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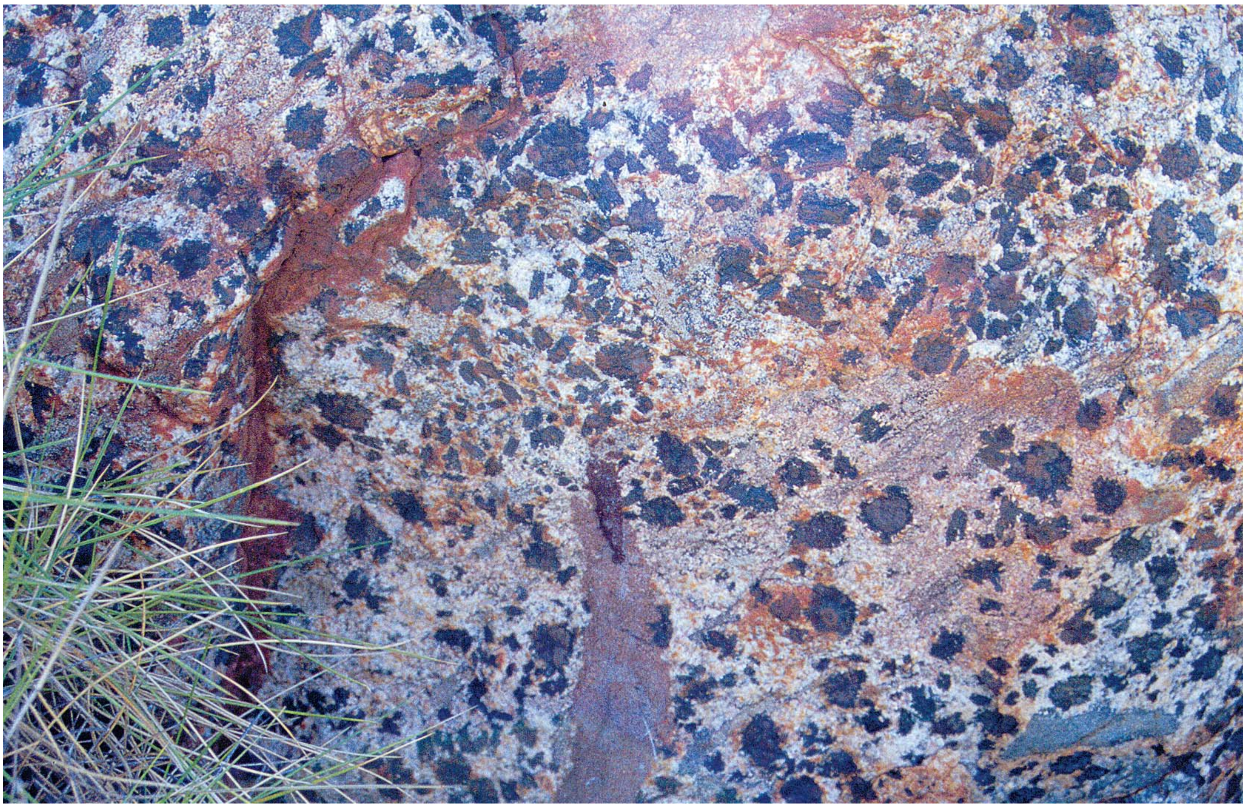
Mineral and Petroleum Resources

EXPLANATORY NOTES

GEOLOGY OF THE WALLARINGA 1:100 000 SHEET

by R. H. Smithies, D. C. Champion, and R. S. Blewett

1:100 000 GEOLOGICAL SERIES



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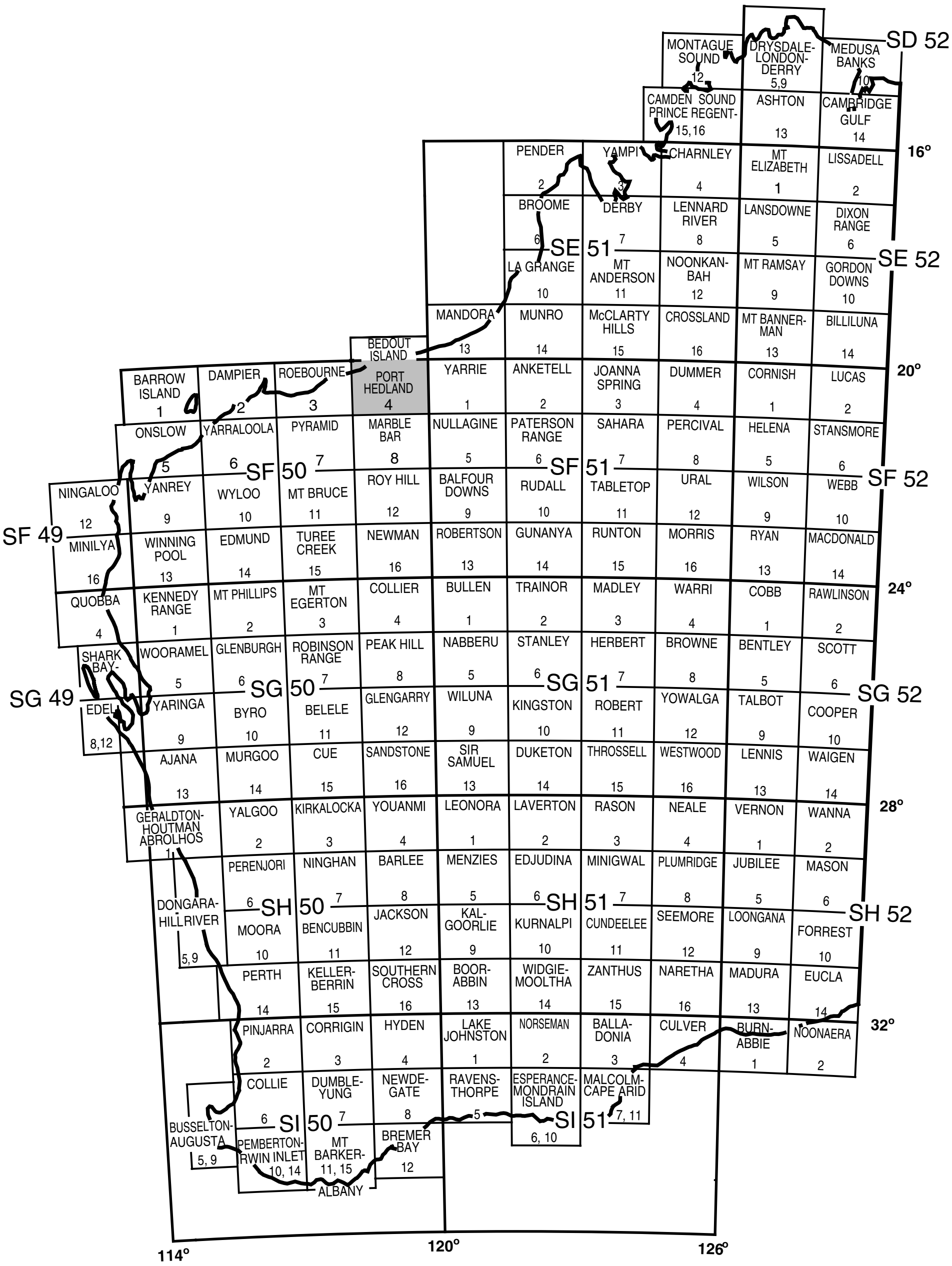

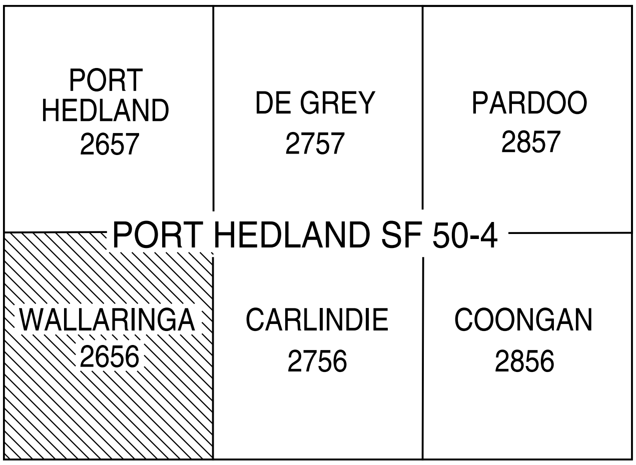

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGY OF THE WALLARINGA 1:100 000 SHEET

by
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Perth 2002

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Cover photograph:
Tonalite with megacrysts of hornblende, 3 km south of Mallindra Well, on the WALLARINGA 1:100 000 sheet

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Geology of the Wallaringa 1:100 000 sheet

by
R. H. Smithies, D. C. Champion*, and R. S. Blewett*

Abstract

The WALLARINGA 1:100 000 geological 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 eastern part of the c. 3000 Ma Mallina Basin, which is preserved as a belt of metasedimentary rocks within, and immediately northwest of, the major Tabba Tabba Shear Zone, which bisects the sheet area in a northeasterly direction. Remnants of the Mallina Basin also form xenoliths, including roof-pendants, in granites of the Pippingarra Granitoid Complex, which comprises a series of 2955–2850 Ma tonalites to monzogranites within and northwest of the Tabba Tabba Shear Zone. The older rocks of the Pippingarra Granitoid Complex developed syntectonically with the main mylonitic fabric within the Tabba Tabba Shear Zone. That fabric preserves oblique sinistral, south-side-up movement. Some of the granites were intruded during the development of a releasing bend within the shear zone system. Some metasedimentary rocks within the Tabba Tabba Shear Zone can be correlated with the c. 3020 Ma Cleaverville Formation of the West Pilbara Granite–Greenstone Terrane, but locally abundant mafic and ultramafic schist cannot be confidently assigned to any established lithostratigraphic unit.

Southeast of the Tabba Tabba Shear Zone, the Carlindi Granitoid Complex contains granitoids that range in age from c. 3485 to c. 2850 Ma. The older rocks have been folded around the nose of the Pilgangoora Syncline, in the southeast of WALLARINGA, where greenstones of the c. 3515 Ma Coonterunah Group outcrop. Production of 3843 kg of gold has been recorded from the Pilgangoora Syncline.

KEYWORDS: Archaean, Pilbara Craton, regional geology, Mallina Basin, Tabba Tabba, East Pilbara Granite–Greenstone Terrane.

Introduction

The WALLARINGA† 1:100 000 geological sheet (SF 50-4, 2656; Smithies et al, 2001a) covers the southwestern part of the PORT HEDLAND – BEDOUT ISLAND 1:250 000 map sheet, in the central-western Pilbara region. It is bounded by longitudes 118°30'E and 119°00'E, and latitudes 20°30'S and 21°00'S.

Outcrop is good throughout the eastern half of the sheet, but more scattered throughout the western half, and particularly poor in the northwestern quarter.

The rocks on WALLARINGA form part of the granite–greenstone succession of the Archaean Pilbara Craton. The sheet area straddles the boundary between the East Pilbara Granite–Greenstone Terrane and the Central Pilbara Tectonic Zone (Fig. 1) as defined by Hickman (2000) and Van Kranendonk et al. (in press). Granite is the most commonly exposed rock type, and forms part of the Carlindi Granitoid Complex in southern WALLARINGA and part of the Pippingarra Granitoid Complex in the north.

Greenstones are assigned to the Pilbara Supergroup (Hickman, 1983). Three discrete zones of greenstones are defined on WALLARINGA:

- The closure of the north-trending Pilgangoora Syncline forms the northern part of the Pilgangoora greenstone belt in the southeastern part of the sheet area (Fig. 2). It includes units of the c. 3515 Ma Coonterunnah Group (Buick et al., 1995; Van Kranendonk et al., in press) and the c. 3460 Ma Warrawoona Group (Hickman, 1983), representing the oldest exposed greenstones within the Pilbara Craton.
- In the northwestern part of the sheet area, c. 2990–2940 Ma metasedimentary rocks of the Mallina Basin (Smithies et al., 2001b) form an easterly tapering wedge between the Pippingarra Granitoid Complex to the north and the Tabba Tabba Shear Zone to the south. This basin includes the youngest exposed greenstones within the Pilbara Craton.

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

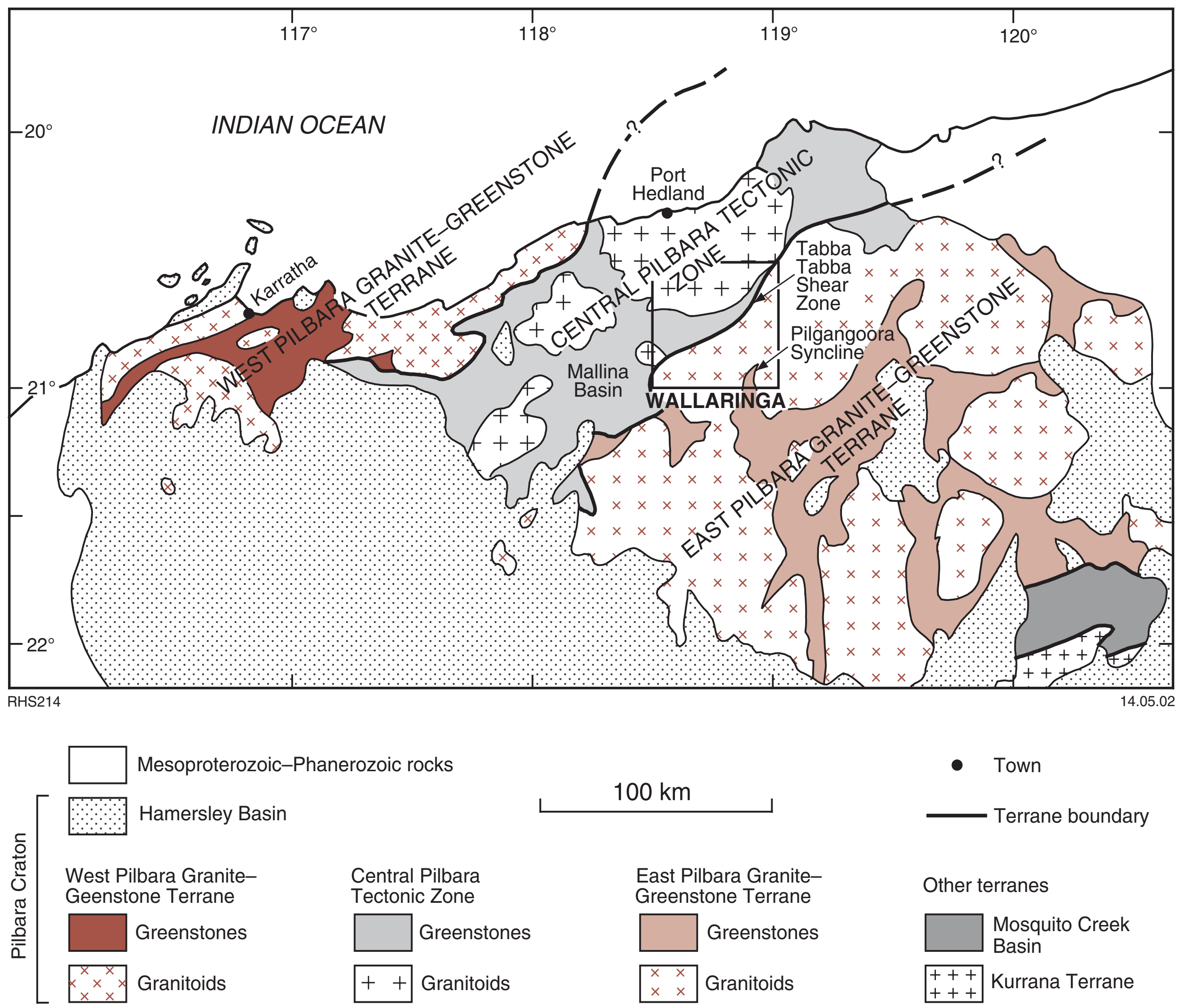


Figure 1. Regional geological setting of WALLARINGA

- The northeast-trending Tabba Tabba Shear Zone bisects the sheet area and forms the southern margin of the Mallina Basin. Greenstone components within the shear zone are similar to those in the stratigraphically lower parts of the Mallina Basin to the southwest, on SATIRIST.

Access and land use

The Great Northern Highway crosses the southwestern and northwestern corners of WALLARINGA (Fig. 3). Port Hedland, about 25 km to the north, can be reached via the Great Northern Highway or either the unsealed old Port Hedland – Wittenoom road or the unsealed private road that services and runs alongside the Port Hedland – Mount Newman railway line. Both unsealed roads and the railway line run from north to south in the western half of the sheet area.

An unsealed track connects the railway line service road to Wallareenya Homestead* in the central part of the sheet (Fig. 3), and from there continues northeast to the abandoned Tabba Tabba mine, as the main haul road linking mine to both the old (unsealed) and new (sealed) Marble Bar roads.

There are two occupied homesteads on WALLARINGA: Indee Homestead in the central west, and Wallareenya Homestead (Fig. 3). The land is divided between the Mugarinya Aboriginal Community to the southwest, Indee Station in the central west, Boodarie Station in the northwest, Carlindi Station in the northeast, and Wallareenya Station in the southeast. Grazing is the sole agricultural activity.

Tantalum and beryllium were extracted from pegmatite at the Pippingarra mine in the north, and felspar continues to be mined there. It is the only currently active mine on WALLARINGA, but tantalum and tin were previously extracted from pegmatite at the abandoned Tabba Tabba mine and gold was produced from the abandoned Cookes

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

Hill mine in the central-western part and from the mines in the Pilgangoora Syncline area in the extreme southeast.

Physiography

The northwest-flowing Turner River is the only large drainage system on WALLARINGA (Fig. 3). The river splits into two branches: the Turner River and the Turner River East, which traverses much of the sheet area in a northwesterly direction. The main period of river flow is during the summer wet season.

WALLARINGA is generally flat lying, forming part of the low hills and sandplain physiographic subdivisions, with elevations typically less than 150 m (Fig. 3). However, outcrops within the Pilgangoora Syncline and the Tabba Tabba Shear Zone locally form strike-controlled ridges with elevations up to 200 m.

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): granite–greenstones that formed between c. 3600 and c. 2800 Ma (Hickman, 1983, 1990; Barley, 1997), and the unconformably overlying volcano-sedimentary sequences (Mount Bruce Supergroup) of the c. 2770–2400 Ma Hamersley Basin (Arndt et al., 1991).

The granite–greenstones of the Pilbara Craton are exposed mainly in the north and northeast of the craton where erosion has removed all but local remnants of the Mount Bruce Supergroup. This region has recently been subdivided into the East and West Pilbara Granite–Greenstone Terranes, separated by the northeast-trending Central Pilbara Tectonic Zone (Fig. 1; Hickman, 2000; Van Kranendonk et al., in press). The East Pilbara Granite–Greenstone Terrane consists of large ovoid granitoid–gneiss complexes partially surrounded by belts of tightly folded and near-vertically dipping volcanic and sedimentary rocks typically metamorphosed to greenschist facies. The oldest greenstones so far dated are c. 3515 Ma rocks in the Coonterunnah Group (Buick et al., 1995; Van Kranendonk, 1998). Accumulation of greenstones occurred until c. 2940 Ma, although the majority were deposited before c. 3230 Ma. Felsic magmatism occurred periodically between c. 3600 and c. 2850 Ma. Although the majority of granitoid rocks in the eastern part of the terrane intruded before c. 3240 Ma, monzogranite dated at between c. 2945 and 2930 Ma forms a volumetrically significant and locally dominant component of granitoid complexes in the western part of the terrane, which includes WALLARINGA.

In contrast to the characteristic ovoid outcrop pattern of the East Pilbara Granite–Greenstone Terrane, the West Pilbara Granite–Greenstone Terrane consists of more linear northeast-trending granitoid complexes and greenstone belts dated at between c. 3270 and c. 2925 Ma.

The northeast-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. The Whim Creek greenstone belt of mafic to felsic volcanic and volcaniclastic rocks forms the northwestern margin of the basin, which is elsewhere dominated by a thick sequence of tightly folded turbidite and mass-flow deposits (Smithies et al., 2001b). The contact between the rocks of the Whim Creek greenstone belt and the West Pilbara Granite–Greenstone Terrane is a locally faulted unconformity between c. 3010 Ma volcanic rocks at the base of the Whim Creek Group and basalts and banded iron-formation of the c. 3125 Ma Whundo Group and the c. 3020 Ma Cleaverville Formation respectively (Hickman, 1997).

The boundary between the East Pilbara Granite–Greenstone Terrane and the Central Pilbara Tectonic Zone is the basal contact between the Mallina Basin and the underlying granite–greenstone sequences. This contact is a fault, which may locally be a 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). Deposition of the Cleaverville Formation is the earliest known greenstone-forming event common to both the East and West Pilbara Granite–Greenstone Terranes; although the c. 3280–3235 Ma Sulphur Springs Group, of the East Pilbara Granite–Greenstone Terrane, and the Roebourne Group may also be correlated (Van Kranendonk et al., in press).

The maximum age of the Mallina Basin is constrained by the c. 3020–3015 Ma age of the underlying Cleaverville Formation. Maximum depositional ages of c. 3000 and c. 2995 Ma for the sedimentary rocks of the basin were obtained from detrital zircons in samples from SHERLOCK to the west (Nelson, 1997, 2000). Inherited zircon populations in granitoids that intrude those rocks suggest that sedimentation within the basin began before c. 2970 Ma (Smithies et al., 2001b). The majority of the basin rocks must have been deposited and tightly folded before c. 2950 Ma, at which time they were intruded by the Peawah Granodiorite and Portree Granite. However, the age of detrital zircons from a wacke of the Mallina Formation, near Egina Well on SATIRIST, shows that deposition continued until at least c. 2940 Ma, and indicates an as yet unidentified unconformity within the Mallina Basin stratigraphy. Shear zones both within and along the margins of the Mallina Basin are parallel to the northeast-trending basin axis. Major shear zones like the Mallina and Tabba Tabba Shear Zones mark basement structures related to early basin formation (Smithies, 1999). The basement structures were reactivated, probably under extension, at c. 2950 Ma and intruded by dioritic to granodioritic rocks such as the Peawah Granodiorite (Smithies and Champion, 2000). It is likely that this extensional event initiated the second phase of deposition within the Mallina Basin.

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

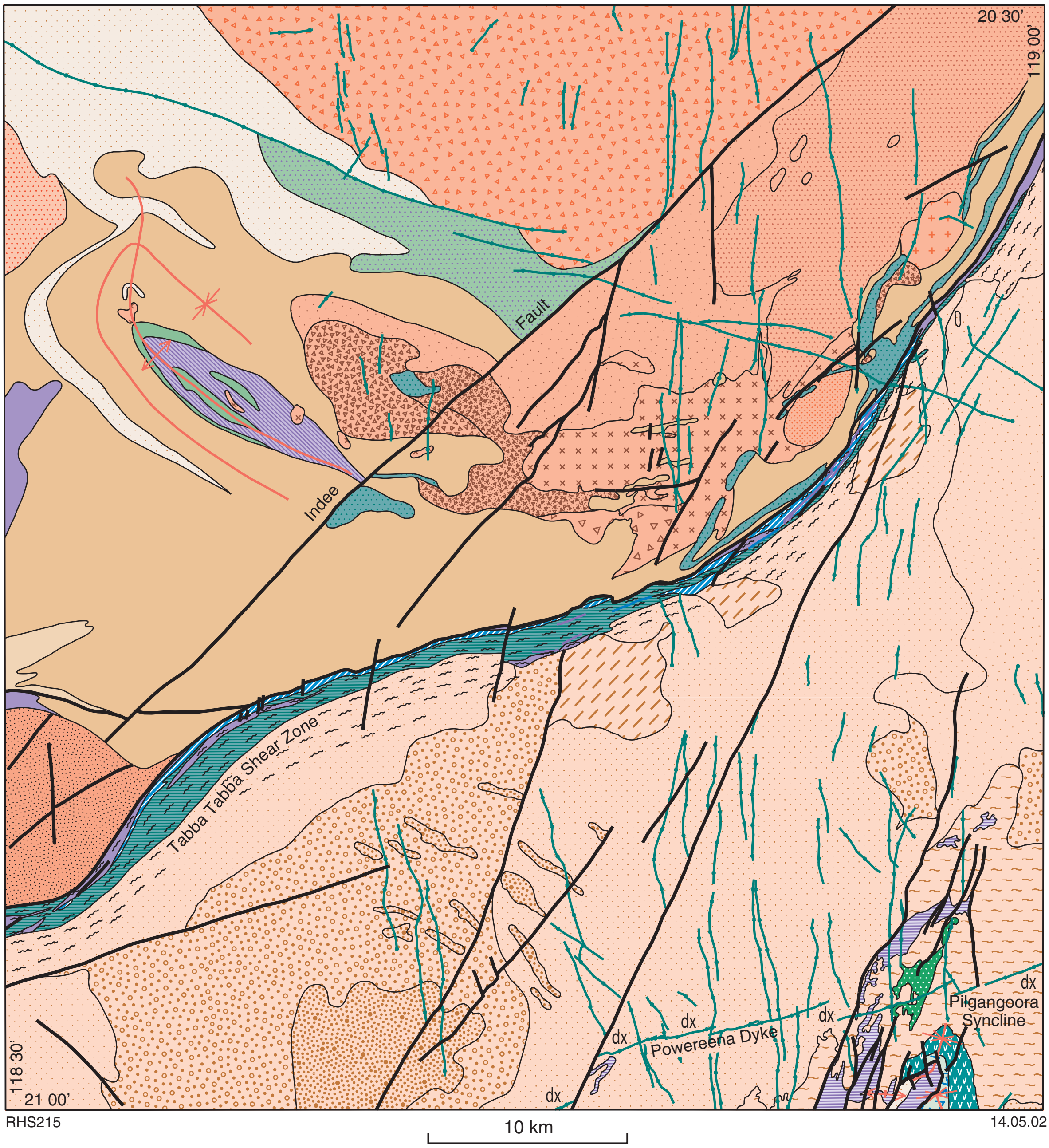
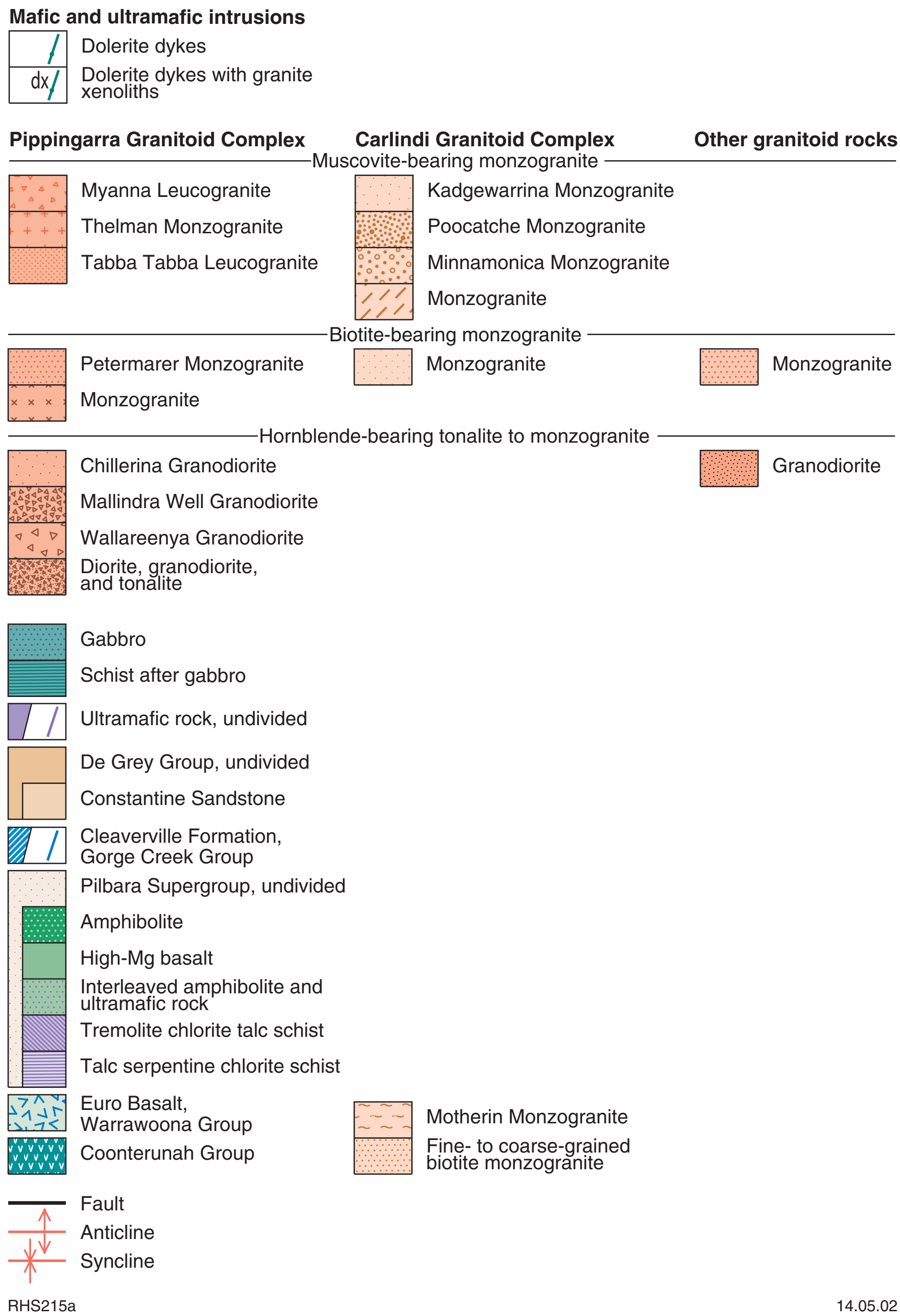


Figure 2. Interpreted bedrock geology

which clastic material was derived from essentially contemporaneous stable volcanic margins. The northwestern margin lay in the Mons Cupri – Roebourne region (on SHERLOCK and ROEBOURNE) whereas the Teichmans region (on SATIRIST) formed the southeastern margin. The entire volcano-sedimentary sequence was defined as the Roebourne Group, and appears as such on the PYRAMID 1:250 000 map sheet (Kriewaldt and Ryan, 1963). This group 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 revised stratigraphy. The felsic to intermediate volcano-sedimentary rocks on SHERLOCK were shown to lie unconformably on 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 greenstone belt (formerly the Whim Creek Belt; Fitton et al., 1975) was called the Mallina Formation and the underlying sandstone was called the Constantine Sandstone (Fitton et al., 1975). Fitton et al. (1975) originally correlated both the Mallina Formation and Constantine Sandstone with the Whim Creek Group. Hickman (1977), however, redefined the Whim Creek Group to exclude these two units that he believed belonged to the older Gorge Creek Group, which outcrops extensively in the eastern part of the Pilbara Craton.



On the regional scale, correlations between well-exposed rock successions in the eastern part of the craton and lithologically similar sequences in the western part (Fitton et al., 1975; Hickman, 1983) indicated that the greenstones could be collectively assigned to a single stratigraphic package that Hickman (1983) called the Pilbara Supergroup. These correlations incorporated a reinterpretation of the Whim Creek area, which suggested that the Mallina Formation and Constantine Sandstone were older than the Whim Creek Group, but younger than the Gorge Creek Group. The Mallina Formation and Constantine Sandstone were therefore placed within the De Grey Group (Hickman, 1990). Thus, the Pilbara Supergroup comprised four lithostratigraphic groups, which from oldest to youngest included the predominantly mafic and ultramafic volcanic rocks of the Warrawoona Group, and the predominantly sedimentary and felsic volcanic rocks of the Gorge Creek, De Grey, and Whim Creek Groups.

Metasedimentary rocks outcropping on the western side of WALLARINGA belong to the Mallina Formation and form part of what is currently called the Mallina Basin. Hickman and Gibson (1981) speculated that these rocks extended northeasterly across WALLARINGA and on to adjacent CARLINDIE. They suggested that the southern margin to this belt of rocks (their Indee Syncline) was a faulted contact (now called the Tabba Tabba Shear Zone)

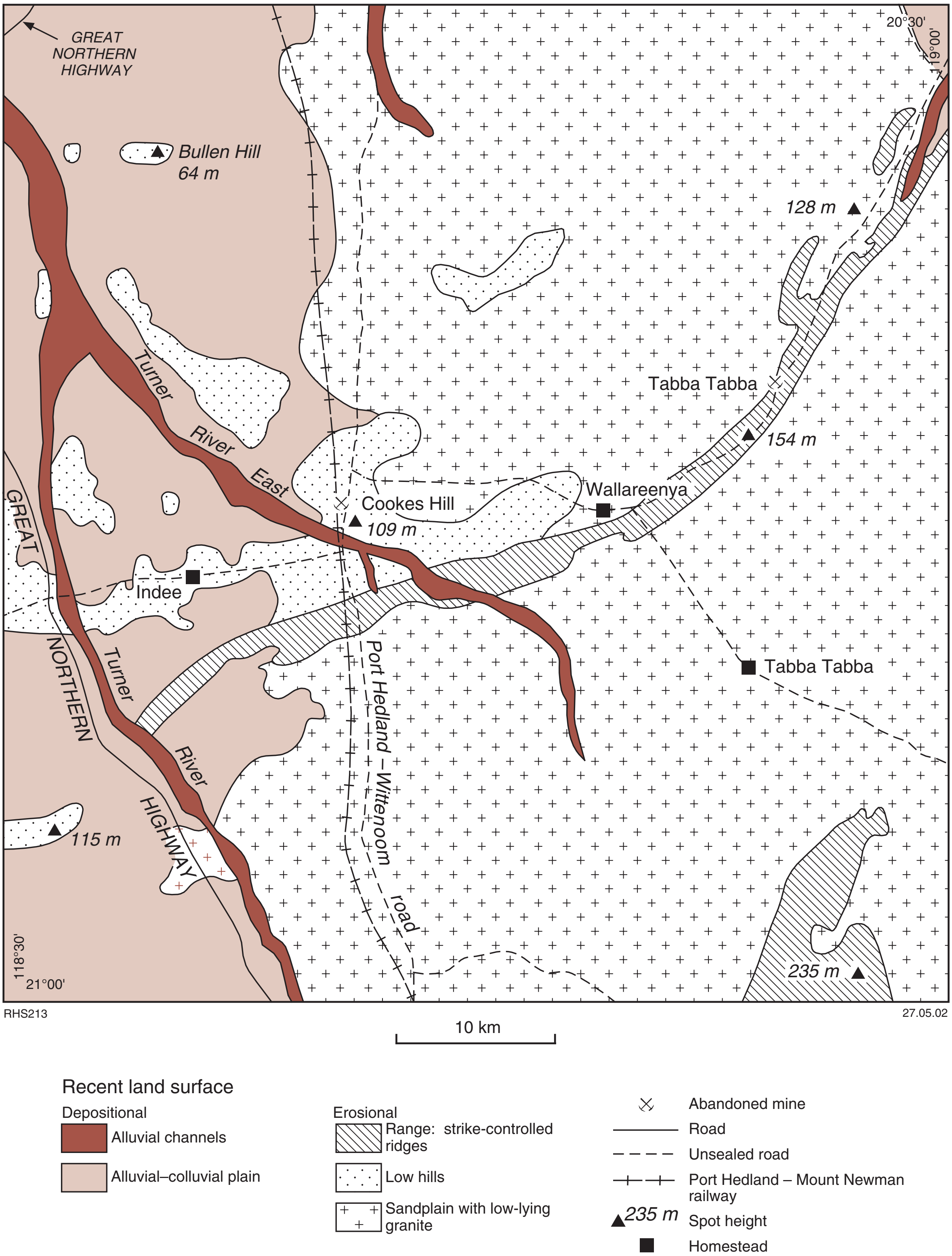


Figure 3. Physiographical features of WALLARINGA

with granites and rocks of the Warrawoona Group, whereas to the north the rocks unconformably overlay the Warrawoona Group. Although no rocks of the Warrawoona Group are now believed to be in contact with the Mallina Formation, mapping during the current project has confirmed the northeasterly extent of the Mallina Basin.

Recent mapping and sensitive high-resolution ion microprobe (SHRIMP) U–Pb dating have led to major revisions of the Pilbara Supergroup. Two new groups (Roebourne and Whundo) have been defined in the West Pilbara Granite–Greenstone Terrane for rocks that were formerly assigned to the Warrawoona Group (Hickman, 1997). In the East Pilbara Granite–Greenstone Terrane west of Marble Bar, various sequences formally assigned to the Warrawoona Group have also been reassigned. Van Kranendonk and Morant (1998) identified the younger, c. 3280–3235 Ma (Van Kranendonk et al., in press) Sulphur Springs Group. Buick et al. (1995) recognized the c. 3515 Ma Coonterunnah Group, which represents the oldest exposed greenstones within the Pilbara Craton, and forms part of the Pilgangoora Syncline on WALLARINGA. It has also been shown that some successions from the De Grey and Whim Creek Groups, in the Central Pilbara Tectonic Zone, are time-equivalent facies of the same depositional basin (Smithies, 1997; Smithies et al., 1999, 2001b; Huston et al., 2000), supporting earlier stratigraphic correlations by Fitton et al. (1975) and Horwitz (1990).

Archaean rocks

Introduction

All granite–greenstones on WALLARINGA 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 close to the late granitoids of the Carlindi and Pippingarra Granitoid Complexes. Where the protolith of a contact metamorphic rock is known, the metamorphic rock has been grouped under that protolith.

The Archaean geology of WALLARINGA is summarized on Figure 2 and the geological history of the area is presented in Table 1. No remnants of the Mount Bruce Supergroup are preserved. WALLARINGA straddles the boundary between the East Pilbara Granite–Greenstone Terrane and the Mallina Basin (Fig. 1). Granitoids dominate the outcrop, and are grouped into two distinct granitoid complexes separated by the northeast-trending Tabba Tabba Shear Zone, which roughly bisects the sheet area. To the north the Pippingarra Granitoid Complex contains rocks dated at between c. 2955 and c. 2930 Ma (Nelson, 2001), although voluminous muscovite(–garnet)-bearing leucogranite is suspected to be c. 2850 Ma in age based on dating of similar lithologies elsewhere in the Pilbara Craton (Nelson, 1998). Granitoids to the south of the Tabba Tabba Shear Zone form part of the Carlindi Granitoid Complex. The Motherin Monzogranite, in the southeast of the sheet area, has been folded around the nose of the Pilgangoora Syncline and dated at c. 3475 Ma (Baker, D. E. L., 2001, written comm.). A monzogranite that outcrops in the far southeast of the sheet was dated at c. 3485 Ma (Nelson, 1999). However, a large proportion of the Carlindi Granitic Complex on WALLARINGA comprises muscovite-bearing monzogranite thought to be c. 2850 Ma in age.

Outcrop of greenstones on WALLARINGA is essentially confined to three areas: in the western and northwestern corners (Mallina Basin), in and adjacent to the Tabba Tabba Shear Zone, and in and around the Pilgangoora Syncline (Pilgangoora greenstone belt) in the far southeast. These greenstone successions are described below along with a general description of the geology and geological history of those regions.

Mallina Basin

Rocks of the De Grey Group, representing the Mallina Basin, form scattered outcrop mainly in the west and northwest. All granitoids of the Pippingarra Granitoid Complex and most of the granitoids of the Carlindi Granitoid Complex within about 15 km of the Tabba Tabba Shear Zone are younger than the De Grey Group. Sedimentary rocks typically form cordierite hornfels close to these granitoids. These metasedimentary rocks are siliciclastic turbidites that have been assigned to either the Mallina Formation or the Constantine Sandstone, or remain unassigned. Based on contact relationships with dated granitoids and age ranges within suites of detrital zircons, the main sedimentary succession within the basin has been constrained between 2970 and 2955 Ma (Smithies et al., 1999, 2001b). A subsequent, and poorly preserved, depositional event occurred between 2945 and 2935 Ma (Smithies et al., 1999, 2001b). The metasedimentary rocks of the De Grey Group on WALLARINGA are intruded by c. 2955 and c. 2945 Ma granitoids and so pre-date that second depositional event.

Outcrop of the De Grey Group includes a series of large isolated roof pendants over granitoids in the southern part of the Pippingarra Granitoid Complex. Sheared hornfels immediately northwest of the Tabba Tabba Shear Zone forms a northeast-trending belt across the sheet. It is clear from these outcrops that the Mallina Basin originally extended farther north and east than present exposures suggest. The De Grey Group does not outcrop southeast of the Tabba Tabba Shear Zone, consistent with the dominantly southeast-side-up movement along this zone (see below).

Rocks that form the local basement to the Mallina Basin outcrop within an inlier near Carubumya Well along the southwestern exposed margin of the Pippingarra Granitoid Complex. These basement rocks include mafic and ultramafic rocks, chert, and rocks interpreted to be paragneiss, and have not been assigned to a particular lithological group. Contact relationships between rocks of the Mallina Basin and interpreted basement rocks are not exposed on WALLARINGA. There is a similarity in the lithological range of inferred basement rocks that outcrop along the southwestern exposed margin of the Pippingarra Granitoid Complex and rocks found in the Tabba Tabba Shear Zone.

Table 1. Summary of the geological history of Wallaringa

Age (Ma)	*Central Pilbara Tectonic Zone*	*East Pilbara Granite–Greenstone Terrane*
c. 3515		Deposition of rocks of the Coonterunnah Group, preserved now in the Pilgangoora greenstone belt
>3470		Development of S_1 fabrics in rocks of the Coonterunnah Group
c. 3470		Coonterunnah Group intruded by oldest components of the Carlindi Granitoid Complex (Motherin Monzogranite)
c. 3310–3470		Deposition of rocks of the Warrawoona Group, preserved now in the Pilgangoora greenstone belt
c. 3420–3240		Development of S_2 fabrics in rocks of the Pilgangoora greenstone belt
?		Deposition of unassigned units interpreted to be older than the Gorge Creek Group
?		Development of S_3 fabrics in rocks of the Pilgangoora greenstone belt
?		Early development of the Tabba Tabba Shear Zone
3020–3015	.... Deposition of Cleaverville Formation (Gorge Creek Group)	
2970–2955	Deposition of the De Grey Group in the Mallina Basin	
?	East- and then north- to northwest-trending folds	Development of S_{5-6} fabrics in rocks of the Pilgangoora greenstone belt
2955–2940	.... Major sinistral and normal movement along the Tabba Tabba Shear Zone, development of the Wallareenya releasing bend and northerly trending folds in rocks of the Mallina Basin	
2955–2930	Sequential intrusion of tonalites and granodiorites, followed by monzogranites, forming the early phase of the Pippingarra Granitoid Complex. Contact metamorphism of rocks within the Tabba Tabba Shear Zone and of the De Grey Group	
2940–2930		Intrusion of monzogranite of the Carlindi Granitoid Complex
?	East-northeasterly trending folds in the Mallina Basin	Development of S_7 fabrics in rocks of the Pilgangoora greenstone belt
c. 2850	.... Intrusion of muscovite(–garnet) leucogranites	
2770 and younger	.... Dip-slip faulting along major northeasterly trending faults	

The Tabba Tabba Shear Zone

The northeast-trending Tabba Tabba Shear Zone forms the southern margin of the eastern part of the Mallina Basin. The zone is up to 3 km wide and the enclosed rocks vary locally from weakly foliated to mylonitic. Foliations within this zone typically dip steeply to the north or northwest. The shear zone is distinctly sinusoidal in plan view, and the latest major movement was dominantly normal (northwest-side-down), but with a significant sinistral component. An age of c. 2940 Ma from a mylonitized granitoid along the southern margin of the shear is interpreted to be a primary crystallization age (Nelson, 2001) and therefore represents a maximum age for preserved deformation within the shear zone. This interpretation is supported by shearing of c. 2955 Ma granites and surrounding hornfels (Mallina Formation) along the northern margin of the shear zone. Unfoliated muscovite granite, interpreted to be c. 2850 Ma in age, intruded the shear zone.

Chert, banded iron-formation, serpentinite, ultramafic schist, gabbro, mafic schist, and granites outcrop along the Tabba Tabba Shear Zone, and range from weakly deformed to isoclinally folded and mylonitic. In zones of low strain the chert locally shows well-developed banding, continuous over many metres, and is interpreted to be sedimentary in origin. Very well banded quartz–magnetite–grunerite rock represents a primary chemical or fine-grained clastic metasedimentary rock. These cherts and magnetite-bearing rocks can be traced discontinuously in a southwest direction to the Kangan area on SATIRIST, where similar lithologies were interpreted to be part of the c. 3020 Ma Cleaverville Formation of the Gorge Creek Group (Smithies and Farrell, 2000).

Various mafic schists within and marginal to the Tabba Tabba Shear Zone are strongly sheared, isoclinally folded, locally mylonitized, and locally intensely silicified and epidotized gabbro. Massive to weakly foliated gabbro is preserved northwest of the shear zone, north of Boundary Well, although it is not clear whether this gabbro is the same as that within the shear. Gabbro and mafic schist within the Tabba Tabba Shear Zone are interleaved with locally abundant ultramafic schist, but this is not a feature of gabbro north of Boundary Well.

Ultramafic schist within the Tabba Tabba Shear Zone is derived from a dunite or (more commonly) lherzolite protolith, and locally preserves a medium-grained olivine-cumulate texture. At some localities (e.g. MGA 705000E 7719300N) a coarse olivine-spinifex texture is preserved, suggesting that at least a minor proportion of the ultramafic rocks was derived from an extrusive or high-level intrusive protolith.

Sinistral transtensional movement along the sinusoidal Tabba Tabba Shear Zone caused local extension along northeast-trending segments. A releasing bend east and north of Wallareenya Homestead (Smithies and Champion, 2002) appears to have been exploited by intruding magmas; intrusive rocks account for about two-thirds of exposures within the Wallaringa releasing bend. This structure comprises an extensively faulted zone up to 15 km wide between the Tabba Tabba Shear Zone and the northeast-trending Indee Fault.

Pilgangoora Syncline

The nose of the north-trending Pilgangoora Syncline lies in the southeastern corner of WALLARINGA, where it forms the northern part of the Pilgangoora greenstone belt. The main part of the syncline continues south onto WODGINA where it has been studied in detail by Blewett (2002) and Blewett et al. (in prep.). On WALLARINGA the upright syncline plunges to the southwest and folds rocks of the Coonterunah and Warrawoona Groups. In the core of the fold is a sequence of fine-grained metasedimentary rocks of unknown affinity. The western margin of the structure is transected by a northeast-trending sinistral shear zone.

Coonterunah Group

The Coonterunah Group (Buick et al., 1995; Van Kranendonk, 1998) forms the oldest recognized component of the Pilbara Supergroup and has been dated at c. 3515 Ma (Buick et al., 1995). The group consists of mafic volcanic rocks, interbedded iron formation and chert, and felsic volcanic rocks metamorphosed to lower amphibolite facies. Van Kranendonk (1998) subdivided the Coonterunah Group into the basal Table Top Formation, the Coucal Formation, and the overlying Double Bar Formation. Only the lower two formations outcrop on WALLARINGA, where they form the stratigraphically lowest part of the Pilgangoora Syncline in the far southeast.

Table Top Formation (*Aot, Aotbc*)

The Table Top Formation (Van Kranendonk, 1998) is predominantly composed of fine- to medium-grained amphibolite after tholeiitic basalt and dolerite (*Aot*). The typically massive nature of this rock is partly due to metamorphic recrystallization close to later intrusions of the Carlindi Granitoid Complex. The tholeiitic rocks are fine- to medium-grained intergrowths of actinolite, plagioclase, and opaque minerals. Most feldspar laths retain their igneous shape, but have been extensively sericitized and have recrystallized margins intergrown with actinolite.

A 200 m-thick member of interleaved mafic chlorite schist, amphibolite, and lesser talc schist together with minor banded iron-formation (*Aotbc*) defines a low ridge coinciding with a magnetic high zone along the eastern edge of the northern Pilgangoora greenstone belt.

Coucal Formation (*Aocb*)

Mafic schist and amphibolite (*Aocb*) with variable degrees of silicification wraps around the northeastern part of the Pilgangoora greenstone belt. Silicification is typically, but not invariably, concordant to the composite penetrative fabric within the most intensely fractured and foliated rock types, and produces light-coloured alteration bands that can be readily distinguished in the field.

Warrawoona Group — Euro Basalt

The Warrawoona Group consists of up to 15 km of predominantly volcanic rocks that Hickman (1983) subdivided into nine formations. Only the upper formation, the Euro Basalt, is present on WALLARINGA, where it forms the stratigraphically higher part of the Pilgangoora Syncline.

Mafic schist and amphibolite after basalt (*Aweb, Awebc*)

The majority of rocks within the Euro Basalt are either fine-grained mafic schist or fine- to medium-grained massive amphibolite, after basalt, high-Mg basalt, and dolerite sills (*Aweb*). Alteration associated with local mineralization systems has resulted in bleaching of the mafic schists into carbonate-altered and schistose basalt (*Awebc*), with locally intense silicification producing 'cherty' rocks. On WALLARINGA the carbonate-altered and silicified unit is only exposed near the McPhees West Lode opencut, but farther south on WODGINA it forms a major unit widely associated with larger mineralization systems, including the Lynas Find deposits. Both the alteration zones and 'cherts' crosscut the main foliation (Blewett et al., in prep.). According to Blewett et al. (in prep.), many of the 'cherts' are only present high in the landscape passing gradationally into sheared mafic schist on the lower slopes of hills and in valleys, suggesting that they are silcretes developed in a regolith (possibly as inverted relief).

Komatiitic basalt and komatiite (*Awebk*)

Narrow outcrops of coarse-grained olivine-spinifex textured, massive and pillowed komatiitic basalt and komatiite (*AWebk*) wrap around the Pilgangoora Syncline. The rocks are locally transformed into mafic schist in high-strain zones.

Carbonate-altered and silicified mafic schist (*Awec*)

Bands of carbonate-altered and silicified mafic schist after basalt (*AWec*) are interbedded with komatiite towards the top of the unit of coarse-grained spinifex-textured, massive and pillowed komatiite (*AWebk*). These cherty bands pass upward into amphibolite and mafic schist (*AWeb*).

Unassigned units

Numerous units throughout WALLARINGA could not be confidently assigned to a particular group, typically because the rocks:

- are isolated in granitoids, for example as roof pendants or xenoliths;
- form basement inliers in the Mallina Basin, with no reasonable lithological similarity to basement rocks of known, or more reliably inferred, age;
- are intensely sheared (e.g. in the Tabba Tabba Shear Zone), with no continuity to rocks of known age;
- intruded the rocks of the Coonterunah and Warrawoona Groups, but show no relationship to younger supracrustal rocks.

In most cases geological relationships suggest that these unassigned rocks are older than the De Grey Group (Mallina Basin) and probably also the Cleaverville Formation, but are younger than the Warrawoona Group, and have therefore been placed between the Gorge Creek Group and the Warrawoona Group on the map legend.

Ultramafic rocks (*Aubs, Aur, Aurs, Aurg, Aus, Aut, Aud, Auts*)

Talc–tremolite–chlorite schist interleaved with 'knockers' of amphibolite and actinolite schist (*Aubs*) forms the core of the Pilgangoora Syncline. This unit hosts the McPhees gold deposits.

Tremolite–chlorite–talc schist (*Aur*) forms a major component of the basement inlier exposed through rocks of the De Grey Group southwest of Carubumya Well. The rock consists of a very fine to medium-grained assemblage of tremolite, chlorite, and talc. A typically well developed foliation is defined by the alignment of chlorite and talc and overprinted by abundant prismatic to acicular, light-green to colourless amphibole in the compositional range of tremolite to actinolite. Growth of acicular amphibole locally produces a secondary spinifex texture. Along the southwestern edge of the basement inlier this schist is interleaved with metasedimentary rocks (*Aurs*). Tremolite–chlorite–talc schist is locally intruded by abundant granitic dykes (*Aurg*). These monzogranite and feldspar-porphyry dykes are possibly related to intrusion of a leucocratic monzogranite phase of the Pippingarra Granitoid Complex that has been dated at c. 2940 Ma (Nelson, 2000) from an outcrop near Carubumya Well.

Local metre-scale layering within outcrops of tremolite schist (*Aur*) is defined by regular variations in grain size and possibly reflects original grain size variations. In the least deformed fine-grained rocks, rounded aggregates of chlorite and epidote are preserved, which may be relict vesicles, along with rounded blebs of serpentine, which are probably pseudomorphed olivine phenocrysts. Acicular chlorite pseudomorphs what is possibly an original pyroxene-spinifex texture. Therefore, the protolith to the schist is interpreted to have included an ultramafic volcanic component, although a large proportion is more likely to have been intrusive in origin.

Ultramafic rocks in the Tabba Tabba Shear Zone exhibit a mineralogical range from largely serpentine to variations between serpentine–tremolite–talc–chlorite schist and talc–serpentine–tremolite–chlorite schist. Massive examples of serpentinite and serpentine–tremolite-rich rock (*Aus*) and talc–serpentine–chlorite schist (*Aut*) are exposed at a number of localities within the shear zone (MGA 664500E 7693500N and 663000E 7705000N respectively). These are medium-grained rocks that typically preserve an orthocumulate texture, with pseudomorphed olivine crystals (now largely serpentine) surrounded by pseudomorphed oikocrysts of clinopyroxene (now largely tremolite). The protolith of these rocks and of their schistose equivalents was lherzolite. Dunite replaced by serpentine (–talc–tremolite–chlorite) is a massive or weakly foliated rock (*Aud*) derived from a nearly monomineralic accumulation of olivine that typically preserves an adcumulate texture. These are rare in the Tabba Tabba Shear Zone, but a similar rock forms what appears to be an intrusion into metabasalts of the Warrawoona Group in the Pilgangoora Syncline.

Considerably more common in the Tabba Tabba Shear Zone is fine- to medium-grained talc–serpentine–chlorite schist (*Aut*), which is typically interleaved with metamorphosed chert and mafic schists. On the northwestern margin of the Tabba Tabba Shear Zone, about 1 km east of Tabba Bore, talc–serpentine–chlorite schist shows an intimate metre-scale tectonic interleaving with metasedimentary rocks (*Auts)* of the De Grey Group.

Much of the talc–serpentine–chlorite schist (*Aut*) is probably derived from an intrusive dunitic to lherzolitic protolith, but at least at one locality (MGA 705000E 7719300N, about 600 m southeast of Tabba Bore) weakly deformed examples preserve a sheath-like olivine-spinifex texture and may be metamorphosed komatiite. Talc–serpentine–chlorite schist is also abundant north and west of the Pilgangoora Syncline, where it forms xenoliths in the c. 3475 Ma Motherin Monzogranite (Baker, D. E. L., 2001, written comm.).

Mafic rocks (*Aog, Aogm, Aogs, Aogsf, Abus, Ab, Abao, Abaoz, Abau, Abaog, Aba, Aod, Abm*)

Unassigned mafic rocks outcrop along the length of the Tabba Tabba Shear Zone, as well as adjacent to the shear zone in the Tabba Tabba region, immediately north of the Pilgangoora Syncline, east of Mallindra Well, and west of Carubumya Well.

Medium- to coarse-grained metamorphosed gabbro (*Aog*) and melanogabbro (*Aogm*) intruded rocks of the Mallina Basin along the northwestern margin of the Tabba Tabba Shear Zone. The age of the gabbro is constrained between that of the local rocks of the De Grey Group (<2970 Ma; Smithies et al., 2001b) and c. 2950 Ma, the age of granodiorite of the Pippingarra Granitoid Complex that locally intruded the gabbro. Smithies and Champion (2002) suggested that the gabbro units represent the earliest magmatism related to voluminous c. 2950 Ma granodiorite magmatism within the Pippingarra Granitoid Complex; a similar association of rocks is exposed to the west, south of Mallindra Well. Near the northwestern margin of the Tabba Tabba Shear Zone, gabbro outcrops form what appear to be two consecutive doubly plunging folds, but these formed through the structurally controlled emplacement of the gabbro into northeast and east-northeast fractures (see **Structure**).

Petrographically, metagabbro (*Aog*) and metamorphosed melanogabbro (*Aogm*) differ only in the higher proportion of mafic minerals (now actinolite) in the latter. Both rocks are typically medium to coarse grained, massive and equigranular, although mottled textures produced by small clots of mafic minerals are locally present, and rocks closer to the Tabba Tabba Shear Zone become increasingly deformed. Actinolite is the sole mafic phase, but is entirely metamorphic in origin. It forms ragged crystals and aggregates, but also clearly pseudomorphs subhedral to euhedral primary hornblende, and possibly also pyroxene as suggested by a distinct pale core in some crystals. Plagioclase is an intergranular phase and is now partly to completely altered to a combination of sericite, an epidote mineral, and calcite.

Plagioclase–amphibole–epidote schist (*Aogs*) locally contains interleaved ultramafic schist and, in places, this unit is interleaved with quartz–sericite–epidote schist (*Aogsf*). A related rock type is the interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*). Together, rocks included within these three mapping units comprise the vast majority of mafic rock in the Tabba Tabba Shear Zone. They are typically more deformed than, and locally intruded by, the gabbroic rocks (plagioclase–amphibole–epidote schist; *Aog* and *Aogm*). The mafic rocks in the Tabba Tabba Shear Zone are predominantly medium grained and probably derived from intrusive protoliths (gabbro and lesser peridotite), but an extrusive origin for some cannot be excluded, particularly for components of the interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*) unit. The mafic rocks in the shear zone are clearly older than the gabbros northwest of the shear zone, but their relationship to the metasedimentary rocks of the c. 3020 Ma Cleaverville Formation, with which they are tectonically interleaved, has not been determined.

The mineralogy of the plagioclase–amphibole–epidote schist (*Aogs*) may be dominated by either plagioclase (partly altered to sericite and epidote) or actinolite. Both minerals are typically preserved as subhedral to anhedral grains. The typically strong foliation of the rock is defined by oriented actinolite, but actinolite also locally preserves evidence that it overprints hornblende. The mineralogy of these rocks suggests synchronous retrograde recrystallization and shearing of a hornblende-bearing metagabbro or amphibolite. The felsic component in the plagioclase–amphibole–epidote schist with interleaved quartz–sericite–epidote schist (*Aogsf*) unit locally shows a seriate texture with 2 mm blebs of granoblastic quartz, possibly indicating a poorly sorted clastic protolith. Rare deformed garnet crystals indicate pre-deformation, medium- to high-grade metamorphism, consistent with the presence of hornblende in the associated mafic schist.

Locally plagioclase-phyric metabasalt (*Ab*) forms a small outcrop within the Tabba Tabba Shear Zone, on the western part of the sheet area (MGA 773500E 7698700N). Interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*) is closely associated with plagioclase–amphibole–epidote schist (*Aogs* and *Aogsf*), differing essentially in the presence of a component of high-Mg to ultramafic composition. This additional component can be divided into three types. The first and most common type is petrographically similar to other varieties of ultramafic schist within the Tabba Tabba Shear Zone. The second type comprises a fine-grained assemblage of clinopyroxene that has been partly to totally replaced by actinolite, in a recrystallized groundmass of actinolite, sericite, epidote, chlorite, and quartz. The clinopyroxene can define a secondary acicular spinifex texture that overgrows the foliated groundmass assemblage and is, in turn, deformed and recrystallized. These relationships indicate that shearing within the Tabba Tabba Shear Zone locally occurred both before and after medium- to high-grade metamorphism. The third of the lithological types that form the ultramafic schist component of the interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*) unit, is fine- to medium-grained quartz–cordierite–anthophyllite schist. According to Yardley (1989) such assemblages may result from high-temperature (sillimanite zone) metamorphism of a hydrothermally altered mafic protolith.

Highly silicic, ‘cherty’ rock, comprising a strongly foliated assemblage dominated by quartz, epidote, and actinolite forms 1–5 m-wide, discontinuous bands within plagioclase–amphibole–epidote schist (*Aogs* and *Aogsf*) and interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*). These are silicified zones of mylonitization related to movement along the Tabba Tabba Shear Zone.

Medium-grained amphibolite (*Abao*), silicified amphibolite (*Abaoz*), and interleaved amphibolite and talc–tremolite–serpentine–chlorite schist (*Abau*) outcrop east of Mallindra Well. These rocks are massive to well foliated and consist of, or include, a granoblastic assemblage of hornblende, plagioclase, and lesser quartz. Plagioclase is typically highly altered to sericite and epidote. Well-foliated examples show limited mineral segregation into layers rich in hornblende and quartz, and plagioclase-rich layers. Also in this area (MGA 675000E 7716000N) and south of Mallindra Well (at MGA 678000E 7715600N), medium-grained, mesocratic to melanocratic garnet-bearing paragneiss was incorrectly mapped as garnetiferous amphibolite (*Abaog*). There is no garnetiferous amphibolite on WALLARINGA. This paragneiss contains plagioclase, biotite, garnet, and quartz, with minor tourmaline. Porphyroblasts of garnet are up to 1 cm in diameter and poikiolitically enclose the well-foliated biotite-rich groundmass. Garnet porphyroblasts were deformed, rolled, and mantled by biotite during the development of a crenulation cleavage that also affected the adjacent intrusive rocks of the Pippingarra Granitoid Complex. The latter rocks have been dated at c. 2945 Ma (Nelson, 2001), which provides a maximum age for the development of the crenulation cleavage and a minimum age for the metamorphic event that crystallized garnet in the paragneiss. Limited mineral segregation produces plagioclase-rich layers and biotite–garnet-rich layers.

Medium-grained and well-foliated amphibolite (*Aba*) outcrops west of Mindra Well, and north of the Pilgangoora Syncline. Interleaved with the amphibolite are thin sheared zones of porphyroblastic pelitic schist, and highly magnetic ultramafic rocks. The foliation is parallel to the sinistral shear zone that truncates the western limb of the Pilgangoora Syncline, and is well developed in biotite-rich bands of pelitic schist. Fault-bounded amphibolite also outcrops within the Pilgangoora Syncline.

A 1.5 km-long by 200 m-wide body of metadolerite (*Aod*) intruded rocks of the Coucal Formation (*AOcb*) in the northern closure of the Pilgangoora Syncline. The outcrop is characterized by an elevated thorium anomaly on the γ-ray spectrometric data, low rounded hills, and darker tones on the colour aerial photographs. The dolerite is metamorphosed and folded about the major Pilgangoora Syncline.

High-Mg basalt and olivine basalt (*Abm*) outcrops in the area west of Carubumya Well, forming a component of the basement inlier exposed through rocks of the De Grey Group. Here it is interlayered with tremolite–chlorite–talc schist (*Aur*).

Felsic rocks (*Afp, Afpx, Afs*)

Feldspar(–hornblende) porphyry (*Afp*), locally containing abundant greenstone xenoliths (*Afpx*), forms 1–5 m-wide dykes that intrude tremolite–chlorite–talc schist (*Aur*) southwest of Carubumya Well (at MGA 670300E 7710300N). These dykes are possibly related to the intrusion of a leucocratic monzogranite phase of the Pippingarra Granitoid Complex that has been dated at c. 2940 Ma (Nelson, 2000) from an outcrop near Carubumya Well.

Fine- to medium-grained felsic schist containing quartz, sericite, feldspar, chlorite, epidote, and actinolite (*Afs*) outcrops within the Tabba Tabba Shear Zone (e.g. at MGA 679000E 7699400N) and probably represents highly sheared tonalite or granodiorite.

Sedimentary rocks (*Aci, Acil, Acq, Anp, As*)

Chert and iron formation form part of the northern basement to the Mallina Basin, and are exposed at and west of Bullen Hill. About 4 km west of Bullen Hill, banded iron-formation (*Aci*) has a recrystallized, granoblastic, and medium-grained assemblage comprising centimetre-scale bands of quartz and bands containing up to 80% grunerite and hematite. At Bullen Hill banded iron-formation is strongly recrystallized and limonitized (*Acil*). In the same area banded white and grey chert and quartzite, with minor jaspilite and iron formation, locally includes banded quartz–grunerite rock (*Acq*). Possible correlatives to these rocks in the Tabba Tabba Shear Zone have been assigned to the Cleaverville Formation of the Gorge Creek Group.

Small outcrops of paragneiss (*Anp*), about 3 km north of Mallindra Well (at MGA 677000E 7720300N), consist of foliated felsic gneiss interpreted to be of sedimentary origin. These form part of the northern basement to the Mallina Basin. They are possibly related to the garnet-bearing paragneiss (incorrectly shown on WALLARINGA as *Aboag*) that outcrops south of Mallindra Well, adjacent to rocks of the Pippingarra Granitoid Complex. The foliated felsic paragneiss (*Anp*) shows a discontinuous banding produced by biotite-rich segregations (now chlorite). Although typically medium grained, the rock locally shows grain size variation to fine-grained layers. The rock locally contains up to 80% quartz. Plagioclase is the dominant feldspar, suggesting a tonalitic source for the inferred feldspathic sandstone protolith.

In the core of the Pilgangoora Syncline metamorphosed sedimentary rock (*As*) includes strongly foliated and lineated quartzite, muscovite schist, and andalusite–muscovite schist. The main foliation in the schist and quartzite is folded about the north- to northeast-trending major syncline. Subordinate associated rock types include black and white banded chert and mafic schist. The mafic schist has chlorite porphyroblasts, which are overprinted by later crenulation cleavage.

Gorge Creek Group

Cleaverville Formation (*AGlc, AGlcw, AGls, AGli*)

Chert and iron formation form prominent ridges within and parallel to the Tabba Tabba Shear Zone. The rocks are typically strongly sheared. They are interpreted as either primary chemical sediments or silicified shale, and are distinct from the cherty quartz–epidote–actinolite mylonites in the mafic schist within the Tabba Tabba Shear Zone. The chert and iron formations in the shear zone have been assigned to the Cleaverville Formation of the Gorge Creek Group, based upon near complete continuity, in both outcrop and geophysical features, with similarly assigned rock in the Kangan area to the southwest on SATIRIST (Smithies and Farrell, 2000).

Tectonic interleaving within the Tabba Tabba Shear Zone involves chert (*AGlc*), grey and white banded chert (*AGlcw*), banded iron-formation (*AGli*), and associated fine- to medium-grained wacke locally interleaved with ultramafic schist (*AGls*). These metasedimentary units locally form outcrops up to 400 m wide and 5 km long. The chert ranges from off-white to black and from massive to well layered. The layering typically ranges from 0.1 mm to about 40 mm in thickness, and is locally continuous at outcrop scale. In some rocks an irregular wavy lamination is developed locally, and in many outcrops such rocks are transitional to silicic or ferruginous shale (or both). Zones of tectonic brecciation and anastomosing zones of mylonitization are locally abundant. Fine- to medium-grained granoblastic textures are locally preserved, and a foliation defined by ribbon quartz is common. Layering is defined by variation in the proportion of graphite and opaque minerals. Grunerite is present in some samples, but is commonly pseudomorphed by quartz, goethite, and opaque minerals. Layering is also defined by changes in grain size. Rarely preserved truncations in layering and scouring appear to be primary sedimentary features and indicate a clastic protolith to the chert.

Banded iron-formation (*AGli*) shows banding on a 1–15 mm scale, which is typically tectonically disrupted, but continuous at outcrop scale in places. Bands of recrystallized chert consist of fine- to medium-grained, granoblastic quartz and are typically strongly limonitized. Dark layers comprise opaque minerals (commonly hematite), quartz, grunerite, garnet, graphite, and apatite. Some samples contain separate opaque-rich and grunerite(–garnet)-rich layers. Local layers of grunerite, up to 10 cm thick, consist of up to 85% grunerite and are typically highly sheared. At some localities, however, they show well-developed banding defined by grain size variations and variable abundances of graphite, garnet, and goethite (e.g. at MGA 700200E 7712300N). Graphite-rich layers (up to 4 mm thick) preserve fine laminations, but have been totally replaced by garnet, which has in turn been partly recrystallized to grunerite. Grunerite is locally recrystallized to actinolite and quartz. The garnet-rich layers probably represent original graphitic and ferruginous pelitic sediments.

De Grey Group

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

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

Constantine Sandstone (*ADcs*)

Interbeds of poorly sorted, medium- to coarse-grained subarkose, wacke, and shale (*ADcs*) outcrop on the western edge of WALLARINGA. This mixed unit forms the inferred stratigraphic top of the Constantine Sandstone in the northern part of MOUNT WOHLER, with the proportion of shale and wacke increasing upward 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 both overlain and underlain by units that cannot be confidently assigned to either the Constantine Sandstone or the Mallina Formation. These relationships reinforce the complicated sedimentary architecture of the Mallina Basin (Smithies and Farrell, 2000).

Medium- to coarse-grained subarkose forms the major component of the poorly sorted subarkose and wacke (*ADcs*). Angular to subrounded grains of quartz and minor plagioclase are in 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, in a sericite- and chlorite-rich matrix that also contains clay minerals and minor tourmaline.

Unassigned units of the De Grey Group (*AD(t), AD(tqc)*)

Medium- to coarse-grained turbiditic wacke with abundant chert clasts, and local shale, subarkose, conglomerate, and pebble beds (*AD(t)*) has well-developed graded units and outcrops on the western edge of WALLARINGA. It differs from the Mallina Formation in that it includes coarse-grained wacke.

Fine- to coarse-grained turbiditic wacke (*AD(tqc)*) with associated fine-to medium-grained clastic units outcrops 1 km southwest of Indee Homestead where it is associated with rocks of the Mallina Formation. The fine- to coarse-grained wacke unit also appears to be more siliceous than rocks of the Mallina Formation.

Mallina Formation (*A*D*m, A*D*mhl, A*D*mhh*)

Interbedded shale, siltstone, and medium- to fine-grained wacke with minor chert (*A*D*m*) forms isolated outcrops in the central-western part of WALLARINGA. Shale within the Mallina Formation is commonly laminated and ferruginous. Angular silt-sized grains of chert and quartz are common, and plagioclase is rare. Clay minerals comprise the bulk of the groundmass and are accompanied by abundant chlorite, sericite, quartz, and minor zoisite. There is a prominent slaty cleavage defined by the alignment of mica. Carbonate minerals locally overprint the slaty cleavage and may constitute up to 50% of some rocks. Chlorite-rich laminated shale and siltstone (*A*D*mhl*) outcrops at a few localities adjacent to the Tabba Tabba Shear Zone (e.g. at MGA 670800E 7698300N).

The wacke component of the Mallina Formation ranges in grain size from sand to silt and individual beds commonly fine upward. The rocks are poorly sorted and the grains are angular to subrounded. The abundance of quartz commonly exceeds that of feldspar. Lithic fragments are abundant, particularly in the coarser grained rocks. The dominant lithic component is grey chert, with lesser fragments of shale and basalt. 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 carbonated.

Immediately north of the Tabba Tabba Shear Zone, and close to all contacts with granitoids, rocks of the Mallina Formation have been contact metamorphosed and are now cordierite hornfels (*A*D*mhh*; see **Metamorphism**). The contact metamorphic assemblage has been affected by the latest movement along the shear zone, and therefore the intrusive age of the granitoids (c. 2940 Ma; Nelson, 2001) represents a maximum age for the latest major shearing event.

Felsic intrusions

Granitoids form about 75% of the outcrop on WALLARINGA, and are divided between two granitoid complexes: the Pippingarra and Carlindi Granitoid Complexes, separated by the northeast-trending Tabba Tabba Shear Zone. To the north the Pippingarra Granitoid Complex can be essentially subdivided into three components:

- hornblende-bearing tonalite to monzogranite, dated at 2955–2945 Ma (Nelson, 2001), including the Wallareenya Granodiorite, Mallindra Well Granodiorite, and the Chillerina Granodiorite;
- biotite-bearing monzogranite dated at 2940–2930 Ma (Nelson, 2001), including the Petermarer Monzogranite;
- late muscovite(–garnet) monzogranite, including the Tabba Tabba Leucogranite, Thelman Monzogranite, and the Myanna Leucogranite.

The age of the voluminous muscovite(–garnet)-bearing leucogranite is thought to be c. 2850 Ma based on dating of similar lithologies elsewhere in the Pilbara Craton (Nelson, 1998).

Granitoids south of the Tabba Tabba Shear Zone form part of the Carlindi Granitoid Complex. In the southeast of the sheet area this complex contains very old crustal components. The Motherin Monzogranite has been folded around the nose of the Pilgangoora Syncline and is dated at c. 3475 Ma (Baker, D. E. L., 2001, written comm.); a monzogranite that outcrops in the far southeast of the sheet was dated at c. 3485 Ma from a sample taken on NORTH SHAW (Nelson, 1999). The remainder of the complex on WALLARINGA can again be divided into biotite-bearing monzogranite and younger muscovite (–garnet) monzogranite. Strongly foliated biotite-bearing monzogranite along the southern margin of the Tabba Tabba Shear Zone has been dated at c. 2940 Ma (Nelson, 2001), and is intruded by unfoliated muscovite(–garnet) monzogranite.

Pippingarra Granitoid Complex

*Wallareenya Granodiorite (Ag*I*wa)*

Massive to moderately foliated granodiorite and tonalite of the Wallareenya Granodiorite (*Ag*I*wa*) outcrop at, and north and west of, Wallareenya Homestead. This unit has been dated at 2954 ± 4 Ma (Nelson, 2000) and forms part of the Pilbara high-Mg diorite suite (Smithies and Champion, 2000). It consists of medium- to coarse-grained, generally equigranular hornblende–biotite granodiorite and subordinate tonalite. The rock contains up to 15% mafic minerals with subhedral hornblende crystallized either interstitially to plagioclase or as aggregates with biotite, magnetite, and titanite. Biotite forms subhedral to anhedral crystals, in places partially surrounding hornblende. Microcline microperthite forms a late, minor to accessory phase. Accessory minerals include titanite, apatite, zircon, rutile, and magnetite. A characteristic feature of these rocks, and of other rocks of the Pilbara high-Mg diorite suite, is the abundant rounded cognate xenoliths of diorite and granodiorite (Smithies and Champion, 2000).

*Hornblende–biotite diorite and granodiorite (Ag*I*d, Ag*I*dc, Ag*I*dh, Ag*I*di, Ag*I*dl)*

A range of unnamed rocks that vary from hornblende–biotite-bearing diorite to granodiorite (*Ag*I*d*) outcrop between Wallareenya Homestead and Mallindra Well. These rocks range from medium to coarse grained and from massive to moderately foliated. There are four broad lithological subdivisions:

1. Coarse-grained diorite and granodiorite (*Ag*I*dc*) outcrops about 1.7 km north of Toodigrina Well, forming a large, east-trending xenolith in, or pendant on, later leucogranite. The rock is weakly to moderately foliated and comprises abundant euhedral phenocrysts of zoned plagioclase up to 1 cm in length, with intergranular plagioclase, hornblende, and quartz, locally partly enclosed by late minor microcline. Plagioclase is partly altered to sericite and epidote, and hornblende (which forms up to 10% of the rock) is partly altered to chlorite, epidote, and calcite.
2. Hornblende-megacrystic, coarse-grained diorite and gabbro (*Ag*I*dh*) forms minor outcrops about 3.5 km

south of Mallindra Well, where it has intruded the oldest phase of the Chillerina Granodiorite. The rock has a distinctive texture with euhedral megacrysts of hornblende up to 2.5 cm long, commonly with a sieve-textured core of abundant small remnants of clinopyroxene. The clinopyroxene remnants show optical continuity, indicating that they originally formed a single crystal. The groundmass is a medium-grained assemblage of subhedral crystals of plagioclase, hornblende, and quartz. Late and minor microcline partly replaces and rims plagioclase. Quartz forms about 10% of the rock.

3. Magmatically interleaved metagabbro and coarse-grained diorite and granodiorite (*Ag*ɪ*di*) outcrops about 3.5 km south-southeast of Mallindra Well and represents dykes and intrusive sheets of gabbro (*Aog*) and dioritic to granodioritic units (*Ag*ɪ*d, Ag*ɪ*lw*, and *Ag*ɪ*ch*) that are interleaved at metre scale.
4. Coarse-grained, leucocratic biotite(–hornblende) granodiorite and monzogranite (*Ag*ɪ*dl*) outcrops about 1 km northeast of Bluff Well. It is typically moderately to well foliated and contains subhedral phenocrysts of zoned plagioclase, up to 7 mm long, and elongate schlieric patches rich in biotite and lesser hornblende. The groundmass comprises a medium-grained assemblage of plagioclase, quartz, and biotite, with late minor microcline forming irregular patches that enclose other groundmass phases. Mafic phases form up to 10% of the rock and are partly to completely altered to chlorite and epidote.

*Mallindra Well Granodiorite (Ag*ɪ*lw)*

The Mallindra Well Granodiorite (*Ag*ɪ*lw*) is exposed on the western edge of the Pippingarra Granitoid Complex, about 3 km north of Cosacana Well. It is mineralogically very similar to the Wallareenya Granodiorite, although with up to 20% mafic minerals (hornblende>biotite) it is possibly slightly more mesocratic.

*Chillerina Granodiorite (Ag*ɪ*ch, Ag*ɪ*chn, Ag*ɪ*chd, Ag*ɪ*chi, Ag*ɪ*chm, Ag*ɪ*chp)*

The Chillerina Granodiorite (*Ag*ɪ*ch*) forms a large portion of the Pippingarra Granitoid Complex in the area between the Tabba Tabba Shear Zone and the Indee Fault. It comprises five lithological types ranging from granodiorite to monzogranite. The age of these rocks is well constrained. The oldest phase is a strongly foliated biotite(–hornblende) granodiorite to monzogranite and granitic gneiss (*Ag*ɪ*chn*) with a crystallization age of 2946 ± 3 Ma (Nelson, 2001) that is indistinguishable from the 2945 ± 2 Ma age of undeformed granodiorite (Nelson, 2001). Leucogranite possibly belonging to the Petermarer Monzogranite (*Ag*ɪ*pr*) has intruded all phases of the Chillerina Granodiorite and been dated at 2940 ± 2 Ma (Nelson, 2001).

Strongly foliated biotite–hornblende granodiorite to monzogranite and granitic gneiss (*Ag*ɪ*chn*) outcrops about 1 km south of Mallindra Well. To the north it is in contact with medium-grained, mesocratic to melanocratic garnet-bearing paragneiss (shown as *Abaog*), which either represents metamorphosed rocks of the De Grey Group (Mallina Basin) or, more likely, locally preserved basement to the Mallina Basin. The granodiorite to monzogranite is a leucocratic rock containing only about 5% mafic minerals, which are now secondary (green) biotite and chlorite that have been concentrated into schlieric layers during deformation and recrystallization. The rock has a flattened granoblastic texture, but preserves subhedral relicts of zoned plagioclase phenocrysts. Microcline comprises between 10 and 15% of the granoblastic groundmass. The foliation of the rock is locally intersected by cleavage planes that trend approximately 300° and give the rock a distinctive crenulation. However, deformation of this rock is primarily due to flattening, with only a limited amount of sinistral shear. Comagmatic phases of the Chillerina Granodiorite are massive or only weakly deformed, and therefore the deformation seen in the strongly foliated biotite–hornblende granodiorite to monzogranite and granitic gneiss (*Ag*ɪ*chn*) unit is interpreted here to be a late-stage feature of granitoid emplacement.

Throughout the central portion of the Chillerinna Granodiorite body (*Ag*ɪ*ch*), at and south of Chillerinna Well, granodiorite has been intruded on a centimetre to metre scale by sheets of coarse-grained and in places K-feldspar-porphyritic leucocratic biotite monzogranite, possibly related to the Petermarer Monzogranite (*Ag*ɪ*pr*). The monzogranite has locally entrained schlieric wisps of host granodiorite. The resulting rock was mapped as a unit of magmatically interleaved granitoids (*Ag*ɪ*chi*), and was assigned to the Chillerinna Granodiorite because granodiorite is typically the dominant component. Monzogranitic sheets locally form up to 40% of the outcrop, producing a conspicuous layering. This layering is locally chaotically folded (Fig. 4), but neither the monzogranite nor the host granodiorite show evidence for strong solid-state deformation, therefore the folding almost certainly reflects synmagmatic movements within the magma chamber. More typically, the layering dips gently (<30°), but does not follow any regional or local pattern of deformation. It possibly parallels an undulating upper contact between the granodiorite and its metasedimentary host rocks. In a small outcrop, about 1.5 km northeast of Deep Well, the granodiorite has been net-veined by a medium-grained dioritic to gabbroic phase before intrusion of sheets of granodiorite and monzogranite (*Ag*ɪ*chd*).

The granodiorite component of the magmatically interleaved rock (*Ag*ɪ*chi*) is medium to coarse grained and leucocratic to mesocratic, containing up to 10% mafic minerals. Hornblende is typically the most abundant mafic phase, but biotite dominates locally, and in places both are concentrated into clots up to 1 cm in diameter. Plagioclase forms subhedral crystals and is the dominant feldspar, although late interstitial microcline is locally sufficiently abundant for the rocks to be classified as monzogranite. Microcline is also increasingly abundant to the north, and a transitional contact gives way to K-feldspar-porphyritic monzogranite (*Ag*ɪ*chm*).

Plagioclase-porphyritic granodiorite (*Ag*ɪ*chp*), with plagioclase phenocrysts up to 1 cm long, outcrops along a north-trending splay of the Indee Fault, about 1.2 km

Figure 4. Chaotically folded fine-scale layering in granites within the Wallareenya releasing bend, produced by the intrusion of leucocratic monzogranite into granodiorite. The layering varies within a single outcrop from centimetre to millimetre scale (lens cap is ~5cm in diameter). Neither monzogranite nor diorite shows significant mineral elongation or flattening, or other evidence for significant deformation in the solid state

west of Chillerinna Well. Close to the fault the porphyritic granodiorite is strongly deformed, showing a steeply westerly plunging stretching lineation defined by elongate plagioclase phenocrysts. However, away from the fault, the plagioclase alignment defines a magmatic flow foliation that parallels the fault.

Biotite monzogranite (Agıms, Agımsx, Agımsl)

Seriate to porphyritic biotite monzogranite (*Agıms*) forms a complex body immediately north and west of Grass Plain Well. The rocks have intruded all earlier rocks of the Pippingarra Granitoid Complex as well as rocks of the De Grey Group. A strong east-trending map pattern is produced by cogenetic dykes and by roof-pendants of rocks from the De Grey Group that are preserved as elongate fault-controlled blocks (half grabens). The monzogranite locally includes abundant xenoliths of greenstones and of earlier granitoid phases of the Pippingarra Granitoid Complex (*Agımsx*), and is locally ghost banded (*Agımsl*). The rocks are typically massive to weakly foliated, but locally show a strong foliation in and adjacent to east-trending faults (see **Structure**). Two rocks give ages of 2928 ± 6 and 2940 ± 2 Ma (Nelson, 2001).

These rocks are medium to coarse grained, seriate to porphyritic, and range in composition from tonalite to monzogranite. This compositional range, together with the range in known intrusion age, indicates that numerous different and possibly genetically unrelated granite magmas comprise the granitoid unit. Grouping the various rocks that contribute to the typically complexly sheeted and interleaved outcrop is unavoidable at the scale of mapping. Unifying these rocks is a leucocratic mineralogy, typically with less than 10% mafic minerals of which biotite (now mostly chlorite) is the main, and commonly sole, mafic phase. Seriate-textured rocks are characterized by large crystals of subhedral to euhedral plagioclase. Porphyritic varieties contain phenocrysts of either plagioclase (tonalite, granodiorite, and monzogranite) or perthite (granodiorite and monzogranite). Some rocks contain subhedral crystals of magnetite, up to 3 mm, commonly with a bleached halo free of biotite.

Leucocratic biotite monzogranite (Agıml)

Leucocratic biotite monzogranite (*Agıml*) outcrops about 3 km northeast of Bluff Well. It appears to be homogeneously monzogranitic and is typically highly leucocratic, but is otherwise very similar to the seriate to porphyritic biotite monzogranite (*Agıms*).

Leucocratic and porphyritic biotite monzogranite (Agımq)

Leucocratic and porphyritic biotite monzogranite (*Agımq*) outcrops west of Carubumya Well. It is also similar to the seriate to porphyritic biotite monzogranite (*Agıms*), but is consistently monzogranitic in composition and typically has a massive to weakly foliated seriate texture characterized by phenocrysts of both subhedral to euhedral plagioclase and lobate quartz. A sample from a quarry about 1.2 km west of Carubumya Well gave an age of 2941 ± 4 Ma (Nelson, 2000), within error of the large range shown by the seriate to porphyritic biotite monzogranite (*Agıms*).

Petermarer Monzogranite (AgIpr)

The Petermarer Monzogranite (*AgIpr*) is a uniform body of seriate to more typically porphyritic monzogranite that outcrops extensively in the northeastern part of WALLARINGA, south of the Indee Fault. Euhedral phenocrysts of microcline, up to 2 cm long, are typically strongly aligned into a northeast-trending igneous foliation, but contain abundant inclusions of quartz and plagioclase, and appear to be a late crystallizing phase. The foliation, therefore, most probably reflects late-stage crystallization under southeast-directed compression rather than a flow foliation. Biotite is the sole mafic phase and its abundance never exceeds 5%. The rock is typically very similar to K-feldspar-porphyritic monzogranites grouped into the seriate to porphyritic biotite monzogranite (*AgIms*) lithotype, and may form part of the same c. 2940–2930 Ma magmatism, although it locally also intruded and contains xenoliths of biotite monzogranite (*AgIms*). In places it also contains abundant xenoliths derived from the Chillerina Granodiorite (*AgIch*).

Tabba Tabba Leucogranite (AgItt)

Originally delineated by Hickman (1983), this late-tectonic granite intruded greenstones and granites adjacent to the Tabba Tabba Shear Zone, in the northeastern part of WALLARINGA (MGA 697000E 7712000N). The Tabba Tabba Leucogranite (*AgItt*) comprises equigranular to, more commonly, sparsely feldspar(–quartz)-porphyritic, fine- to medium-grained biotite monzogranite.

The unit is locally finer grained along the eastern and southeastern margins, representing either a more rapidly cooled marginal facies or a separate phase of the intrusion. The unit also becomes increasingly porphyritic to the northwest. The foliation is also less well developed in the western part, away from the main part of the Tabba Tabba Shear Zone, where only a mild to moderate fabric is present. As noted by Hickman (1983) there is a moderate to strong foliation along the eastern margin of the unit, with the development of local banding. Other features along the eastern margin include relatively common fine-grained mafic clots and xenoliths of greenstone up to 6 cm in diameter, and pegmatite dykes, which become abundant along the contact and within the nearby greenstones. Other enclaves within the granites include ovoid to elongate granitic enclaves, up to 1 m long, and larger pods and pendants of the Chillerina Granodiorite (*AgIch*); the latter are particularly prevalent northwest and west of the Tabba Tabba Leucogranite (*AgItt*).

Thelman Monzogranite (AgIth)

The Thelman Monzogranite (*AgIth*) forms a small well-outcropping unit (<10 km^2) about 7 km northeast of the Tabba Tabba Leucogranite. The rock is an equigranular to weakly feldspar porphyritic, fine- to medium-grained muscovite–biotite monzogranite. The Thelman Monzogranite is readily recognized by its well-jointed bouldery outcrop pattern and distinctive muscovite flakes, particularly on weathered surfaces. The unit has a mild foliation defined by alignment of biotite. Common to abundant garnet–muscovite–biotite pegmatite dykes and sills, up to 3 m in width, intruded the unit. The unit intruded the Petermarer Monzogranite (*AgIpr*) to the north and west, and greenstones to the east.

Pegmatite (AgIpe)

Intrusions of pegmatite (*AgIpe*), ranging from thin dykes and sills to moderate-sized bodies several hundred metres wide, intruded granitoids of the Pippingarra Granitoid Complex and greenstones. Pegmatites range from relatively simple, unzoned, very coarse to coarse-grained garnet–muscovite–biotite granites to large, complexly zoned tourmaline–garnet–muscovite–biotite granite, with zoning defined by large changes in grain size and modal mineralogy (e.g. garnet-rich layers, tourmaline-rich layers). The best exposure of one of the larger complexly zoned masses is in and around a large road-metal quarry east of Newman Well (at MGA 671800E 7729200N). Here the pegmatite exhibits good examples of both grain size layering and mineralogical layering, with varying contents of tourmaline (1–5 cm), biotite (up to 10%), muscovite (commonly with unidirectional growth textures), and garnet.

Myanna Leucogranite (AgImy)

The Myanna Leucogranite (*AgImy*) outcrops extensively in the northern part of WALLARINGA, north of the Indee Fault. It is a coarse-grained, massive to weakly foliated, equigranular to porphyritic muscovite–biotite monzogranite. Phenocryst minerals are microcline and, less commonly, quartz. Coarse radiating grains of muscovite along with quartz form clots up to 8 mm in diameter. Biotite has been totally chloritized and is a late acicular phase, typically less common than muscovite.

Carlindi Granitoid Complex

Fine- to coarse-grained biotite monzogranite (AgLm, AgLmx)

Fine- to coarse-grained biotite monzogranite (*AgLm*) outcrops in the far southeastern corner of WALLARINGA, whereas rocks that differ only in containing abundant greenstone xenoliths (fine- to coarse-grained biotite monzogranite, with abundant greenstone xenoliths; *AgLmx*) outcrop about 22 km to the west (MGA 685200E 7678000N) along the eastern side of a major north-northeasterly trending fault. Similar monzogranite was mapped on NORTH SHAW, although it was ubiquitously fine grained (Van Kranendonk, 2000). The rocks are typically weakly foliated to unfoliated, equigranular biotite monzogranites. A sample from NORTH SHAW has been dated at 3484 ± 4 Ma (Nelson, 1999).

Motherin Monzogranite (AgLut, AgLutx)

The Motherin Monzogranite (*AgLut*) outcrops in the southeastern and southern parts of the Carlindi Granitoid Complex on WALLARINGA. The unit is more extensive on WODGINA, where it has been described in detail by Blewett et al. (in prep.). The unit is heterogeneous and comprised variably quartz–feldspar-porphyritic, medium- to coarse-grained, biotite monzogranite to (hornblende–)biotite granodiorite, with common to abundant dykes of various lithologies. The unit is typically moderately to strongly foliated, with local unfoliated rocks. The rocks are faintly to strongly banded, and locally gneissic. Banding is defined by biotite-rich (8 to 15%) layers, and schlieren are commonly folded. A major characteristic of the Motherin Monzogranite is the presence of at least four phases of dykes or pods (or both) including:

- foliated, fine- to medium-grained, equigranular biotite monzogranite to granodiorite;
- variably foliated biotite leucogranite;
- massive to moderately foliated, equigranular, sparsely (quartz–)feldspar porphyritic, locally muscovite bearing, biotite monzogranite;
- various generations of pegmatite.

Pegmatite bodies, which are locally very common, are both concordant and discordant, and include foliated and massive variants. The granite unit also includes isolated greenstone xenoliths, and delineated regions of more common greenstone enclaves (largely amphibolite, peridotite, and ultramafic schists) can be separated at map scale. The main phases of the Motherin Monzogranite are magnetic (up to 600×10^{-5} SI units), and the unit is clearly defined on regional aeromagnetic images. Metamorphic grade is typically high (middle amphibolite facies) but does not appear to have reached temperatures required for partial melting.

Diorite, granodiorite, and monzogranite (AgLdmf)

Strongly foliated diorite, granodiorite, and monzogranite (*AgLdmf*) is confined to the Tabba Tabba Shear Zone in the area around Pingina Well. It contains abundant highly elongate mafic xenoliths and less common felsic xenoliths. Deformation of the diorite, granodiorite, and monzogranite is directly related to the development of the Tabba Tabba Shear Zone. The rocks show petrographic similarities to the granodioritic phases of the Pippingarra Granitoid Complex and, in particular, the xenolith-rich rocks of the Wallareenya Granodiorite.

Biotite monzogranite (AgLmp, AgLmf, AgLmm)

Seriate to porphyritic biotite monzogranite (*AgLmp*) forms a large proportion of the Carlindi Granitoid Complex on WALLARINGA. It is typically weakly foliated, but becomes increasingly strongly foliated (*AgLmf*) towards the Tabba Tabba Shear Zone. Within and along the southern margins of the shear zone the monzogranite is mylonitized (*AgLmm*). A sample of mylonitized biotite monzogranite from the western edge of CARLINDIE (immediately east of WALLARINGA) has been dated at 2940 ± 3 Ma (Nelson, 2001), providing a maximum age for the last major phase of movement along that shear.

In the less deformed varieties of biotite monzogranite, euhedral phenocrysts of microcline are up to 2.5 cm long, contain abundant inclusions of quartz and plagioclase, and appear to be a late crystallizing phase. Biotite is the sole mafic phase and its abundance never exceeds 5%. These rocks closely resemble seriate to K-feldspar-porphyritic monzogranites of the Yule Granitoid Complex (e.g. the Powdar and Mungarinya Monzogranites on SATIRIST), which have been dated at between 2935 and 2930 Ma (Nelson, 1999).

Within about 5 km of the Tabba Tabba Shear Zone, recrystallization of intergranular quartz becomes extensive and original brown biotite is altered to a combination of chlorite, green biotite, and sericite. Closer to the shear zone, flattening of quartz and alignment of mica together define a foliation that becomes increasingly pronounced as feldspar crystals become rounded and are rotated into the foliation plane. Mylonitized monzogranite (*AgLmm*) forms an elongate outcrop along the eastern edge of the Tabba Tabba Shear Zone in the northern half of WALLARINGA (MGA 708000E 7722000N), continuing onto CARLINDIE. The unit is strongly foliated, locally with a strong mylonitic fabric, and typically with a mineral lineation that plunges steeply to the northwest. The contact with the greenstones to the northwest is a fault. The unit is a grey and white, fine- to medium-grained, sparsely feldspar porphyritic biotite monzogranite. Feldspar phenocrysts are up to 1 cm across. Biotite comprises between 7 and 9% of the rock, but has segregated into layers richer (up to 30%) and poorer (leucogranitic with 5% biotite) in biotite, typically producing an incipient gneissic banding. Banding is also defined by subparallel pegmatite and aplite dykes. Pegmatite dykes locally form up to 30% of the unit. Fine-grained granite dykes up to 1 m wide are commonly boudinaged. Pegmatites, aplites, and granite dykes are largely unfoliated and discordant to the fabric. Locally these late pegmatites fill dextral shears that cut the main foliation.

Biotite(–muscovite) monzogranite (AgLmw)

Equigranular to weakly K-feldspar porphyritic biotite (–muscovite) monzogranite (*AgLmw*) outcrops immediately south of the Tabba Tabba Shear Zone, in the central and eastern parts of WALLARINGA. Intrusion into deformed biotite monzogranite (*AgLmf*) shows the biotite(–muscovite) monzogranite to be younger than the last major phase of movement along the shear zone. However, a locally developed foliation that parallels that shear indicates intrusion either at a late stage of the last major phase of movement or during a subsequent minor deformation event.

The rock ranges in composition from monzogranite to syenogranite. It locally contains perthite phenocrysts up to 1.5 cm in length, which overgrow all other major mineral phases, and are clearly a late crystallizing phase. Microcline is an abundant groundmass phase. Irregular grains of muscovite are an alteration feature of K-feldspar, but subhedral grains of muscovite, up to 2 mm across, within the groundmass are possibly primary. Biotite is the sole mafic mineral and typically forms less than 5% of the rock.

Minnamonica Monzogranite (AgLmi)

The Minnamonica Monzogranite (*AgLmi*) is a grey to white, medium-grained, sparsely quartz–feldspar porphyritic muscovite–biotite monzogranite that varies from massive to very weakly foliated. Feldspar forms sparse phenocrysts (<3% of the rock) up to 1.5 cm across and quartz forms phenocrysts up to 1 cm across. Biotite is the dominant mica mineral (5–6% of the rock with grains up to 5–8 mm in size), with subordinate muscovite (<3% of the rock). Mica is locally concentrated into schlieren. The unit contains rare biotite-rich or granodioritic enclaves, up to 15 cm across, as well as rare pegmatite dykes. The unit is strongly reduced, forming a magnetic low on aeromagnetic images.

Fine- to coarse-grained muscovite–biotite monzogranite (AgLmb)

Fine- to coarse-grained muscovite–biotite monzogranite (*AgLmb*) is massive to weakly foliated, and restricted to a small (about 1 km^2) outcrop in the far southeastern corner of WALLARINGA. The rock is petrographically very similar to the equigranular to weakly K-feldspar porphyritic biotite(–muscovite) monzogranite (*AgLmw*), but contains more muscovite, locally forming 'books' up to 8 mm across.

Poocatche Monzogranite (AgLpo)

The Poocatche Monzogranite (*AgLpo*) outcrops in the southern part of WALLARINGA. It intruded the Minnamonica Monzogranite (*AgLmi*) and forms a large irregular body, but also forms a series of discontinuous linear intrusions concentric to, and up to 10 km from, the main body. It is most likely that the Poocatche Monzogranite forms a sheet-like intrusion, locally exposed through minor faulting and gentle folding of the country rocks, although the possibility that it forms a series of discontinuous ring dykes around the main body cannot be ruled out.

The Poocatche Monzogranite is typically a very coarse to coarse-grained, seriate to K-feldspar-porphyritic muscovite–biotite monzogranite. The rocks are massive to weakly foliated. Phenocrysts of microcline enclosing all groundmass minerals are a late crystallizing mineral. Biotite is commonly the sole mafic phase, but accessory garnet is noted in some samples. Muscovite is both an alteration product of microcline and infills intergranular spaces where it forms late-magmatic euhedral 'books' up to 5 mm across. Fracture surfaces are also commonly lined with muscovite.

Pegmatite (AgLpe)

Intrusions of pegmatite (*AgLpe*) range from thin dykes and sills up to bodies several hundred metres wide, and intruded granitoids of the Carlindi Granitoid Complex as well as greenstones. There are no clear differences between these pegmatites and those that intruded the Pippingarra Granitoid Complex.

Kadgewarrina Monzogranite (AgLkd)

The Kadgewarrina Monzogranite (*AgLkd*) is a medium-grained, equigranular to sparsely (quartz–)feldspar porphyritic and locally garnetiferous muscovite–biotite monzogranite that outcrops in the central-eastern part of WALLARINGA and continues east onto CARLINDIE. The unit has a mild foliation defined by the alignment of micas. The Kadgewarrina Monzogranite clearly intruded the mylonitized monzogranite (*AgLmm*), post-dating the deformation fabric in the latter.

Feldspar and quartz are typically rare, but locally more common as phenocrysts up to 1.5 and 1 cm respectively. Biotite is the dominant mica (up to 7% of the rock) and is locally concentrated into subparallel schlieren and thin bands up to 1–2 cm thick. The unit also contains rare biotite-rich enclaves. Muscovite is an accessory phase forming up to 3% of the rock. The Kadgewarrina Monzogranite locally contains accessory garnet up to 3 mm across. Fine- to medium-grained granite and pegmatite dykes are a minor component of the unit. The Kadgewarrina Monzogranite is strongly reduced, forming a magnetic low on aeromagnetic images.

Dolerite and gabbro dykes and quartz veins (*d, dx, q*)

Dolerite and gabbro dykes (*d*) of variable age, but probably mainly late Archaean, outcrop throughout WALLARINGA, but are most common in areas of granite and particularly in the eastern half of the sheet area. The dykes are dominantly north-northeasterly trending, although major structures such as the Tabba Tabba Shear Zone appear to have locally influenced trends.

The east-northeasterly trending Powereena dyke can be traced for hundreds of kilometres and cuts the southeastern corner of WALLARINGA. On sheets to the west (SATIRIST and MOUNT WOHLER) the dyke comprises fresh dolerite, but on WALLARINGA the rock is extensively altered and locally crowded with subrounded and partially resorbed granite and quartz (?vein) xenoliths (*dx*), up to 10 cm across. All primary mafic minerals have been replaced by chlorite and epidote. The plagioclase is extensively sericitized and xenoliths show a distinct 1 to 10 mm halo of dark-pink (?potassic) alteration.

Quartz veins (*q*) outcrop throughout the sheet area and are mainly oriented north-northeast or north-northwest.

Quartz(–feldspar) porphyry dykes (*Apf*)

Quartz(–feldspar) porphyry (*Apf*) forms a small north-northeasterly trending dyke, about 1 m wide, that has intruded the Myanna Leucogranite of the Pippingarra Granitoid Complex in the far northeastern part of WALLARINGA.

Cainozoic deposits

Calcrete (*Czak, Czrk*)

Massive, nodular, and cavernous calcrete, present throughout WALLARINGA, is either residual in origin (*Czrk*) or alluvial (*Czak*), forming along old drainage channels.

Pisolitic limonite (*Czaf*)

Pisolitic limonite deposits (*Czaf*) developed along palaeodrainage lines are now exposed on small plateau surfaces east of Cookes Hill (at MGA 676300E 7704300N), where they overlie ferruginous shale.

Colluvium (*Czc, Czcf*)

Dissected and consolidated colluvium (*Czc*) is exposed mainly in the central part of WALLARINGA, where it is primarily derived from local outcrops and is deposited on adjacent low-angle slopes. These deposits consist of clay- or silica-cemented, poorly stratified silt, sand, and gravel. Adjacent to deposits of pisolitic limonite these colluvium deposits locally contain abundant ferruginous silt, sand, and gravel, bound by a limonitic cement (*Czcf*).

Gravel deposits (*Czag, Czaq*)

High-level alluvial gravel deposits (*Czag*), unrelated to recent drainage, are exposed in the northern half of the sheet area, particularly in the northeastern corner where they extensively overlie granite. They typically consist of clay-cemented, poorly stratified gravel, sand, and silt. High-level alluvial gravel deposits close to quartz veins are dominated by vein-quartz debris (*Czaq*).

Quaternary colluvium, sheetwash, and quartzofeldspathic eluvial sand (*Qc, Qw, Qrg*)

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

Sheetwash, including sand, silt, and clay (*Qw*), is deposited on distal outwash fans. Locally reworked by wind action, the sand deposits have generally been stabilized by extensive grass and shrub cover.

Quartzofeldspathic eluvial sand with quartz and rock fragments (*Qrg*) overlies, and has been derived from, a large proportion of granites of both the Pippingarra and Carlindi Granitoid Complexes.

Quaternary alluvial deposits (*Qaa, Qab, Qac, Qao, Qaoc*)

Present-day drainage channels contain alluvial clay, silt, and sand in channels on floodplains, and sand and gravel in rivers and creeks (*Qaa*). Alluvial clay, silt, and sand form overbank deposits on floodplains (*Qao*) and locally include gilgai (*Qab*). Gilgai is a clay-rich silt or sand deposit characterized by the development of numerous cracks and sinkholes. The clay expands and contracts according to water content, and in dry conditions produces an irregular 'crabhole' surface. In areas immediately adjacent to rivers, alluvial floodplains also include small, abundant, scattered lacustrine or claypan deposits (*Qaoc*) of clay, silt, and evaporite in claypans and other shallow depressions (*Qac*).

Metamorphism

Rocks of the Mallina Basin and the Pippingarra and Carlindi Granitoid Complexes have typically only been metamorphosed to lower to middle greenschist facies. There are exceptions at or close to contacts with granites, and the contact metamorphic features that result are best seen in supracrustal rocks, and in particular in the pelitic metasedimentary rocks of the Mallina Basin.

All supracrustal rocks exposed in the Tabba Tabba Shear Zone are close to intrusive contacts with granites. These granites include rocks of the high-Mg diorite suite, which are typically very high temperature (about 1000°C) subvolcanic intrusions (Smithies and Champion, 2000). In the northwestern part of the shear zone, metamorphic grades vary from greenschist facies in the metasedimentary rocks in the north to amphibolite facies in the mafic schists in the south. This variation largely reflects proximity to intrusive contacts with granites, but may also result from uplift due to dip-slip movement along the shear zone.

Mafic schist units within the Tabba Tabba Shear Zone contain metamorphic hornblende and garnet that are locally overprinted by oriented actinolite, which defines the typically strong foliation of the rock. The mineralogy of these rocks suggests early medium-grade metamorphism followed by synchronous retrograde recrystallization and shearing. A similar paragenesis can be inferred from some ultramafic schist that locally comprise a sheared quartz–cordierite–anthophyllite assemblage that, according to Yardley (1989), may result from high-temperature (sillimanite zone) metamorphism of a hydrothermally altered mafic protolith. Within and adjacent to the shear zone, rocks of the Mallina Basin are now cordierite hornfels (*ADmhh*). This contact metamorphic assemblage has been affected by the latest movement along the shear zone. The c. 2940 Ma intrusive age (Nelson, 2001) of mylonitized monzogranite (*AgLmm*) thus represents a maximum age for the latest phase of shearing.

Some units of interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*) within the Tabba Tabba Shear Zone contain clinopyroxene that overgrows a foliated groundmass assemblage and is, in turn, deformed and recrystallized. These relationships indicate that shearing within the Tabba Tabba Shear Zone locally occurred both before and after medium- to high-grade metamorphism.

South of Mallindra Well medium-grained, mesocratic to melanocratic paragneiss (*Abaog*) contains porphyroblasts of garnet that are up to 1 cm in diameter and poikiloitically enclose the well-foliated biotite-rich groundmass. Garnet porphyroblasts were deformed, rolled, and mantled by biotite during the development of a crenulation cleavage that also affected the adjacent intrusive rocks of the Pippingarra Granitoid Complex. The latter rocks have been dated at c. 2945 Ma (Nelson, 2001), which places a maximum age on the development of the crenulation and a minimum age on the metamorphic event that crystallized garnet in the paragneiss.

Structure

The Pilgangoora greenstone belt includes rocks of the Coonterunah Group, deposited at c. 3515 Ma (Buick et al., 1995), and shows a protracted, early deformation history that is not recorded throughout the rest of the sheet area. The structural history of the Pilgangoora greenstone belt has been discussed in detail by Van Kranendonk (2000) and Blewett (2002), and is summarized here. Most of the outcrop on WALLARINGA is dominated by weakly foliated to massive granites that are probably between c. 2850 and 2940 Ma in age and post-date most major deformational events within the region. The c. 2940 Ma granites only become strongly foliated adjacent to the Tabba Tabba Shear Zone and major northeast-trending faults, constraining the last major movement along these zones as younger than c. 2940 Ma. Movement along the northeast-trending faults is primarily dip-slip (normal). Some of the faults may reflect late reactivation of old structures, as is possibly the case for the shear zone marking the western edge of the Pilgangoora greenstone belt. The structural evolution of the Tabba Tabba Shear Zone is described in more detail below.

Foliation trends in rocks of the Mallina Basin typically parallel trends identified in rocks in the central and western parts of the basin (Smithies, 1998; Smithies and Farrell, 2000). These relate mainly to the development of early northerly to northwesterly trending folds and later east-northeasterly trending folds. In the northwestern part of the sheet basement rocks to the Mallina Basin are exposed in a north- to northwest-trending anticline. This has refolded a syncline with an originally easterly trending axis, possibly related to the earliest deformation of rocks in the western part of the Mallina Basin (Smithies, 1998), which resulted in poorly preserved easterly trending folds. A late, east-northeasterly trending folding event affected all rocks of the Mallina Basin, including those deposited during the last depositional event after c. 2940 Ma (Smithies et al., 1999, 2001b). This late depositional event has been related to normal movement along the Tabba Tabba Shear Zone (Smithies and Champion, 2000), consistent with the development of oblique sinistral shear sense indicators (see below) in granites that intruded the shear zone at c. 2940 Ma.

Tabba Tabba Shear Zone

The most conspicuous structural element on WALLARINGA is the northeast-trending Tabba Tabba Shear Zone, which forms the eastern margin of the Mallina Basin. Although not directly continuous with the Mallina Shear Zone to the southwest, both shears show a similar sense of movement, and have been interpreted as the result of reactivated basement faults related to formation of the Mallina Basin (Smithies, 1998; Smithies and Champion, 2000). The structures in the Tabba Tabba Shear Zone record two clear deformational phases: a major oblique sinistral phase and a minor late dextral phase (Beintema et al., 2001). However, local evidence for an early dextral phase of movement (Beintema et al., 2001) is strongly supported by the observation that in some units of interleaved actinolite schist, ultramafic schist, and quartz–sericite schist (*Abus*), clinopyroxene has overgrown a foliated groundmass assemblage, and has in turn been deformed and recrystallized during the main sinistral phase of movement.

Locally well developed C–S fabrics and rotated feldspar phenocrysts indicate a sinistral component of displacement during the major oblique deformational phase in the development of the Tabba Tabba Shear Zone. This movement also resulted in the formation of moderately northwesterly plunging to down-dip mineral and stretching lineations, suggesting that this steep, commonly northwesterly dipping shear zone had a normal displacement component (Hickman et al., 2001). During this phase of deformation the shear zone was intruded by a range of mafic to felsic rocks that were emplaced into a releasing bend (Fig. 5; Smithies and Champion, 2002). West of the shear zone, the northeast-trending Indee Fault marks the western margin of granite intrusion related to development of this releasing bend. Pegmatites, aplites, and granite dykes have intruded granite that has been mylonitized (*AgLmm*) during the major oblique sinistral movement along the shear zone. These later intrusions are largely unfoliated and discordant to the main fabric, and locally fill dextral shears that cut the main foliation.

Evolution of the Wallareenya releasing bend

The relationship between the development of the Wallareenya releasing bend and the emplacement history of magmas indicates that the Tabba Tabba Shear Zone was active, at least periodically, from 2955 to c. 2945 Ma. Dating of mylonitized monzogranite (*AgLmm*; Nelson, 2001) that earlier intruded the southeastern edge of the Tabba Tabba Shear Zone extends the period of activity to at least 2940 ± 3 Ma. This period coincides with the latest depositional event within the Mallina Basin, estimated to have occurred between 2950 and 2935 Ma, based on the ages of detrital zircons and the age of syntectonic granite intrusion into the western parts of the Mallina Basin (Smithies et al., 2001b). The presence of gabbro and high-Mg diorite shows that the crustal-scale Tabba Tabba Shear Zone provides a control on the migration and emplacement of mantle-derived magmas (e.g. Smithies and Champion, 2000).

The Wallareenya releasing bend formed by north-block-down sinistral transtensional displacement. An internal mosaic of smaller, northeast-oriented diamond-shaped segments is defined by a network of faults, dykes, and sheared magma conduits (Fig. 5). This is perhaps best shown in the central part of the shear zone on WALLARINGA. Here structurally controlled magmatic

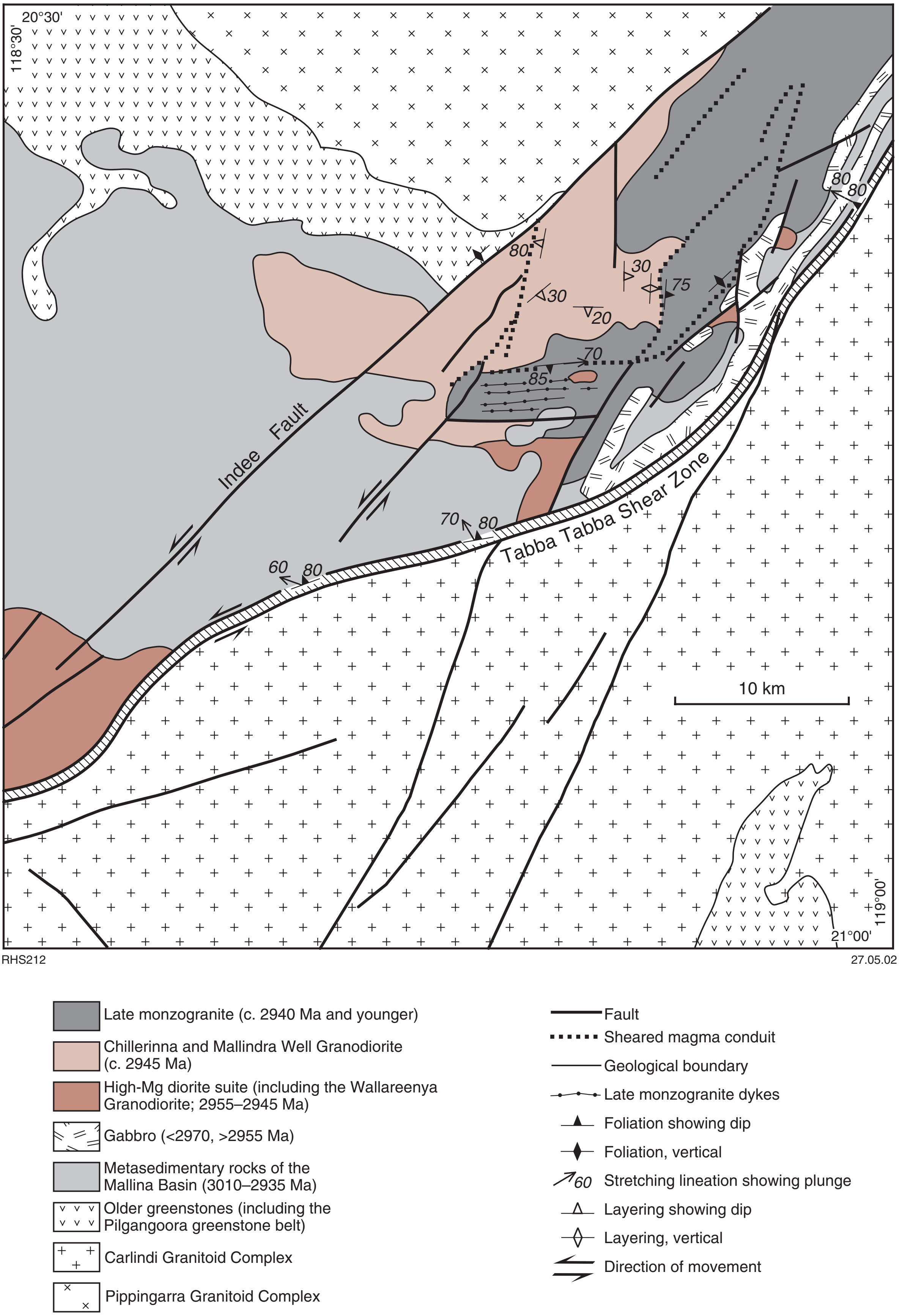


Figure 5. Schematic geological map of the Wallareenya area, showing the Wallareenya releasing bend and summary structural data

emplacement of gabbro (*Aog*) into northeasterly and east-northeasterly fractures mimics two consecutive doubly plunging folds.

Magma conduits preserved within the Wallareenya releasing bend have been exploited by up to five separate batches of magma, and have also been active zones of deformation throughout this multiple intrusive history. The clearest evidence for this is the presence of multi-generation xenolith suites, including xenoliths within xenoliths, showing a range in the degree of post-crystallization deformation. Conduits that include xenoliths of gabbro, high-Mg diorite, Chillerinna Granodiorite and late monzogranite have been exploited by migrating magma, at least periodically, for up to 15 million years.

Pilgangoora greenstone belt

Blewett (2002) detailed the structural geology of the Pilgangoora greenstone belt, the northernmost tip of which outcrops on WALLARINGA. The earliest fabric, a slaty cleavage or schistosity (S_1), is only developed in the 3515 Ma Coonterunnah Group. The second regional fabric is a bedding-parallel schistosity (S_2) developed in the Warrawoona Group that unconformably overlies the Coonterunnah Group. The ‘main’ fabric in the Warrawoona Group is a composite fabric produced by crenulation (S_3) of S_2 schistosity, and is best identified in the pits of the McPhees gold workings (on the sheet boundary with WODGINA).

In the centre of the Pilgangoora greenstone belt, formation of talc–chlorite–carbonate and talc–actinolite schists in the Lynas Find shear system represents a fourth deformational event. In this area, S_3 crenulation cleavages were deformed by the Lynas Find shear system (D_4) that was in turn folded by the regional Pilgangoora Syncline (D_5)

Northerly to north-northeasterly striking sinistral D_4 shear zones along the western margin of the Pilgangoora greenstone belt deformed andalusite porphyroblasts in pelitic schist and clinozoisite porphyroblasts in mafic (chlorite) schist. In the Lynas Find shear system, C′ planes defined by the alignment of muscovite record sinistral shear. Granitoid rocks of the Yule and Carlindi Granitoid Complexes have sinistral S–C fabrics and associated subhorizontal stretching lineations.

North-striking S_5 crenulation cleavages are axial planar to a series of south-plunging, upright, tight F_5 folds. These folds overprint the S_{2+3} composite fabric, earlier folds, shear zones, and the alteration and mineralization at Lynas Find. Metamorphic grade during D_5 was locally high enough to form biotite.

Progressive deformation during D_6 resulted in east-northeasterly oriented folds and reactivation of the D_4 shear zones, and these are in turn overprinted by fine-scaled S_7 crenulation cleavages that strike northwesterly and overprint all other fabric elements.

Economic geology

A detailed description of the mineral occurrences and exploration history and potential of WALLARINGA is provided by Ferguson and Ruddock (2001), from which the following summary is drawn.

Gold

Lost Arc, Last Crusade, WMC, and Turner River are all vein and hydrothermal gold prospects hosted by rocks within the Tabba Tabba Shear Zone (Ferguson and Ruddock, 2001). Exploration drilling at the first three of those deposits intersected gold mineralization that includes 8 m at 5.62 g/t Au and 28 m at 1.13 g/t Au (Winter, 2000).

The major occurrence of gold mineralization on WALLARINGA is in the northern part of the Pilgangoora greenstone belt, on the nose of the Pilgangoora Syncline. Deposits here form the northern part of the Pilgangoora mining centre, and include many of the deposits of the McPhees group and the Birthday Gift mine. Gold production from this mining centre totalled 3843 kg up to 1998 (Ferguson and Ruddock, 2001). There are no currently active mines in the mining centre.

The deposits in the Pilgangoora mining centre show evidence for a strong structural control, with mineralization concentrated into breccia zones and favourable zones created by contrasts in the competency across lithological contacts (Ferguson and Ruddock, 2001).

Base metals

Known base metal mineralization is restricted to four locations: veined and hydrothermal copper mineralization at the Boodarrie Station abandoned opencut, veined and hydrothermal lead mineralization is noted from the Tabba Tabba mineral occurrence and the Lynas Find mine, whereas pegmatite-hosted copper mineralization is noted at the Mallindra Well Southwest abandoned opencut. Of these the only recorded production figures are from the Boodarrie Station opencut, where a total of 0.07 t of contained copper was extracted in 1956 (Ferguson and Ruddock, 2001).

Pegmatite-hosted mineralization

Pegmatite-hosted mineralization is the only currently exploited mineralization on WALLARINGA and can be divided into four types. Mineralized pegmatites are in both the Pippingarra and Carlindi Granitoid Complexes, typically in pegmatites that are closely spatially related to late muscovite-bearing granites, and in all but one case (deposits at and near the Pippingarra mine), where the pegmatites have intruded into or close to mafic supracrustal rocks. Minor tin, tantalum, and lithium mineralization is present at the Bore Creek prospect, although no production details are available (Ferguson and Ruddock, 2001).

Pegmatite at Tabba Tabba mine intruded gabbro (*Aog*) immediately north of the Tabba Tabba Shear Zone. The pegmatite hosts tin and tantalum(–niobium) mineralization and contains beryl. Production figures from these deposits include a total of 10.55 t of tantalite ore and concentrate mined between 1928 and 1969, and a total of 131.92 t of tin and tin-ore concentrate mined between 1916 and 1960 (Ferguson and Ruddock, 2001).

Pegmatite intruded in and around talc–serpentine–chlorite schist immediately north of the Pilgangoora Syncline and the Trig Hill Well and Trig Hill Well Southeast abandoned opencuts contained tantalum mineralization and beryl respectively. A total of 0.079 t contained Ta_2O_5 was mined between 1966 and 1969 (Ferguson and Ruddock, 2001).

Pegmatites that intruded muscovite-bearing granites of the Pippingarra Granitoid Complex at and around the Pippingarra mine are the only significantly mineralized pegmatites that are not close to outcropping mafic supracrustal rocks on WALLARINGA. These pegmatites contain tantalum mineralization as well as deposits of mica, feldspar, and beryl. The Pippingarra mine is the only operating mine on WALLARINGA and is currently being mined for feldspar. Production from the mine has included 3.246 t of Ta_2O_3 mined between 1953 and 1958, and 0.267 t of BeO (from beryl) mined in 1955 (Ferguson and Ruddock, 2001).

Regolith mineralization

Pisolitic iron deposits exist as small scattered remnants of Cainozoic palaeodrainage systems, forming the Indee East mineral occurrence and the Wallaringa Peak prospect.

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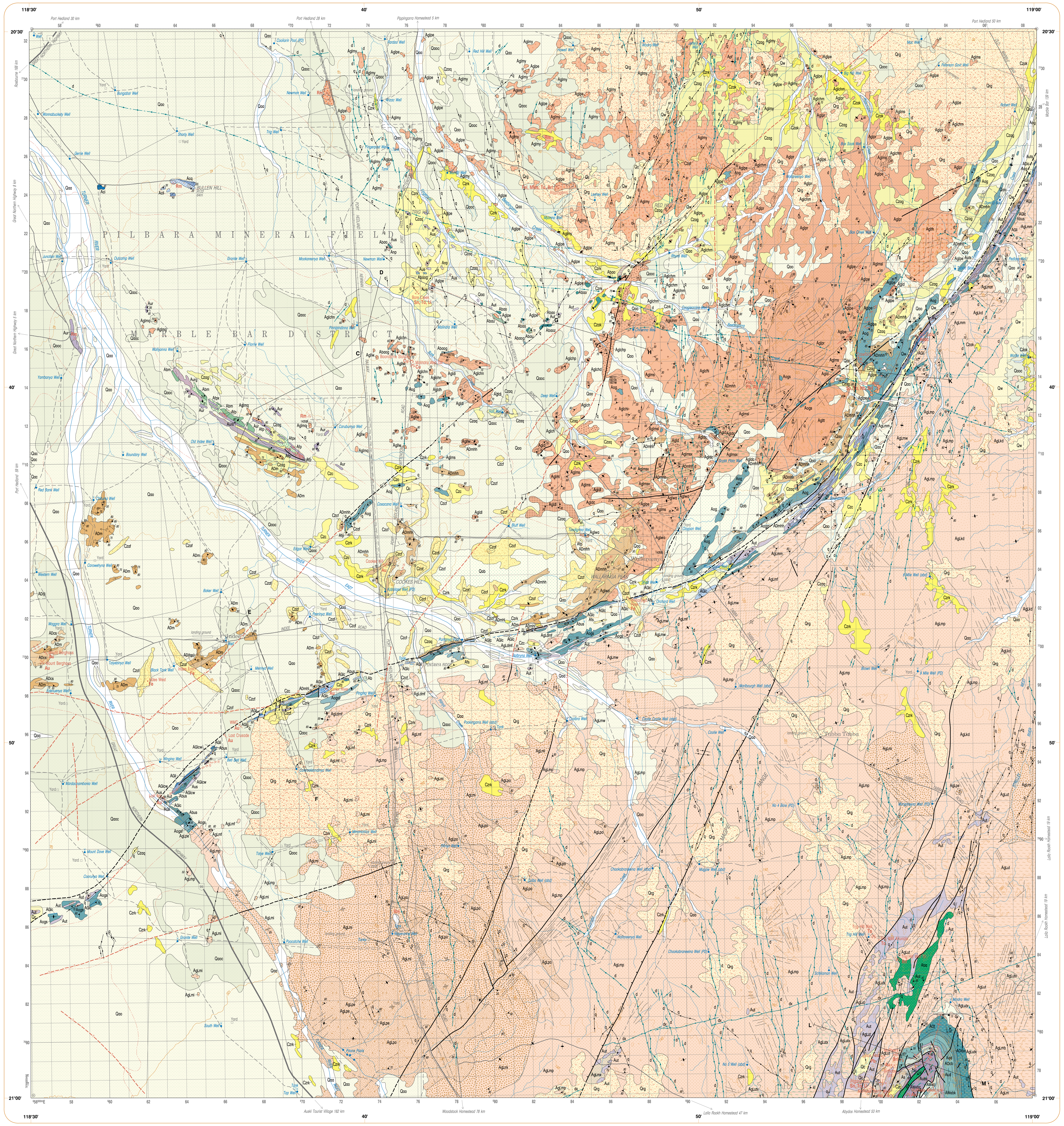
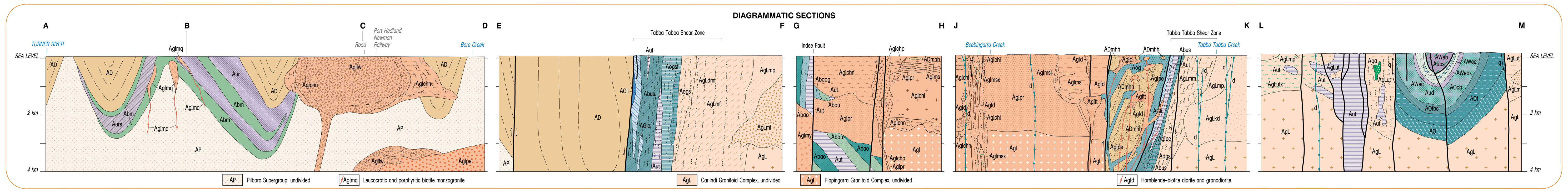
Appendix 1

Gazetteer of localities

Place name	MGA coordinates	
	Easting	Northing
Birthday Gift mine	700700	7678200
Bluff Well	680100	7706600
Boodarrie Station opencut (abandoned)	676000	7715100
Bore Creek prospect	676400	7718700
Boundary Well	697800	7708000
Bullen Hill	664700	7724400
Carubumya Well	672100	7711800
Chillerinna Well	687700	7716700
Cookes Hill mine (abandoned)	674500	7704400
Cosacana Well	675400	7707700
Cosacana Well	675400	7707700
Deep Well	685600	7713300
Grass Plain Well	691800	7709800
Indee East mineral occurrence	664700	7699300
Indee Homestead	666300	7700700
Last Crusade prospect	666200	7695800
Lost Arc prospect	662900	7692600
Lynas Find mine	700300	7678700
Mallindra Well	678400	7717000
Mallindra Well Southwest opencut (abandoned)	676100	7714900
McPhees West Lode opencut	701500	7676800
Mindra Well	703700	7681600
Newman Well	670850	7729000
Pingina Well	674000	7697800
Pippingarra mine	683700	7724100
Tabba Bore	704400	7719700
Tabba Tabba mine (abandoned)	700300	7713700
Tabba Tabba mineral occurrence	694500	7713700
Toodigrina Well	685000	7706000
Trig Hill Well opencut (abandoned)	699700	7685000
Trig Hill Well Southeast opencut (abandoned)	700900	7683800
Turner River prospect	671500	7698100
Wallareenya Homestead	689000	7704400
Wallaringa Peak prospect	687200	7702700
WMC prospect	667000	7696300



DIAGRAMMATIC SECTIONS



PHANEROZOIC — CAINOZOIC — QUATERNARY

Qaa Alluvial sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains
Qac Clay and silt in claypan deposits on floodplains
Qao Alluvial sand, silt, and clay on 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 Sheetwash deposits — silt, sand, and pebbles on distal outwash fans; no defined drainage
Qc Colluvium — sand, silt, and gravel in outwash fans; scree and talus; proximal mass-wasting deposits
Qrg Quartzofeldspathic eluvial sand with quartz and rock fragments; overlying and derived from granitoid rock

Czag Alluvial gravel, unrelated to recent drainage; dissected by present-day drainage
Czaq Alluvial gravel deposits, dominated by vein-quartz debris, unrelated to recent drainage; dissected
Czak Alluvial calcrete; massive, nodular, and cavernous limestone; variably silicified; dissected by present-day drainage
Czc Colluvium — dissected consolidated clay, silt, and sand deposits; derived from adjacent rock outcrops
Czcf Ferruginous silt, sand, and gravel; variably consolidated and dissected
Czaf Pisolitic limonite deposits, developed along palaeodrainage lines; dissected by present-day drainage
Czrk Residual calcrete; massive, nodular, and cavernous limestone; mainly silicified

ARCHAEAN

d Dolerite and gabbro dykes; interpreted from aeromagnetic data where dashed
dx Dolerite dykes, with abundant granite xenoliths locally; potassic alteration
q Quartz vein

Apf Quartz(–feldspar) porphyry dyke; fine-grained; massive

CARLINDI GRANITOID COMPLEX
AgLpe Pegmatite; metamorphosed
AgLkd **KADGEWARRINA MONZOGRANITE:** muscovite–biotite(–garnet) monzogranite; equigranular to weakly porphyritic; massive to weakly foliated; metamorphosed
AgLpo **POOCATCHE MONZOGRANITE:** muscovite–biotite monzogranite; seriate to porphyritic; massive to weakly foliated; locally abundant pegmatite; metamorphosed
AgLmb Fine- to coarse-grained muscovite–biotite monzogranite; massive to weakly foliated; metamorphosed
AgLmi **MINNAMONICA MONZOGRANITE:** porphyritic biotite(–muscovite) monzogranite; fine- to coarse-grained; quartz and K-feldspar phenocrysts; massive to weakly foliated; metamorphosed
AgLmw Biotite(–muscovite) monzogranite, equigranular to weakly K-feldspar porphyritic; locally highly leucocratic and ghost-banded; massive to weakly foliated; metamorphosed
AgLmf Biotite monzogranite, strongly foliated; seriate to K-feldspar porphyritic; related to AgLmp; metamorphosed

PIPPINGARRA GRANITOID COMPLEX

Pilbara Supergroup — Unassigned

Afp Feldspar porphyry; locally with hornblende phenocrysts; metamorphosed
Afpx Metamorphosed feldspar porphyry containing abundant greenstone xenoliths
Afs Quartz–sericite(–feldspar–epidote–actinolite) schist

Aod Dolerite; metamorphosed
Aog Medium- to coarse-grained metagabbro; foliated to massive
Aogm Melanogabbro; massive to moderately foliated; metamorphosed
Aogs Fine- to medium-grained plagioclase–hornblende–actinolite–epidote schist after gabbro; locally includes interleaved talc–serpentine–chlorite schist
Aogsf Fine- to medium-grained plagioclase–hornblende–actinolite–epidote schist; includes abundant interleaved quartz–sericite–epidote schist

Ab Metabasalt; locally plagioclase-phyric
Aba Amphibolite; fine- to medium-grained amphibole–plagioclase–quartz–sericite–epidote rock
Abao Medium-grained amphibolite
Abaog Medium-grained garnetiferous amphibolite
Abaoz Amphibolite; silicified
Abau Interleaved amphibolite and talc–tremolite–serpentine–chlorite schist
Abm High-Mg basalt and olivine basalt; locally preserved pyroxene-spinifex textures; metamorphosed
Abus Interleaved actinolite schist, talc–tremolite–chlorite schist, and quartz–sericite schist; locally mylonitized

Aubs Talc–tremolite–chlorite schist interleaved with amphibolite and actinolite schist
Aud Dunite replaced by serpentine(–talc–tremolite–chlorite) rock; locally preserved, medium-grained olivine-cumulate texture
Aur Tremolite–chlorite–talc schist
Aurg Tremolite–chlorite–talc schist; intruded by abundant granitic dykes
Aurs Tremolite–chlorite–talc schist interleaved with metasedimentary rocks
Aus Serpentinite; serpentine–tremolite(–talc–chlorite) rock after peridotite; locally preserved, medium-grained olivine-cumulate texture
Aut Talc–serpentine–chlorite schist; locally preserved olivine- and pyroxene-spinifex textures
Auts Interleaved talc–serpentine–chlorite schist, quartz–sericite schist, cordierite hornfels, and actinolite schist

Warrawoona Group

EURO BASALT
AWeb Fine- to medium-grained mafic schist and amphibolite; after tholeiitic and high-Mg basalt, and dolerite sills
AWebc Carbonate-altered and schistose basalt; local intense silicification; metamorphosed
AWebk Komatiitic basalt and komatiite; locally pillowed and with olivine-spinifex texture; metamorphosed
AWec Carbonate-altered and silicified, fine- to medium-grained mafic schist after basalt

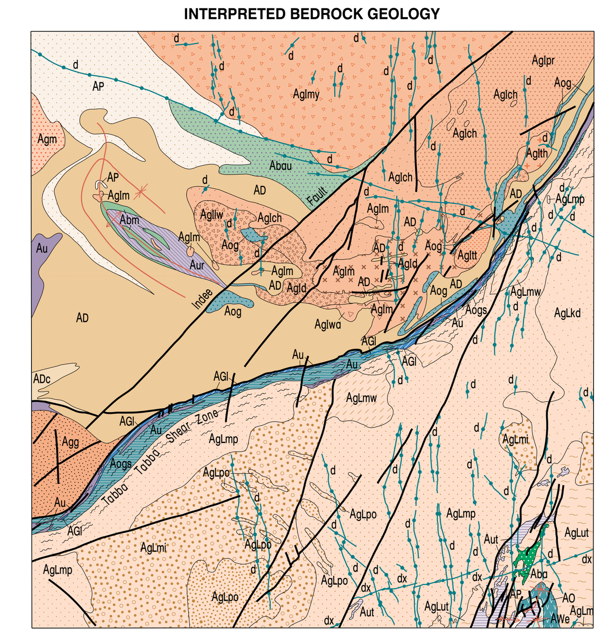
CARLINDI GRANITOID COMPLEX
c. 3475 Ma[7] AgLut **MOTHERIN MONZOGRANITE:** interleaved monzogranite, granodiorite, gneiss, and pegmatite; moderately to strongly foliated; and intruded by abundant sheets of massive to weakly foliated muscovite-bearing monzogranite and pegmatite; metamorphosed
AgLutx Interleaved monzogranite, granodiorite, gneiss, and pegmatite, with abundant greenstone xenoliths; metamorphosed
c. 3485 Ma[4] AgLm Fine- to coarse-grained biotite monzogranite; metamorphosed
AgLmx Fine- to coarse-grained biotite monzogranite, with abundant greenstone xenoliths; metamorphosed

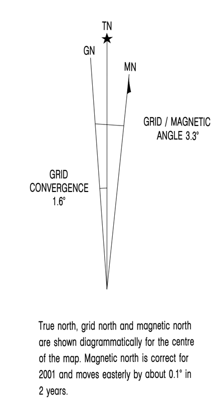
Pilbara Supergroup — Coonterunah Group

c. 3515 Ma[1] AOcb **COUCAL FORMATION:** mafic schist and amphibolite; locally silicified

AOt **TABLE TOP FORMATION:** fine- to medium-grained amphibolite; after tholeiitic basalt and dolerite
AOtbc Interleaved chlorite schist, amphibolite, talc schist, and metamorphosed banded iron-formation

INTERPRETED BEDROCK GEOLOGY





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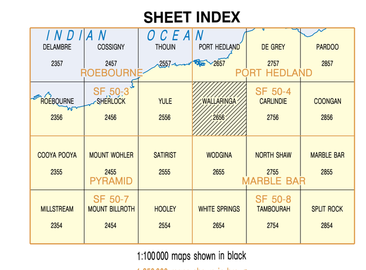

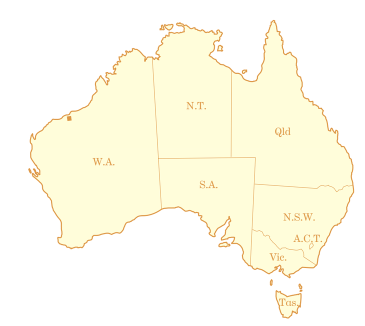

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Geochronology by:
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(7) D. E. L. Baker, written communication, 2001.

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SCALE 1:100 000

Metres 1000 0 1 2 3 4 5 6 7 8 9 10 Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: GEOCENTRIC DATUM OF AUSTRALIA 1994
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM

Grid lines indicate 1000 metre interval of the Map Grid Australia Zone 50

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

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

WALLARINGA

SHEET 2656 FIRST EDITION 2001

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