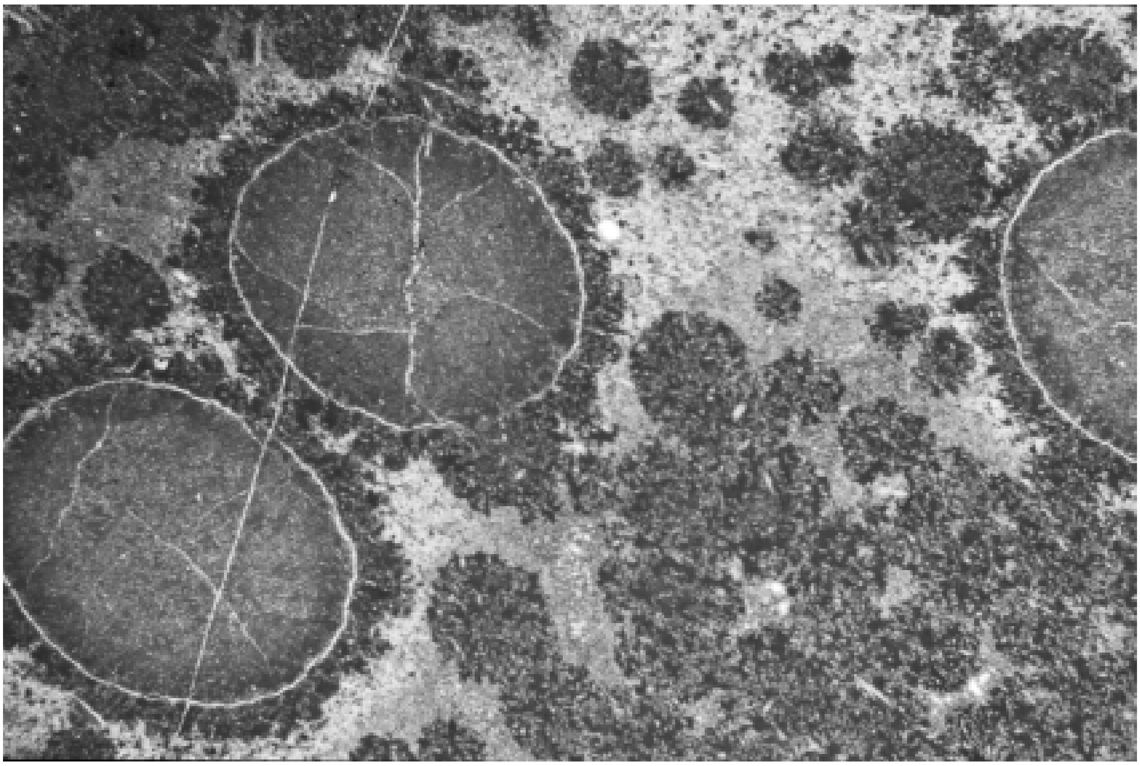

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Figure 7. Spherulitic structures in a metamorphosed variolitic high-Mg basalt from the Pilbara Well greenstone belt. The structures are larger than the surrounding varioles, and have an enclosing amphibole fringe (or 'beard') texturally and mineralogically similar to the varioles. GSWA 137588, MGA 380590. Plane-polarized light, width of field 1.7 mm

RHS145 19.5.00

Figure 8. Coarse-grained mafic fragmental-rock from the Annie Gap area in the Pilbara Well greenstone belt. Contains large, irregularly shaped fragments of basalt. Note the cuspate fragments in the bottom left corner of the photograph. MGA 369585

fine-grained gabbro (*Aogz*) is present at the southwestern end of the unit. The gabbro is strongly bleached but has a well-preserved granular texture. It is cut by zones of intense silicification, abundant quartz veins, and quartz-cemented hydrothermal breccia.

Silicified high-Mg basalt (*Abmz*) outcrops in zones up to about 150 m wide that are parallel to stratigraphy (e.g. MGA 326527). In these zones, the basalt is bleached and cut by numerous quartz veins. Patches of coarse-grained quartz–epidote–amphibole alteration are also present in interpillow areas. Some parts of the sequence also have silica-filled vesicles and silica-cemented breccias (?hydrothermal breccia).

A mafic volcaniclastic breccia (*Abx*), 3.5 km northeast of the Hong Kong mine, contains angular and cuspate fragments of altered basalt in a tuffaceous sandstone matrix (Fig. 8). The breccia is extensively altered to secondary silica, chlorite, very fine white mica, and fine-grained opaque minerals. Clasts of amygdaloidal basalt have quartz(–chlorite)-filled vesicles, quartz pseudomorphs of ?pyroxene phenocrysts, and relict igneous textures outlined by concentrations of ultrafine opaque minerals. The breccia matrix has relics of shard-like fragments up to 2.0 mm long, some of which are cuspate or have partial vesicle walls (Fig. 9). These are interpreted to be altered fragments of basaltic glass. The unit is poorly sorted and appears to be thick bedded, suggesting a mass flow deposit. The low diversity of lithic clast types and the predominance of glassy shards within the matrix, plus the preservation of delicate cusps on both shards and lithic fragments, suggests that the deposits may have been syneruptive.

Amygdales and pipe vesicles (Fig. 10) filled with quartz or carbonate are a common feature in the high-Mg basalts, particularly in the area near Black Gin Well. However, they are irregularly distributed and therefore amygdaloidal basalt (*Aby*) is mapped only in areas where the amygdales are abundant. The amygdales are typically 3–5 mm in diameter, but may be up to 15 mm. Scattered clusters of altered ?pyroxene phenocrysts are present in some cases. The rocks are extensively altered; the groundmass is replaced by chlorite, quartz, carbonate, and opaque minerals, and the phenocrysts are replaced by quartz and chlorite.

Mafic to intermediate rocks (*Abi*), tentatively identified as andesite, outcrop in the hinge zone of the John Bull synform, about 5 km northwest of the Friendly Creek mining centre. They contain sparse, small (up to 1 mm) euhedral phenocrysts of hornblende and plagioclase, and a few quartz-lined vesicles. Intermediate rocks also outcrop as thin layers (typically less than 2 m thick) intercalated with mafic rock, on the eastern side of the John Bull mine (MGA 358550). Here, the rocks consist mainly of interlocking plagioclase (up to 1.5 mm long) and subordinate chlorite, biotite, and white mica after igneous ?hornblende. The interstitial areas comprise quartz, chlorite, biotite, and fine-grained opaque minerals. Although the intermediate rocks are similar to the

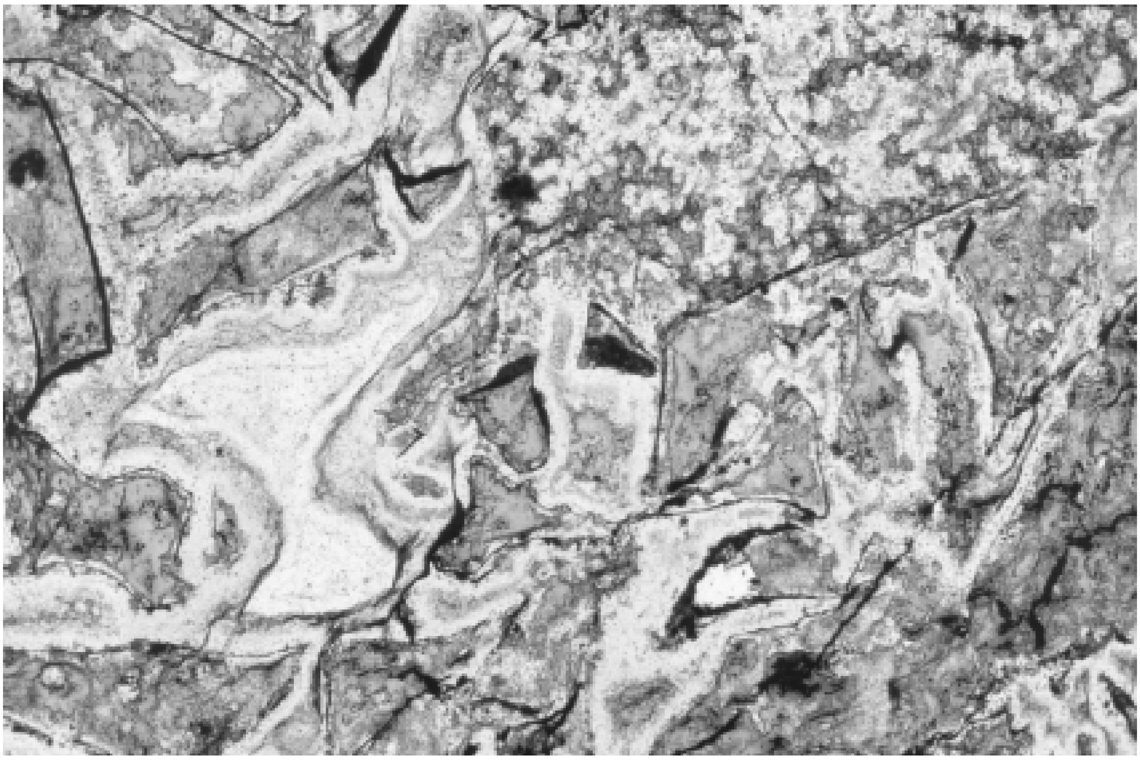

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Figure 9. Photomicrograph of an altered mafic fragmental-rock from the Annie Gap area. Contains angular and cuspate lithic fragments replaced by quartz (white) and chlorite (green). GSWA 161021, MGA 351571 Plane-polarized light, width of field approximately 3 mm

RHS147 19.5.00

Figure 10. Pipe vesicles in a metamorphosed, pillowed, high-Mg basalt in the Pilbara Well greenstone belt. The vesicles are approximately perpendicular to the upper flow margin, which is overlain by a thin layer of fine-grained, laminated inter-flow sedimentary rock. MGA 298495

plagioclase–hornblende porphyry dykes (*Afp*) in the Pilbara Well greenstone belt, they are clearly older because they are conformable with the mafic sequence and are cut by felsic dykes.

In the vicinity of Cheearra Hill and towards the east-southeast, rocks of mafic and ultramafic composition have been extensively metamorphosed and deformed, and it is unclear if their protoliths were intrusive or extrusive. These rocks were mapped as undivided ultramafic rocks (*Au*), undivided amphibolite (*Aba*), or undivided and interleaved mafic- and ultramafic-rock (*Abu*). The latter incorporates components of both *Au* and *Aba*.

Undivided amphibolite (*Aba*) is typically fine- to medium-grained with a granoblastic assemblage that includes plagioclase, actinolite/hornblende, quartz, epidote, and rare clinopyroxene, and in places, is highly silicified (*Abaz*). The rock has a variably developed foliation and is locally banded. The bands are 2–5 cm thick and comprise quartz–biotite-rich bands that alternate with plagioclase–amphibole-rich bands. Some bands contain up to 30% quartz. A prominent lineation produced by the alignment of acicular amphibole is present in some samples. The amphibolite commonly contains sparse, multiply deformed quartz–plagioclase leucosomes. Mafic gneiss, containing abundant leucosomes, is present in a few locations, and mafic amphibolite and hornblendite (?metapyroxenite) are present in some parts of the sequence. The amphibolite forms part of a sequence that includes metasedimentary rocks (*Asq, Asc* — see below) and therefore some of the quartz-rich bands and leucosomes may be metamorphosed layers of quartz-rich clastic material.

Undivided felsic rock (*Af*)

Undivided felsic rocks (*Af*) outcrop in a few locations within the Pilbara Well greenstone belt (e.g. MGA 334499) and are associated with felsic volcaniclastic sandstone (*Asf*). They are typically intensely silicified and primary textures have consequently been obliterated. Five kilometres west of Friendly Creek mining centre, a small exposure of a silicified, coarse-grained felsic ?porphyry contains relict plagioclase crystals (up to 17 mm in length) and rounded quartz and plagioclase, which are set in a dynamically recrystallized matrix of quartz and plagioclase. Scattered aggregates of chlorite – white mica – iron oxides within the matrix may be after igneous biotite. The plagioclase commonly has albite rims and is partly replaced by chlorite and white mica. Although the rock is extremely altered, it appears to be a plagioclase porphyry.

Sedimentary rocks (As, Asb, Asc, Asf, Ash, Asq, Asqb, Assq)

Sedimentary rocks are a minor, widespread component of the Pilbara Well greenstone belt, but form a significantly greater proportion of the Cheearra greenstone belt.

Most of the sedimentary rocks of the Pilbara Well greenstone belt are strongly deformed and deeply weathered, and have been variably silicified, possibly shortly after deposition. Fine-grained sedimentary rocks are particularly difficult to classify and have generally been mapped as undivided sedimentary rock (*As*).

An extensive unit of mafic volcaniclastic conglomerate, sandstone, and siltstone (*Asb*) lies immediately below a chert layer on the northwestern limb of the John Bull synform. Most of the unit is strongly weathered and intensely silicified. The rocks contain abundant clasts of amygdaloidal basalt and possible pillow fragments, up to 60 cm in size, as well as sparse chert clasts near the top of the unit. Rocks at the base of the unit (near the northeastern end) contain highly irregular and angular clasts, whereas farther upsequence and along strike to the southwest, the clasts are smaller and more rounded.

Felsic volcaniclastic sedimentary rocks (*Asf*) are common where adjacent to chert horizons. They are typically well foliated, thin bedded, siliceous, and fuchsite bearing, and are interbedded with thin layers of chert (< 10 cm thick). In thin section, the rocks are typically pervasively silicified, and contain altered clasts up to 2.0 mm that are outlined by variations in the concentration of ultrafine opaque minerals and white mica. The clasts are angular to rounded but their composition is uncertain because of their intense alteration; however, some clasts have a shard-like morphology that indicates a volcanic provenance.

Siliceous siltstone and shale (*Ash*) are a minor component of the Pilbara Well greenstone belt. In most outcrops they are thinly interbedded with other sedimentary rocks and cannot be represented at 1:100 000 scale. A small exposure of weathered fine-grained sedimentary rock is present in the mafic sequence 3 km west of Black Gin Well. The rocks at this location are very fine grained and thin bedded, with a strong slaty cleavage and tight small-scale folds. Associated pods and lenses of greenish siliceous rock, may be silicified ultramafic rock.

Fine-grained quartz sandstone and siltstone (*Assq*) outcrops in a northeasterly trending belt about 3 km northwest of Friendly Creek mining centre. The rocks are well foliated and thin- to medium-bedded and are intercalated with subordinate coarse-grained quartz sandstone, shale, and thin layers of chert. The sequence is locally silicified, typically in zones that contain thin interbeds of chert. The sandstone contains abundant relict quartz clasts (0.05–0.4 mm in size) in a fine-grained recrystallized matrix of white mica, quartz, ?plagioclase, and dispersed fine-grained opaque minerals. Narrow zones (parallel to the foliation) of white mica and opaque minerals are also present, as well as rare recrystallized lithic fragments that are rimmed by concentrations of fine-grained opaque minerals. Some rocks in the unit contain abundant angular and cuspate fragments (?former glass shards) that are replaced by quartz and have optically continuous quartz overgrowths. These rocks may be silicified tuffaceous sandstones.

In the Cheearra greenstone belt, metamorphosed conglomerate (*Asc*) is found in the northwestern foothills of Cheearra Hill. The rock is strongly foliated and the pebble- to cobble-sized clasts are highly flattened. The protolith of most clasts is uncertain, but some appear to be metamorphosed granite and chert. The clasts lie in a granoblastic matrix of quartz (>50%), microcline, actinolite, and clinopyroxene. Quartz–muscovite schist and quartzite (*Asq*), after subarkose, is a major component of the Cheearra greenstone belt in the vicinity of, and to the east-southeast of, Cheearra Hill. Where it is locally interleaved with undivided amphibolite (*Aba*), it has been mapped separately (*Asqb*). Quartz–muscovite schist and quartzite contains between 70 and 95% quartz. The less quartz-rich rocks are locally well banded. The bands are defined by plagioclase-rich layers or a prominent schistosity produced by alignment of muscovite, or a combination of both. The more quartz-rich rocks are typically massive and comprise a granoblastic assemblage of quartz–plagioclase (now epidote and sericite) and rare microcline and clinopyroxene, with actinolite as a late-crystallizing acicular mineral.

Chert (*Ac*)

Thin layers of chert (*Ac*) are common in the Pilbara Well greenstone belt, typically in zones of strongly silicified rock. The texture of the cherts is variable, and many are probably derived from silicification of sedimentary or mafic rocks. The 'Hong Kong Chert' (Fitton et al., 1975) comprises thin, prominent layers of chert in a sequence of silicified mafic and sedimentary rocks. In the vicinity of the Hong Kong mine, the chert lies on a silicified basal sequence of coarse mafic-volcaniclastic rocks (*Asb*). This sequence comprises a lower chert zone, an intervening succession of silicified basalt, gabbro (*Aogs*), and sedimentary rocks, and an upper chert zone. The chert zones typically contain one or more conformable chert layers, less than 20 m thick, in poorly exposed, silicified ?sedimentary rock. The chert layers are commonly stacked in an en echelon arrangement. In a few locations, there are transgressive, massive grey cherts that branch off the underside of the conformable chert layers and cut across the underlying sequence at a high angle. These have previously been called tectonic cherts (or T-cherts, Hickman, 1983), but here they are interpreted as fissures or extinct hydrothermal vents that were filled with silica precipitates at the time of chert deposition.

On the northern limb of the John Bull synform, the 'Hong Kong Chert' overlies volcaniclastic breccia, conglomerate, and sandstone, but on the southern limb it overlies siltstone and fine-grained sandstone, with abundant thin cherty layers. The lower chert zone comprises numerous thin chert layers that are typically less than about 20 m thick (except towards the southwest, where there is one main layer about 50 m thick). The texture and colour of the cherts is highly variable; off-white to black and non-layered to well layered. The layering is typically between 0.1 mm and about 40 mm thick, and the thicker layers commonly also have fine, internal laminae. An irregular wavy lamination is developed locally, as well as a porous box-work, which is possibly due to silica pseudomorphs of gypsum or anhydrite.

The upper chert zone typically contains alternating dark grey and cream or pale-grey layers, which are up to about 700 mm thick; the thicker layers commonly have very fine internal laminae. On the southern limb of the synform, the upper chert zone shows more textural variation than on the northern limb. The layering is not as well developed and the unit contains grey and white layered chert, and creamy brown to off-white non-layered chert.

The rocks between the two chert zones in the John Bull synform are deeply weathered and poorly exposed. In better exposed areas, the rocks are extensively silicified and include fine-grained gabbro, pillowed basalt, pyroxene-spinifex textured high-Mg basalt, siltstone, and fine-grained sandstone. Clastic sedimentary rocks are more abundant on the southern limb of the synform, approximately 3 km northwest of the Friendly Creek mining centre.

Gorge Creek Group

The Gorge Creek Group on SATIRIST can broadly be divided into two lithologically distinct units: a thin, lower, dominantly felsic unit, and an overlying dominantly chert and BIF unit. The felsic unit contains a variety of felsic clastic sedimentary rocks, and minor rhyolite and trachyte. Silicification of the sequence is widespread and locally intense. The overlying chert and BIF unit has been assigned to the Cleaverville Formation. It consists of layered chert and silicate-facies BIF, with minor poorly exposed clastic sedimentary rocks, felsic schist, and foliated basalt. The western end of the unit, north of Black Gin Well, is dominated by layered chert, locally ferruginous, whereas BIF is more abundant at the eastern end towards Kangan Gap.

Felsic rocks (*AG*(*f*), *AG*(*fy*), *AG*(*sfc*), *AG*(*sfs*), *AG*(*shg*))

Much of the felsic sequence on SATIRIST is strongly silicified and cut by silica veins, and silica-cemented ?hydrothermal breccias (Fig. 11) are common in some areas (e.g. 2 km northwest of Black Gin Well). Felsic rocks that are too altered or too fine grained for identification of the protolith have been mapped as undivided felsic rocks (*AG(f)*). They are typically cream to pale-grey or pale-brown, fine grained, and massive.

Felsic rock types identified in areas of less intense alteration include: aphyric ?lava (with a localized wispy flow lamination), trachyte (*AG(fy)*), felsic volcaniclastic sandstone (*AG(sfs)*), poorly sorted pebbly sandstone and conglomerate (*AG(sfc))*, and carbonaceous shale and siltstone (*AG(shg)*). In some kaolinized exposures, relict quartz, fine-grained white mica, and clay pseudomorphs of feldspars are present.

Trachyte (*AG(fy))* is present in one location (MGA 395581) in the upper part of the sequence, approximately 3 km north-northwest of Black Gin Well. The trachyte is a pale greenish-grey, massive, aphyric rock. In thin

RHS148 19.5.00

Figure 11. Hydrothermal breccia in an intensely silicified felsic rock from the base of the Gorge Creek Group. The rock is cut by a network of thin, secondary silica veins. MGA 391566

section, it has a well-developed trachytic texture, with K-feldspar laths up to 0.8 mm in length. Interstitial areas contain fine-grained recrystallized feldspar, epidote, white mica, carbonate, and opaque minerals. The trachyte also has elliptical patches of coarse-grained quartz, with subordinate epidote, ?clinopyroxene, and opaque minerals, surrounded by a diffuse halo of variable concentrations of fine-grained sphene and epidote. These patches are possible relict amygdales.

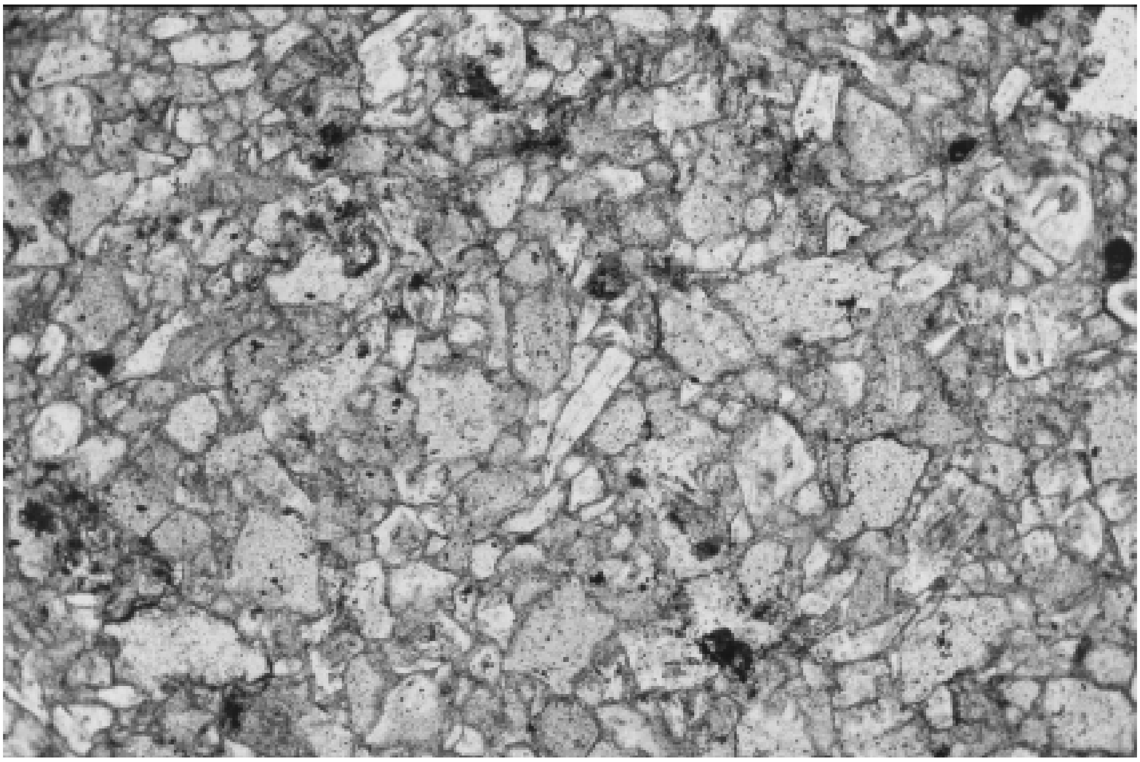
The most abundant rock type in the felsic sequence is a medium- to thick-bedded, feldspathic sandstone and siltstone (*AG(sfs)*). This is a moderately foliated rock showing various degrees of silicification. Graded bedding in an outcrop 4 km northeast of Black Gin Well, indicates that the sequence youngs to the northwest in that area. In thin section, these rocks have a varied composition, but they typically contain subangular clasts (up to 0.5 mm) of plagioclase, K-feldspar, and various fine-grained felsic rocks (Fig. 12).

A bedded felsic sequence north of Black Gin Well also contains interbedded coarse-grained volcaniclastic sandstone and conglomerate (*AG(sfc)*). These rocks contain a variety of felsic rock clasts, up to 300 mm in size (Fig. 13), which include plagioclase-phyric ?rhyolite–dacite, spherulitic rhyolite, and plagioclase-rich trachytic rock. Much of the sequence is pervasively silicified and there is localized carbonate alteration.

A minor rock type in the felsic sequence is carbonaceous siltstone and shale (*AG(shg)*). These rocks are extensively silicified and recrystallized and are mesoscopically similar to layered chert. The siltstone contains relict clasts of quartz, K-feldspar, and ?plagioclase up to 0.3 mm, in a very fine-grained, recrystallized matrix of white mica, quartz, and feldspars. The carbonaceous material is mostly concentrated in discrete layers but is also disseminated throughout the rock.

Cleaverville Formation (*AGlc*, *AGlcx*, *AGli*, *AGlix*)

Chert (*AGlc*) and BIF (*AGli*) form prominent ridges that trend northeastwards along the northern margin of the Pilbara Well greenstone belt in the northeast corner of SATIRIST. The chert (*AGlc*) has a variable texture; from relatively massive with diffuse patches and swirls of colour to well layered and finely laminated. The iron-oxide content is highly variable and is typically reflected by the colour of the chert; from cream or pale grey to dark blue-grey or dark brown. Some layers contain abundant dispersed magnetite and iron hyroxides, and in places, the rock has a distinct centimetre-scale banding. This banding comprises alternating layers of white and red chert (jasper), or layers with up to 70% magnetite (BIF). Graphite is a minor component of many of the rocks, which have discontinuous layers, up to 5 mm thick and containing up to 30% graphite, in places. In areas of the Mallina Basin, where the Cleaverville Formation is exposed in the cores of tight anticlines (for example at



RHS143 19.5.00

Figure 12. Photomicrograph of a felsic volcaniclastic sandstone from the base of the Gorge Creek Group. GSWA 137593, MGA 394578. Plane-polarized light, width of field approximately 3 mm

RHS149 19.5.00

Figure 13. Poorly sorted pebble conglomerate with sparse, angular to subangular cobbles of silicified ?felsic rock. From the base of the Gorge Creek Group. MGA 394576

RHS150 19.5.00

Figure 14. Chert-clast conglomerate from the Constantine Sandstone. MGA 378617

Mount Langenback), local chert breccia units (*AGlcx*) contain angular blocks of chert up to 1 m in size within a very fine-grained cherty matrix.

Banded iron-formation (*AGli*) consists of 1–2 cm-thick bands of magnetite-free to magnetite-rich chert, and forms mappable layers that alternate with chert units (*AGlc*) in the Kangan Gap area and to the east of the Yule River. In these areas, dark grey and dark-red layered BIF forms a mixed unit (*AGlix*) with tremolite–chlorite schist (?after high-Mg basalt), talc schist, and strongly foliated ferruginous siltstone. In the area northeast of Kangan Gap, BIF units have been locally metamorphosed to at least upper greenschist facies, producing banded grunerite schist (see **Metamorphism**).

De Grey Group

Rocks of the De Grey Group outcrop extensively in the northwestern part of SATIRIST and have undergone contact metamorphism where they are in proximity to the Satirist Granite and the Peawah Granodiorite. Strongly metamorphosed rocks of the De Grey Group are described with their weakly metamorphosed equivalents. For discussion on the style and grade of metamorphism, see **Metamorphism**.

On SHERLOCK and MOUNT WOHLER, rocks of the De Grey Group were divided into either the Mallina Formation or the underlying Constantine Sandstone on the basis of distinct and persistent compositional and textural features. Together, these formations constitute the clastic section of the Mallina Basin. Both formations were originally named and defined by Fitton et al. (1975) and are of turbiditic origin (Hickman, 1977; Eriksson, 1982; Barley, 1987; Horwitz, 1990). The Mallina Formation is primarily a sequence of interbedded, well-graded, medium- to fine-grained wacke and shale, with rare, thick, massive units. In contrast, the Constantine Sandstone is mostly a medium- to coarse-grained, poorly sorted subarkose to wacke, with common conglomerate layers, and is thicker bedded than the Mallina Formation. The differences between these formations are probably a combined result of differing environments of deposition and source regions. The Constantine Sandstone on MOUNT WOHLER contains features consistent with upper-fan deposition within a submarine fan (Eriksson, 1982), whereas the Mallina Formation contains features more typical of proximal-lobe deposition within a submarine fan, transitional to a basin-plain environment (Smithies et al., 1999).

Nevertheless, it has been recognized on MOUNT WOHLER and on YULE (Smithies, 1999) that rocks closely resembling those of the Mallina Formation locally form a large, but never dominant, proportion of some sequences 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. For example, outcrop of wacke on both map sheets is locally similar in mineralogy to wacke of the Mallina Formation, but is more like the Constantine Sandstone in terms of grain-size, the presence of minor pebble beds, and the lack of associated shale interbeds. The distinction between Mallina Formation and the Constantine Sandstone is not always simple and it is likely that the two formations are locally gradational. Consequently, many rocks of the De Grey Group on SATIRIST and 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, were they mapped as such on YULE and SATIRIST.

The thickness of units belonging to the De Grey Group cannot be established from exposures on SATIRIST. However, estimates of the maximum thickness of the Mallina Formation on SHERLOCK range between 2.5 km (Fitton et al., 1975) and 10 km (Miller, 1975), and the maximum thickness of the Constantine Sandstone on MOUNT WOHLER was estimated at about 3.5 km (Smithies, 1998b).

Constantine Sandstone (*ADc, ADch, ADcs, ADcq, ADcc*)

Conglomerate (ADcc)

Polymictic conglomerate (*ADcc*) forms layers up to 500 m thick along the base of the Mallina Basin and is locally intercalated with a pebble-rich, coarse-grained, poorly sorted, litharenite.

A prominent south-southwesterly trending ridge of conglomerate, to the southwest of Teichmans Well, marks the faulted edge of the Mallina Basin beneath the rocks of the Fortescue Group. The polymictic conglomerate contains subrounded cobbles of chert up to 20 cm in size, smaller pebbles of silicified komatiite, and rare pebbles of felsic volcaniclastic rock (Fig. 14). At some localities (e.g. MGA 202435), angular blocks of chert, up to 50 m long, are present within the conglomerate. The matrix to the conglomerate consists of medium- to coarse-grained, poorly sorted litharenite.

The basal conglomerate extends along the northern edge of the Pilbara Well greenstone belt in the area north of Black Gin Well. The original thickness of the conglomerate is difficult to estimate due to the locally high strain and multiple deformation. The main rock types in this area are poorly sorted coarse-grained litharenite, pebbly sandstone, and conglomerate. The rocks contain clasts of chert (> 80 vol. %), unidentified silicified rock, and rare vein quartz. Some of the silicified rock fragments contain carbonaceous material. A variety of chert types are present, including both layered and non-layered varieties. The clasts have a wide angularity and sphericity range, although most are subangular to subrounded. In most cases the clasts are less than 150 mm in size, but there are rare boulders of chert up to 1.5 m in diameter. The matrix is completely silicified and recrystallized. At the eastern end of the unit, 4 km southeast of Satirist Outcamp Well, the rocks contain very angular chert fragments and are difficult to distinguish from fractured chert of the Cleaverville Formation.

Figure 15. Poorly sorted lithic subarkose of the Constantine Sandstone. MGA 147596

Poorly sorted subarkose (ADcq)

On SATIRIST, poorly sorted, medium- to coarse-grained, subarkose, locally interbedded with thin units of litharenite, conglomerate, and shale (*ADcq*), forms the most prominent outcrops of the Constantine Sandstone. It outcrops against the southeastern margin of the Satirist Granite and in the area between the Empress mine and a point approximately 3 km northeast of Kangan Gap. The subarkose is pale brown to pale grey, thick bedded, and medium- to coarse-grained. Grains of quartz and minor feldspar are angular to subrounded, and commonly supported by a matrix of quartz, sericite, chlorite, feldspar, and clay minerals. Scattered granules and small pebbles of green (fuchsitic) and black chert are up to 50 mm in size (Fig. 15). Litharenite is typically darker in colour and is dominated by dark-grey chert clasts. Thin beds of pebbly sandstone and chert-clast pebble conglomerate are present locally.

Poorly sorted subarkose and wacke (ADcs)

Interbedded, poorly sorted, medium- to coarse-grained subarkose, wacke and shale form a unit (*ADcs*) up to 1 km thick in the central-western part of SATIRIST, close to the contact with the Satirist Granite. This unit forms the inferred stratigraphic top of the Constantine Sandstone in the northern part of MOUNT WOHLER; the proportion of shale and wacke increasing upwards towards a gradational contact with the Mallina Formation. On SATIRIST, rocks assigned to the poorly sorted subarkose and wacke unit of the Constantine Sandstone are overlain and underlain by units that cannot be confidently assigned to either the Constantine Sandstone or the Mallina Formation. This relationship forms part of the complicated sedimentary architecture of the Mallina Basin, and casts further doubt on the usefulness of the locally established stratigraphic nomenclature of the De Grey Group.

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

Laminated shale (ADch)

Well-laminated shale with minor interbeds of poorly sorted subarkose (*ADch*), is typically poorly exposed and deeply weathered. The most prominent exposure on SATIRIST is a layer up to 200 m thick in the central-western part of the sheet area. Here, the shale is underlain by siliceous siltstone (*AD*(*hs*)) and overlain by poorly sorted subarkose and wacke (*ADcs*). The shale consists of angular quartz, abundant chlorite and biotite, and minor sericitized plagioclase. Variations in the ratio of quartz to mica define a primary bedding lamination, whereas a preferred orientation of mica defines a slaty cleavage.

Some layers are ferruginous and contain chlorite- and magnetite-rich laminations. Muscovite locally overprints the slaty cleavage and is a result of contact metamorphism.

Unassigned units of the De Grey Group

Wacke units (AD(q), AD(qc), AD(t), AD(tqc), AD(tqp), AD(s))

Fine- to coarse-grained wacke (*AD(t)*) contains abundant chert clasts, has well developed graded units, and locally includes shale, subarkose, conglomerate, and pebble beds. This unit outcrops extensively throughout the Mallina Basin on SATIRIST and differs from the Mallina Formation in that it includes coarse-grained wacke. The fine- to coarse-grained wacke unit also appears to be more siliceous than rocks of the Mallina Formation. However, in several outcrops, it appears that the Mallina Formation (*ADm*) grades into rocks of the *AD(t)* unit; the development of deformational fabric decreases with proximity to the locally silicified tops of large outcrops. It is possible, therefore, that *ADm* and *AD(t)* are the same primary rock type or are gradational.

Coarse-grained wacke (*AD(tqc)*), locally associated with fine- to medium-grained clastic units, forms minor outcrops throughout the Mallina Basin, but is widely exposed in the central-western part of SATIRIST. Polymictic conglomerate containing abundant cobbles of chert (*AD(tqp)*), is locally associated with the coarse-grained wacke unit (e.g. MGA 219521, MGA 301767). These units (*AD(tqc)* and *AD(tqp)*) are petrographically similar to the poorly sorted subarkose and wacke (*ADcs*) and the polymictic conglomerate (*ADcc*) units respectively, of the Constantine Sandstone. However, they are unassigned because they form components of sequences that are atypical of that formation elsewhere in the Mallina Basin. For the same reason, medium-grained, poorly sorted subarkose (*AD(q)*), and coarse-grained, poorly sorted subarkose (*AD(qc)*) have been separated from the poorly sorted subarkose (*ADcq*) unit of the Constantine Sandstone.

A unit of coarse-grained wacke (*AD(tqc)*) outcrops approximately 1 km to the southeast and east of the Satirist Granite. Here, it is overlain by a distinctive chlorite–actinolite-rich schist unit representing metamorphosed high-Mg basalt and lesser komatiite. This coarse-grained wacke unit is different from *AD*(*tqc*) in that it locally contains interbeds, up to 1 m thick, of fine- to medium-grained wacke that is interpreted to be of volcaniclastic origin. The wacke has a bimodal grain-size distribution, is fine- to medium-grained, and comprises angular to subhedral quartz and plagioclase grains set in a recrystallized fine-grained matrix. The immature and angular nature of the grains, plus the lack of any coarse-grained component, possibly indicates derivation from a fine- to medium-grained source.

A distinct mixed unit (*AD(s)*) forms mappable layers immediately to the south of the Peawah Granodiorite in the northwest of the sheet area, and to the east of the Satirist Granite (e.g. MGA 146612). The unit is dominated by fine-grained metamorphosed clastic rocks, locally with 1–2 cm-thick interbeds of poorly sorted, fine- to medium-grained sandstone, and also contains abundant metamorphosed iron-formation, ferruginous siltstone and shale, and serpentine- and tremolite-rich schist. This unit possibly represents a sheared medium-grained wacke (?*AD(t)*) with tectonically interleaved slices of associated sedimentary and igneous rock units.

Shale units (AD(h), AD(he), AD(hil), AD(hs))

Laminated shale, including rare layers of poorly sorted subarkose (*AD(h)*), outcrops throughout the Mallina Basin, but is well exposed in the area 2–4 km west of Teichmans Well. The shale consists of quartz, chlorite, sericite, and minor epidote and goethite (after pyrite). Laminations are up to 3 mm thick and are defined by variations in the proportion of chlorite. Poorly sorted, fine- to medium-grained subarkose forms interbeds up to 1 m thick, and locally has well-developed grading.

Finely laminated siliceous siltstone (*AD(hs)*) outcrops as thin layers, predominantly in the central-western part of SATIRIST. It is present to the south of the Satirist Granite, where it is typically associated with ferruginous and chloritic siltstone, (*AD(hil)*), or iron formation (*AD(he)*). These three units may locally be interbedded. However, close to the inferred stratigraphic base of the Mallina Basin, either siliceous siltstone (*AD(hs)*) or iron formation (*AD(he)*) is dominant. The finely laminated siliceous siltstone (*AD(hs)*) comprises fine- to very fine-grained granoblastic quartz, and up to 5% iron oxide (now goethite) that defines the primary lamination. Sericite and a carbonate mineral are common accessory minerals. Some siltstones contain rare clasts of quartz up to 1 mm in size. The siltstones are derived from a highly siliceous source; they are either recrystallized chert or clastic rocks derived from a chert-rich hinterland.

Ferruginous siltstone and shale, and iron formation (*AD(he)*), locally with abundant layers of siliceous siltstone (*AD(hs)*) and subordinate layers of ferruginous shale (*AD(hil)*), sandstone (*AD(tqc)*), and mafic rock (*AD(bm), AD(us), Aog*), are exposed in the cores of anticlines (e.g. MGA 063462, MGA 157561) in the western and eastern parts of the Mallina Basin, on SATIRIST. The siltstone and shale (*AD(he)*) contains quartz, iron oxides (now goethite), biotite, sericite, clay minerals, chlorite, and zoisite. Iron formation contains up to 50% iron oxides (now goethite), and has local centimetre-scale banding defined by variations in the abundance of goethite. The rocks locally contain 1–2 cm-thick interbeds of poorly sorted, fine- to medium-grained sandstone containing quartz, biotite, feldspar, and chlorite. On MOUNT WOHLER, this unit underlies subarkose and shale units (*ADcq, ADch,* and *ADcs*) of the Constantine Sandstone but was interpreted to overlie the coarse-grained, proximal-fan facies of the Constantine Sandstone (*ADcc*) at Nunyerry Gap (Smithies, 1998a).

The ferruginous siltstone and shale, and iron-formation unit (*AD(he)*) shows increasing degrees of contact metamorphism towards contacts with granitoid rocks (see **Metamorphism**).

Laminated shale and siltstone is locally ferruginous or highly chloritic, or both (*AD(hil)*). The unit includes layers of iron formation, siliceous siltstone and wacke, and appears to be transitional with laminated shale (*AD(h)*). The two most abundant components of (*AD(hil)*) are chlorite-rich laminated siltstone and shale, and ferruginous shale. The unit outcrops extensively throughout the Mallina Basin and is particularly well exposed in an area approximately 2 km south-southeast of Satirist Peak.

The chlorite-rich siltstone and shale (*AD(hil)*) comprises quartz and chlorite, with lesser amounts of sericite and minor epidote, goethite, and biotite. Biotite locally forms ragged porphyroblasts that overprint primary layering and define a late foliation. Chlorite is either randomly distributed throughout the rock, or defines the primary bedding-parallel lamination as near-monomineralic layers up to 2 mm thick that pass either gradationally or sharply into quartz–chlorite layers. Chlorite-rich siltstone locally resembles light-green chert. Many samples of chlorite-rich siltstone and shale contain randomly distributed clasts of subangular to subrounded quartz up to 1 mm in size. Rarely, with increasing abundance of quartz clasts and lithic fragments, siltstone and shale grade into wacke. The lithic fragments include shale, arkose, and chert.

Layers of metamorphosed high-Mg basalt (*AD(bm)*), including hyaloclastite breccia, are locally interlayered with, or lie stratigraphically close to, units of laminated shale and siltstone (*AD(hil)*). All clastic rocks within the succession immediately above these basalt flows are locally chlorite rich. It is likely that the abundance of chlorite in the laminated shale and siltstone (*AD(hil)*) can be at least partly attributed to the sedimentary reworking of syndepositional basalt and high-Mg basalt flows.

Basalt and high-Mg basalt units (AD(dm), AD(bm), AD(bmx), AD(bms), AD(us))

Basalt and high-Mg basalt forms a minor but widespread component of the De Grey Group in the northern portion of the Mallina Basin. On SATIRIST, massive and vesicular high-Mg basalt units (*AD(bm)*) are best exposed in the Wattle Creek Well area, near the Egina mine, and about 2 km southwest of Two Mile Well. The rocks comprise up to 80% acicular tremolite, after clinopyroxene, with interstitial plagioclase and quartz. The tremolite is either randomly orientated or is present as radiating clusters. Vesicles up to 4 mm in diameter are locally common and filled with quartz. Composite layers are up to 150 m thick and can be traced over 7 km along strike; however, thinner and less continuous units are typical, and thin layers of (?eroded) high-Mg basalt are locally interbedded with wacke (*AD(bms)*) (e.g. MGA 121751). Hyaloclastite breccia (*AD(bmx)*) is locally well preserved (e.g. MGA 161701, MGA 378686). Sills of fine-grained dolerite (*AD(dm)*)(e.g. 3 km northwest of Station Peak) outcrop either within the flow units, or stratigraphically beneath them, and differ from those units only in grainsize.

Chlorite–actinolite–serpentine–epidote schist after high-Mg basalt and locally komatiite (*AD(us)*), is interbedded with the Constantine Sandstone and unassigned fine- and coarse-grained clastic rocks of the De Grey Group. This interbedded sequence is adjacent to the southern and eastern margins of the Satirist Granite and is interpreted as dominantly extrusive in origin. The unit is up to 300 m thick and commonly comprises a series of individual layers (?flow units) up to 20 m thick. Interlayered (?interflow) sedimentary rocks are mostly fine grained (e.g. *AD(he), AD(hil), AD(hs)*), whereas sedimentary rocks bounding the unit are mainly coarse grained (*ADcq, ADcs*). Many samples of high-Mg basalt are schistose and extensively to totally replaced by combinations of chlorite, actinolite, serpentine, talc, carbonate, and quartz. However, spinifex textures are locally preserved and include both randomly orientated acicular grains of actinolite, after clinopyroxene, and sheath spinifex, with talc and carbonate replacing original olivine. On MOUNT WOHLER, only schistose rocks of this unit were examined and consequently incorrectly incorporated with rocks of the layered mafic–ultramafic Millindinna Intrusion. Tremolite- and serpentine-rich schist (*AaMu* but not *AaMut*) in the Powereena and Croydon Anticlines on MOUNT WOHLER, should now be considered part of the high-Mg basalt to transitional komatiite (*AD(us)*) unit as defined here.

Tourmalinized wacke (AD(r))

In proximity to faults and the axial planes of major folds, clastic rocks of the De Grey Group (*AD(r)*) have locally undergone boron metasomatism. As a consequence, all aluminous minerals have been altered to tourmaline, leaving rocks with an assemblage of quartz and tourmaline (*Aqt*).

Mallina Formation (*ADm*)

Interbedded shale, siltstone, and medium- to fine-grained wacke of the Mallina Formation (*ADm*) forms isolated outcrops in the area around Egina Well. Shale within the Mallina Formation is generally laminated and ferruginous. Angular silt-sized grains of chert and quartz are common and plagioclase is rare. Clay minerals constitute the bulk of the groundmass, and are accompanied by abundant chlorite, sericite, quartz, and minor zoisite. There is a prominent slaty cleavage defined by alignment of mica, which is locally overprinted by carbonate minerals that may represent up to 50% of some rocks.

Wacke of the Mallina Formation is typically poorly sorted, and contains sand- to silt-sized angular to subrounded grains and common fining upward beds. The proportion of quartz exceeds that of feldspar. Lithic fragments are abundant, particularly in coarser grained varieties. The dominant lithic component is grey chert, but fragments of shale and basalt are also present. The matrix is rich in clay minerals and chlorite, with lesser quartz, plagioclase, biotite, epidote, zoisite, and pyrite. The rocks are commonly iron stained and some are strongly carbonate altered.

Dacite *(Afd)*

Two outcrops of dacite (*Afd*), the largest less than 0.5 km^2, are present approximately 6 km to the north-northeast of

Egina Well (MGA 319723). In outcrop, the rock is dark grey, very fine grained, with sparse euhedral plagioclase phenocrysts up to 2 mm in length, and is locally spherulitic and strongly flow banded. Local brecciation may be flow related; however, all contacts with surrounding rocks are obscured by sand and the dacite contains no internal features that are particular to an intrusive or extrusive origin.

In thin section, the dacite consists of an unfoliated, very fine-grained groundmass of plagioclase and quartz. The plagioclase is locally sericitized and carbonate altered. Phenocrysts of plagioclase and quartz, or aggregates of these minerals, are up to 1.5 mm in diameter and quartz is locally strongly embayed. No mafic minerals are preserved. Rounded, sericite-rich spots are up to 2 mm in diameter and represent relict spherulites.

Mafic and layered mafic–ultramafic intrusions

Fitton et al. (1975) collectively referred to the voluminous mafic and layered mafic–ultramafic intrusions within the Mallina Basin as the 'Millindinna Complex' (renamed the Millindinna Intrusion, Smithies, 1997b). Smithies (1998b) noted that intrusions assigned to this unit are present at various stratigraphic levels and may not represent a single intrusive event. On SATIRIST, there are two distinct types of intrusions that consistently occupy different stratigraphic levels within the De Grey Group. Massive to schistose gabbro and melanogabbro have intruded the lower exposed parts of the Mallina Basin, and are well exposed between the Satirist Granite and Station Peak. A layered mafic–ultramafic intrusion(s), best exposed at Millindinna Hill, has intruded the stratigraphic interval above the gabbros and commonly immediately overlies the basalt and high-Mg basalt-bearing stratigraphic interval. No basalt or high-Mg basalt (*AD(bm)*) is present above that intrusion. Contact metamorphic relationships show that both intrusions pre-date intrusion of the Peawah Granodiorite, although Smithies and Champion (1998) speculated that the granodiorite and many of the mafic intrusions are part of the same intrusive event.

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

Only the layered mafic–ultramafic intrusion(s) is referred to here as the Millindinna Intrusion. The intrusion forms a sill, up to 400 m thick, and contains a distinct compositional layering that comprises: a basal serpentine-rich rock (primarily lherzolite, *AaMus*), a middle actinolite–chlorite-rich rock (pyroxenite, *AaMoe*), and an upper typically thin layer of actinolite–chlorite–epidote–plagioclase rock (melanogabbro, *AaMog*). This compositional layering persists over a minimum continuous strike length of about 20 km. Outcrops of ultramafic rock in the central part of the Mallina Basin (mapped as *AaMu* on the southeastern part of YULE) may be tectonically dismembered components of this sill; however, they show no clear evidence of layering. Furthermore, outcrop farther to the east, on WALLARINGA, contains evidence for an extrusive origin (Smithies et al., in prep.).

There is no clear evidence for more than a single layered mafic–ultramafic sill on SATIRIST. However, the Millindinna Intrusion lies at a lower inferred stratigraphic level in the vicinity of Mount Langenbeck than at Millindinna Hill. Therefore, either (a) the sill locally transgresses the primary sedimentary layering of the De Grey Group; (b) the area around Mount Langenbeck is a basement high; (c) a local unconformity exists between Mount Langenbeck and Millindinna Hill; or (d) there is locally more than one layered sill.

Ultramafic schist is dominated by medium-grained tremolite- and serpentine-rich rock (*AaMu*). Rock samples that show no contact metamorphism vary in mineralogy 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 more commonly lherzolite. The latter contains crystals of pyroxene (now tremolite and chlorite), up to 1 cm in size, that poikilitically enclose olivine (now mainly serpentine). The abundance of pyroxene increases towards contacts with pyroxenite.

Metapyroxenite (*AaMoe*) and metamorphosed melanogabbro (*AaMog*) typically contains up to 85% and 60% pyroxene (now actinolite), respectively. Some samples contain serpentine and talc, suggesting an olivine-bearing protolith.

Gabbro (*Aog*, *Aoge*, *Aogep*, *Aogh*, *Aoghp*, *Aogq*, *Aogs*)

Medium- to coarse-grained mesocratic to leucocratic gabbro (*Aog*) is typically massive to weakly foliated. Subhedral to euhedral hornblende, with rare clinopyroxene cores, forms an interlocking network that includes intergranular plagioclase and late patches of quartz–plagioclase granophyric intergrowth. Most of the rocks show at least partial recrystallization to epidote, actinolite, and chlorite. In some intrusions, amphibole is distinctly acicular (*Aogh*). Coarse-grained (pegmatoid) gabbro with acicular amphibole (*Aoghp*) outcrops in the vicinity of Mount Langenbeck and Station Peak. Quartz gabbro (*Aogq*) intrudes rocks of the Yule Granitoid Complex and the overlying greenstones in the southwestern part of the Cheearra greenstone belt, forming part of a zoned intrusion that ranges from a melanogabbro margin, through gabbro, to a quartz gabbro core. The presence of up to 10% quartz is the only feature that distinguishes the quartz gabbro from medium- to coarse-grained mesocratic to leucocratic gabbro (*Aog*). Melanogabbro (*Aoge*) typically consists of 50–60% amphibole (now actinolite) and locally contains around 5% phenocrysts of plagioclase, up to 1.5 cm in length (porphyritic melanogabbro, *Aogep*). It intrudes clastic and high-Mg basaltic rocks of the De Grey Group adjacent to the margin of the Satirist Granite, and is locally schistose (*Aogs*).

Felsic intrusions

Felsic intrusive rocks on SATIRIST include three granitoid plutons or complexes (the Yule Granitoid Complex, the Satirist Granite, and the Peawah Granodiorite), six unassigned granitoid rocks, and two mineralogically distinctive types of porphyry dykes and sills.

The Yule Granitoid Complex (*AgY*) covers much of the eastern and southern parts of SATIRIST. It can be divided into eight individual intrusions — Ellawarrina Monzogranite, Pilbara Creek Monzogranite, Mungarinya Monzogranite, Powdar Monzogranite, Mungaroona Granodiorite, Yandeearra Granodiorite, Cheearra Monzogranite, and Yallingarrintha Tonalite — many of which consist of several distinct phases. The Yallingarrintha Tonalite is dated at c. 3420 Ma (Nelson, 1999) and is the oldest known unit on SATIRIST. Only ambiguous dates have been obtained on the Yandeearra Granodiorite and the Cheearra Monzogranite — an abundant population of zircons dated at between 3200 and 3150 Ma may represent xenocrysts (Nelson, D. R., 1999, pers. comm.), but provides a maximum intrusive age for these rocks. Both granitoids are intruded by the Mungaroona Granodiorite, which forms the southwestern part of the granitoid complex on SATIRIST, and has been dated at c. 2945 Ma (Nelson, 1999). The Mungarinya Monzogranite outcrops along the southeastern edge of SATIRIST and has been dated at between c. 2940 and 2935 Ma (Nelson, 1999). The Powdar Monzogranite, which forms the central and southern part of the granitoid complex on SATIRIST, has been dated at c. 2935 Ma (Nelson, 1999). No age has yet been obtained for the Pilbara Creek Monzogranite, but on the basis of structural information, the monzogranite is unlikely to be older than the Powdar Monzogranite.

The Peawah Granodiorite (*Agpe*) has intruded the central-northwestern part of the sheet area. Similar rocks form a discontinuous series of xenoliths within the outer portion of the Satirist Granite, and as isolated intrusions within the De Grey Group immediately adjacent to that granite. The Peawah Granodiorite has been dated at 2948 ± 5 Ma (Nelson, 1997).

On the western portion of SATIRIST, the Satirist Granite (*Agsa*) intrudes rocks of the Mallina Basin and rocks similar to those of the Peawah Granodiorite. The granite locally contains porphyritic (*Agsap*) and equigranular (*Agsae*) phases, dated on MOUNT WOHLER at between c. 2930 and 2940 Ma (Nelson, 1998). Rocks similar to those of the Peawah Granodiorite outcrop locally as xenoliths and rafts around the entire circumference of the exposed Satirist Granite, forming a crudely zoned complex.

Intrusion of feldspar porphyry (*Afp*) and quartz–feldspar porphyry (*Apf*) post-dates deposition of all greenstones on SATIRIST, and at least most of the Mallina Basin succession. A quartz–feldspar porphyry from near Millindinna Hill has been dated at 2941 ± 4 Ma (Nelson, 1999).

Yule Granitoid Complex (*AgY*)

Yallingarrintha Tonalite (AgYla)

The Yallingarrintha Tonalite (*AgYla*) includes moderately to strongly foliated, coarse-grained rocks of mostly tonalitic composition. These form rare xenoliths, up to 2 km in size, within the Cheearra Monzogranite and the Yandeearra Granodiorite. The rocks range from biotite(–hornblende) granodiorite to hornblende(–biotite) tonalite.

Biotite(–hornblende) granodiorite is a strongly foliated rock that has a well-formed mineral segregation defined by tectonic elongation of originally porphyritic plagioclase and quartz. Hornblende(–biotite) tonalite has an intergranular texture with subhedral to euhedral grains of plagioclase, up to 0.8 cm in size, forming an interlocking framework enclosing hornblende, biotite, and quartz. Hornblende and biotite together constitute less than 15% of the rock. Hornblende is typically altered to actinolite or chlorite, or both, biotite is locally altered to chlorite, and plagioclase is locally altered to sericite and epidote. Quartz is typically strongly granoblastic.

Cheearra Monzogranite (AgYch, AgYchm, AgYchn, AgYchp, AgYchx)

Rocks of the Cheearra Monzogranite (*AgYch*) are mostly medium-grained, moderately foliated to gneissic, and range from tonalite to monzogranite with the latter predominating.

Moderately to strongly foliated monzogranite (*AgYchm*) is present in the central and central-northern parts of the granitoid complex, on SATIRIST, and as a discontinuous apron of roof pendants or xenoliths along the northerly trending contact between the Powdar and Mungarinya Monzogranites. The rocks are seriate to locally porphyritic in texture, with K-feldspar phenocrysts up to 2 cm in length. A foliation is defined by alignment of biotite and chlorite and flattened quartz grains, or zones of granoblastic quartz, micaceous schlieren, and K-feldspar phenocrysts. Rocks of granodioritic, and less commonly tonalitic composition, contain hornblende and biotite, the later commonly rimming the former. Biotite is the only mafic silicate mineral in the monzogranite and typically comprises less than 8% of the rock. Quartz (typically granoblastic), perthite, and biotite form interstitially to plagioclase; however, they are all locally included within large, late-crystallizing grains of microcline. Hornblende is locally altered to actinolite, epidote, and chlorite. Biotite is typically partially to completely chloritized, and feldspars are typically partially altered to sericite and epidote. Accessory minerals include apatite, zircon, rutile, titanite, allanite, and magnetite (now leucoxene).

A discrete body of Cheearra Monzogranite lies immediately to the south of the Pilbara Creek Monzogranite, and mostly differs from the moderately to strongly foliated monzogranite (*AgYchm*) by containing abundant K-feldspar phenocrysts (*AgYchp*). The porphyritic monzogranite is also typically more mafic than the moderately to strongly foliated monzogranite, with up to 10% mafic minerals, including both hornblende and biotite.

Monzogranitic to tonalitic gneissic granitoid rock (*AgYchn*) forms the main component of the Cheearra Monzogranite in the southwestern portion of the granitoid complex, on SATIRIST. This rock locally contains abundant xenoliths of either greenstones or earlier granitic rocks such as the Yallingarrintha Tonalite, and has been mapped separately (*AgYchx*). Contacts with the supracrustal rocks of the Cheearra greenstone belt are unclear; however, gneissic granitoid is locally finely interleaved with these rocks. Since there is no structural evidence that this interleaving is the result of tight folding, it is likely that the protolith to the gneissic granitoid locally intruded the greenstone sequence as a series of sills.

Monzogranitic to tonalitic gneissic granitoid rock (*AgYchn*) includes hornblende-rich granodioritic and tonalitic varieties, and is mineralogically identical to, and texturally transitional from, moderately to strongly foliated monzogranite (*AgYchm*). Mesocratic and leucocratic bands are locally well developed (Fig. 16) and stromatic banding is present in some outcrops. Leucogranitic and pegmatitic patches, commonly with mafic selvedges, also appear to have accumulated in fractures or in hinge zones of minor folds, and suggest local, incipient, partial melting of the gneissic granitoid rock. However, these features, are not homogeneously developed throughout the southwestern portion of the granitoid complex but become more prominent and better developed toward the south. Consequently, there is a clear increase in metamorphic grade from north to south. Another feature, which is well developed in the central and southern exposures of monzogranitic to tonalitic gneissic granitoid rock, is diatexitic injection migmatite (Figs 17 and 18). The leucosomal (injected) component is undeformed (post-tectonic) and is of two distinct types: monzogranite, compositionally similar to either the Mungarinya or Powdar Monzogranite; or rocks in the compositional range of low-Al tonalite and granodiorite.

Yandeearra Granodiorite (AgYya)

The Yandeearra Granodiorite (*AgYya*) outcrops along the western edge of the Yule Granitoid Complex. The rock contains xenoliths of the Yallingarrintha Tonalite and has been intruded by the Mungaroona Granodiorite, but its age with respect to the Cheearra Monzogranite is not clear. Although granodiorite is the dominant rock type, tonalite and monzogranite are also present. The rocks are typically medium- to coarse-grained, seriate to equigranular, and have a foliation defined by the alignment of biotite and flattened quartz. Subhedral laths of zoned plagioclase are up to 7 mm long and form a semi-connected framework. Quartz (typically granoblastic) and biotite are interstitial phases. Biotite is the sole mafic silicate mineral and typically forms less than 5% of the rock. K-feldspar is a late-crystallizing phase and accessory minerals include

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Figure 16. Well developed gneissic banding within a K-feldspar porphyritic rock of the Cheearra Monzogranite. Lens cap is 5 cm in diameter. MGA 334395

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Figure 17. Diatexite developed within the Cheearra Monzogranite. Large subrounded to subangular blocks of foliated to gneissic granitoid rock surrounded by massive to strongly flow-banded leucogranite forming a diatexitic injection-migmatite (cf. Fig. 18). MGA 339403

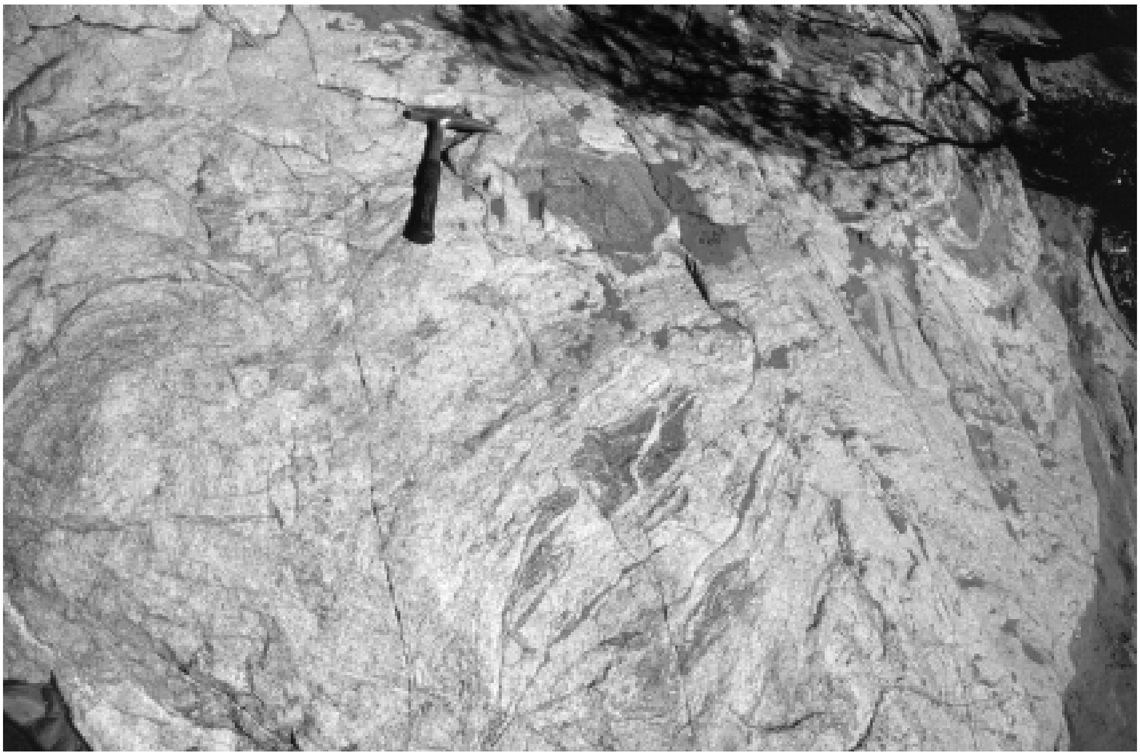

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Figure 18. Diatexite developed within the Cheearra Monzogranite, showing dissagregated xenoliths of various sizes within leucogranite. Possibly a more evolved stage of injection migmatite than that in Figure 17. MGA 255390

apatite, zircon, titanite, rutile, and magnetite (now leucoxene).

Ellawarrina Monzogranite (AgYel)

Deeply weathered biotite monzogranite (*AgYel*) is exposed in the southwestern corner of SATIRIST, where the incised course of the Sherlock River has exposed rocks that underlie the Fortescue Group.

Mungaroona Granodiorite (AgYmu, AgYmux)

The Mungaroona Granodiorite (*AgYmu*) outcrops in the southwestern corner of the Yule Granitoid Complex. It intrudes the monzogranitic to tonalitic gneissic granitoid rock of the Cheearra Monzogranite (*AgYchn*) and the supracrustal rocks of the Cheearra greenstone belt, and has been mapped separately (*AgYmux*) where it contains abundant xenoliths of these rocks. The unit is a medium- to coarse-grained and mostly equigranular rock, ranging from hornblende–biotite granodiorite to rarer biotite monzogranite. It contains up to 10% mafic minerals crystallized either interstitially to plagioclase or as aggregates. Microcline microperthite forms a late, minor to accessory phase.

Powdar Monzogranite (AgYpo, AgYpoa, AgYpop, AgYpoq, AgYpos)

The Powdar Monzogranite (*AgYpo*) includes four distinct mineralogical and textural varieties (*AgYpoa, AgYpop, AgYpoq*, and *AgYpos*). Seriate-textured monzogranite (*AgYpos*), weakly porphyritic monzogranite (*AgYpoq*), and porphyritic monzogranite (*AgYpop*) differ only in the abundance of K-feldspar (microcline microperthite) phenocrysts. The phenocrysts are tabular, up to 3 cm in length, and are late-crystallizing phases that overgrow all other major mineral phases. The fourth variety of the Powdar Monzogranite is aplite (*AgYpoa*). All four varieties are typically very leucocratic, with biotite (now mostly chlorite) being the sole mafic silicate mineral and comprising less than 5% of the rock. The rocks are commonly massive to weakly deformed but locally have a strong foliation defined by flow alignment of K-feldspar phenocrysts. Accessory minerals include apatite, zircon, allanite, titanite, rutile, and opaques.

Mungarinya Monzogranite (AgYug)

The Mungarinya Monzogranite (*AgYug*) is petrographically similar to the Powdar Monzogranite except that it contains more biotite (typically between 5 and 10%), and is texturally transitional between the weakly porphyritic monzogranite (*AgYpoq*) and porphyritic monzogranite (*AgYpop*) of the Powdar Monzogranite. The rock is mostly massive to weakly deformed, but has a well developed flow-foliation defined by alignment of K-feldspar phenocrysts. It also has a locally prominent 'ghost banding' produced by vague mineralogical bands within individual parallel intrusive sheets of monzogranite.

Pilbara Creek Monzogranite (AgYic)

The Pilbara Creek Monzogranite (*AgYic*) is a fine- to medium-grained, equigranular rock which is typically massive to weakly foliated. The rock is highly leucocratic with biotite being the only mafic phase and comprising less than 5% of the rock. Accessory minerals include apatite, zircon, allanite, titanite, fluorite, and opaques.

Peawah Granodiorite and related diorite (*Agpe, Agpee, Agpes, Agg, Agdme, Agdms*)

The Peawah Granodiorite (*Agpe*) consists mainly of medium- to coarse-grained, mostly equigranular hornblende–biotite granodiorite and subordinate tonalite. The rock contains up to 15% mafic minerals with subhedral hornblende crystallized either interstitially to plagioclase or in aggregates with biotite, magnetite, and titanite. Biotite forms subhedral to anhedral crystals, in places partially surrounding hornblende. Microcline microperthite forms a late, minor to accessory phase. Accessory minerals include titanite, apatite, zircon, rutile, and magnetite.

Seriate to porphyritic diorite (*Agpes*) and equigranular diorite (*Agpee*) form sills and dykes within rocks of the De Grey Group, and lie at the contact between those rocks and the Peawah Granodiorite. The diorites also outcrop as subrounded to rounded xenoliths within the Peawah Granodiorite.

The seriate to porphyritic diorite (*Agpes*) is fine- to medium-grained and contains phenocrysts of plagioclase, hornblende, and clinopyroxene, and 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 equigranular diorite (*Agpee*) is medium- to coarse-grained and subhedral grains of plagioclase and hornblende are the main components. Clinopyroxene is an early crystallizing phase that forms subhedral to rounded cores to hornblende. Quartz and perthite are late interstitial phases, and biotite forms rims on, and partially replaces, hornblende.

Sills and plugs of rocks similar to Peawah Granodiorite and associated diorites, have intruded the De Grey Group adjacent to the Satirist Granite, and also form xenoliths within that granite. The largest of these intrusions is about 4 km^2, which together with the other intrusions, form a discontinuous rim around the Satirist Granite on SATIRIST. All of these rocks have lithological equivalents within, or associated with, the Peawah Granodiorite, but have been excluded from that body because of slight compositional differences (Smithies and Champion, in press). *Agg, Agdms,* and *Agdme* are lithologically equivalent to *Agpe, Agpes,* and *Agpee* respectively.

Satirist Granite (*Agsap*, *Agsae*)

The Satirist Granite has a marginal zone of early equigranular to slightly porphyritic granite (*Agsae*) that surrounds a relatively homogeneous core of porphyritic syenogranite (*Agsap*). Equigranular to slightly porphyritic granite (*Agsae*) has been dated, on MOUNT WOHLER, at 2938 ± 4 Ma, whereas porphyritic syenogranite (*Agsap*) has been dated at 2931 ± 5 Ma (Nelson, 1998).

The equigranular to slightly porphyritic granite (*Agsae*) is a biotite-bearing, leucocratic monzogranite to syenogranite, containing rare tabular phenocrysts of microcline microperthite up to 2 cm in size. These phenocrysts contain inclusions of plagioclase, biotite, and quartz. The rock contains up to 10% biotite, usually as aggregates of subhedral crystals. Plagioclase is normally zoned and is locally rimmed by K-feldspar. Subangular xenoliths, up to 40 cm in length, are dominantly of the De Grey Group or of the Peawah Granodiorite, and concentrate in particular zones where they locally form up to 40% of the outcrop (Fig. 19). The porphyritic syenogranite (*Agsap*) differs from the equigranular granite only by containing more K-feldspar (microcline microperthite), mostly as abundant tabular phenocrysts up to 2 cm in size. Accessory minerals within the rocks of the Satirist Granite include apatite, zircon, rutile, muscovite, fluorite, allanite, and magnetite (now leucoxene).

Feldspar porphyry and quartz–feldspar porphyry (*Afp*, *Apf*)

The feldspar porphyry (*Afp*) and quartz–feldspar porphyry (*Apf*) form sills up to 300 m thick and dykes up to 12 m wide. They are widely distributed throughout most areas of granite–greenstone terrain on SATIRIST. The feldspar porphyry is typically granodioritic to tonalitic, and the quartz–feldspar porphyry is monzogranitic or syenogranitic.

Quartz–feldspar dykes typically contain phenocrysts of quartz and plagioclase, and less abundant biotite, hornblende, and ?ilmenite. The matrix comprises a fine-grained equigranular groundmass of quartz, plagioclase, K-feldspar, with minor biotite, hornblende, opaque minerals, and secondary white mica and carbonate. The quartz phenocrysts are up to about 3.5 mm in size and are typically rounded or embayed. By contrast, the plagioclase phenocrysts are subhedral, commonly form clusters of crystals, and are up to 4.5 mm in size. Plagioclase is wholly or partly replaced by fine-grained white mica(– carbonate). Mafic phenocrysts are replaced everywhere by greenschist-facies metamorphic assemblages of chlorite–?ilmenite(– white mica – carbonate). Biotite is the most common mafic mineral, although some quartz–feldspar porphyry dykes have pseudomorphs of both biotite and hornblende, and a few have hornblende as the sole mafic phase. Scattered hydrous iron-oxides, up to 0.6 mm in size, may be former pyrite crystals.

The feldspar porphyry (*Afp*) is weakly deformed, seriate textured to porphyritic, and contains crystals of plagioclase, hornblende, and altered biotite, in a fine-grained groundmass of quartz, plagioclase, hornblende, minor K-feldspar, and very fine opaque minerals (Fig. 20). The more mafic varieties contain phenocrysts of clinopyroxene. Biotite is mostly replaced by metamorphic

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Figure 19. Abundant subrounded to subangular xenoliths within the Satirist Granite. Most xenoliths are metasedimentary inclusions of the De Grey Group, but diorite and granodiorite inclusions from the Peawah Granodiorite are also present. MGA 094582

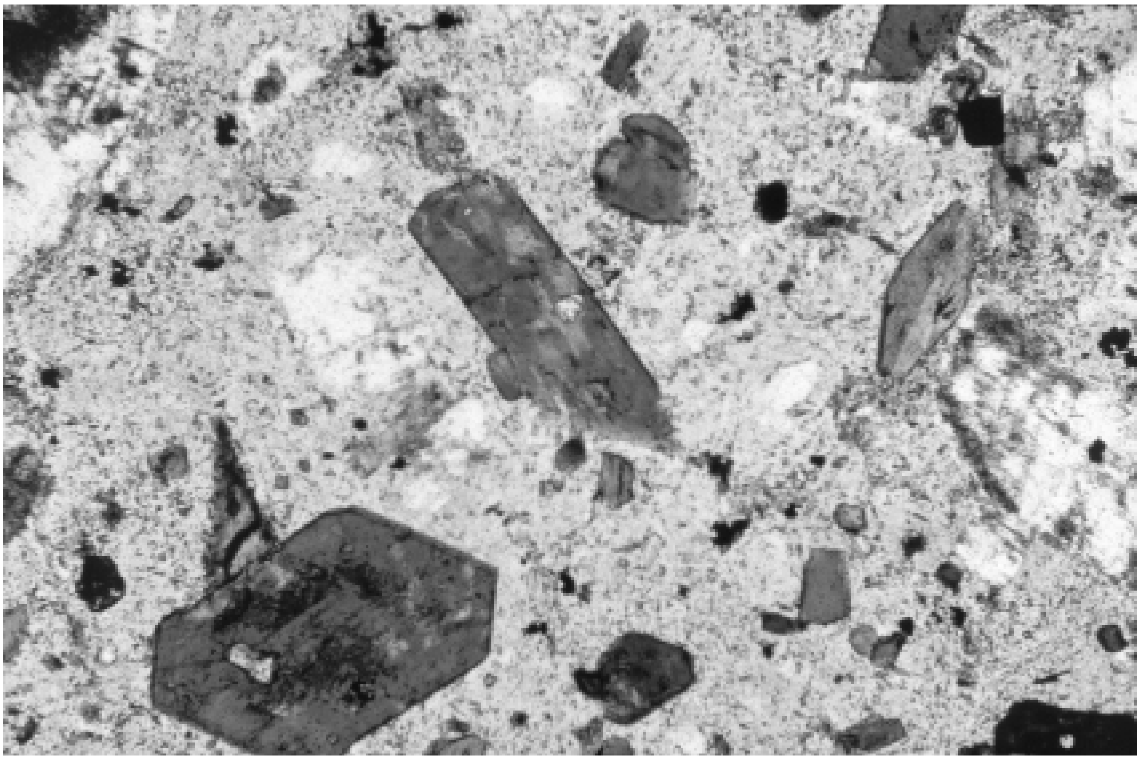

Figure 20. Photomicrograph of a feldspar porphyry. The porphyry contains abundant phenocrysts of subhedral to euhedral hornblende (green-brown), and plagioclase (white). GSWA 161015, MGA 376570. Plane-polarized light, width of field approximately 3 mm

assemblages of chlorite–sphene(–epidote–opaque minerals), but in places, fresh red-brown biotite is preserved. It is typically subhedral to euhedral, although there are rare examples of embayed biotite with igneous hornblende overgrowths. Minerals formed by secondary (?metamorphic) alteration of the groundmass include fine-grained white mica and epidote, and sporadically distributed carbonate.

Unassigned granitoid rocks (*Ag*, *Agd*, *Agl*, *Agmh, Agp*)

Unassigned and undivided granite (*Ag*) outcrop as dykes adjacent to the northern margin of the Satirist Granite, typically intruding gabbro. These dykes locally form a net-vein complex. Small dykes of pegmatite (*Agp*) outcrop throughout the sheet area, particularly within the younger phases of the Yule Granitoid Complex, such as the Pilbara Creek, Mungarinya, and Powdar Monzogranites. Two larger pegmatite dykes intrude the Cheearra greenstone belt adjacent to the Powdar Monzogranite. A minor and deeply weathered outcrop of leucogranite (*Agl*) is present in the northeastern part of SATIRIST, associated with mafic and ultramafic rocks. A large granitoid pluton is interpreted to lie immediately to the northeast of this locality based on magnetic data, and it is possible that the leucogranite is associated with that pluton.

Quartz diorite (*Agd*) is present in several small intrusive bodies that outcrop 5 km south-southwest of the Hong Kong mine. Individual intrusions are less than 500 m in diameter and follow a northwesterly trend that cuts across the John Bull synform. The diorite is porphyritic to intergranular and it comprises mainly hornblende and plagioclase. It also contains rounded mafic enclaves up to 10 cm in size. Microscopically, it comprises plagioclase (up to 3 mm in coarser zones), hornblende and chloritized biotite, in a fine-grained groundmass of quartz, plagioclase, K-feldspar, hornblende, opaque minerals, and accessory sphene and apatite. In some places, the rock contains large interstitial K-feldspar between elongate crystals of plagioclase and hornblende.

Patchy outcrops of a late hornblende monzogranite to hornblende–quartz monzogranite (*Agmh*) are present 3.5 km north of Black Gin Well. The intrusion cuts across the early folds (F_2) and its long axis is parallel to the axial surface trace of the John Bull synform. The rock is fine grained and weakly deformed, and contains zoned plagioclase, K-feldspar, various amounts of quartz and hornblende, minor green-brown biotite, and accessory sphene and opaque minerals. Small clots of hornblende (with or without plagioclase and opaque minerals) up to 4.0 mm in diameter are common. The rock also contains rounded, finer grained mafic enclaves up to 10 cm in diameter.

Fortescue Group

The Fortescue Group is a c. 2770–2680 Ma succession of dominantly basaltic rocks that extends across much of the

Pilbara Craton. Its contact with the granite–greenstone terrain is an angular unconformity. A polymictic conglomerate containing subrounded clasts derived from the underlying granite–greenstone terrain, locally marks the base of the group on SATIRIST, but is too thin and irregular to be represented at 1:100 000 scale. The Fortescue Group outcrops mainly in the southwestern corner of SATIRIST. The rocks typically dip shallowly to the south with a resultant gradual southerly progression to higher stratigraphic levels. In detail, however, numerous northerly trending faults complicate this pattern. The regional stratigraphy of the group has been reviewed by Hickman (1983) and Thorne and Trendall (in prep.).

Mount Roe Basalt (*AFr, AFrs*)

The Mount Roe Basalt (*AFr*) forms the basal unit of the Fortescue Group on SATIRIST. Here, the bulk of this unit is composed of either vesicular or glomeroporphyritic basalt. The vesicular basalt contains rare, squat, subhedral phenocrysts of plagioclase and clinopyroxene, and quartz–calcite-filled vesicles in a groundmass rich in plagioclase laths, with interstitial chlorite and epidote (after mafic phases and glass). The glomeroporphyritic rocks differ from the vesicular variety only in that they contain abundant aggregates of plagioclase up to 2 cm in size. Both the vesicular and glomeroporphyritic basalt are locally pillowed. Sedimentary rocks are interlayered with the basalts and include well-laminated mudstone and siltstone, and fine- to medium-grained, poorly sorted and matrix-supported arkose (*AFrs*), commonly with well-developed graded bedding, ripple cross-bedding, and mud cracks.

Hardey Formation (*AFh*, *AFhc*, *AFhs*, *AFhu*)

The Hardy Formation (*AFh*) conformably overlies the Mount Roe Basalt and is dominated by medium- to coarse-grained, poorly sorted subarkose and well laminated siltstone, locally with layers of conglomerate (*AFhs*). This unit was originally referred to as the Hardey Sandstone but was later renamed by Thorne et al. (1991). Matrix-supported polymictic conglomerate (*AFhc*) with clasts derived from the Pilbara Supergroup, locally forms a layer up to about 20 m thick at the base of the Hardey Formation. The conglomerate is overlain by a sequence of poorly sorted, medium- to coarse-grained, volcanolithic sandstone, interbedded with well-laminated siltstone, fine-grained tuffaceous sedimentary rock, and conglomerate (*AFhu*).

Kylena Formation (*AFk*)

The Kylena Formation (*AFk*), previously the Kylena Basalt but renamed and redefined by Kojan and Hickman (1998), conformably or disconformably overlies the Hardey Formation. On SATIRIST, the Kylena Formation comprises flows of massive to amygdaloidal basalt and andesite.

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Figure 21. Replacement tourmalinite within the De Grey Group. The layering is primary, with tourmaline preferentially replacing the more aluminous, or arkosic, layers. MGA 099521

Tumbiana Formation (*AFt*)

The Tumbiana Formation (*AFt*), which conformably overlies the Kylena Formation, is a layered sequence that includes volcanic sandstone of mafic to intermediate composition, tuff, fine-grained clastic sedimentary rocks, basalt, chert, and dolomite.

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

Quartz veins (*q*) outcrop along, and are parallel to, mostly late northwesterly trending faults. In proximity to faults and the axial planes of major folds, clastic rocks of the De Grey Group (*AD(r)*) have locally undergone boron metasomatism. As a consequence, all aluminous minerals have been altered to tourmaline, leaving rocks with an assemblage of quartz and tourmaline (*Aqt*). Primary sedimentary structures, including bedding (Fig. 21) and grain-size grading, are commonly preserved. The timing of metasomatism is difficult to constrain; however, tourmaline-rich quartz veins are locally associated with the c. 2935 Ma Satirist Granite (MOUNT WOHLER, SATIRIST) and with the c. 2765 Ma Opaline Well Granite on SHERLOCK (Smithies, 1997b).

Dolerite and gabbro dykes (*d*)

Dolerite and gabbro (*d*) of variable age, but probably mainly late Archaean, forms dykes throughout the sheet area, most commonly within granitoid rocks. The dykes are dominantly north-northeasterly trending. Intrusion of these dykes post-dates the deposition of the Pilbara Supergroup and at least some may be related to volcanism within the Mount Bruce Supergroup. The east-northeasterly trending Powereena Dyke is a prominent feature that more or less bisects SATIRIST. Intrusion of this dyke post-dates deposition of the Maddina Formation on MOUNT WOHLER and intrudes the Marra Mamba Iron Formation (Kriewaldt and Ryan, 1963) of the Hamersley Group to the southwest of SATIRIST.

Cainozoic deposits

Siliceous caprock (*Czru*)

Siliceous caprock over ultramafic rock (*Czru*) is associated with altered outcrop of the Millindinna Intrusion and unassigned ultramafic rocks.

Calcrete (*Czrk*)

Massive, nodular, and cavernous calcrete, of residual origin (*Czrk*), locally replaces many rock types on SATIRIST, particularly along faults and shear zones. It is well developed over mafic and ultramafic rocks, where it is locally associated with minor deposits of magnesite.

Ferruginous caprock (*Czrfb*)

Ferruginous caprock over basalt (*Czrfb*), including limonitic gravel, is locally developed over the Fortescue Group in the southwestern corner of SATIRIST.

Ferricrete (*Czrf*)

Ferricrete (*Czrf*), including ferruginous and pisolitic ironstone, is locally developed in the southern part of SATIRIST, particularly over inferred contacts between granitoid rocks and supracrustal rocks.

Colluvium (*Czcb*)

High-level deposits of coarse colluvium (*Czcb*) derived mainly from erosion of Fortescue Group rocks, are present southwest of Hong Kong mine.

Gravel deposits (*Czag, Czaq*)

High-level gravel deposits that are unrelated to recent drainage (*Czag*), are present throughout SATIRIST. However, they are most common in the southern part of the sheet area, proximal to the elevated land surface of Fortescue Group outcrop. High-level gravel deposits close to quartz veins are locally dominated by vein-quartz debris (*Czaq*).

Quaternary alluvial and lacustrine deposits (*Qaa, Qal, Qao, Qaoc, Qab*)

Present-day drainage channels contain alluvial clay, silt, sand, and gravel (*Qaa*). Alluvial clay, silt, and sand forms overbank deposits on floodplains (*Qao*) and locally includes 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 is locally flanked by alluvial deposits of sand and gravel in levees and sandbanks (*Qal*). In areas immediately adjacent to rivers, alluvial floodplains also include small, abundant, scattered lacustrine or claypan deposits (*Qaoc*), consisting of clay and silt.

Quaternary colluvium, outwash-fan deposits, and eolian sand (*Qw, Qws, Qc, Qs*)

Colluvium, consisting of sand, silt and gravel (*Qc*), is locally derived from elevated outcrops and deposited as proximal 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 mostly been stabilized by extensive grass and shrub cover.

Eolian sand (*Qs*) forms east-southeasterly trending unstable dunes in the northeastern corner of SATIRIST.

Metamorphism

On SATIRIST, metamorphism that took place before deposition of the Fortescue Group appears to relate primarily to granite intrusion. Overall, rocks of the East Pilbara Granite–Greenstone Terrane are metamorphosed at low to middle greenschist facies, characterized by the presence of chlorite–actinolite–albite(–epidote) in mafic rocks and albite–biotite(– white mica – chlorite) in pelitic metasedimentary rocks. Amphibolite facies metamorphism of rocks of the East Pilbara Granite–Greenstone Terrane is recognized in four areas (Fig. 22) — the area northeast of Kangan Gap, the southern margin of the Pilbara Well greenstone belt, the area surrounding the Peawah Granodiorite and the Satirist Granite, and in the Cheearra greenstone belt.

The greenstone sequence in the area north of Kangan Homestead (on WODGINA) is wedged between two areas dominated by younger granitoid rocks. In this region, units of ferruginous chert, ironstone, and BIF (*AGli*) of the Cleaverville Formation, have been locally metamorphosed to para-amphibolite. Grunerite forms the dominant metamorphic mineral, commonly as clusters or mats of acicular grains, or rosettes of radiating grains. Some layers contain up to 80% grunerite. Euhedral garnet is an accessory mineral in some grunerite-rich bands. In nearby shale units of the De Grey Group (*AD(he)*), the iron formation and ferruginous siltstone component is metamorphosed to grunerite- and garnet-bearing schist, and the shale and minor wacke component includes the metamorphic assemblage of garnet and actinolite. Within the iron formation, garnet forms euhedral porphyroblasts, up to 3 mm in size, that overgrow a foliated groundmass of fibrous grunerite. The distribution of both grunerite and garnet appears to be directly related to intrusion of younger granitoid rocks. Crystallization of the late euhedral-garnet porphyroblasts probably reflects the post-intrusive, static, thermal peak of contact metamorphism.

The highest metamorphic grade in the Pilbara Well greenstone belt is in a narrow zone along the granite–greenstone contact with the Yule Granitoid Complex (Fig. 22). Peak metamorphism adjacent to the granitoids was probably upper amphibolite facies, based on the metamorphic assemblage of Ca-plagioclase–hornblende (–clinopyroxene) in mafic rocks. The grade decreases rapidly to the north, away from the contact, and is lower greenschist facies through most of the belt, apart from small zones of contact metamorphism around late granitoids (e.g. north of Black Gin Well). Mafic rocks in the centre of the belt typically contain the metamorphic assemblage quartz–chlorite–albite–actinolite(–epidote–sphene–carbonate), which is diagnostic of the greenschist facies. Metamorphosed sedimentary rocks characteristically contain quartz–albite – white mica(–chlorite), which also indicates lower greenschist facies.

The metamorphic and structural history of the area surrounding the Peawah Granodiorite and the Satirist Granite (Fig. 22) is complicated by the multiple intrusion of voluminous magma at c. 2950 Ma (Peawah Granodiorite and associated mafic sills) and c. 2935 Ma (Satirist Granite), and by final emplacement mechanisms that have folded the country rock in a way that does not accord with any regional structural trend (see **Structure**). Rocks similar to those of the Peawah Granodiorite are locally present as xenoliths and rafts around the entire circumference of the exposed Satirist Granite, forming a crudely zoned complex. Consequently, it is difficult to assign specific metamorphic assemblage to either intrusive event, even where overprinting relationships are observed.

In the area surrounding the Peawah Granodiorite and the Satirist Granite, the iron-formation component of shale units (*AD(he)*) within the De Grey Group is characterized by the same grunerite(–garnet)-bearing metamorphic assemblage present in iron formation northeast of Kangan Gap. All shale and wacke units within the De Grey Group, including shale interbeds within the Constantine Sandstone, have a range of typically low-pressure metamorphic assemblages. In many rocks, biotite defines an early foliation (?local D_1 — see **Structure**). This early foliation is overprinted by a rarely preserved metamorphic assemblage that changes from sillimanite–staurolite to andalusite–staurolite with increasing distance from intrusive contacts. Cordierite overprints the staurolite-bearing assemblages, particularly close to contacts with granitoid rocks. It is locally preserved as subhedral pinitized porphyroblasts up to 4 cm in length (Fig. 23), commonly defining a foliation parallel to the contact between the De Grey Group and the Satirist Granite. Garnet is a common euhedral phase, up to 4 mm in size, which appears to have crystallized with, and after, cordierite.

The mineral assemblages of rocks surrounding the Peawah Granodiorite and the Satirist Granite are typical of contact metamorphic terranes; the presence of andalusite indicating pressures below about 350 MPa (Spear, 1993). The spatial changes in early metamorphic assemblages from sillimanite–staurolite to andalusite–staurolite are interpreted as a reflection of decreasing temperature (metamorphic field gradient) away from intrusive contacts. Overprinting relationships, from sillimanite–staurolite or andalusite–staurolite, are prograde. Peak temperatures greater than 600°C (middle to upper amphibolite facies) can be inferred for the sillimanite-bearing zone close to the intrusive contacts, and around 550°C (middle amphibolite facies) for the more regionally extensive andalusite-bearing zone. Cordierite-bearing assemblages are either retrograde or related to a subsequent contact metamorphic event. It is possible that the sillimanite- and andalusite-bearing assemblages relate to intrusion of the Peawah Granodiorite and the cordierite-bearing assemblages relate to the subsequent intrusion of the Satirist Granite.

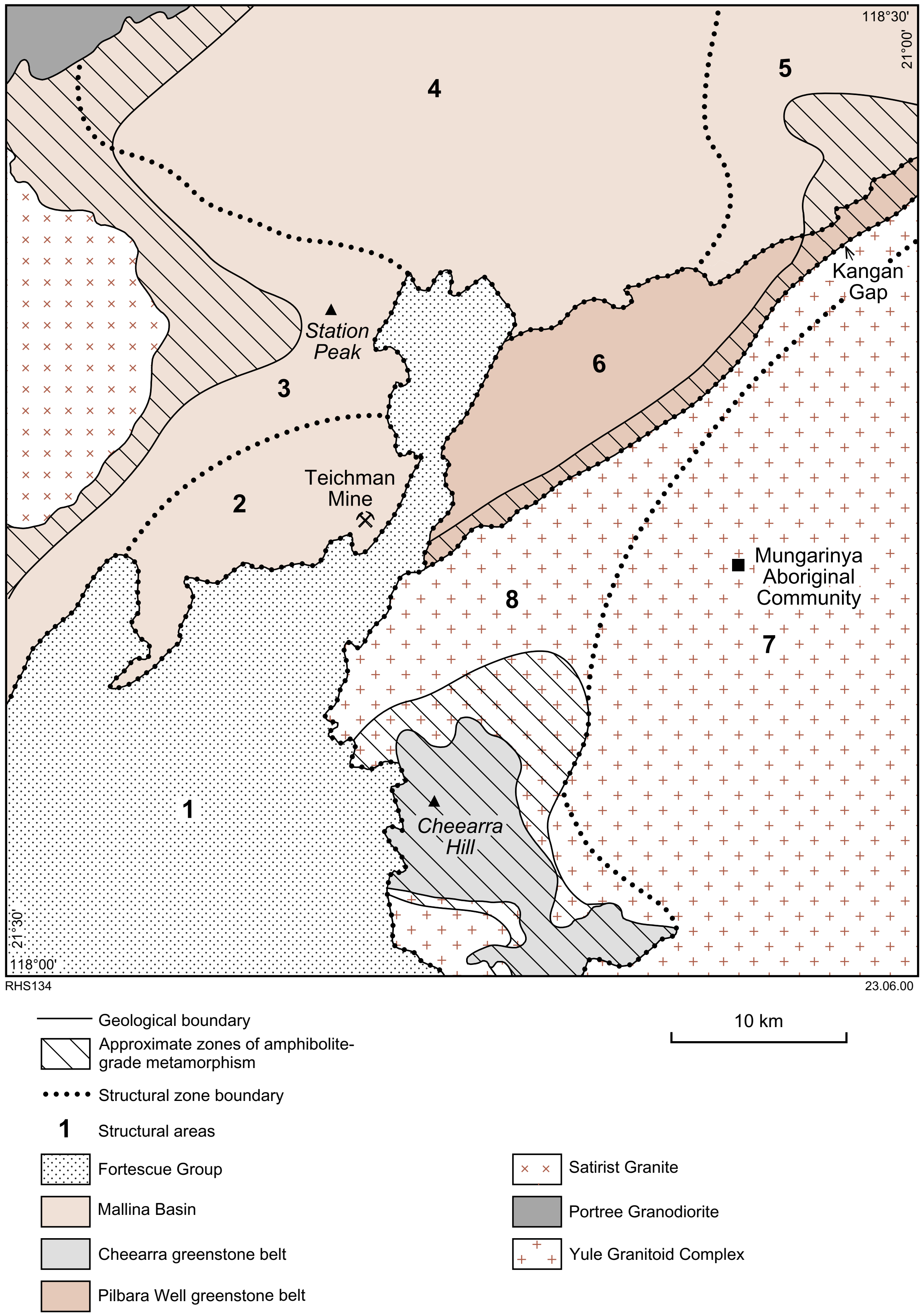

Figure 22. Map showing metamorphic and structural domains on SATIRIST

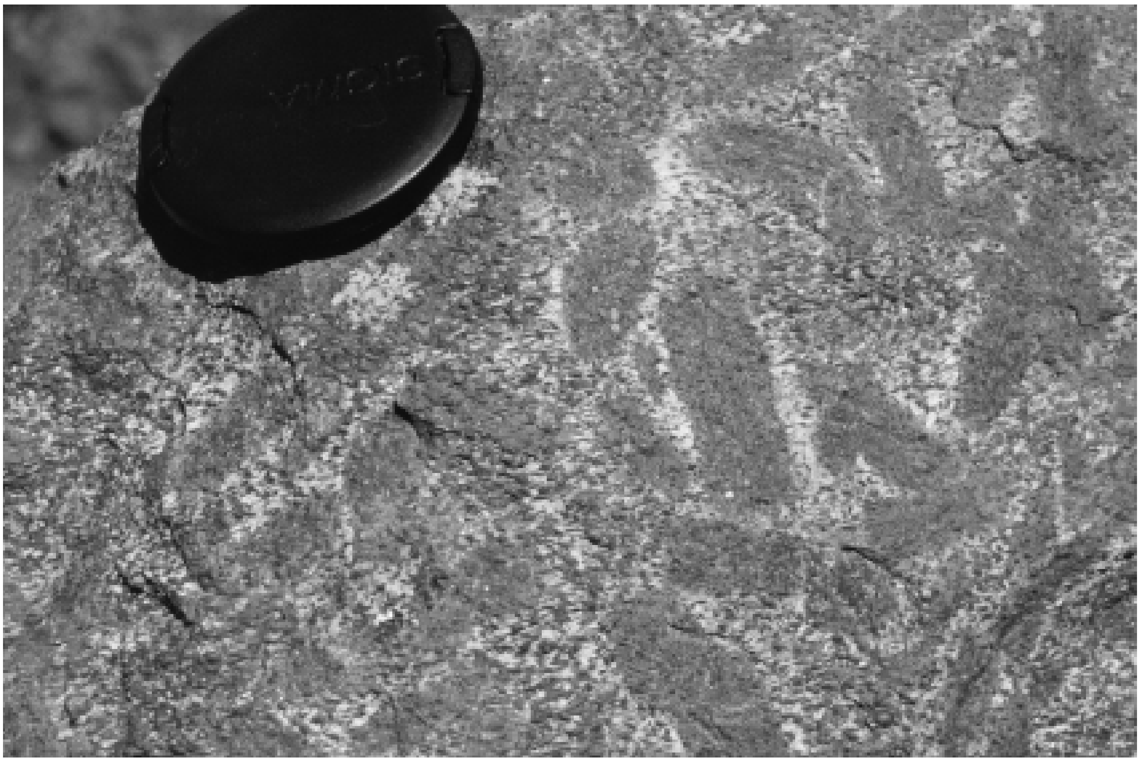

Figure 23. Large cordierite porphyroblasts within a spotted hornfels of the De Grey Group, which surrounds the Satirist Granite and the Peawah Granodiorite. MGA 071724

The Cheearra Monzogranite of the Yule Granitoid Complex, has a progressive southerly increase in metamorphic grade, with the highest grade present in the Cheearra greenstone belt. It is not clear if this metamorphism is related to local intrusion of granitoid rocks or is more regional in nature. Stromatic banding is a feature of some outcrops near the Cheearra greenstone belt. Leucogranitic and pegmatitic patches, commonly with mafic selvedges, appear to have accumulated in fractures or in hinge zones of minor folds, suggesting local, incipient, partial melting of the gneissic granitoid rock. The Mungaroona Granodiorite (*AgYmu*), which intrudes both the gneissic granitoid rocks and the greenstones at c. 2945 Ma, provides a minimum age for metamorphism.

Mafic rocks of the Cheearra greenstone belt (e.g. *Aba*) contain metamorphic actinolite and clinopyroxene, indicating at least lower amphibolite facies (Spear, 1993). It is unclear whether this metamorphic gradation reflects a northerly decrease in structural depth, and hence significant differential uplift of the southern area before c. 2945 Ma, or is a result of the localized intrusion of the mafic Mungaroona Granodiorite itself.

The rocks of the Fortescue Group have been subject to low-grade metamorphism, characterized in the mafic rocks by an assemblage containing chlorite and epidote.

Structure

All four phases of deformation recognized on MOUNT WOHLER (Smithies, 1998a,b; local D_{1-4}) are locally recognized on SATIRIST. These include: early, east- to northeasterly trending folds (D_1); major, tight, upright to overturned folds with northerly trending axial planes (D_2), which developed between c. 3000 and 2950 Ma; large-scale open folds with steeply dipping, east-northeasterly trending axial planes (D_3), which developed between c. 2940 and 2930 Ma, and; faulting, dominantly along major north-northeasterly trending fault planes that displace rocks of the Fortescue Group (D_4). An additional phase of deformation developed locally close to the granite–greenstone contact, along the southeastern margin of the Pilbara Well greenstone belt. SATIRIST has been subdivided into eight areas of similar structural history (Fig. 22).

Exposed areas of the Fortescue Group

The Fortescue Group includes the youngest and structurally simplest rocks on SATIRIST. The group outcrops almost continuously in the southwest corner of the sheet, with a northeasterly trending tongue extending to the north of the Hong Kong mine. Bedding surfaces typically dip at a shallow angle, predominantly to the south-southwest, and contrast the highly folded and steeply dipping rocks of the unconformably underlying Pilbara Supergroup. Northeasterly trending faults are a common and significant feature throughout SATIRIST, and in many cases, the latest phase of movement probably post-dated deposition of the Fortescue Group. These faults contain evidence of both strike-slip and dip-slip displacements; however, the latter appears to typify displacement after deposition of the Fortescue Group. A northeasterly trending fault at No 6 Bore juxtaposes the Mount Roe Basalt against rocks of the De Grey Group. Approximately 16 km to the northeast, the same fault juxtaposes amphibolite facies rocks of the De Grey Group against lower greenschist facies rocks of the same group, thereby requiring a considerable west-side-up displacement.

Exposures of the De Grey Group to the west and southwest of the Teichman mine

Exposures of the De Grey Group (Mallina Basin) west and southwest of the Teichman mine, contain structures that can be related to the D_1, D_2, and D_3 events recognized on MOUNT WOHLER, to the west. An early, southeasterly trending syncline (D_1) is refolded into a tight, upright, anticline with a northeasterly trending axial plane (D_2), and refolded again into open folds with east-northeasterly trending axial planes (D_3). The dominant foliation and fold pattern in this region relate to the second (i.e. northeasterly trending) event. Major faults in the region are north-northeasterly to northeasterly trending and east-north-easterly trending. The former set show a strike-slip component, but are dominated by dip-slip displacements that are most obvious where these faults also intersect rocks of the Fortescue Group (see above). The east-northeasterly trending faults both cut and cross cut by these faults.

The area surrounding the Satirist Granite, including Station Peak

The area surrounding the Satirist Granite and the Station Peak mining centre is dominated by rocks of the De Grey Group, including metamorphosed high-Mg basalt that is possibly transitional to komatiite (*AD(us)*), and abundant gabbro sills representing at least two intrusive events. This entire sequence was subsequently intruded, first by the Peawah Granodiorite, and then by the Satirist Granite.

There is a distinct spatial and temporal zonation associated with the Satirist Granite: an outer, older zone consisting of extensive gabbro sills in the country rock surrounding the granite; a middle zone consisting of the Peawah Granodiorite, now preserved as xenoliths in the granite and as minor intrusions within the country rocks, and; a younger, inner zone consisting of the Satirist Granite. Away from the granite contact, for example, in exposures of the De Grey Group west and southwest of the Teichman mine (see above), structures can be related to the D_1 and D_2 events recognized on MOUNT WOHLER. Close to that contact, it appears that these have been destroyed and the folding patterns are related directly to granitoid intrusion rather than to any recognized regional or local structural fabric. However, an east-northeasterly trending foliation that is related to the D_3 event recognized on MOUNT WOHLER is readily observed within all rocks of the area. This suggests that D_3 post-dates intrusion of all granitoid rocks, including the Satirist Granite.

The complex intrusive history of the area surrounding the Satirist Granite prohibits the definitive assignment of structural features to a particular intrusive event. The country rocks adjacent to the Satirist Granite are overturned, forming an anticline with an axis that parallels the granite–country-rock contact, and an axial plane that dips away from that contact. Early foliations (?D_1 and ?D_2) in the country rock are overprinted by a strong foliation that parallels the granite–country-rock contact (and the anticline axial plane). This foliation is intersected by a weaker foliation at an acute angle that remains constant around the granite–country-rock contact. These structural features appear consistent with the forcible emplacement of the earlier Peawah Granodiorite or late Satirist Granite, or both. In the northwestern corner of SATIRIST, folding patterns are also consistent with the supracrustal rocks having been squeezed between the main exposed portion of the Peawah Granodiorite (to the northwest) and the Satirist Granite (including Peawah Granodiorite — now as xenoliths), again suggesting forcible emplacement of the granitoid rocks.

Between the Satirist Granite and Station Peak, the rocks of De Grey Group and the gabbro sills appear to have been uplifted into a broad, eastward trending anticline. The contact metamorphic aureole that relates to intrusion of the Peawah Granodiorite or the Satirist Granite, or both, follows the trend of this fold (Fig. 3). This strongly suggests that the fold is also related to emplacement of granitoid rocks, which must underlie the area at shallow depth.

Exposures of the De Grey Group on the northern half of SATIRIST

In the area around Millindinna Well, in the northern half of SATIRIST, the De Grey Group and Millindinna Complex are folded into tight, upright folds with an east-northeasterly trend, consistent with D_3 folds recognized on MOUNT WOHLER (Smithies, 1998a,b). In the central-northern part of SATIRIST, around Mount Langenbeck, a faulted, northerly trending anticline possibly developed synchronously with major anticlines on MOUNT WOHLER (e.g. the Croydon Anticline), which were assigned to a local D_2 event (Smithies, 1998a,b).

The area northeast of Kangan Gap

Northeast of Kangan Gap, the Constantine Sandstone unconformably overlies chert that is assigned here to the Cleaverville Formation of the Gorge Creek Group. The unconformity can be traced southwest to an area immediately north of the Empress mine. There is no evidence that this contact is extensively faulted, as was suggested by Fitton et al. (1975) (i.e. the Empress Fault). Fitton et al. (1975) suggested that the two chert ridges at, and to the north of, Kangan Gap, formed the north and south limbs of the 'Kangan Syncline'. Despite large differences in the proportion of chert and ironstone between the two chert ridges, mapping of the apparent closure of this structure immediately to the east, on WODGINA, (Blewett et al., in prep.) supports the interpretation of a syncline.

The Pilbara Well greenstone belt

Rocks in the Pilbara Well greenstone belt are multiply deformed and metamorphosed. Up to three phases of ductile deformation are inferred from the overprinting of different sets of structures. A late-stage brittle deformation event has resulted in the formation of east-northeasterly trending faults with dextral offsets that cut through both the greenstone belt and the overlying Fortescue Group.

The strain is low throughout most of the belt and the rocks are heterogeneously deformed. The deformation sequence has therefore been established, in part, through the interpretation of fold relationships that are based on outcrop patterns. Localized areas of higher strain are present along granite–greenstone contacts and in shear zones.

The earliest recognizable structures are a set of upright, approximately northerly trending folds that possibly correspond to F_2 of Smithies (1998a,b). Large-scale F_2 folds are refolded by a later generation of folds to produce Type 2 and 3 fold-interference patterns (Ramsay, 1967). The F_2 folds are largely interpreted from outcrop patterns and it is not clear if they have an axial-plane foliation. In some areas, early fabrics that are now almost completely transposed into the regional foliation, may be relics of S_2. Outcrop-scale F_2 folds in chert of the Cleaverville Formation (MGA 411608) have moderate to steep northwesterly plunges. Some small-scale folds in cherts close to the granite–greenstone contact, 3 km east-northeast of Black Gin Well (MGA 444567), may also be D_2 structures.

Structures that overprint D_2 structures within the Pilbara Well greenstone belt show the same orientation as other structures assigned to D_3 on SATIRIST. The main structures assigned to D_3 in the Pilbara Well greenstone belt are the John Bull synform (the John Bull Syncline of Fitton, et al., 1975), and the regional foliation (S_3), which is axial planar to F_3 folds and is present throughout the belt. The John Bull synform is a tight, upright, northeasterly plunging fold. The plunge of the fold axis is inferred to be approximately 40–75° to the northeast, based on the orientation of small-scale F_3 folds. A mineral lineation that is parallel to the axes of the small-scale folds is present in some locations. This lineation is also parallel to a lineation resulting from the intersection of S_0 and S_3.

A later deformation event is interpreted to have resulted in the formation of a shallowly plunging mineral lineation in both granitoids and greenstones in a high-strain zone along the granite–greenstone contact; particularly to the west of Friendly Creek mining centre. Lineations in this orientation are not observed either in any other part of the belt or elsewhere on SATIRIST. They are probably post-D_3 because they are not folded by small-scale D_3 folds and the high-strain zone is not repeated on the other limb of the John Bull synform. They also pre-date northeasterly trending faulting of the Fortescue Group, assigned to D_4 by Smithies (1998a,b).

The eastern part of the Yule Granitoid Complex, on SATIRIST

The Yule Granitoid Complex on SATIRIST, comprises numerous generations of granitoid rocks, with ages between c. 3420 and 2930 Ma. All phases show a weak east-northeasterly foliation consistent with the late (i.e. late- to post-Satirist Granite) deformation event designated D_3 on MOUNT WOHLER (Smithies, 1998a,b). This foliation is the only deformational fabric developed in the younger (c. 2930 to 2945 Ma) rocks of the complex. However, porphyritic phases of the Mungarinya Monzogranite, the Powdar Monzogranite, and the Pilbara Creek Monzogranite, locally show an alignment of K-feldspar phenocryst parallel to this late foliation direction, possibly reflecting late-tectonic intrusion.

The western part of the Yule Granitoid Complex, including the Cheearra greenstone belt

In the central part of the Yule Granitoid Complex, the late east-northeasterly trending foliation overprints gneissic banding in rocks of the Cheearra Monzogranite (*AgYchn*). This gneissic banding dips steeply, and in the northern outcrops of the gneissic granitoid rock strikes at about 080°. Toward the south, the strike of the gneissic banding is progressively rotated until it parallels the trend of the interleaved felsic sedimentary and mafic rocks of the east-southeasterly trending, amphibolite-grade Cheearra greenstone belt. The rocks of the greenstone belt are folded, and have steep east-southeasterly trending axial planes, and a prominent axial-planar foliation.

Economic geology

A detailed description of the mineral occurrences and exploration potential of SATIRIST is provided by Ruddock (1999), from which the following summary is drawn.

Gold

The main gold rush of the Pilbara Craton started in 1888, with discoveries at Mallina (YULE), and Egina and Pilbara Creek (SATIRIST). These were followed by discoveries on SATIRIST at Hong Kong in 1895, and Station Peak in 1897 (Woodward, 1890; Maitland, 1909). There are no producing gold mines in the area at present, but since 1997 there has been active and successful exploration in the Mallina Basin, to the north of SATIRIST.

Vein and hydrothermal deposits

The Station Peak mining centre, in the northwestern part of SATIRIST, has been the largest gold producer in the western part of the Pilbara Craton. Here, gold is present in quartz veins within an altered gabbro body that intrudes metasedimentary rocks of the Mallina Basin. Total-mined gold production was 366.895 kg, plus 6.257 kg of alluvial and dollied gold (Ruddock, 1999).

Significant gold mineralization is present in the greenstone sequence that unconformably underlies the De Grey Group in the Teichmans–Empress–Friendly Creek area (see Ruddock, 1999, and references therein). This area lies within the Yandeearra Aboriginal Land.

The main old mining areas are at Pilbara, Hong Kong, Empress, and Teichman. The Pilbara mining centre is historically one of the richest nugget fields — an area where gold veins intersect an east-northeasterly trending belt of schistose mafic metavolcanic and gneissic rocks extending for about 12 km along the northwestern contact of the Yule Granitoid Complex. At the Hong Kong mining centre, there is a line of workings extending for about 850 m along a northeasterly trending zone of auriferous veins that intersect mafic metavolcanic rocks. About 2 km northeast of this zone, there are other old workings at Princess May and Princess May East in which mineralization is present within quartz veins and associated pyritic quartz-porphyry dykes that cut mafic meta-volcanic rocks. At Empress and Teichman, a number of quartz vein deposits are present in mafic metavolcanic rocks. About 1.5 km southwest of Teichman, at Mountain Maid, a vein deposit has developed in mafic rocks of the Pilbara Supergroup and in mafic rocks of the unconformably overlying Fortescue Group. Unfortunately, the official records of gold production (82.1 kg) give a poor impression of the actual, large amount, of gold removed from this area between 1888 and 1920 (Ruddock, 1999).

Gold in regolith

The most important occurrences of gold in regolith on SATIRIST are those that were discovered between 1888 and 1892 at Pilbara, Egina, and Womerina. Although there are no complete official production figures from these mining centres, it is clear from early accounts of mining history that these were very rich areas for nuggets, slugs, and finer eluvial and alluvial gold. A substantial amount of alluvial gold has also been extracted from the Friendly Creek alluvial tin operation (see below).

Base metals

At the Egina copper mine, in the northwestern part of SATIRIST, stratabound mineralization appears to have become remobilized and concentrated in fold hinges of clastic metasedimentary rocks of the Mallina Basin (Marston, 1979). Total production from Egina was 550.67 t of copper ore and concentrates, plus 29.05 t of cupreous ore (Ruddock, 1999).

In the northwestern part of SATIRIST, minor copper–zinc–lead was recorded by Mallina Mining NL near Mount Satirist and Youlingoorina Hill. In these areas, sulfides are present in quartz veins within rocks of the De Grey Group, close to contacts with layered mafic sills of the Millindinna Intrusion. A galena vein was also reported near Station Peak gold mine, although its exact location is unknown (Montgomery, 1907; Blockley, 1971).

Tin

The only significant alluvial tin deposits in the western part of the Pilbara Craton are present on SATIRIST, at Friendly Creek. The deposits are located about 3 km east of the Pilbara gold mining centre and have been described in detail by Blockley (1980). The source for the cassiterite is considered by Blockley (1980) to be a series of aplite pegmatites, probably related to a granite stock within the Yule Granitoid Complex. Production of 165.7 t of tin concentrate has been recorded from this locality (Ruddock, 1999).

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Appendix 1

Gazetteer of localities

Place name	*MGA coordinates*	
	Easting	*Northing*
Annie Gap	636639	7658356
Black Gin Well (abd)	640939	7655656
Cheearra Hill	628339	7631855
Egina mine (Cu)	626939	7666336
Egina alluvial gold	629739	7666156
Egina Well (abd)	629139	7666956
Empress mine	634039	7658246
Friendly Creek mining centre	637359	7650535
Hong Kong mine	633729	7656906
Hong Kong mining centre	636448	7656652
Kangan Gap	651139	7664156
Millindinna Hill	616939	7673455
Millindinna Well	616939	7675956
Mount Langenback	626639	7675656
Mount Satirist	618339	7667755
Mountain Maid mine	623639	7647005
Mugarinya Aboriginal Community	645439	7645755
No 6 Bore	604140	7639055
Pilbara mining centre	635385	7650475
Princess May East mine	636939	7657856
Princess May mine	636859	7657606
Satirist Outcamp Well (abd)	635239	7663150
Station Peak	622439	7660455
Station Peak mining centre	622639	7659806
Teichman mine	624639	7647305
Teichman Well (abd)	624739	7646955
Two Mile Well	617539	7671255
Wattle Creek Well (abd)	609839	7674155
Womerina	647686	7672426
Youlingoorina Hill	622439	7661256

Appendix 2

Definition of stratigraphic names from the SATIRIST 1:100 000 sheet

Yallingarrintha Tonalite (*AgYla*)

Derivation of name: Yallingarrintha Pool (MGA 281411)

Distribution: Scattered xenoliths and roof pendants within younger rocks of the western part of the Yule Granitoid Complex. Examples at MGA 296436 and 334411.

Type area: MGA 296436

Lithology: Moderately to strongly foliated, coarse-grained hornblende(–biotite) tonalite to biotite(–hornblende) granodiorite. Monzogranite is rare.

Relationships: Preserved as rare xenoliths and roof pendants, up to 2 km in size, within the Cheearra Monzogranite and the Yandeearra Granodiorite (see below).

Age: Biotite monzogranite, to the north of Kangan Homestead on WODGINA, is interpreted to be part of the Yallingarrintha Tonalite and was dated at c. 3420 Ma by Nelson (1999). Other outcrops pre-date intrusion of Cheearra Monzogranite and the Yandeearra Granodiorite.

Cheearra Monzogranite (*AgYch*)

Derivation of name: Cheearra Hill (MGA 283318)

Distribution: Outcrops to the northeast of Yandeearra Pool (MGA 488591), between exposures of the Mungarinya Monzogranite and the Pilbara Well greenstone belt, to a point as far east as MGA 548619, and probably eastwards onto WODGINA. To the south of Yandeearra Pool, the Cheearra Monzogranite is exposed as scattered outcrops to a point approximately 2 km south of Cheearra Hill. Except to the north of Yandeearra Pool, the Cheearra Monzogranite does not outcrop to the east of the Yule River.

Type area: Moderately to strongly foliated phase — MGA 440510; gneissic phase — immediately to the north of Cheearra Hill; porphyritic phase — MGA 386504

Lithology: Rocks of the Cheearra Monzogranite are typically medium grained, moderately foliated to gneissic, and tonalitic to monzogranitic, the latter predominating. The rocks are seriate to locally porphyritic, with K-feldspar phenocrysts up to 2 cm in length. Rocks of granodioritic and tonalitic composition contain both hornblende and biotite. Hornblende is absent from the monzogranite. Monzogranitic to tonalitic gneissic granitoid rock forms the main component of the Cheearra Monzogranite in the southwestern portion of the granitoid complex on SATIRIST.

Relationships: Includes xenoliths of Yallingarrintha Tonalite and greenstones, and is intruded by the Mungaroona Granodiorite, and the Mungarinya, Powdar, and Pilbara Creek Monzogranites.

Age: Intruded by Mungaroona Granodiorite at c. 2945 Ma. Maximum age not known but xenocrystic zircon dated at 3150–3200 Ma is common (Nelson, D. R., 1999, pers. comm.).

Yandeearra Granodiorite (*AgYya*)

Derivation of name: Yandeearra Station

Distribution: Outcrops between Quartz Hill (MGA 331475) to the north and Yallingarrintha Pool to the south, and between Pilbara Creek to the east and outcrop of the Fortescue Group to the west.

Type area: Warden Pool (MGA 369448)

Lithology: Dominantly leucocratic granodiorite, but ranges in composition to tonalite and monzogranite. The rocks are typically medium- to coarse-gained, seriate to equigranular, and weakly to moderately foliated. Biotite is the sole mafic silicate mineral.

Relationships: The rock contains xenoliths of the Yallingarrintha Tonalite and has been intruded by the Mungaroona Granodiorite, but its age with respect to the Cheearra Monzogranite is uncertain.

Age: Intruded by Mungaroona Granodiorite at c. 2945 Ma. Maximum age not known but xenocrystic zircon dated at 3150–3200 Ma is common (Nelson, D. R., 1999, pers. comm.).

Mungaroona Granodiorite (*AgYmu*)

Derivation of name: Mungaroona Range National Reserve (northeastern corner at MGA 188449).

Distribution: Outcrops between exposures of the Fortescue Group to the west, and Cheearra Hill to the east.

Type area: Northwest of Cheearra Hill (MGA 248370).

Lithology: The rock is a medium- to coarse-grained and typically equigranular hornblende–biotite granodiorite.

Relationships: It intrudes the monzogranitic to tonalitic gneissic granitoid rock of the Cheearra Monzogranite (*AgYchn*) and the supracrustal rocks of the Cheearra greenstone belt.

Age: Dated at c. 2945 Ma by Nelson (1999).

Powdar Monzogranite (*AgYpo*)

Derivation of name: Powdar Creek (joins the Yule River at MGA 481371).

Distribution: Outcrops to the south of Mungarinya Aboriginal Community and to the west of the Yule River.

Type area: MGA 471377

Lithology: The rock ranges from a highly leucocratic seriate to porphyritic monzogranite, but also includes aplite. It is typically massive to weakly deformed but locally has a strong foliation defined by flow alignment of K-feldspar phenocrysts, which are up to 3 cm in length. Biotite (now mostly chlorite) is the sole mafic silicate mineral, forming less than 5% of the rock.

Relationships: Intrudes the Cheearra Monzogranite.

Age: Dated at c. 2935 Ma by Nelson (1999).

Mungarinya Monzogranite (*AgYug*)

Derivation of name: Mungarinya Aboriginal Community.

Distribution: Forms two large plutons to the south of Kangan Gap (MGA 511641), which straddle the boundary between SATIRIST and WODGINA.

Type area: MGA 541472

Lithology: The Mungarinya Monzogranite is petrographically similar to the Powdar Monzogranite except that it contains more biotite (typically between 5 and 10%). It is typically massive to weakly deformed, but has a well-developed flow-foliation defined by alignment of K-feldspar phenocrysts. Locally, it has a prominent 'ghost banding', produced by vague mineralogical bands within individual parallel intrusive sheets of monzogranite.

Relationships: Intrudes the Cheearra Monzogranite.

Age: Dated at 2940–2935 Ma by Nelson (1999).

Pilbara Creek Monzogranite (*AgYic*)

Derivation of name: Pilbara Creek, 2.5 km to the south of Quartz Hill.

Distribution: Outcrops around the Friendly Creek mining centre (MGA 373504), forming a southwesterly trending body, approximately 1.5 km wide and 10 km long, between the Cheearra Monzogranite and the Pilbara Well greenstone belt.

Type area: MGA 346493

Lithology: The Pilbara Creek Monzogranite is a fine- to medium-grained, equigranular rock, which is typically massive to weakly foliated. The rock is highly leucocratic with biotite as the sole mafic phase and comprising less than 5% of the rock.

Relationships: Intrudes the Cheearra Monzogranite.

Age: Younger than the Cheearra Monzogranite. Possibly the same age as the Mungarinya and Powdar Monzogranites.

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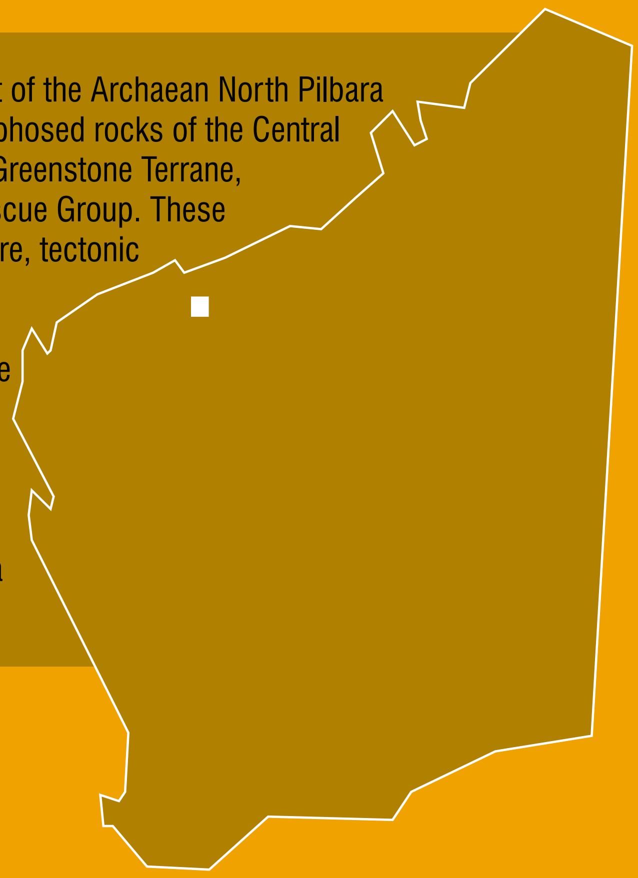
NELSON, D. R., 1999, Compilation of SHRIMP U–Pb zircon geochronology data, 1998: Western Australia Geological Survey, Record 1999/2, 222p.

The SATIRIST 1:100 000 sheet lies in the central part of the Archaean North Pilbara Terrain. It contains multiply deformed and metamorphosed rocks of the Central Pilbara Tectonic Zone and the East Pilbara Granite–Greenstone Terrane, as well as part of the overlying late Archaean Fortescue Group. These Explanatory Notes describe the stratigraphy, structure, tectonic evolution, and mineralization of this part of the Pilbara Craton. The greenstones on SATIRIST are assigned to the Pilbara Supergroup, which forms the Pilbara Well and Cheearra greenstone belts, and the 3000 Ma Mallina Basin. Three distinct granitoid bodies are recognized on SATIRIST — the Satirist Granite, the Peawah Granodiorite, and the Yule Granitoid Complex (3420 Ma to 2930 Ma). The area is prospective for gold, copper, zinc, lead, and tin.



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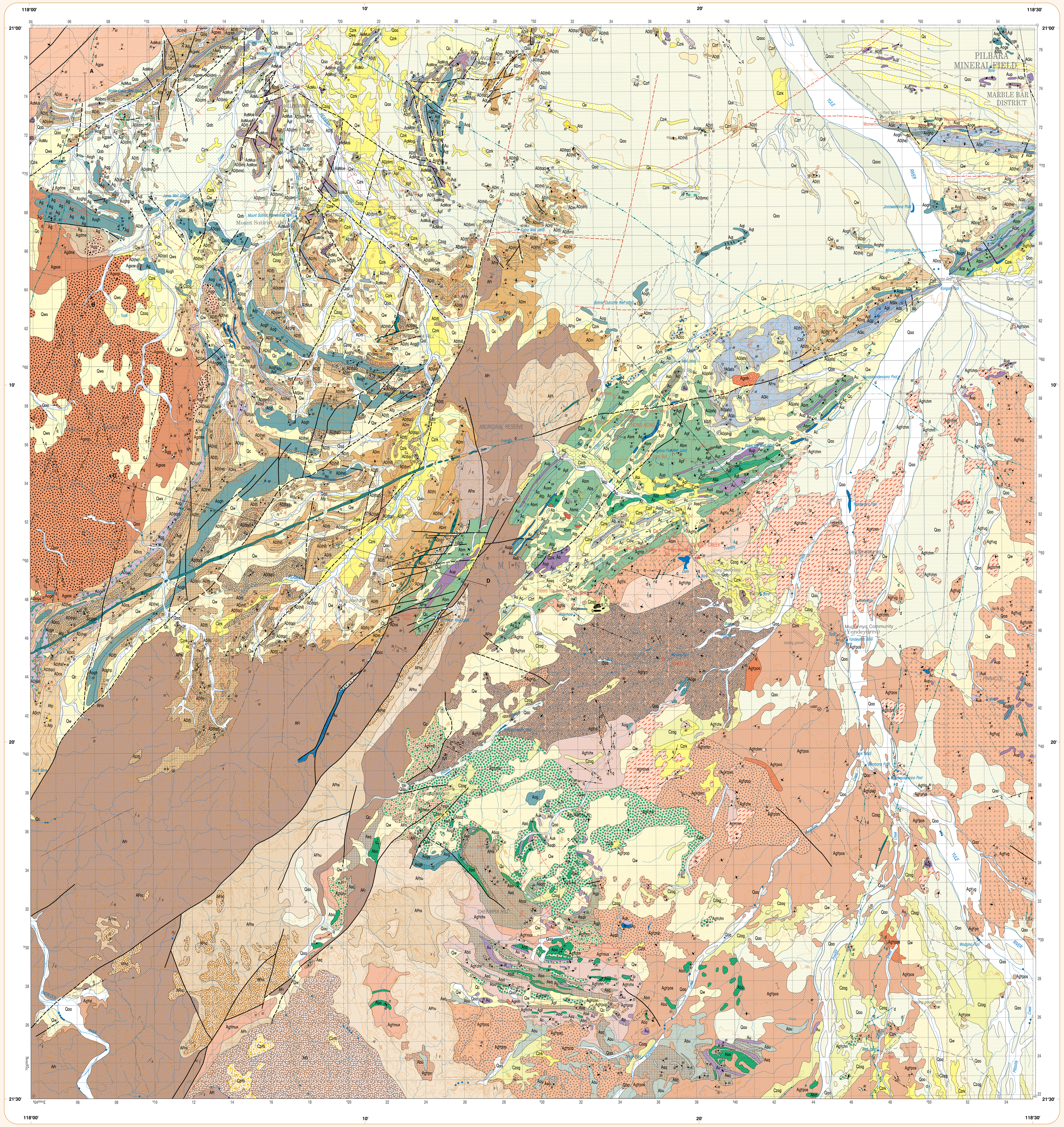
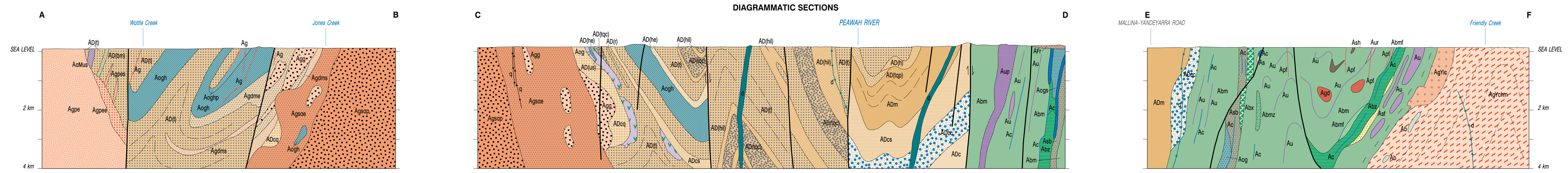
SATIRIST

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA



DIAGRAMMATIC SECTIONS



QUATERNARY

Qaa	Alluvium — sand and gravel in rivers and creeks; clay, silt, and sand in channels and on floodplains
Qal	Alluvial sand and gravel levees, and sandbanks
Qao	Alluvial sand, silt, and clay in floodplains
Qaoc	Mixed floodplain deposits with numerous small claypans
Qab	Alluvial sand, silt, and clay in floodplains, with gilgai surface in areas of expansive clay
Qw	Low-gradient sheetwash deposits — silt, sand, and pebbles in distal outwash fans; no defined drainage
Qws	Sand in distal outwash fans; no defined drainage
Qc	Colluvium — sand, silt, and gravel in outwash fans; scree and talus; proximal mass-wasting deposits
Qs	Eolian sand — red-yellow, wind-blown sand; local ridges

CAINOZOIC

Czag	Gravel deposits; unrelated to recent drainage; dissected
Czaq	Gravel deposits; dominated by vein-quartz debris; unrelated to recent drainage; dissected
Czcb	Colluvium; dissected gravel deposits derived from **Fortescue Group**
Czrf	Ferricrete; includes ferruginous and pisolitic ironstone; residual origin; dissected by present-day drainage
Czrfb	Ferruginous caprock over basalt
Czrk	Calcrete; massive, nodular, and cavernous limestone; mainly silicified; residual origin
Czru	Siliceous caprock over ultramafic rock

d	Dolerite and gabbro dykes; interpreted from aeromagnetic data where dashed
q	Quartz vein

Mount Bruce Supergroup — Fortescue Group (HAMERSLEY BASIN)

AFt	**TUMBIANA FORMATION:** mafic to intermediate volcaniclastic sandstone, tuffaceous siltstone, argillite, tuff, and stromatolitic dolomite and limestone; minor basalt and chert
AFk	**KYLENA FORMATION:** massive and amygdaloidal basalt, basaltic andesite, and dacite; local high-Mg basalt and rhyolite
AFh	**HARDEY FORMATION:** sandstone, conglomerate, siltstone, shale, and tuff
AFhc	Conglomerate; polymictic
AFhs	Medium- to coarse-grained, poorly sorted sandstone, and well-laminated siltstone
AFhu	Tuff, tuffaceous sandstone, siltstone, and shale; interbedded; local conglomerate
AFr	**MOUNT ROE BASALT:** massive, vesicular, and glomeroporphyritic basalt
AFrs	Laminated shale, siltstone, and poorly sorted tuffaceous sandstone

Aqt	Quartz–tourmaline vein or replacement tourmalinite

YULE GRANITOID COMPLEX

AgYic	**PILBARA CREEK MONZOGRANITE:** biotite-bearing monzogranite and syenogranite; leucocratic; weakly foliated to massive; metamorphosed
AgYug	**MUNGARINYA MONZOGRANITE:** biotite-bearing monzogranite and syenogranite; weakly foliated to massive; metamorphosed
AgYpo	**POWDAR MONZOGRANITE:** biotite-bearing monzogranite and syenogranite; weakly foliated to massive; metamorphosed
AgYpoa	Aplite
AgYpop	Porphyritic monzogranite
AgYpoq	Weakly porphyritic monzogranite; medium- to fine-grained
AgYpos	Seriate-textured monzogranite
AgYmu	**MUNGAROONA GRANODIORITE:** mesocratic to leucocratic hornblende(–biotite)-bearing granodiorite and monzogranite; foliated to massive; metamorphosed

SATIRIST GRANITE

c. 2930 Ma	Agsap	Metamorphosed biotite(–hornblende)-bearing porphyritic granite
c. 2940 Ma	Agsae	Metamorphosed biotite(–hornblende)-bearing equigranular granite

Pilbara Supergroup — Gorge Creek Group

CLEAVERVILLE FORMATION

AGlc	Chert; white and grey; locally banded; minor jasperlite and iron formation; metamorphosed
AGlcx	Chert breccia; clast supported; metamorphosed
AGli	Banded iron-formation; metamorphosed
AGlix	Iron formation, tremolite schist, talc schist, and banded iron-formation; metamorphosed

Unassigned

AG(f)	Felsic rock, undivided; metamorphosed; typically silicified
AG(fy)	Trachyte; metamorphosed; typically silicified
AG(sfc)	Felsic volcaniclastic conglomerate and pebbly sandstone; metamorphosed
AG(sfs)	Felsic volcaniclastic sandstone; metamorphosed
AG(shg)	Carbonaceous shale and siltstone; metamorphosed

No stratigraphic subdivision

As	Sedimentary rock, undivided; metamorphosed
Asb	Mafic volcaniclastic conglomerate, sandstone, and siltstone; metamorphosed
Asc	Conglomerate; metamorphosed
Asf	Felsic sandstone and volcaniclastic rock; metamorphosed
Ash	Shale and siltstone; metamorphosed
Asq	Quartz–muscovite schist and quartzite
Asqb	Quartz–muscovite schist and quartzite; includes abundant mafic schist and amphibolite locally
Assq	Fine-grained quartz sandstone and siltstone; minor shale and chert; metamorphosed
Ac	Chert; metamorphosed
Af	Felsic rock, undivided; metamorphosed; typically silicified

Ab	Mafic rock, undivided; metamorphosed
Aba	Amphibolite
Abaz	Amphibolite; partially silicified
Abm	Variolitic high-Mg basalt; commonly with pyroxene spinifex texture; local pillow structures; metamorphosed
Abmf	Strongly foliated, variolitic high-Mg basalt; metamorphosed
Abmz	Silicified, variolitic high-Mg basalt; metamorphosed
Abx	Mafic volcaniclastic breccia; metamorphosed
Abi	Mafic to intermediate rock; metamorphosed
Aby	Amygdaloidal basalt; metamorphosed
Abu	Interleaved mafic and ultramafic rocks, undivided; metamorphosed
Abz	Strongly silicified mafic rock; includes silicified sedimentary rock and chert

Aogz	Strongly silicified gabbro; metamorphosed

Au	Ultramafic rock, undivided; metamorphosed
Aud	Dunite; serpentinized
Auk	Serpentine–talc–tremolite rock after komatiite; pseudomorphed olivine spinifex textures
Aup	Metaperidotite; serpentinized
Aur	Tremolite-rich schist; probably after ultramafic rock
Auxo	Olivine pyroxenite; metamorphosed

YULE GRANITOID COMPLEX

AgYel	**ELLAWARRINA MONZOGRANITE:** biotite-bearing monzogranite; metamorphosed
AgYya	**YANDEEARRA GRANODIORITE:** biotite-bearing granodiorite; weakly to strongly foliated; metamorphosed
	CHEEARRA MONZOGRANITE
AgYchm	Monzogranite; moderately to strongly foliated
AgYchn	Monzogranitic to granodioritic, gneissic granitoid rock
AgYchp	Porphyritic (K-feldspar) monzogranite and granodiorite; foliated
AgYchx	Monzogranitic to tonalitic, gneissic granitoid rock; locally contains abundant greenstone rafts and xenoliths
AgYla	**YALLINGARRINTHA TONALITE:** biotite–hornblende-bearing tonalite; moderately to strongly foliated; metamorphosed

c. 3420 Ma

undivided granitoids

Ag	Metamorphosed granite, undivided
Agd	Diorite; mesocratic to melanocratic; hornblende–(biotite)-bearing; weakly foliated to massive
Agl	Leucogranite
Agmh	Monzogranite; hornblende(–biotite)-bearing
Agp	Pegmatite

Symbols

Geological boundary
- exposed
- concealed

Fault
- exposed
- concealed
- concealed, interpreted from aeromagnetic data
- horizontal relative displacement

Strongly foliated rock

Fold, showing axial trace and generalized plunge direction
- anticline; exposed, concealed
- syncline; exposed, concealed
- overturned anticline; exposed, concealed

Small-scale fold axis, showing trend and plunge
- unspecified (40)
- Z-vergence (70)
- S-vergence (55)
- M-vergence (60)

Bedding, showing strike and dip
- inclined (65)
- vertical
- overturned (85)
- trend of bedding

Way-up indicator
- igneous layering or differentiation
- pillow structure
- graded bedding

Metamorphic foliation, showing strike and dip
- inclined (70)
- vertical

Cleavage, showing strike and dip
- inclined (75)
- vertical

Mineral lineation, showing trend and plunge (30)

Bedding–cleavage intersection, showing trend and plunge (56)

Airphoto lineament
- unspecified
- fracture pattern

Isotopic age determination site with identification number (142936)

Track

Fence, generally with track

Homestead — Yandeyarra

Reserve boundary

Building

Yard — Yard

Microwave repeater station

Contour line, height in metres — 120

Watercourse, with ephemeral pool or waterhole

Waterhole — Waterhole

Bore, well — Bore, Well

Windpump

Tank — Tank

Abandoned — (abd)

Mineral field boundary

Mining centre — HONG KONG

Mine (gold, unless otherwise indicated) — Foochow

Mine, abandoned (for commodities other than gold)

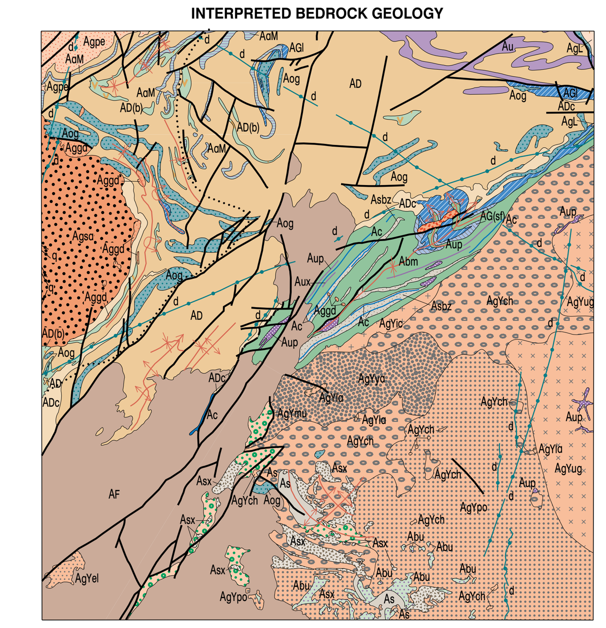
Alluvial workings

Prospect

Treatment plant, abandoned

Mineral occurrence
- Beryl — Brl
- Copper — Cu
- Gold — Au
- Lead — Pb
- Tin — Sn
- Tungsten — W
- Zinc — Zn

INTERPRETED BEDROCK GEOLOGY



Geology by R. H. Smithies and T. R. Farrell 1997–1999
For sources of geochronology data, see Explanatory Notes
Edited by N. Tetlaw and G. Loan
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Topography from the Department of Land Administration Sheet SF 50-7, 2555, with modifications from geological field survey
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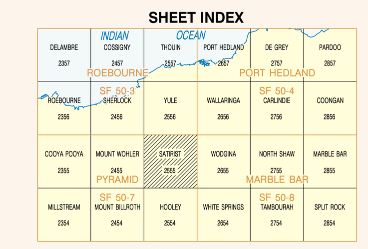

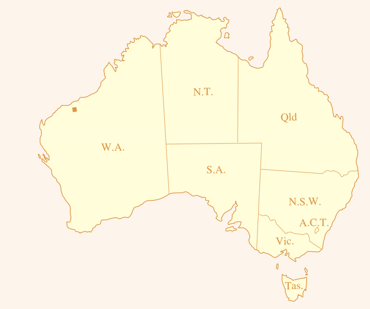

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Geological Survey of Western Australia

SCALE 1:100 000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION

HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994

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SATIRIST

SHEET 2555 FIRST EDITION 2000
Version 1.1 — July 2003