Government of **Western Australia**
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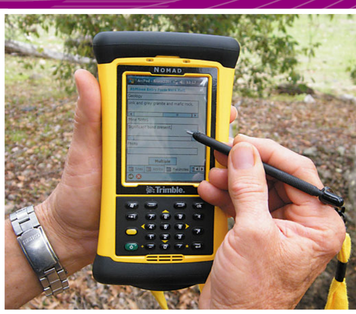
RECORD 2014/8

LINKING GRAIN-SCALE TO CRUSTAL-SCALE STRUCTURES ALONG THE YOUANMI SEISMIC TRAVERSE — A FIELD GUIDE

by
I Zibra, MJ Pawley, and S Wyche

Geological Survey of Western Australia

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Contents

Figures

Linking grain-scale to crustal-scale structures along the Youanmi seismic traverse — a field guide

by

I Zibra, MJ Pawley, and S Wyche

Introduction

This guide describes a field traverse across the northwestern part of the Yilgarn Craton, mainly following the Youanmi seismic line that was acquired in 2010 (Wyche et al., 2013; Fig. 1). The traverse shows some of the main structural elements across this area and how they fit into recognized geological histories with respect to the main deformation and mineralization events. This guide to the traverse also gives some insight into how Geological Survey of Western Australia (GSWA) researchers recognize, unravel and interpret the structural features that can be seen in the poorly exposed Yilgarn Craton.

Geology of the northern Yilgarn Craton

The field traverse crosses two of the terranes proposed for the Yilgarn Craton by Cassidy et al. (2006), begins to the east of the Ida Fault and Waroonga Shear Zone in the Eastern Goldfields Superterrane (Fig. 2), and finishes in the western part of the Youanmi Terrane. The Eastern Goldfields Superterrane comprises four terranes — the Kalgoorlie, Kurnalpi, Burtville, and Yamarna terranes (Cassidy et al., 2006; Pawley et al., 2012), and was previously known as the Eastern Goldfields Province (Gee et al., 1981). Terrane divisions are based on geological, geophysical, geochemical, isotopic and geochronological data. The region west of the Ida Fault, now called the Youanmi Terrane, forms the nucleus of the craton and has been interpreted to represent a protocraton onto which the Eastern Goldfields Superterrane was accreted (Cassidy et al., 2006).

Geology of the Eastern Goldfields Superterrane

by Pawley, MJ

The lithostratigraphic succession in the westernmost Kalgoorlie Terrane is most studied to the south, where it includes the 2715–2692 Ma mafic–ultramafic Kambalda Sequence, overlain by felsic volcanic and volcaniclastic rocks of the 2686–2666 Ma Kalgoorlie Sequence (Kositcin et al., 2008). These rocks were interpreted as having been deposited in an extensional back-arc setting (Krapež and Barley, 2008), with a plume inferred by the widespread presence of ultramafic lavas. A similar assemblage of rocks has been recognized in the Agnew area where a c. 2700 Ma mafic–ultramafic package is overlain by two cycles of felsic volcaniclastic and siliciclastic rocks. The first cycle includes the feldspathic rocks of the Worrunga Formation (previously called the ‘Vivien Metasediments’) that crops out around the Mount White Syncline, and the c. 2664 Ma Scotty Creek Formation that crops out between the Waroonga Shear Zone and Emu Fault. The western Kurnalpi Terrane contains 2695–2675 Ma bimodal (basalt–rhyolite) volcanic rocks (Kositcin et al. 2008), which were interpreted to represent a rifting mature arc system (Barley et al., 2008). The eastern part of the Kurnalpi Terrane contains the 2715–2704 Ma calc-alkaline andesite-dominated complexes of the Kurnalpi Sequence, which were interpreted as a series of intra-arc complexes (Barley et al. 2008). The rocks of the Kalgoorlie and Kurnalpi terranes are overlain by a series of c. 2660 Ma fault-related basins, interpreted to be associated with terrane amalgamation (Krapež et al., 2008).

Five main types of granites have been recognized in the Eastern Goldfields Superterrane (Champion and Sheraton, 1997), with most felsic magmatism occurring between c. 2720 and 2630 Ma (older granites are scattered across the superterrane). Although there is overlap in their ages, the different granite types ‘peaked’ at different times.

- High-HFSE (high field strength element) granites are a minor phase (~5%), generally restricted to the Kurnalpi Terrane, which peaked between c. 2720 and 2680 Ma.
- Mafic granites are a minor phase (~5%) with a peak between c. 2720 and 2680 Ma, but decreasing until <2655 Ma.
- High-Ca granites are the dominant granite type (~60%), and were mostly emplaced between c. 2720 and 2655 Ma.
- Syenitic granites are a minor phase (~1%), ranging from c. 2675 to <2655 Ma, which are mostly restricted to the Kurnalpi Terrane.

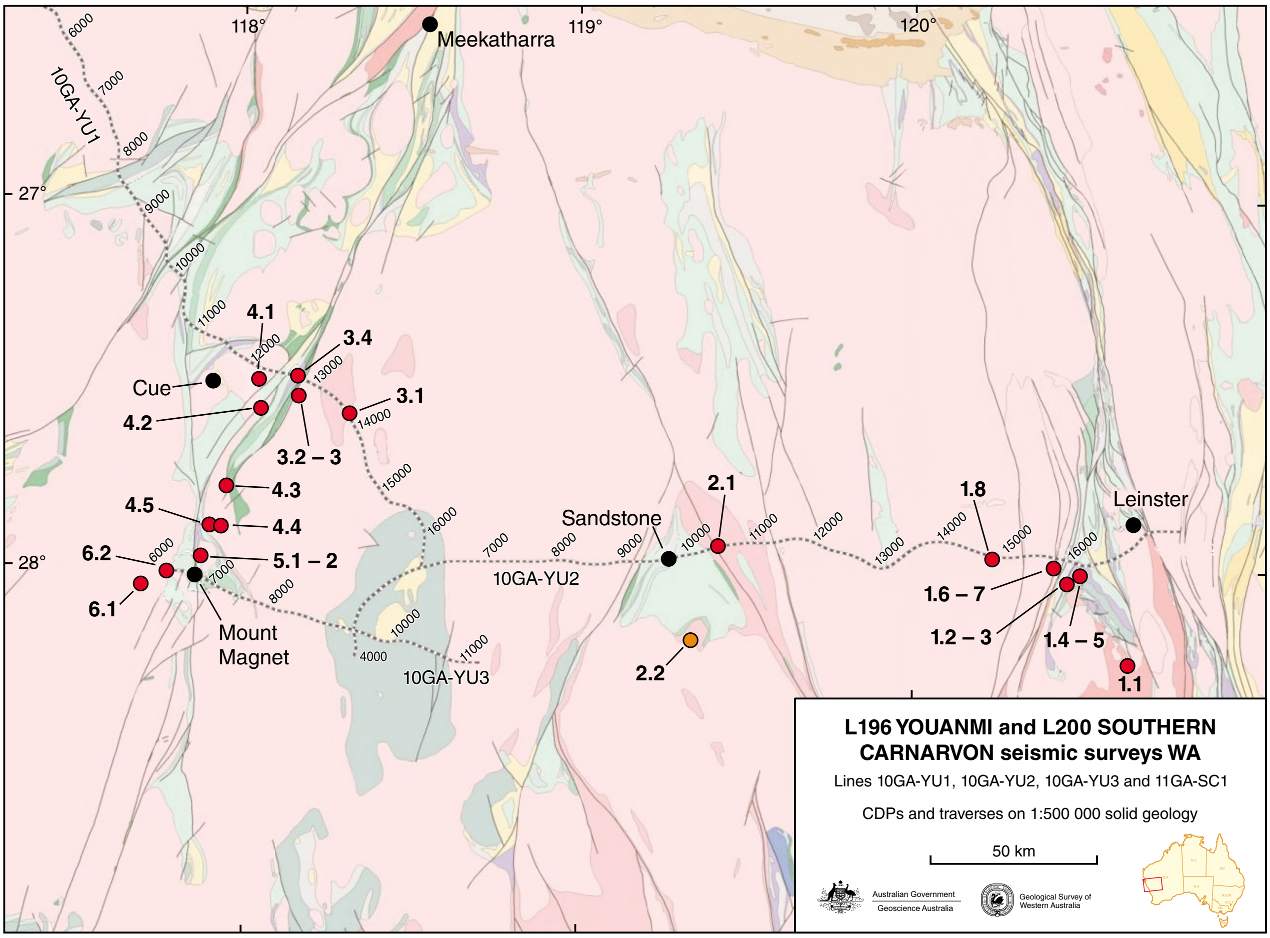

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Figure 1. Simplified geology of the northwestern part of the Yilgarn Craton showing excursion localities. Localities indicated in orange are optional.

- Low-Ca granites are common (~25%), typically younger than c. 2655 Ma, and interpreted to be derived by recycling of the older granites.

All granite types, except the high-HFSE and syenitic granites, have been recognized throughout the Eastern Goldfields Superterrane. The high-HFSE and mafic granites decrease in age from east to west, which is consistent with the pattern revealed by the geochronology of the likely co-magmatic felsic volcanic rocks of the Kurnalpi Terrane.

Structural evolution of the Eastern Goldfields Superterrane

Published structural studies differ in nomenclature (see Blewett et al., 2010 and references therein), but typically recognize six main deformation events in the Eastern Goldfields Superterrane (Fig. 3). Extension between c. 2720 Ma and 2670 Ma was accompanied by deposition of the Kambalda Sequence. This was followed by several cycles of episodic transpression and extension/transtension, between c. 2665 and 2635 Ma (Blewett et al., 2010), including: D_2 north-northwesterly trending upright folding and reverse faulting at c. 2665 Ma; D_3 northeasterly directed extension at 2665–2655 Ma resulting in shear zones that reached the base of the crust and extensional granite doming, followed by deposition of clastic sedimentary ‘late basins’ adjacent to the domes; D_{4a} tightening of the north-northwesterly trending folds and reverse faulting at c. 2655 Ma; D_{4b} north-northwesterly trending sinistral shearing and thrusting at 2655–2650 Ma, interpreted to result from minor rotation of the stress field; and D_5 north-trending dextral strike-slip shearing at 2650–2635 Ma. Czarnota et al. (2010) ascribe this sequence of deformation events to tectonic switching at a convergent boundary. According to Blewett et al. (2010), the final deformation event was locally developed, minor vertical shortening with variable extension vectors after c. 2630 Ma that they attributed to ‘thermal relaxation’.

Isotopic constraints on the Eastern Goldfields Superterrane

Sm–Nd and Lu–Hf isotope data provide insights into crustal growth processes in the Yilgarn Craton. The significance of the Ida Fault is highlighted by the Sm–Nd isotopic data, which indicate a change from older average

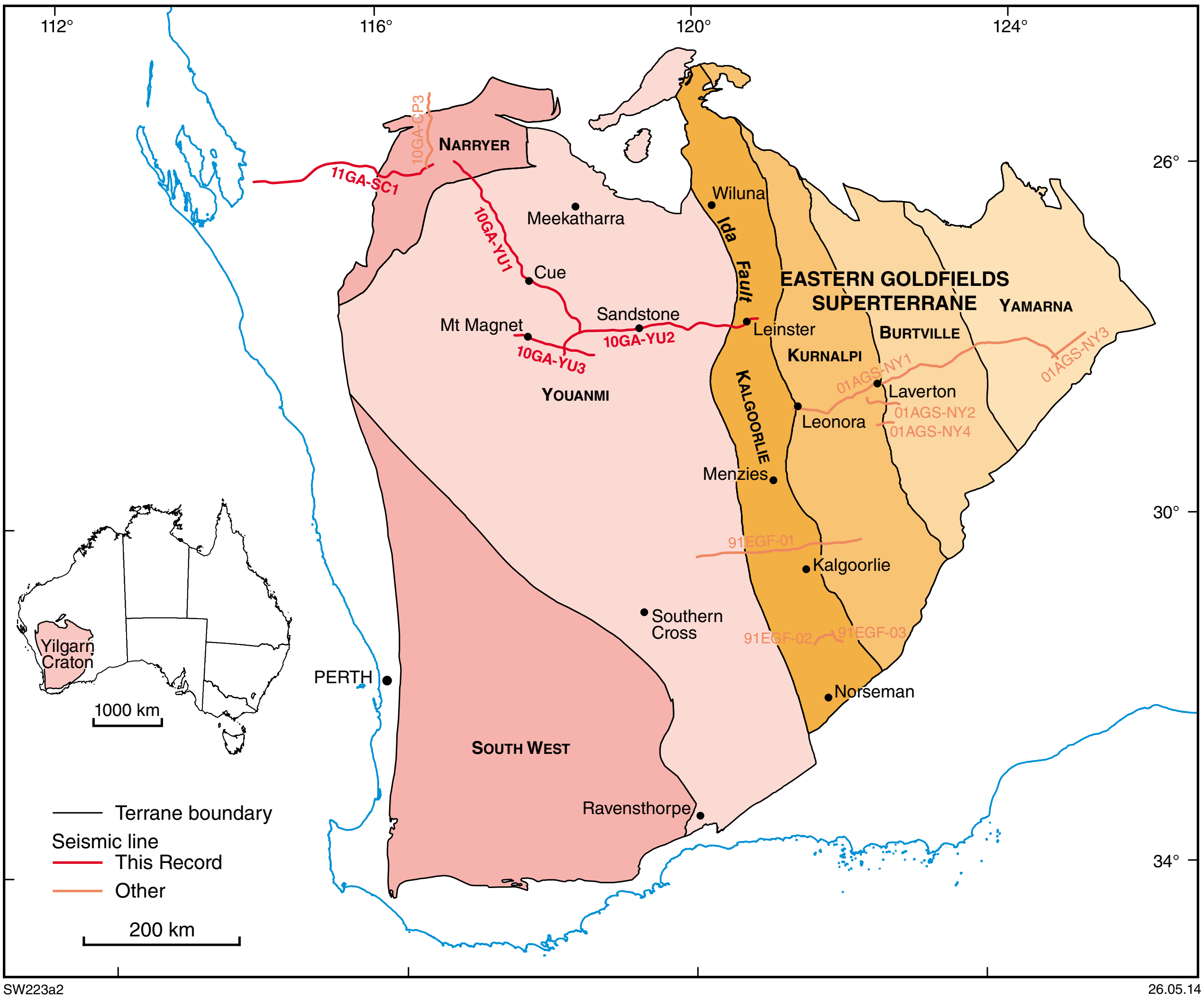


Figure 2. Subdivisions of the Yilgarn Craton (modified from Pawley et al., 2012)

crustal ages in the Youanmi Terrane to younger crustal ages in the Eastern Goldfields Superterrane (Champion and Cassidy, 2007). Similarly, new Lu–Hf isotope data by GSWA reveal several discrete episodes of crustal generation and recycling in the central Yilgarn Craton, whereas only the two youngest episodes are recorded in the Eastern Goldfields Superterrane (Wyche et al., 2012), suggesting that crust formation in the east post-dated the earliest events in the central and western parts of the craton. It also suggests that magmas in the Eastern Goldfields Superterrane had a substantial juvenile input, whereas those in the central Yilgarn Craton record reworking of older crust. Furthermore, the widespread evidence of c. 3100 and 2800 Ma crust formation events indicate that several episodes of major, possibly plume-related, heating occurred across the craton (Wyche et al., 2012). This supports the interpretation that the Burtville and Youanmi Terranes had a common history extending back to c. 2960 Ma.

Gold mineralization in the Eastern Goldfields Superterrane

The Eastern Goldfields Superterrane has world-class gold endowment, with structurally controlled mineralization occurring throughout most of the deformation history, and some deposits recording multiple gold events (see Blewett et al. 2010 and references therein). Only minor gold mineralization has been interpreted during the early (D_1–D_2) deformation (e.g. Tarmoola, near Leonora), with most mineralization during or after D_3. The development of the D_3 extensional shear zones between c. 2665 and 2655 Ma provided a crustal-scale conduit for the transfer of mantle melts, fluids, and metals, as well as sites for gold deposition (e.g. Sons of Gwalia at Leonora). Several gold deposits, such as New Holland, near Agnew, formed during D_{4a} reverse dip-slip faulting, but it was the change in shortening direction during D_{4b} that led to the biggest gold deposits (e.g. Kalgoorlie, Sunrise Dam, St Ives,

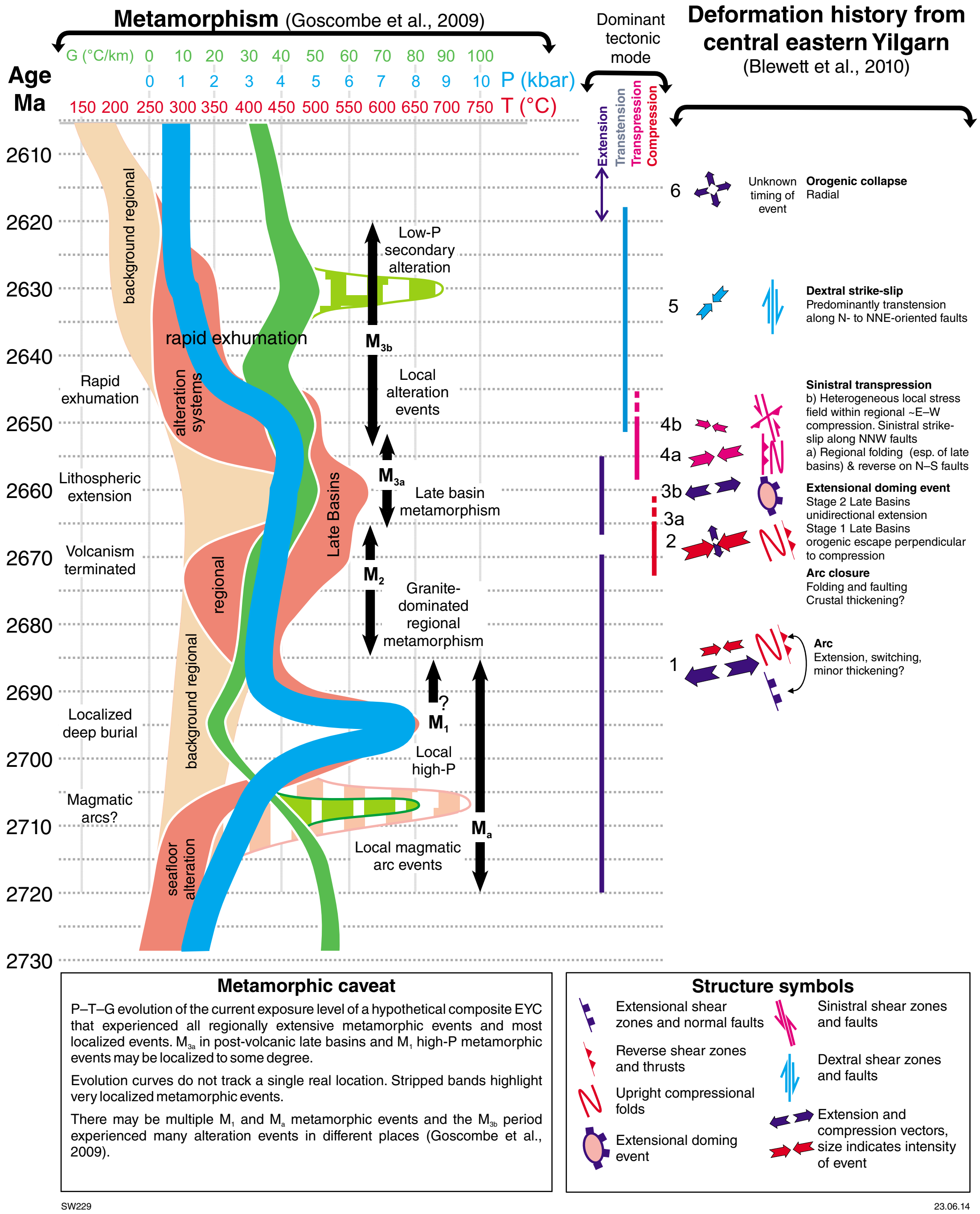


Figure 3. **Metamorphic and structural history of the Eastern Goldfields Superterrane (modified from Czarnota et al., 2010).**

Kanowna Belle, and Lawlers). Blewett et al. (2010) proposed that rotation of the stress axes between c. 2655 and 2650 Ma led to sinistral shearing and the development of a new network of contractional and dilational jogs, which were favourable sites for fluid flow and gold deposition. D_5 transtension resulted in northerly trending, dextral shearing and associated brittle structures which host mineralization at Sunrise Dam, St Ives, and Wiluna.

Geology of the Youanmi Terrane

by Zibra, I

Introduction

The roughly 300 000 km^2 Youanmi Terrane, and the South West and Narryer Terranes, form the western half of the Archean Yilgarn Craton (Fig. 2). The Youanmi Terrane is differentiated from the Kalgoorlie Terrane of the Eastern Goldfields Superterrane to the east by its different stratigraphic components, typically older and more dismembered greenstone belts, and the widespread presence of banded iron-formation. The well-preserved, older geological history of the Youanmi Terrane is recorded in greenstones (c. 2980 Ma) and granitic rocks (c. 3200 Ma, with xenocrystic zircons up to c. 4000 Ma), and reflected in Nd isotope data (Pidgeon and Wilde, 1990; Watkins et al., 1991; Wiedenbeck and Watkins, 1993; Mueller et al., 1996; Schiøtte and Campbell, 1996; Yeats et al., 1996; Nelson et al., 2000; Champion and Cassidy, 2007; Wingate et al., 2012). The boundary between the Youanmi Terrane and Eastern Goldfields Superterrane is the northerly trending Ida Fault, which has been interpreted as a crustal-scale normal shear zone (Blewett et al., 2010). The Youanmi Terrane is also fault-bounded against the Narryer Terrane (famous for its Hadean detrital zircons and Paleoarchean crustal remnants, e.g. Nutman et al., 1993; Wilde et al., 2001) to the northwest, and to the southwest against the South West Terrane, which has a long and complex Meso- to Neoarchean history (Wilde et al., 1996; Wilde, 2001).

Recent mapping by GSWA in the western Youanmi Terrane, in combination with new and previous precise U–Pb zircon and baddeleyite geochronological data, has shown that although the Youanmi Terrane preserves an older crustal history than the Eastern Goldfields Superterrane, it also contains a Neoarchean history of events that is remarkably similar to those across the Eastern Goldfields Superterrane, including eruption of mafic to felsic volcanic rocks, widespread and long-lived emplacement of granitic rocks, and a roughly comparable structural evolution. The Eastern Goldfields Superterrane is characterized by greenstones deposited between c. 2720 Ma and 2660 Ma, and voluminous granitic rocks emplaced between c. 2720 and 2620 Ma. Komatiites are a characteristic feature of the superterrane, as are felsic volcanic rocks that vary in composition from tonalite-trondhjemite-dacite (TTD) to calc-alkaline, within distinct volcanic centres bounded by late strike-slip faults (Morris and Witt, 1997; Barley et al., 2008; Kositcin et al., 2008). Clastic sedimentary basins deposited after c. 2660 Ma (Krapež et al., 2000; Krapež and Barley, 2008) are widespread in the Eastern Goldfields Superterrane. Similar styles of sedimentary successions in the Youanmi Terrane, for example the Diemals Formation (Morris et al., 2007), have not been closely studied but are older and related to different deformation events. Deformation of the Eastern Goldfields Superterrane included alternating periods of extension and compression from c. 2705 to 2630 Ma, with gold mineralization largely accompanying the development of anastomosing north-northwesterly to north-northeasterly striking brittle–ductile shear zones from c. 2660 to 2630 Ma (Bateman and Hagemann, 2004; Blewett and Czarnota, 2007). Map, geochemical, and geochronological data have been used to develop a new stratigraphic scheme for the northern part of the Youanmi Terrane, where four main greenstone packages, locally separated by angular unconformities, were deposited between c. 2940 and 2700 Ma (Van Kranendonk et al., 2013). Suites of mafic–ultramafic rocks were emplaced as layered intrusions during accumulation of the main part of greenstone succession.

Structural evolution of the Youanmi Terrane

Between c. 2720 and 2600 Ma, the Youanmi Terrane was characterized by a 120 Ma period of widespread and voluminous granitic magmatism, which ended with several suites of post-tectonic granites (from c. 2640 to 2600 Ma). All granites are crustal melts and represent an extremely long period of crustal reworking (Rey et al., 2003). Because Neo-archean lithosphere is regarded as hot and weak as a result of extensive mantle melting and high internal heat from radioactivity, Neoarchean tectonics is thought to have been largely accommodated by shearing of partially molten gneisses and by syntectonic granitic magmatism. However, direct field examples of such strain localization are relatively scarce, and little is known as yet about emplacement style and about the relationship between granite emplacement and regional deformation. The Archean Yilgarn Craton, which is made up of volumetrically dominant granites and granitic gneiss (Myers and Swager, 1997), is a natural laboratory for studying the effect of melting on continental deformation. Nevertheless, structural investigations have focused on solid-state structures (see Blewett et al., 2010 for a review).

Figure 4 shows that the Youanmi Terrane is dissected by a network of terrane-scale shear zones (length >100 km). Since these shear zones are interconnected, their rheology likely controlled the rheology of the whole crustal section. The understanding of the structural and rheological evolution of these shear zones is therefore an essential prerequisite for the formulation of any tectonic model. In some domains, these shear zones are parts of conjugate systems where segments of dominant simple shear are linked by zones dominated by coaxial shearing (e.g. Chen et al., 2001). Where exposed, these shear zones generally show a steep solid-state foliation, associated with a shallowly plunging mineral or stretching lineation. As a whole, they reflect east–west shortening and north–south extension.

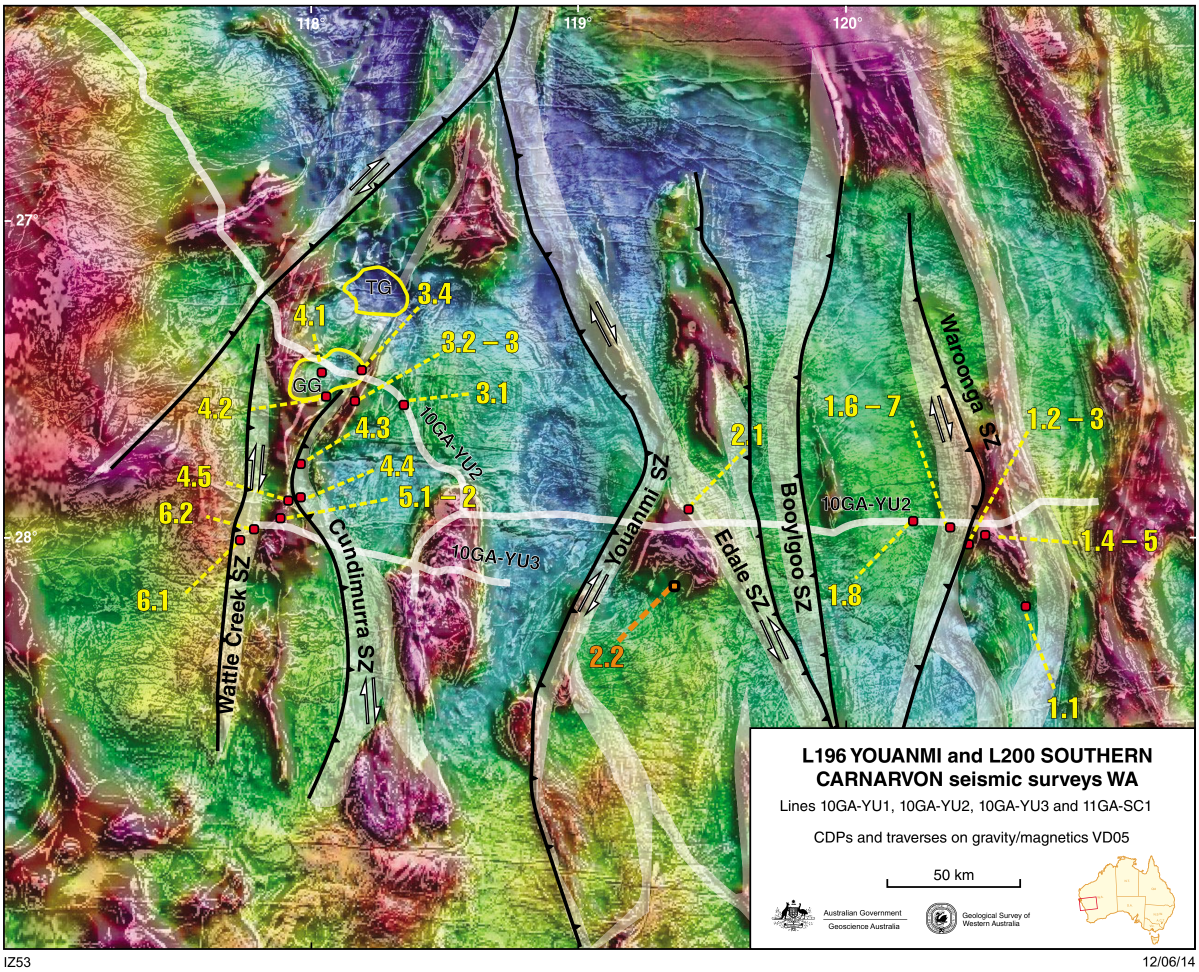


Figure 4. **Geophysical image (gravity on aeromagnetic) showing the trace of the terrane-scale network of late-orogenic shear zones that likely controlled the rheology of the whole crustal section. The post-kinematic pluton Garden Rock Granite, post-dating the development of the shear zone network, is outlined in yellow. Numbers in yellow refer to excursion localities.**

A key study area is in the northeasterly trending corridor between Mount Magnet and Meekatharra (Figs 4 and 5). Here, the main strike-slip shear zone (i.e. belonging to the shear zone network described above) is represented by the Cundimurra Shear Zone, (CMSZ, Fig. 5), which preserves evidence of shearing during incremental pluton emplacement (2680–2660 Ma), and then under retrograde conditions down to greenschist facies temperatures (Fig. 6). Its activity can be constrained to c. 2680–2620 Ma (age of Garden Rock Granite, Figs 4 and 5 post-dating the Cundimurra Shear Zone). The Cundimurra Shear Zone post-dates the emplacement of the adjacent Lakeside and Yarraquin plutons (Fig. 5), which are large-scale composite plutons associated with migmatites (~100 × 50 km wide in map view). These complexes show widespread evidence of deformation during and immediately after pluton crystallization (Zibra, 2012). Therefore, they can be regarded as large-scale, partially molten shear zones, not readily detectable in geophysical images (i.e. compare Figs 4 and 5), which accommodate the emplacement of granite–migmatite domes. The northerly trending, steeply dipping, magmatic to high-temperature solid-state structures preserved in these plutons were likely controlled by active large-scale structures and therefore by the regional stress field that was prevalent in the Youanmi Terrane at c. 2700 Ma. Two seismic lines intersect these complexes (Figs 4 and 5), offering a unique opportunity to constrain their three-dimensional architecture.

The field traverse starts in the Lawlers Anticline in the westernmost portion of the Eastern Goldfields Superterrane, where some of the main structural and lithostratigraphic features in the Agnew–Wiluna greenstone belt (Duuring et al., 2012 and references therein) can be seen. The traverse will then follow a representative cross-section through the eastern and central parts of the Youanmi Terrane by following some key segments of the three 2010 Youanmi seismic lines in the northwestern part of the Youanmi Terrane, between Leinster and Mount Magnet. Particular attention is given to the exposed portions of the terrane-scale shear zone network. Structures on the ground are examined with reference to the seismic data. Emphasis is given to microstructural observations and their links to outcrop- and crustal-scale structures.

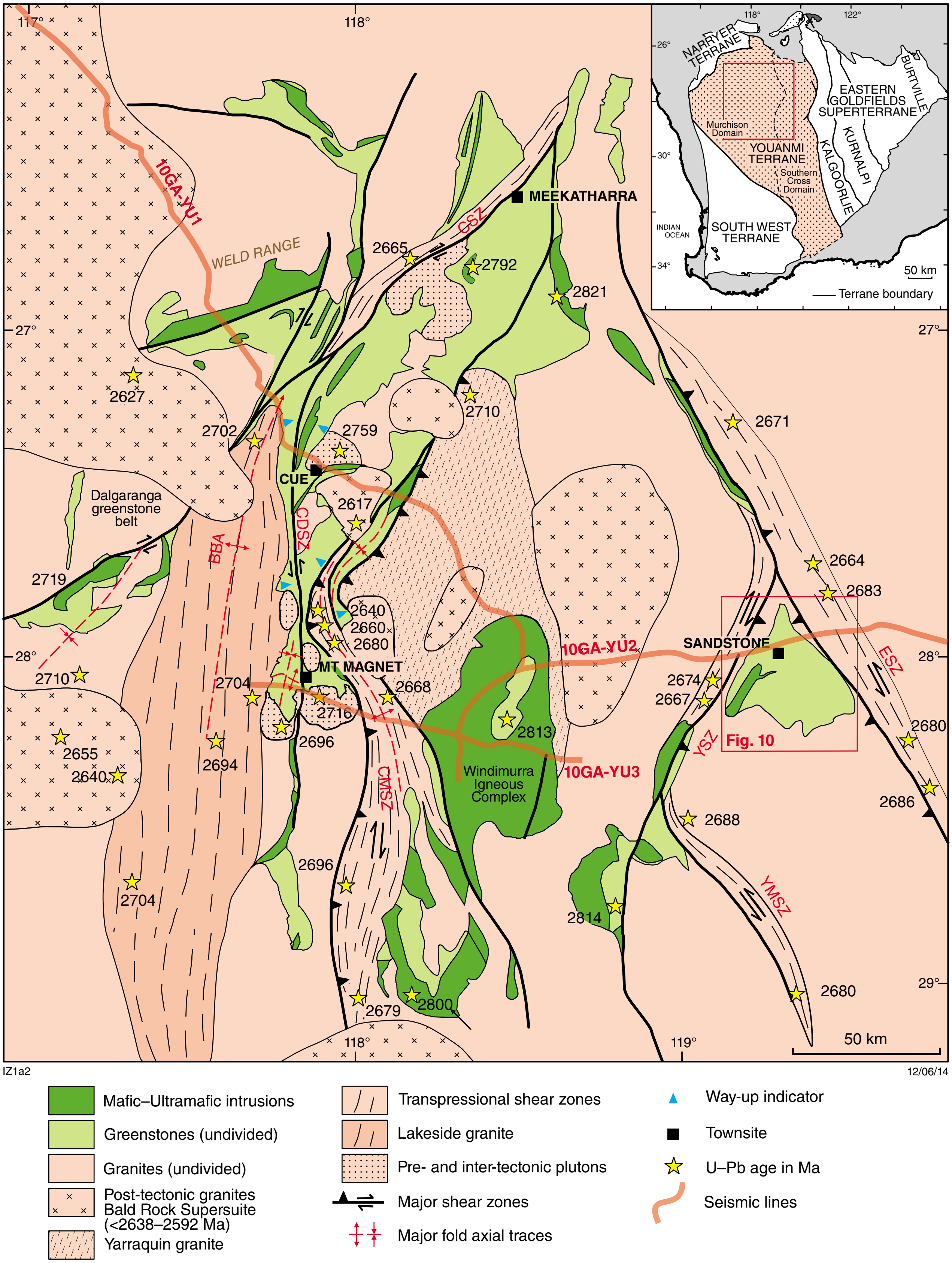


Figure 5. **Simplified geological map of northern Youanmi Terrane. BBA: Big Bell anticline; CMSZ: Cundimurra Shear Zone; CDSZ: Cuddingwarra Shear Zone; CSZ: Chunderloo Shear Zone. ESZ: Edale Shear Zone; YSZ: Youanmi Shear Zone; YMSZ: Yuinmery Shear Zone. Modified from Zibra (2012)**

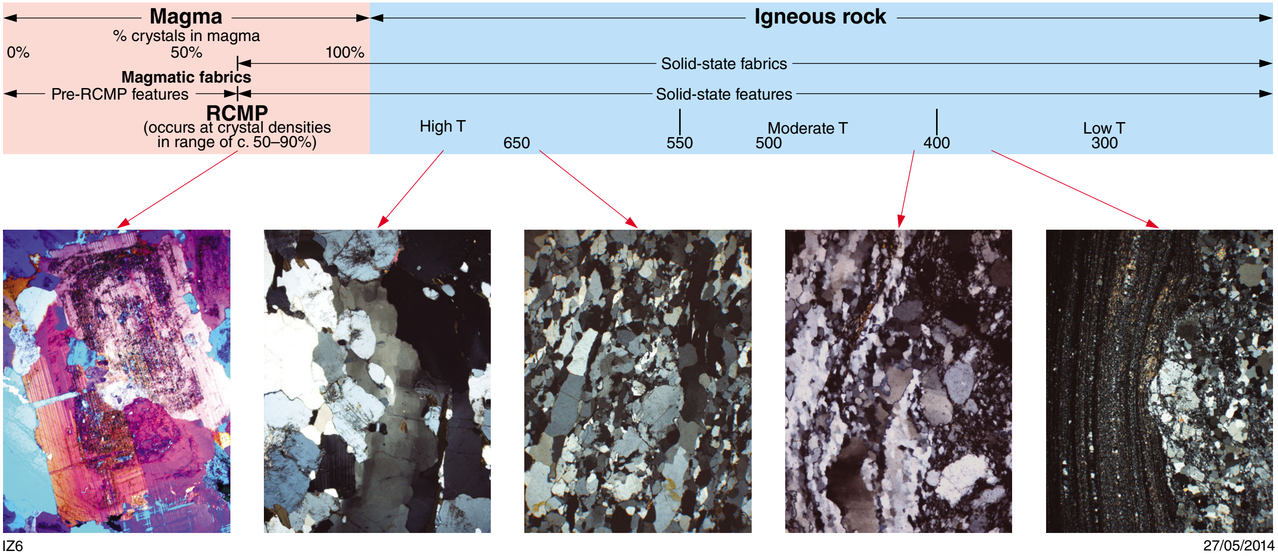


Figure 6. Summary of the wide range of microstructures preserved in the Cundimurra Granite, testifying that deformation started during pluton crystallization and continued during cooling down to greenschist facies temperatures

Excursion localities

Localities 1.1 – 1.5 by Pawley, MJ

Locality 1.1: Poison Creek

From Kalgoorlie, drive north to Leonora on the Goldfields Highway, turn left onto the Old Agnew Road about 9 km north of Leonora, and follow the formed road for about 90 km to Poison Creek. Turn to the left (west) 200 m north of the creek and follow the small track to a large platform on the north bank of the creek (MGA Zone 51 273412E 6872754N).

This location provides an example of the complex magmatic and structural relationships recorded in some of the granites of the Yilgarn Craton. The granites at this site have not been dated but, based on comparisons with similar granite complexes, they are interpreted to include 2675–2665 Ma phases of the high-Ca granite type (i.e. the main host granite), and c. 2640 Ma dykes and sills of the low-Ca granite types (Blewett and Czarnota, 2007). Regionally, this site is located on the east limb of the Lawlers Anticline (Figs 1 and 7), with the main fabric striking north-northwesterly, parallel to the fold limb. According to the scheme proposed by Blewett et al. (2010), this pervasive foliation is interpreted to have developed during D_3 extensional doming. However, extensional kinematics has not been recognized at this site (Blewett and Czarnota, 2007).

The dominant phase at the outcrop is medium- to coarse-grained, pale grey metatonalite, which has a moderately developed north-northwesterly trending solid-state fabric that dips to the east-southeast. This fabric was interpreted to belong to the D_3 extensional doming event at c. 2665 Ma, similar to the deformation recorded at the Sunrise Birthday pit (Blewett and Czarnota, 2007). The metatonalite has been cut by several generations of granite sheets and later fractures. A key point of this outcrop is that there are many subparallel leucosomes, which could be interpreted to have formed during the same event. Crosscutting relations can be used to unravel the magmatic and structural history of the outcrop to show several episodes of magma injection and deformation:

1. The first generation includes north-northwesterly trending, layer-parallel leucosomes, typically on a centimetre scale, which give the rock a layered appearance. There are also scattered sheets of fine- to medium-grained, pale blue tonalite, up to 40 cm wide, which are also parallel to the solid-state foliation.

2. The north-northwesterly trending units are cut by northeasterly trending, fine-grained, blue-grey granitic sheets that are up to 20 cm wide (Fig. 8). Some of the thinner sheets are sinuous, with fine-scale lobate margins that suggest they were injected into a ‘soft’, incompletely crystalline host (Fig. 9). Furthermore, the veins locally appear to follow the boundaries of grains in the host rock, also suggesting that there was a melt phase still present in the host. Overall, these features do not indicate cracking and fracturing of a solid rock and it is possible that these sheets were injected when the rock still contained a melt component.

3. There is a series of northerly trending, fine-grained leucocratic veins with sharp, straight margins which cut the oblique blue-grey sheets.

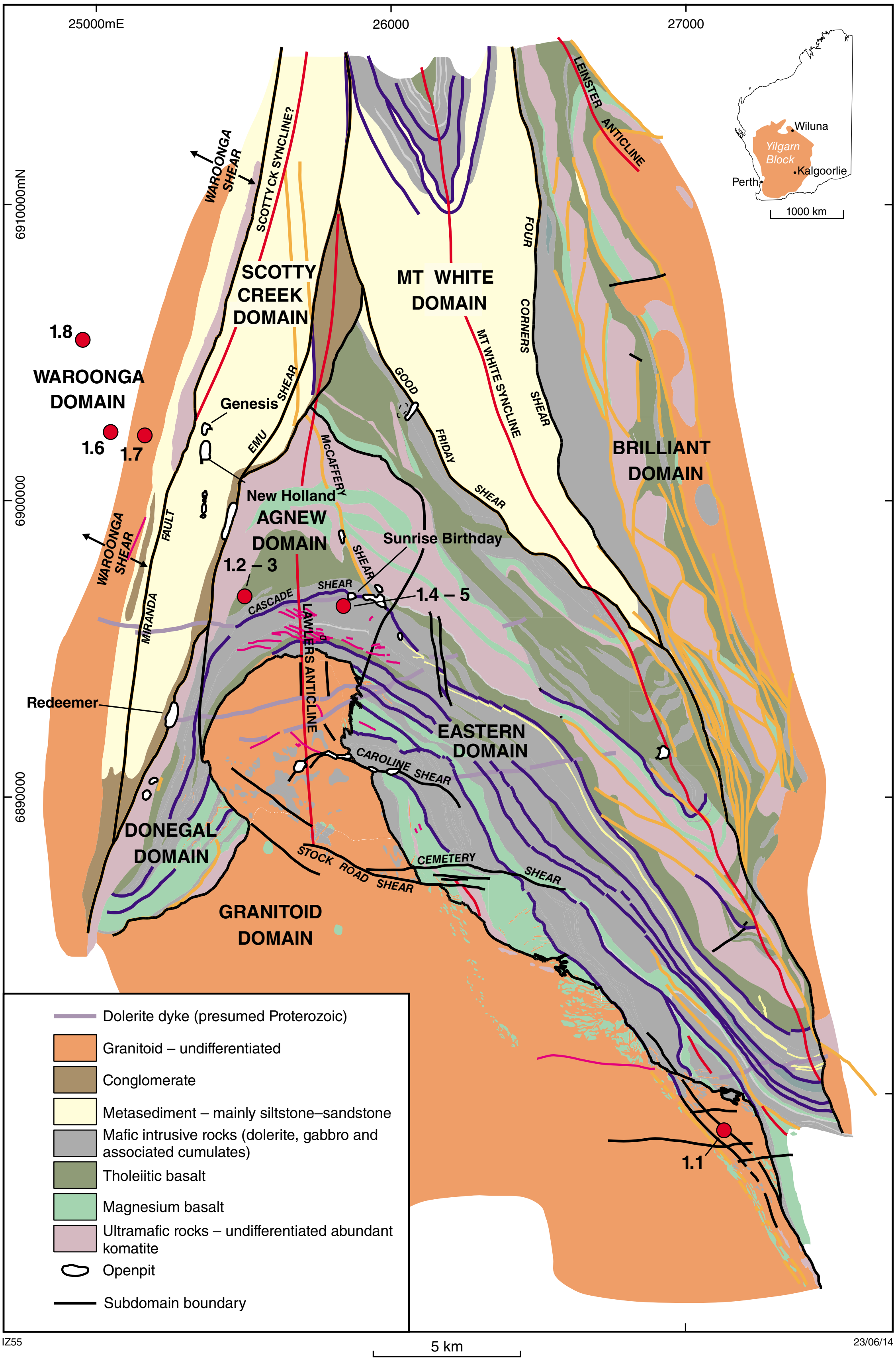
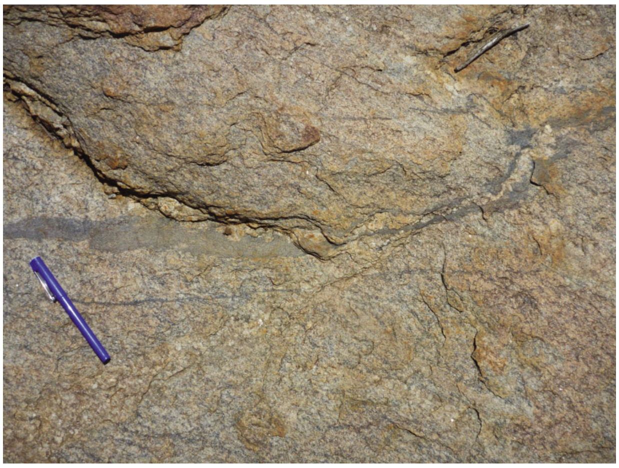


Figure 7. **Interpreted geology of the Lawlers region showing structural subdomains and excursion localities. After Beardsmore (2002)**

IZ37 10/03/14

Figure 8. Northeasterly trending, fine-grained, blue–grey granitic sheets cutting the main fabric in the host layered granitic gneiss



IZ38 10/03/14

Figure 9. A thin, sinuous granitic sheet with fine-scale lobate margins suggesting low-viscosity contrast during dyke emplacement

4. The northerly trending leucocratic veins are cut by northwesterly trending sinistral shear zones. These shear zones are very fine grained and appear to be rich in biotite.
5. Sinuous northerly trending pegmatite veins cut the sinistral shear zones. There are also scattered, metre-scale pods of pegmatite that are texturally similar to the pegmatite veins.
6. A late, easterly trending fracture set overprints all other structures described above.

The structural and magmatic elements at the outcrop can be grouped into two phases of deformation. There is an early phase, attributed to extensional doming during regional D_3, which resulted in the pervasive solid-state foliation, parallel leucosomes and granodiorite sheets, and the oblique, sinuous blue-grey granitic sheets (i.e. features 1, 2 above; Blewett and Czarnota, 2007). This was overprinted by features 3–6, which were interpreted to have formed during regional D_4 east–west shortening (Blewett and Czarnota, 2007).

Locality 1.2: Lawlers stratigraphy

Return to the Old Agnew Road and head north for about 33.5 km, passing through Lawlers. Stop on the side of the road (MGA Zone 51 254813E 6896932N).

Two of the main greenstone units in the Agnew–Lawlers area will be examined at this locality, namely the mafic Never Can Tell Formation and the Agnew Komatiite. These formations are interpreted to represent time equivalents of the Lunnon Basalt and Kambalda Komatiite in the Kalgoorlie region to the south. The rocks at this location are exposed along the Lawlers Anticline, where deformation features are variably developed. Particularly in the case of the mafic unit, deformation is attributable to folding and doming rather than strike-slip shearing.

Locality 1.2a: Basalts of the Never Can Tell Formation

From the vehicle, walk about 150 m up the hill to the southeast to some low rubble outcrop (MGA Zone 51 254942E 6896842E.

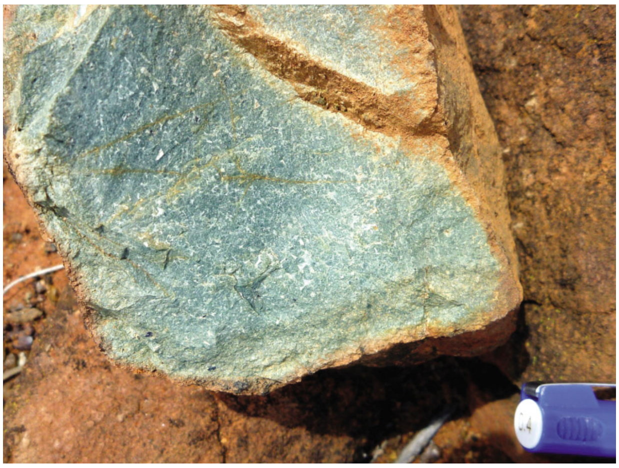
The Never Can Tell Formation (previously known locally as the ‘Lawlers Basalt’) is the tholeiitic mafic volcanic unit that underlies the Agnew Komatiite. It is at the same stratigraphic level as the Lunnon Basalt at Kalgoorlie and Kambalda, although Barnes et al. (2007) found that these two units were geochemically distinct. This formation probably represents several distinct plume-related magma batches (batches with variable degrees of fractionation or crustal contamination), rising through the crust at the same time. At this locality, the Never Can Tell Formation has a poddy outcrop style that is interpreted to represent remnant pillow structures rather than laterally continuous lava flows. The rocks contain scattered flattened amygdales and irregular cavities that may represent primary volcanic features, such as intra-pillow breccias.

The dominant structural element in the area is a stretching lineation defined by rodding of the outcrop, which plunges shallowly to the north. At one place (MGA Zone 51 254942E 6896859N), the pillow forms seem to outline a bedding plane that is cut at a high, oblique angle by a weak fracture foliation.

Locality 1.2b: Cumulate rocks of the Agnew Komatiite

Walk back to the vehicle and continue up the western slope for about 40 m to some low rubble outcrop (MGA Zone 51 254793E 6896963N).

The Agnew Komatiite is a prominent unit that outlines the Lawlers Anticline and Mount White Syncline. The unit varies considerably in thickness along strike, being thickest in the hinge and along the eastern limb of the Lawlers Anticline, and thinner along the western limb. However, it is unclear if this is a primary feature or if it is the result of deformation, with the western limb attenuated and thinned against the Emu Fault. The Agnew Komatiite shows olivine-spinifex textured and cumulate components that typically form a ridge capped by silcrete. At this locality, the komatiite consists of blocky outcrop of relatively massive, medium-grained, equigranular, cumulate ultramafic rock. Despite extensive carbonate and serpentinite alteration, primary textures can still be recognized. For example, remnants of the intercumulus phases can still be recognized on fresh surfaces indicating mesocumulate to orthocumulate textures (Fig. 10). The rock is relatively competent and contains a locally developed, northerly trending fracture pattern, aligned subparallel to the axial plane of the Lawlers Anticline.



IZ39 10/03/14

Figure 10. Fresh surface from a hand sample of the Agnew Komatiite showing mesocumulate to orthocumulate textures

Locality 1.3: Lawlers lookout

Return to the vehicle and continue to the north for about 1.8 km, turning right (east) onto a track (MGA Zone 51 255735E 6898543N). Follow this track south about 750 m, park (MGA Zone 51 255761E 6897768N), and walk about 200 m to the lookout (MGA Zone 51 255871E 6897664N).

This locality lies near the hinge of the Lawlers Anticline. It gives a sense of the regional structural setting and provides a view of the distribution of the major gold deposits. The lookout is located on a siliceous cap that overlies the Agnew Komatiite. The low hills immediately to the south of the cap are composed of basalts of the Never Can Tell Formation, which were visited at the previous locality.

Farther south, and to the southeast, a series of intrusive mafic sills and layered complexes form the prominent, dark brown ridges. One of these units, the Wildcat Gabbro, is host to significant gold mineralization, particularly in the vicinity of the layer-parallel Cascade Shear Zone, which is interpreted as a D_3, syn-doming structure (Blewett and Czarnota, 2007: this will be visited at locality 1.4). For example, the Wildcat deposit is located at the intersection of the Cascade Shear Zone and northwesterly trending faults; the Sunrise Birthday deposit at the bifurcation of the Cascade Shear Zone, and the Mark Twain deposit is hosted by the Cascade Shear Zone where deformation is locally partitioned into a thin shale unit at the upper boundary of the Wildcat Gabbro of Beardsmore (2002).

The flats to the south overlie the core of the anticline/dome, which is composed of numerous granite phases. These include the Lawlers Tonalite, which is dated at c. 2666 Ma (Dunphy et al., 2003) and intrudes the hinge of the anticline. It is interpreted to have been emplaced syntectonically, constraining doming and the Cascade Shear Zone at c. 2666 Ma (Dunphy et al., 2003). The tonalite hosts gold mineralization, with the Lawlers and Great Eastern deposits controlled by the east-southeasterly trending brittle–ductile Caroline Shear Zone of Beardsmore (2002).

To the west, the Emu Fault and adjacent associated minor structures form a north-northeasterly trending corridor that hosts significant gold mineralization. The Emu Fault is a major structure marking the boundary between the greenstones of the Lawlers Anticline to the east, and the volcaniclastic–siliciclastic rocks of the Scotty Creek Syncline to the west.

To the southwest, the Cox Crusader and Deliver deposits are hosted by sheared greenstones of the Agnew Komatiite and the Never Can Tell Formation, and the Redeemer deposit is hosted by mafic and ultramafic conglomerates of the Claudius Formation (locally known as the Mine Conglomerate, Broome et al. [1998]). Mineralization at Redeemer is associated with D_5 dextral shearing, and has been dated at c. 2638 Ma (Blewett and Czarnota, 2007).

To the northwest, the Waroonga (Emu) deposit is controlled by a flexure in the Emu Fault, and hosted by the Claudius Formation and the marginal rocks of the Scotty Creek Formation (Beardsmore, 2002).

Farther to the northwest, the Genesis and New Holland deposits are hosted by metasedimentary rocks of the Scotty Creek Formation. Deformation in the New Holland deposit is strongly controlled by the rheological behaviour of the different lithologies, which in turn affects the distribution of gold mineralization (Broome et al., 1998). The siltstone units are characterized by ductile deformation, resulting in a pervasive, steep, solid-state foliation. In contrast, brittle deformation in the more competent coarse- to medium-grained sandstone units results in a series of discrete, low-displacement faults (that promoted permeability) and veins. The gold is hosted by a series of shallowly dipping tension veins that were interpreted to have formed during regional D_{4a}, when east–west shortening led to inversion of the basin containing the Scotty Creek Formation and reverse faulting (Broome et al., 1998; Blewett and Czarnota, 2007).

Locality 1.4: Sunrise Birthday

Locality 1.4a: Regional north-dipping foliation

This locality has rubble outcrop of medium-grained gabbro, which has two variably developed structural elements. There is a weak solid-state foliation that dips to the north at a moderate angle, and a weak to moderately developed down-dip lineation. Both of these elements are apparent in the broad tabular outcrop pattern.

Locality 1.4b: Extensional shear zone in the Sunrise Birthday pit

Access to Sunrise Birthday is via the haul road some 8 km from the main Barrick office at New Holland.

The Sunrise Birthday deposit is hosted by gabbros of the Wildcat Gabbro (terminology of Beardsmore, 2002) and komatiitic basalts, with mineralization predominantly occurring in a series of quartz veins within chlorite-rich, silica-saturated zones of the east-trending Cascade Shear Zone (Beardsmore, 2002). The veins are very thin at the surface and are up to 10 m wide at depth, with a well-developed pinch-and-swell structure. Minor mineralization occurs in the intensely foliated talc-chlorite schist, which is associated with chlorite, carbonate and pyrite alteration (Beardsmore, 2002). The deposit was worked during three main periods: 1899–1902; 1905–1917; and 1995–1996, for a total of 34 421 oz of gold at an average grade of 4.19 g/t Au (Beardsmore, 2002). Blewett and Czarnota (2007) recognized a lithological control on strain in the area. The komatiitic basalt units underwent ductile deformation, resulting in the well-developed foliation and amphibole mineral lineation, whereas the massive gabbros were relatively competent and mainly recorded brittle failure, associated with the emplacement of carbonate–amphibole veins (Blewett and Czarnota, 2007).

The north-dipping foliation that was seen in the nearby outcrop is exposed in the west wall of the pit. The ductile foliation is variably developed, with greater strain partitioned into two main zones. These correspond to two strands of the Cascade Shear Zone, which bifurcates in the Sunrise Birthday pit. The Cascade Shear Zone has been interpreted as a north-dipping extensional structure that formed during granite emplacement and doming during regional D_3 deformation (Blewett and Czarnota, 2007). The northern strand of the Cascade Shear Zone is most obvious in the west wall of the pit, forming a broad curviplanar zone characterized by considerable variation in the foliation dip, ranging from steep to shallow dipping. The foliation within the shear zone forms a sigmoidal pattern, analogous to C–S fabric, with the asymmetry indicating a top to the north, or extensional, sense of shear. In the lower part of the pit wall, the shear zone appears to contain a large, equant block of material, characterized by Fe-staining and more blocky outcrop, which is probably a more massive remnant of the protolith. This block appears to be enveloped by the sigmoidal foliation, and has geometry similar to σ–porphyroclast in mylonites. Small-scale structures, also indicating top to the north, or extensional, sense of shear, have been observed within the pit. These include S–C fabric and C' shear bands, with well-developed slickensides in the gabbro (Blewett and Czarnota 2007).

The extensional shear zone is overprinted by two phases of brittle deformation (fig. 27, Blewett and Czarnota, 2007). The crosscutting relationship between these two events is unclear at this locality, but they have been assigned to regional deformation events, based on the stress regime (Blewett and Czarnota, 2007). The first is expressed as a series of north-northeasterly trending sinistral and easterly trending dextral carbonate–amphibole veins that formed under northwest–southeast transpression, interpreted to be the regional D_{4b} event. The second is expressed as north-northeasterly trending carbonate-filled dextral faults (fig 26g,h, Blewett and Czarnota, 2007), with these structures interpreted to have formed during the regional D_5 deformation.

Locality 1.5: Agnew stratigraphy and shearing

Leave Leinster and return to the Goldfields Highway. Turn right (north) for 150 m and then turn left (west) onto the Sandstone Road. Continue along the Sandstone Road for 23.5 km, and turn left (south) onto a track (MGA Zone 51 252305E 6902892N). Drive to the southwest along an old track for about 1.3 km and park (MGA Zone 51 252941E 6901848N).

This series of localities includes the package of east-facing supracrustal rocks on the western limb of the Scotty Creek Syncline. This interpretation is based on the order of the rock units, and comparison with those to the east in the Agnew area. The precise position of the Scotty Creek Syncline axis is difficult to pinpoint, largely due to the poor outcrop, although Beardsmore (2002) suggests the axis has been disrupted by the Miranda Shear Zone during deformation within the syncline. This has resulted in a much thinner, attenuated western limb of the Scotty Creek Syncline. These localities will also show the result of increasing deformation westwards towards the Waroonga Shear Zone, which is a major dextral strike-slip shear zone that has been interpreted as the boundary between the Eastern Goldfields Superterrane and the Youanmi Terrane (Cassidy et al., 2006).

Locality 1.5a: Scotty Creek Formation with discrete oblique shear zones

Walk about 400 m to the southeast to a large area of outcrop near a creek (MGA Zone 51 253285E 6901664N).

This area comprises fresh, bouldery outcrop of very thinly to thickly bedded (1–30 cm) quartz-rich, coarse- to medium-grained, well-sorted sandstone of the Scotty Creek Formation. Locally, the sandstones contain scattered, rounded, spherical clasts of massive granite, up to 10 cm in diameter but typically granule size. The rocks are mainly undeformed, although there are scattered east-northeasterly trending quartz veins and fractures that cut bedding at a high angle. Near the eastern edge of the outcrop, bedding is cut at a moderate angle by a localized, northwesterly trending, and anastomosing high-strain zone. The foliation in the high-strain zone is locally deflected against bedding and, in one spot, a second foliation (which dips shallowly to the north) can be seen, although the nature of this second foliation is unclear. Locally preserved cross-bedding indicates younging to the west. The sheared-out hinge of the Scotty Creek Syncline is interpreted to lie just to the west.

Locality 1.5b: Sheared Scotty Creek Formation

Walk about 120 m to the northwest, to a large area of low rubbly outcrop (MGA Zone 51 253216E 6901763E).

The sedimentary rocks of the Scotty Creek Formation are pervasively deformed here. The large area of weathered and rubbly, coarse- to medium-grained, well-sorted sandstone has no obvious bedding or variation in grain size. The rocks have a pervasive, moderately to strongly developed, northerly trending solid-state foliation that is subvertical. There is also a weak to moderate stretching lineation defined by rodding of the outcrop.

Locality 1.5c: Sheared Claudius Formation

Walk about 180 m to the west-northwest to a small area of low rubbly outcrop (MGA Zone 51 253047E 6901822N).

The rocks here include a strongly foliated conglomerate, with centimetre-scale clasts of granite and mafic rock in a mafic groundmass. The conglomerates show a well-developed, northerly trending, subvertical solid-state foliation that has locally developed C–S relationships that indicate a dextral sense of shear. Lineations are difficult to find so the transport direction is unclear. Based on the subhorizontal lineations in the surrounding rocks, it is likely to be strike–slip. This unit, known locally as the Mine Conglomerate, is interpreted to be the sheared equivalent of the Claudius Formation, which comprises several conglomeratic and finer grained facies. The different facies are variously dominated by mafic, ultramafic, felsic volcanic and granite clasts, and appear to reflect the exhumation and erosion of the rocks on the western limb of the Lawlers Anticline. This unit is economically significant as it hosts the Waroonga (Emu) and Redeemer deposits on the east limb of the Scotty Creek Syncline (Broome et al., 1998; Beardsmore, 2002).

Locality 1.5d: Agnew Komatiite

Walk about 100 m to the west-northwest to a small area of low rubbly outcrop (MGA Zone 51 252948E 6901842N).

Ultramafic rocks at this locality are brown, massive, medium-grained and equigranular rock and preserve a remnant cumulate texture. The rock is interpreted as a serpentinized ultramafic cumulate of the Agnew Komatiite (locality 1.2b) as it occurs at the same stratigraphic level. This unit is relatively undeformed, in contrast with the high strain recorded by the surrounding rocks.

Locality 1.5e: Sheared Never Can Tell Formation

Walk about 200 m to the west to a small area of low rubbly outcrop (MGA Zone 51 252749E 6901832N).

The low, rubbly outcrop in this area is likely a mafic schist as it is very fine grained, contains no quartz, and weathers to an ochre-brown colour (suggesting it is Fe-rich). The rock has a strong, northerly trending schistosity that is subvertical so that the dip varies from east to west. A weak to moderate stretching lineation is defined by rodding of the outcrop. This unit could be the equivalent of the Never Can Tell Formation (locality 1.2a) as it lies stratigraphically below the ultramafic unit.

Return to the Sandstone Road and turn left (west).

The Waroonga Shear Zone

by Zibra, I

The Waroonga Shear Zone is an arcuate, northerly trending zone (about 100 km long and 7–15 km wide) of strongly deformed granitic gneiss, exposed along the western side of the Agnew greenstone belt (Platt et al., 1978). The Waroonga Shear Zone is clearly visible on aeromagnetic images and, although mostly poorly exposed, there is relatively good outcrop in the region west of the New Holland openpit, just south of the Agnew–Sandstone road. Here, the Waroonga Shear Zone comprises strongly deformed gneissic granodiorite and granite, which contain thin discontinuous zones of mafic gneisses (at least in part preserving remnants of greenstone packages), and both concordant and discordant granitic dykes and pegmatites. The new seismic data (Wyche et al., 2013) indicate that the Waroonga Shear Zone, which is steeply west-dipping in the field, has listric geometry and flattens out at about 10 km depth. It appears to truncate steeply east-dipping older structures. In the east, the Waroonga Shear Zone deforms the Scotty Creek Formation, which is unconformable on the Agnew greenstone belt (Beardsmore, 2002). Coarse beds from the Scotty Creek sequence near the New Holland deposit host detrital zircons that provided a maximum depositional age for the sandstone of 2664 ± 5 Ma, with inherited zircon population ages of c. 2700–2690 Ma and c. 2820–2810 Ma (SHRIMP U–Pb, Dunphy et al., 2003). On the western side, the Waroonga Shear Zone is intruded by titanite–biotite granodiorite dated at 2655 ± 4 Ma (SHRIMP U–Pb on zircon; Dunphy et al., 2003).

Locality 1.6: High-temperature granitic gneiss

From the Agnew–Sandstone road, turn south (MGA Zone 51 249252E 6903779N) into a small track. Drive south for 1 km and then stop at the junction with an easterly *trending track parallel to a fence line (MGA Zone 51 249294E 6902765N).*

In this area, biotite-rich granodiorite gneisses are generally deeply weathered, but the sheared leucogranitic dykes are commonly fresh and better exposed. Here the main gneissic fabric is evident in some sheared, metre-thick leucogranitic dykes with boundaries subparallel to the north-northeasterly trending, steeply west-dipping gneissic foliation. A pronounced, subhorizontal stretching and mineral lineation is evident on the exposed foliation surface. On horizontal rock exposures, the prevailing dextral shear sense is indicated by S–C fabric, C' shear bands and mantled porphyroclasts (Fig. 11). Microstructures indicate that the main fabric visible here developed at high temperature (>650°C), while some residual melt was still present in the deforming metagranite (Fig. 12). A geochronology sample has been collected near this locality, within large amphibolite xenoliths included in the Waroonga gneiss. The selected sample is a clinopyroxene–plagioclase–quartz leucosome interpreted to represent syndeformational partial melting of amphibolite, which likely occurred during pluton emplacement. This geochronology datum will therefore provide the age of the main shearing event along the Waroonga Shear Zone.

IZ40 10/03/14

Figure 11. Subhorizontal pavement showing the typical outcrop-scale appearance of the Waroonga gneiss, with steeply west-dipping, northerly trending gneissic foliation overprinting intrusive contacts between leucogranitic veins and host granodiorite. Shear band boudins and mantled porphyroclasts point to dextral shear sense.

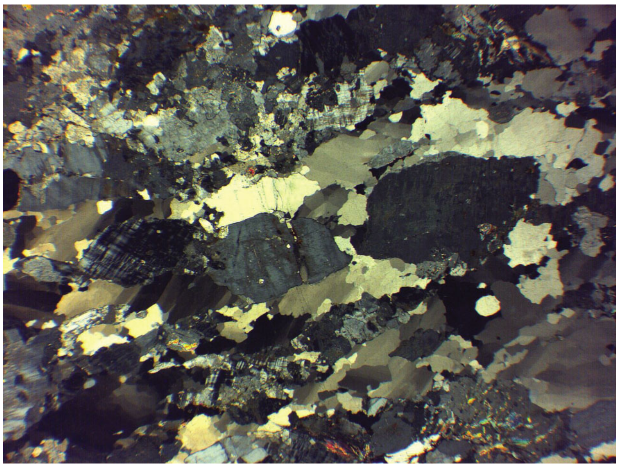


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Figure 12. Typical microstructure from locality 1.6 showing quartz deformation in the high-quartz field (T> ~650°C) and coarse-grained K-feldspar recrystallization. The occurrence of magmatic microfractures suggests melt-present deformation. Crossed polars, base of photo 7 mm

Locality 1.7: Retrograde structures in the Waroonga Shear Zone

From locality A.1, drive back to the Agnew–Sandstone road, turn east and proceed for 2.3 km towards Agnew, and turn south (MGA Zone 51 251395E 6902840N). Follow the track southward, for about 1.5 km, until reaching the breakaway. Walk down the scarp and follow it eastward, for about 1 km (MGA Zone 51 252468E 6901385N).

The granitic gneisses exposed here along the breakaway scarp are generally deeply weathered but, in several domains, the outcrop-scale structural elements are still preserved, with foliation and lineation showing orientation analogous to locality 1.6, together with the prevailing dextral shear sense. Several pegmatites and aplites intrude at a low angle to the main foliation and are sheared together with the host metagranite. These dykes are typically fresh, offering a good chance for sampling (Fig. 13a). Preliminary microstructural investigations (including quartz crystallographic preferred orientation fabric) indicate that the main fabric here developed at relatively high temperature (>~500°C, Fig. 13b), but at a clearly lower temperature than the fabric observed at locality 1.6.

Locality 1.7a

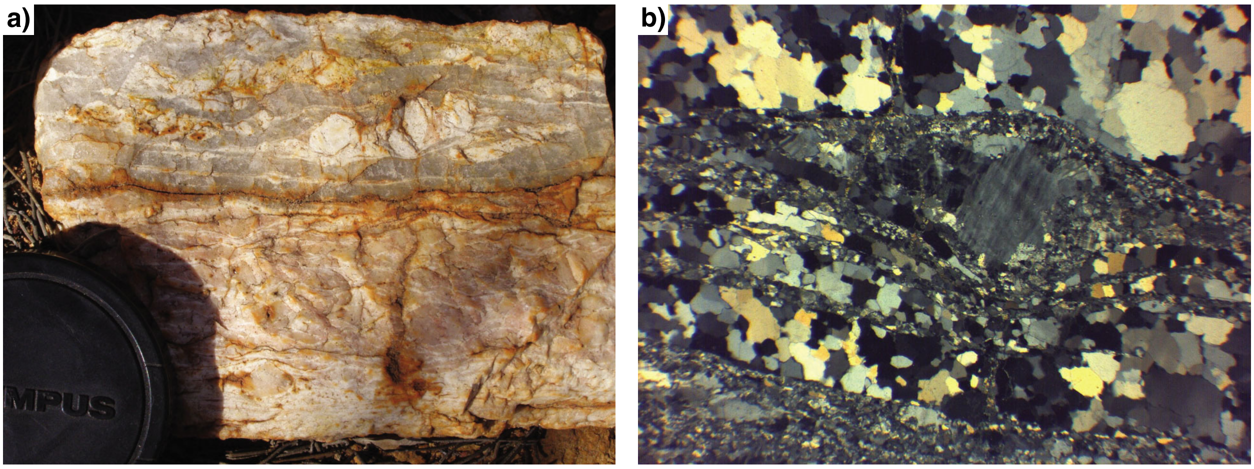
Walk east for about 500 m to the bed of a small creek (MGA Zone 51 842447E 6899021N).

In the creek bed, a sheared sequence of equigranular granite and leucocratic, garnet-bearing felsic veins show a steep, northerly trending mylonitic foliation associated with a subhorizontal stretching lineation, analogous to that seen in the previous outcrops.

Locality 1.7b

After crossing the creek, head towards the small white hill that coincides with the exposure of a north-northeasterly trending, plurimetric quartz vein (MGA Zone 51 842619E 6899047N).

On top of the hill, the outcrop shows that the anastomosing quartz vein was injected into brown-weathered, fine-grained and quartz-rich mica schists (Fig. 14a), representing a sheared sandstone–siltstone sequence



IZ42 11/12/13

Figure 13. Sheared pegmatite within the eastern margin of the Waroonga Shear Zone: a) mantled porphyroclasts and domino-type fragmented plagioclase porphyroclasts indicate dextral shear sense; b) sample from outcrop shown in Figure 13a, showing high-temperature quartz and finer grained feldspar recrystallization. Mantled K-feldspar porphyroclasts indicates dextral shear sense. Crossed polars, base of photo 5 mm

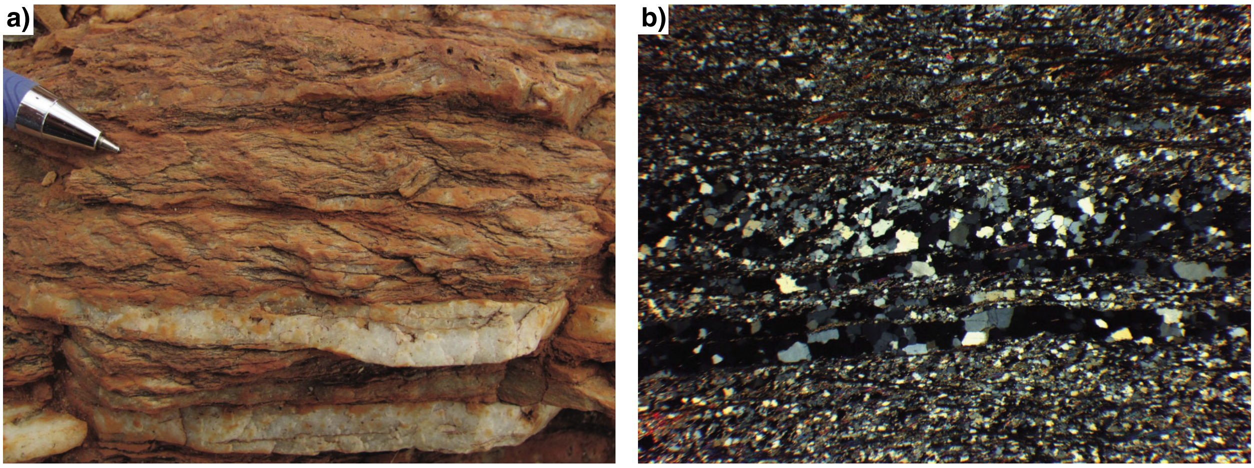


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Figure 14. Quartz-rich mica schist injected by anastomosing quartz veins: a) shear bands indicate dextral shear sense; b) microstructure from quartz mica schists showing S–C fabric defined by aligned white mica flakes and oblique foliation in quartz aggregates. This fabric is deflected by C' shear bands. Crossed polars, base of photo 5 mm

belonging to the Scotty Creek Formation. At this locality the steep north-northeasterly trending foliation (200°/60°) bears a shallow northerly plunging mineral lineation (18°/350°).

Locality 1.8: Post-kinematic granite

Stop on the side of the road (MGA Zone 51 234455E 6902937N) and walk 30 m to south, where there is a large platform and boulders.

The rocks in this area are massive, porphyritic and equigranular monzogranite. The monzogranite contains centimetre-scale, equant to elongate, euhedral feldspars in a coarse- to medium-grained groundmass of euhedral feldspars, irregular quartz, and scattered fine-grained biotite (Fig. 15). The platform is cut by a series of 060º-trending pegmatite veins that are up to 20 cm wide. This granite is interpreted to belong to the widespread low-Ca granite group that was generated by recycling of the mid-crust during the late-orogenic stages. A geochronology sample collected at this locality provided an emplacement age of 2655 ± 4 Ma (SHRIMP U–Pb on zircon; Dunphy et al., 2003). Unlike the granites to the east, this granite is massive and does not show any evidence for pervasive magmatic or ductile solid-state deformation. Instead, the platform is cut by a series of 175º-trending joints, which represent a brittle style of deformation. These joints appear to be refracted across pegmatite veins to form slightly oblique splays.

Figure 15. Equigranular monzogranite with weak northerly trending magmatic foliation, intruded by northeasterly trending pegmatite and cut by northerly trending joints

The Edale Shear Zone

The Edale Shear Zone (ESZ, Figs 4, 5), as defined by (Stewart et al., 1983) is a northwesterly trending, steeply dipping structure developed along the eastern margin of the Sandstone greenstone belt (Fig. 5). This structure is part of a ~400 km long, craton-scale deformation zone that extends from Meekatharra down to west of Menzies. On a larger scale, this structure belongs to the shear zone network of Figure 4. The Edale Shear Zone includes several domains showing different deformation styles and geometry, mainly represented by northwesterly trending, sinistral and northeasterly trending dextral shear zones, linked by zones dominated by coaxial vertical flattening (Eisenlohr et al., 1993; Chen et al., 2001). Zones dominated by simple shear deformation are generally associated with a prominent subhorizontal mineral and stretching lineation and structures with monoclinic symmetry on horizontal pavements. In contrast, zones dominated by pure shear generally lack a well-developed linear fabric and include structural elements with orthorhombic symmetry. A sheared granodiorite sampled some 25 km south-southeast of Sandstone provides a maximum age of 2686 ± 5 Ma for shear zone activity in this area (Nelson, 2004). Other samples collected along this deformation zone provided emplacement ages between c. 2660 and 2680 Ma, being largely coeval with the Cundimurra Granite.

Locality 2.1

Stop on the southern side of the Agnew–Sandstone road (MGA Zone 50 737839E 6904838N) and walk south for a few tens of metres, to the fence line. Here, wide pavements and large boulders offer a good opportunity to examine the three-dimensional features of the Edale Shear Zone.

The main rock type at this locality is represented by granitic gneiss derived from porphyritic granite, as suggested by the widespread occurrence of subhedral to rounded K-feldspar porphyroclasts up to 5 cm in size. These fresh porphyroclasts are readily visible on weathered surfaces and are embedded in a finer grained matrix represented by largely recrystallized plagioclase, quartz and biotite aggregates (Fig. 16a). Some decimetre-sized, fine-grained layers subparallel to the main foliation and devoid of large K-feldspar porphyroclasts likely represent sheared microgranite dykes previously injected into the host porphyritic granite (Fig. 16b).

The main north-northwesterly trending gneissic foliation is steeply east-dipping (335º/80º). Despite the reasonably good rock exposure, a well-defined lineation cannot be easily detected on subvertical exposures. Observations from a polished hand sample cut parallel to the gneissic foliation show that, despite the fact that the orientation of feldspar subhedral porphyroclasts is quite scattered on foliation planes, a weak subhorizontal mineral lineation is defined by the preferential alignment of plagioclase and K-feldspar grains. On subhorizontal rock exposures, K-feldspar mantled porphyroclasts mainly indicate sinistral shear sense (Fig. 16a), but structures with opposite symmetry occur as well in a few domains (Fig. 16a). On vertical exposures, S–C fabrics suggest west-side-up sense of shear. In summary, the observed geometry suggests that a significant component of coaxial shearing accompanied the main sinistral non-coaxial shearing event. Eisenlohr et al. (1993) report that the Edale Shear Zone is a non-coaxial-flow-dominated shear zone flanked by a domain characterized by dominantly coaxial flow. Therefore, the fabric observed at this locality could represent the end product resulting from overprint which in turn resulted from switching or progressive rotation of finite strain axes (Fossen and Tikoff, 1998; Dewey at al., 1998) during the Neoarchean transpressional event.

Microstructural observations indicate that a marked grain size reduction has been achieved through a nearly complete quartz recrystallization and 'low plasticity' deformation in feldspars (Tullis and Yund, 1987), where deformation has been accommodated through microfracturing joined with fine-grained albite-rich neo-crystallization (Fig. 16c). Synkinematic biotite and muscovite flakes locally wrap around feldspar porphyroclasts. Taken together, these microstructures indicate that the main foliation developed at conditions near the greenschist–amphibolite facies transition. However, quartz aggregates in strain-shadow domains locally retain microstructures indicative of higher temperature deformation, suggesting that the Edale Shear Zone might have a retrograde character, with an earlier higher temperature stage. Eisenlohr et al. (1993) describe mylonites in the Edale Shear Zone as consistently overprinting an earlier, coarser grained gneissic fabric.

Locality 2.2: The Gilberts Grave dome

The Gilberts Grave dome is located near the southern margin of the Sandstone greenstone belt (Figs 1 and 4).

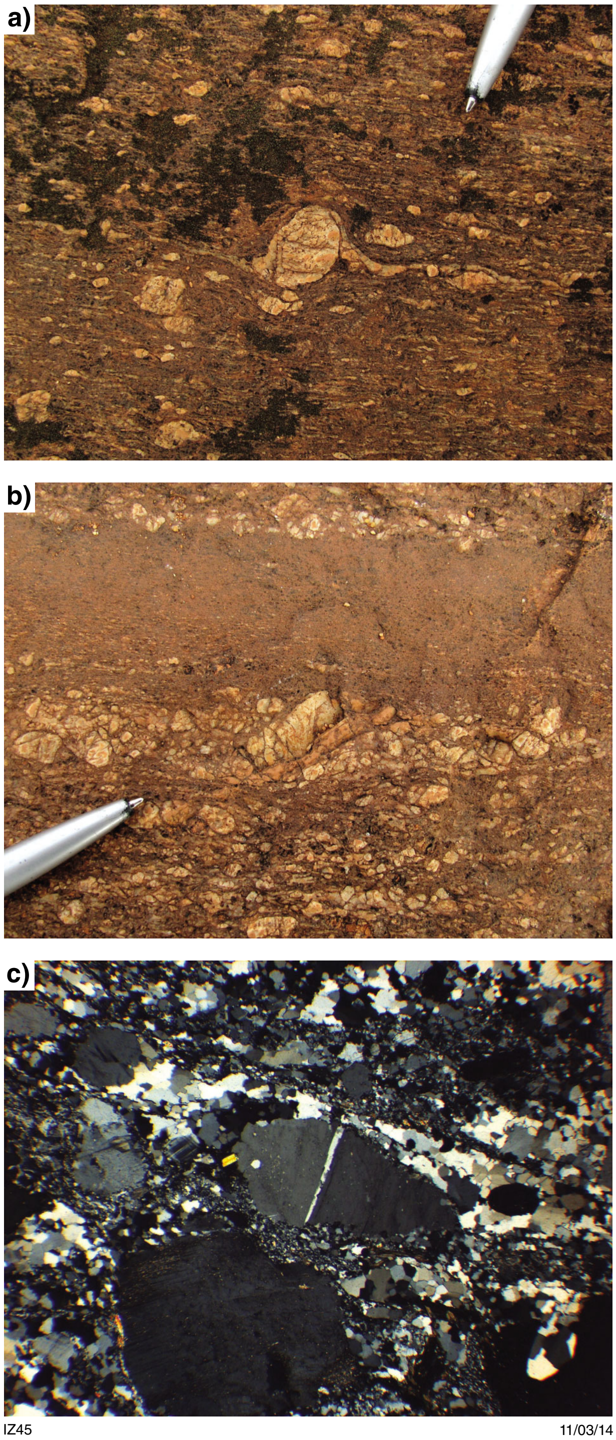


Figure 16. Porphyritic granite: a) delta-type mantled K-feldspar porphyroclast from sheared porphyritic granite. Monoclinic symmetry suggests sinistral shear sense, which seems dominant along this segment of the Edale Shear Zone; b) a layer of fine-grained gneiss, likely representing a microgranite dyke intruded into host porphyritic granite. K-feldspar porphyroclasts in the centre of the photograph suggest dextral shear sense; c) typical microstructure from sheared porphyritic granite at locality 2.1. Quartz-filled tensile microcrack in K-feldspar porphyroclast mantled by fine-grained, albite-rich new grains of plagioclase and completely recrystallized quartz aggregates. Crossed polars, base of photo 10 mm

The core of the dome includes layered granitic gneiss and amphibolite characterized by high-temperature tectonic fabric. The rim of the dome is marked by mid-amphibolite facies orthogneiss, mainly of monzogranitic to leucogranitic composition, which is in contact with highly deformed volcano-sedimentary sequences, mainly represented by amphibolites, ultramafic schists and banded iron-formation. Along the dome margins, the mylonitic foliation runs parallel to the gneiss–greenstone contact, has a prominent northeasterly plunging mineral lineation, and invariably reflects dome-up kinematics with respect to the surrounding greenstones. The architecture of this dome, displaying a map-scale refolded fold in the adjacent eastern greenstone sequence (figs 23 and 24, Eisenlohr et al., 1993), is remarkably similar to the architecture of the Lakeside Pluton (locality 6), as discussed in Zibra (2012). A geochronology sample has been collected (by GSWA) along the sheared leucogranitic dome margin (locality 2.2a) in order to constrain the tectono-magmatic evolution of the Gilberts Grave dome in relation to the late-orogenic transpressional structures, represented in this area by the Edale, Youanmi and Yuinmery Shear Zones (Fig. 5).

Locality 2.2a: Mylonitic granite

From Sandstone, drive southwest on the Sandstone – Paynes Find road (to MGA Zone 50 719909E 6892637N) and turn left (east). Follow the main track and then turn right (southward) at MGA Zone 50 726699E 6888649N. Drive south and then southeast until reaching MGA Zone 50 733219E 6882827N.

At this locality, sheared leucogranites and amphibolites preserve a pronounced, steeply north-plunging stretching (in metagranite, Fig. 17a) and mineral lineation (hornblende in amphibolites). Observations along XZ sections of the finite strain ellipsoid indicate dome uplift with respect to adjacent greenstones (Fig. 17b).

Locality 2.2b: Highly deformed banded iron-formation

On the eastern side of the dome, there is a well-exposed sequence of highly deformed banded iron-formation (Fig. 17c), commonly showing sheath folds with pronounced axial plane foliation and fold axes subparallel to the gneissic foliation and the stretching lineation in the adjacent granitic gneiss, respectively.

The Murchison Domain

The western end of the traverse focuses on the Cue – Mount Magnet region in the Murchison Domain of the Youanmi Terrane (Fig. 5). This area provides key insights into the understanding of deformation style in Neoarchean continental crust and particularly into the understanding of the interplay between magmatism and large-scale continental deformation. The study area includes c. 2810 to 2720 Ma greenstone successions intruded by granitic rocks between c. 2720 and 2590 Ma.

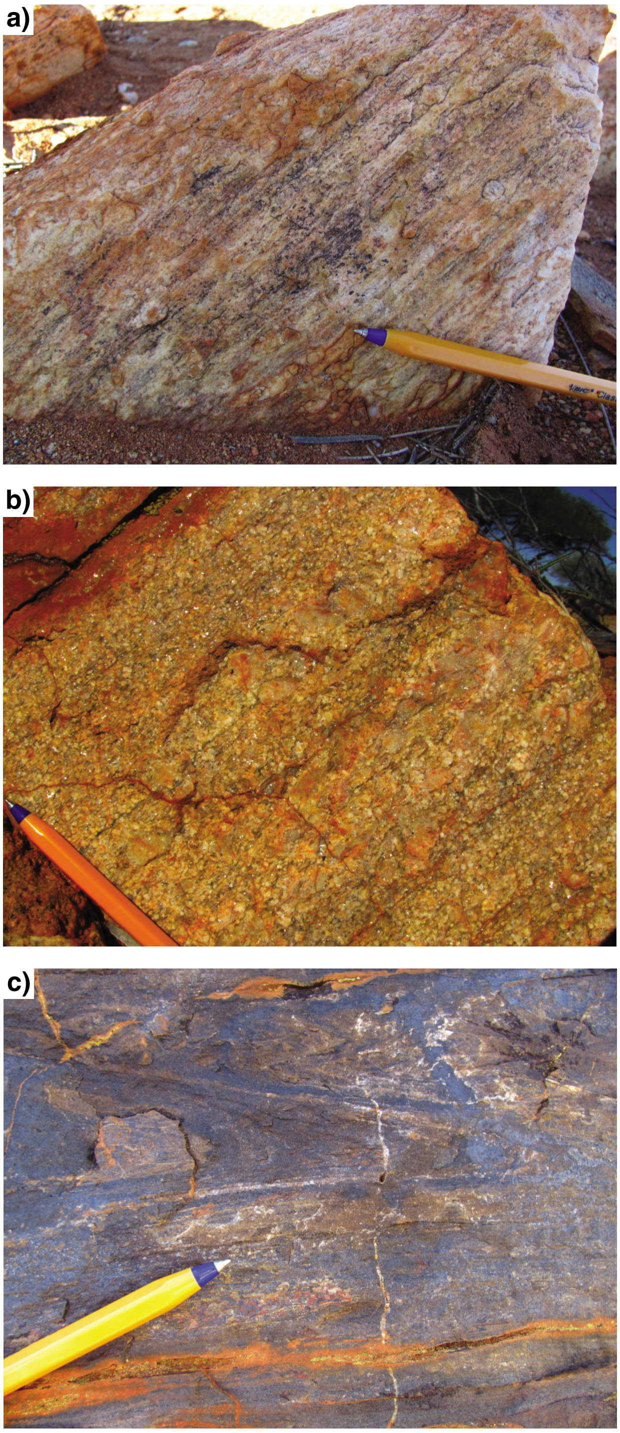


Figure 17. Gilberts Grave dome: a) exposed foliation surface (looking south) in mylonitic leucogranite showing the pronounced northeasterly plunging stretching lineation; b) XZ section of a gneissic granite (looking south) with S–C fabric and C' shear bands indicating top-down kinematics, reflecting dome uplift with respect to adjacent greenstones; f) section nearly perpendicular to the fold axis of a sheath fold in the highly deformed banded iron-formation flanking the granite dome

Some older, generally small, granitic plutons with emplacement ages from c. 2800 to 2750 Ma are preserved within greenstone packages (i.e. north of Cue and near the Narndee Igneous Complex, Fig. 5). A comprehensive summary of the greenstone stratigraphy and granitic suites for the Murchison Domain is given in Van Kranendonk et al. (2013). In this area, granitic plutons range from pre- to post-kinematic, systematically showing different size, shape and aspect ratio. These features are therefore largely related to the role these plutons played during the development of the Neoarchean crustal structure preserved in the northwestern part of the Yilgarn Craton. This area is thus ideal to investigate the interaction between melts and shear zone activity.

Overview of different granitic complexes

a: High-temperature shear zones (c. 2710–2690 Ma)

The Lakeside and the Yarraquin complexes are large-scale complexes (~100 × 50 km in map view, Fig. 5), which preserve widespread evidence of deformation during and immediately after pluton crystallization. These plutons can be regarded as large-scale, partially molten shear zones equivalent to the low-viscosity channels that have been discovered at deep levels of younger orogenic belts. Magmatic to high-temperature structures preserved in these plutons were likely controlled by active large-scale shear zones and, more generally, by the regional stress field active in the Murchison Domain at about 2700 Ma.

b: Pre- and inter-tectonic plutons (c. 2760–2700 Ma)

Partially coeval with the high-temperature shear zones, these plutons usually show circular to ovoid shape in map view (Fig. 5). They typically show a weak magmatic fabric, roughly concordant to pluton margins and, in places, record some localized solid-state overprint (generally concordant to regional-scale structures and unrelated to emplacement processes) along the contacts with the surrounding country rocks (greenstone successions).

c: Plutons emplaced along transpressional shear zones (c. 2680–2660 Ma)

These narrow and elongate plutons show a syn-emplacement structural evolution that is very similar to the one characterizing the high-temperature shear zones. However, in contrast with the former ones, they preserve evidence of several generations of fabric developed during syndeformational cooling from emplacement temperatures down to subgreenschist conditions. The observed geometries testify that these shear zones were associated with a major component of horizontal displacement that, in places, started before complete pluton crystallization. The best example is provided by the Cundimurra Granite, but the roughly coeval Chunderloo Granite and the plutons associated with Edale and Youanmi Shear Zones (Fig. 5e) likely recorded a comparable structural evolution.

d: Post-tectonic plutons (c. 2620–2600 Ma)

These plutons typically show a weak to moderate magmatic fabric roughly concordant to pluton margins. They are typically devoid of any important solid-state fabric, being clearly discordant with all the major regional structures (Figs 4 and 5). Post-tectonic plutons are locally affected by localized easterly striking faults associated with quartz veins. These structures are likely associated with the emplacement of the Proterozoic dyke swarms across the whole Yilgarn Craton. Seismic evidence suggests that, in places, post-tectonic plutons represent sills emplaced above major structural discontinuities represented by moderately dipping shear zones.

The Yarraquin Pluton

The Yarraquin Pluton is a northerly striking gneissic complex (roughly 100 km long by 50 km wide, Fig. 5) exposed between the Tuckabianna Syncline and the Windimurra Igneous Complex (Ivanic et al., 2010). It is mainly composed of high-temperature granitic gneiss associated with numerous xenoliths of mafic gneiss and paragneiss, likely representing fragments of greenstone packages dismembered during granite emplacement and subsequent high-temperature shearing. These xenoliths generally occur as narrow and elongate bodies ranging in size from a few metres to a few kilometres along strike. Granitic rocks are typically poorly exposed, so lithological and structural features are partially unconstrained. The Yarraquin Pluton mainly shows granodioritic to monzogranitic composition, while tonalites are dominant along the western pluton margin. The main north-northeasterly striking, steep fabric ranges from magmatic to high-temperature solid-state, whereas mid-amphibolite facies shear zones occur along the margins of the complex. A sample collected along the northwestern margin of the complex provided an emplacement age of 2710 ± 10 Ma (Wang et al., 1995), which could be representative of the tonalitic marginal facies but not necessarily of the whole complex. New dating along this portion of the pluton is currently in progress.

Locality 3.1: High-temperature ortho- and paragneiss

From the Sandstone – Mount Magnet road, turn right at MGA Zone 50 649195E 6898750N towards Wondinong Station and then towards the town of Cue. Stop along the eastern side on the road at MGA Zone 50 627343E 6944856N.

This locality displays the typical rock association of the Yarraquin Pluton, including high-temperature granitic gneiss, amphibolites, mica schists and minor ultramafic schists. A few kilometres to the south, another composite greenstone xenolith also includes a ~20 m thick layer of quartzite, which is likely equivalent to the quartzite formation exposed further south, along the eastern margin of the Windimurra Igneous Complex. Granitic gneiss has a monzogranitic composition and a northerly striking, steep gneissic foliation parallel to compositional layering (Fig. 18a). Microstructures (including quartz C-axis fabric) indicate that the main fabric developed at a temperature close to granite solidus (T> ~650°C; Fig. 18b).

Amphibolites commonly show hornblende–plagioclase assemblages, but locally contain leucocratic and coarser grained plagioclase–quartz ± clinopyroxene pockets, likely derived from local partial melting of amphibolite, possibly coeval with granite emplacement. A few tens of metres north of this locality, a thick (~50 m thick) unit of mica schists is well exposed on the east side of the road with a quartz – white mica – plagioclase ± biotite ± sillimanite assemblage. These elongate greenstone xenoliths generate significant anomalies in the aeromagnetic map and produce highly reflective markers in the deep-crustal seismic traverses. They therefore represent important markers that can be used to constrain the three-dimensional architecture of the whole complex.

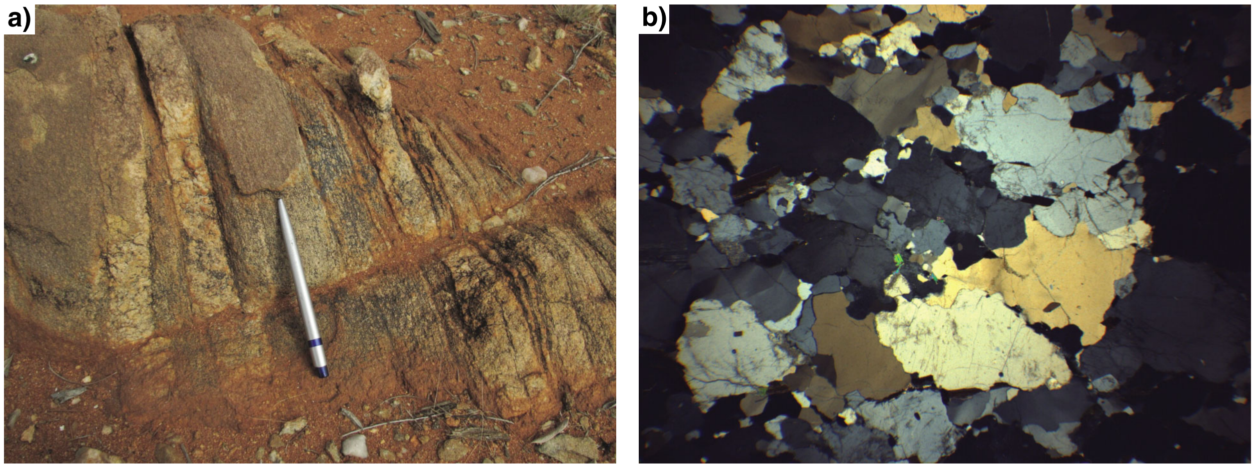
Locality 3.2: The mylonitic margin

From locality 3.1, drive northwest towards the town of Cue. Go through a gate at MGA Zone 50 615014E 6954772N and then proceed west-southwest across the open bushland, until reaching MGA Zone 50 613204E 6954147N.

This locality shows the typical relationships between the Yarraquin Pluton and the greenstone belt along the eastern limb of the Tuckabianna Syncline (Fig. 19). Granites are mainly represented by biotite-bearing (locally two-mica) tonalitic gneiss associated with sheared leucogranitic, muscovite-bearing dykes (Fig. 20a). The main northeasterly striking, steeply east-dipping foliation bears a remarkable, down-dip stretching lineation highlighted by plagioclase, quartz and mica recrystallized aggregates. On sections perpendicular to foliation and parallel to lineation (XZ sections of the finite strain ellipsoid), mantled porphyroclasts and shear bands indicate greenstone-down kinematics with respect to the Yarraquin Pluton. A geochronology sample has been collected from this outcrop. Microstructures at this locality are characterized by ribbons of coarse-grained recrystallized quartz aggregates and largely recrystallized plagioclase aggregates, wrapped by biotite and muscovite flakes (Fig. 20b). The occurrence of fully plastic deformation in plagioclase suggests that this fabric developed at temperatures > ~500°C.

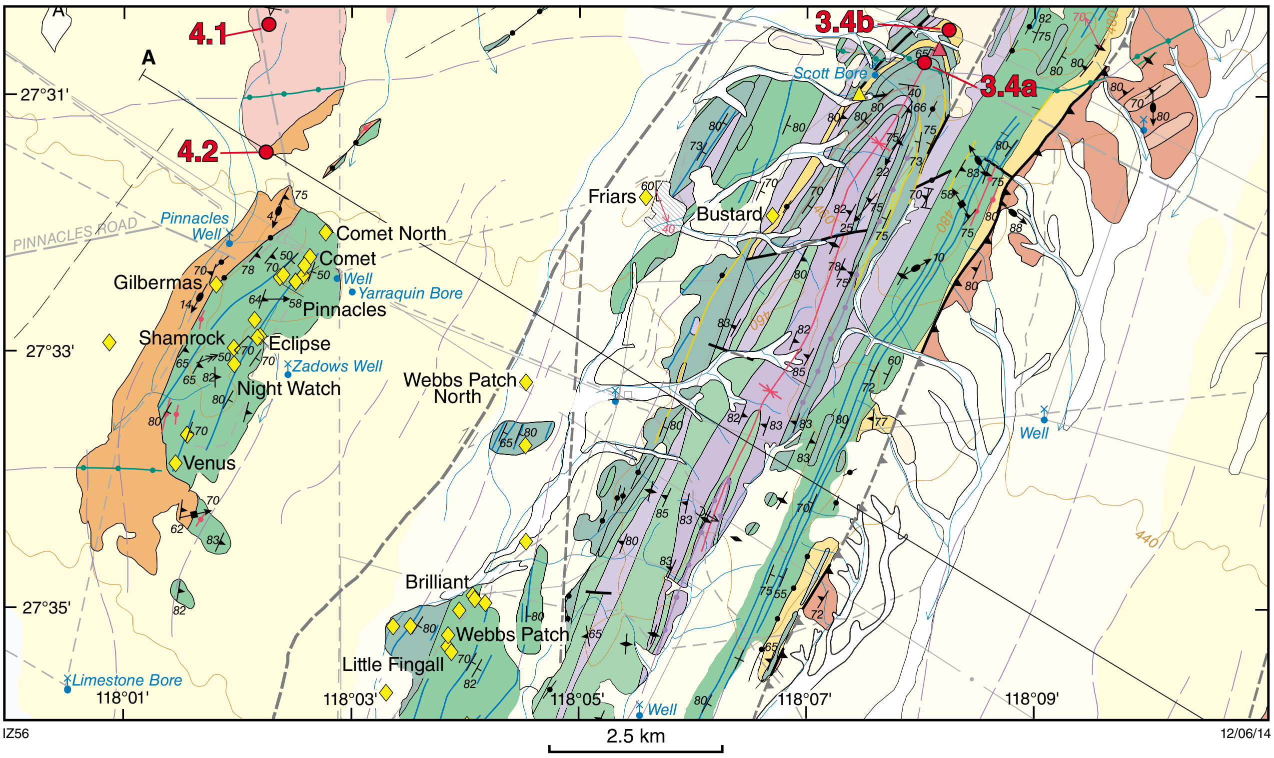
Locality 3.3

From locality 3.2, walk about 500 m to the west to MGA Zone 50 613124E 6954251N.



IZ46 11/12/13

Figure 18. Layered granitic gneiss: a) biotite-free leucogranitic gneiss interlayered with biotite-bearing granodioritic to monzogranitic gneiss; b) typical microstructure from monzogranitic gneiss at locality 3.1. Chessboard subgrain boundary pattern in quartz and lobate quartz–feldspar phase boundaries indicate high-temperature deformation (T> ~650°C). No retrogression is detectable, even at thin section scale. Crossed polars, base of photo 7 mm



IZ56 12/06/14

Figure 19. Extract from the Wynyangoo 1:100 000 geological map (Zibra, 2013), showing surface geology and excursion localities

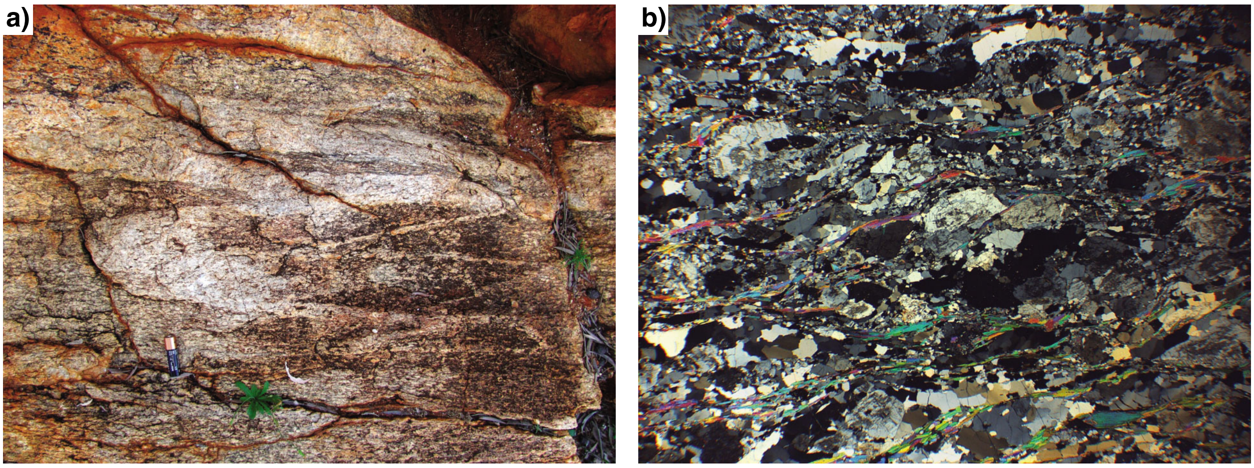


Figure 20. Yarraquin tonalite: a) YZ section of the finite strain ellipsoid of tonalitic gneiss (on a subhorizontal pavement), showing mylonitic folds developed in leucogranitic veins, with steeply plunging axes. Good three-dimensional exposures indicate that fold axes are subparallel to the stretching lineation; b) typical mid-amphibolite microfabric from sheared Yarraquin tonalites, with coarse-grained quartz ribbons and largely recrystallized plagioclase aggregates, wrapped by biotite and muscovite flakes. S–C fabric and C' shear bands define the greenstone-down sense of shear.

This locality lies on the contact between the Yarraquin Pluton and the greenstones of the Yaloginda Formation (Fig. 21) along the western limb of the Tuckabianna Syncline. Granitic gneisses are poorly exposed and are mainly represented by weathered leucogranites and tonalities, with north-northeasterly striking foliation and nearly vertical stretching lineation (025°/80° and 88°/130°, respectively). In the greenstone sequence, the lowermost preserved unit is represented by mica schists derived from felsic volcanic rocks, mainly of andesitic composition. Primary features are almost completely transposed here, but still locally preserved just a few kilometres north along strike, where a geochronology sample was collected. Here, these felsic schists also recorded a north-striking, steep crenulation cleavage (170°/60°), developed at moderate angle with respect to the main gneissic fabric. This unit is overlain by a thick sequence of amphibolites, interlayered with banded iron-formation displaying isoclinal folds (Fig. 22), black shales and leucogranitic dykes that were intruded at low angle from the main foliation. All the lithologies along this section show comparable structural geometry, similar to that observed at locality 3.2.

Locality 3.4a: The Tuckabianna Syncline intruded by a Proterozoic dyke

From locality 3.3, drive back to the Cue–Wondinong road, then drive towards Cue for 2 km and stop at MGA Zone 50 612035E 6956237N.

This locality is located in the hinge of the Tuckabianna Syncline. The area on the southern side of the road is dominated by a sequence of strongly foliated mafic to ultramafic schists, mainly derived from tholeitic and komatiitic basalts of the Meekatharra Formation. On the northern side of the road, there is a fold closure (amplitude ~600 m) in a layered gabbroic sill. The folded sill defines an arcuate hill with an external ultramafic base and a leucogabbro internal layer, linked by a mesocratic gabbro. Primary features are generally well preserved in the sill, where the fold axial-plane fabric is mainly represented by a spaced brittle cleavage. At this locality, the fold is intruded by a mafic dyke belonging to the Proterozoic dyke swarm system that intruded large portions of the Yilgarn Craton (Bodorkos and Wingate, 2007). This steeply dipping dyke stretches parallel to the road and is about 30 m thick here, displaying medium- to coarse-grained diorite textures and doleritic chilled margins. A geochronology sample collected at this locality provided an emplacement age of 1210 ± 11 Ma (Wingate and Kirkland, 2011).

Locality 3.4b: Felsic volcanic rocks in the hinge of the Tuckabianna Syncline

From locality 3.4a, walk 500 m north-northeast to MGA Zone 50 612476E 6956826N.

Here, a well-exposed unit of weakly deformed felsic volcanic rocks (Fig. 23a) has well-preserved primary bedding which is overprinted by a northeasterly striking (050°), subvertical, spaced cleavage subparallel to the axial plane of the Tuckabianna Syncline. The lineation generated by bedding–cleavage intersection (45°/230°, Fig. 23b) can be used as a proxy of the axis of the large-scale syncline. An easterly striking, spaced cleavage is locally developed (Fig. 23c). A geochronology sample collected here provided an age of c. 2810 Ma (GSWA 155506, in prep.). This unit is also exposed along the limbs of the syncline, where it is intensely sheared and reduced to 1–5 m in thickness.

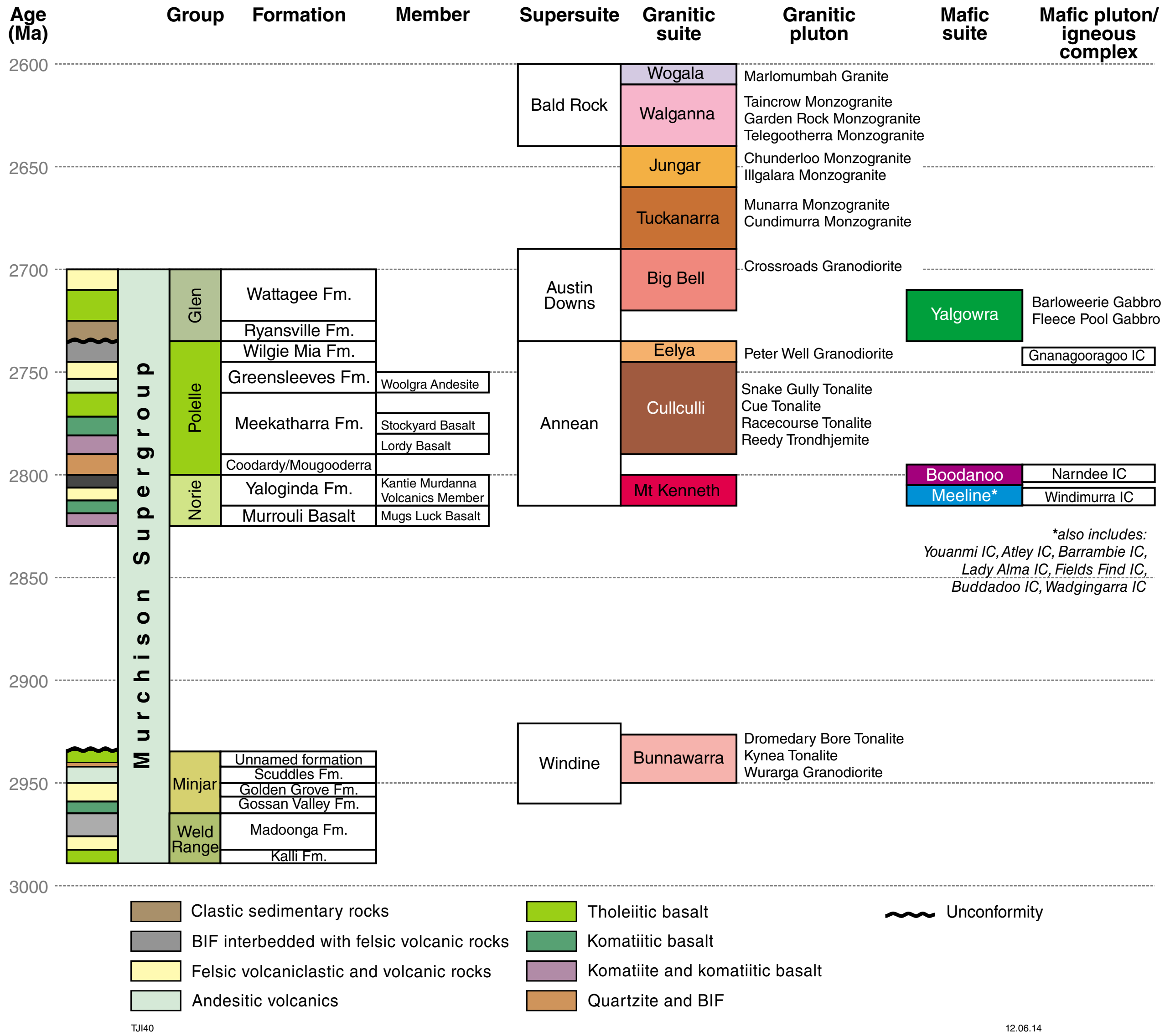


Figure 21. Stratigraphic scheme for the Murchison Domain, divided into three main columns for supracrustal rocks, granitic rocks, and mafic–ultramafic intrusive rocks (after Van Kranendonk et al., 2013)

IZ58 16/12/13

Figure 22. Subhorizontal pavement showing isoclinal folds in banded iron-formation, with axes subparallel to the steeply northerly plunging mineral lineation, analogous to locality 3.2

The Cundimurra Granite and the post-tectonic Garden Rock Monzogranite

The Cundimurra Granite is a narrow (~5–10 km wide and 100 km long), northerly trending elongate granitic complex, which stretches from immediately east of Cue down to the Narndee Igneous Complex (Fig. 5). It consists mainly of medium-grained, biotite-bearing monzogranite associated with porphyritic monzogranite characterized by 2–5 cm K-feldspar phenocrysts. A discontinuous tonalite unit, pre-dating the main monzogranite units, is mainly exposed along the western pluton margins. These rocks are intruded by muscovite-bearing leucocratic microgranite and pegmatitic to aplitic veins. Leucocratic veins contain muscovite and, less commonly, magmatic garnet. The Cundimurra Granite recorded several generations of fabrics developed during emplacement and subsequent syndeformational cooling from emplacement temperatures down to subgreenschist conditions. Magmatic features are better preserved in the southern half and in the centre of the body, away from the sheared contacts with greenstone belts. Magmatic features mainly include a northerly trending, steep, pronounced foliation that is typically associated with a shallowly plunging lineation. Schlieren fabric is commonly observable in monzogranite. Local, small-scale, melt-filled shear zones suggest that magma crystallization likely occurred in a dynamic tectonic setting. Solid-state fabrics are better developed near the boundaries with greenstone belts. Here, a steep northerly trending mylonitic foliation is associated with a subhorizontal stretching lineation and displays dextral kinematics. Metamorphic conditions, estimated by microstructural means, range from the upper amphibolite facies to the mid-greenschist facies. Higher temperature fabrics are locally preserved in the Wynyangoo Hill area, whereas the lower temperature fabrics dominate in the central and northern portions of the body. This mylonitic foliation is locally reactivated by localized retrograde shear zones displaying sinistral sense of shear. As a whole, the observed geometry and kinematics indicate that shearing was associated with a major component of horizontal displacement that, in places, started before complete pluton crystallization.

The two greenstone belts flanking the granitic suite are unrelated, suggesting that the displacement along the strike–slip shear zones is probably in the order of some tens of kilometres. In the west, the granitic suite intrudes near the base of the Murrouli Basalt (Watkins and Hickman, 1990), which is possibly c. 2820 Ma (Fig. 19a, Van Kranendonk et al. 2013, and references therein). This formation is mainly composed of tholeiitic and subordinate komatiitic basalts, associated with mafic to ultramafic sills. The greenstone belt exposed along the eastern pluton boundary includes an association of tholeitic and komatiitic basalts interlayered with thin mafic sills, banded iron-formation, and mica schists. The western side of this greenstone belt is marked by a distinctive unit of foliated amphibolites, likely derived from amygdaloidal basalts. As a whole, this unit could belong to the Meekatharra Formation, which has an estimated age of c. 2760–2800 Ma (Van Kranendonk et al., 2013).

The localities on the Cundimurra Granite illustrate three main features: (i) magmatic structures; (ii) solid-state overprint in the pluton; and (iii) solid-state structures in the adjacent country rocks (i.e. the synkinematic pluton aureole). The available geochronology dataset indicates that the pluton was emplaced incrementally over a ~20 Ma time span (c. 2680 to 2660 Ma). Localities described in this guide show how field and microstructural observations support the analytical result provided by magmatic zircon grains.

All the regional-scale structures visible in the Cundimurra Granite are postdated by the Garden Rock Monzogranite, which represents a medium-sized, slightly east–west elongate, undeformed pluton (~20 × 10 km, Figs 4 and 5). This post-tectonic pluton is therefore a key element in constraining the tectonic evolution of the area. An emplacement age of 2617 ± 24 Ma has been obtained by Wang (1998) and an additional sample collected by GSWA is currently in progress. The Garden Rock Monzogranite is intersected by one of the recently acquired seismic lines. During the excursion, we will discuss its three-dimensional geometry with respect to the geometry of the regional-scale structures.

Locality 4.1: The Garden Rock Monzogranite

Along the Cue–Wondinong road, turn south at the junction (MGA Zone 50 602212E 6958256N). Drive south for 1 km and walk 200 m east to the granite dome (MGA Zone 50 602626E 6957165N).

This outcrop displays the typical outcrop-scale features in the porphyritic variety of Garden Rock Monzogranite. It is characterized by a moderate, easterly to east-southeasterly striking, steep magmatic foliation, highlighted by euhedral K-feldspar phenocrysts. Schlieren layering and elongate biotite- and hornblende-bearing mafic microgranular enclaves of dioritic composition are roughly parallel to the magmatic foliation (Fig. 24a). A weak, steeply plunging magmatic lineation has been observed in laboratory-cut samples but it is not easily measurable at this locality. Typical microstructures in the Garden Rock Monzogranite belong to 'type I' magmatic microfabric (Zibra et al., 2012), where no crystal-plastic deformation is visible at grain scale (Fig. 24b). The presence of mafic microgranular enclaves suggests magma mingling (and mixing?) between a felsic and a more mafic magma during the emplacement of the pluton. Mingling processes locally generated hornblende-bearing granodiorites, which represent a key petrological tool in constraining the P–T conditions of emplacement of this post-tectonic body (Anderson et al., 2008), and therefore in constraining the latest stages of the Neoarchean tectonic evolution of the area.

Locality 4.2: Solid-state fabric in the Cundimurra Granite

From locality 4.1, drive southward for 2.7 km and stop on the western side of the road at MGA Zone 50 602775E 6954451N.

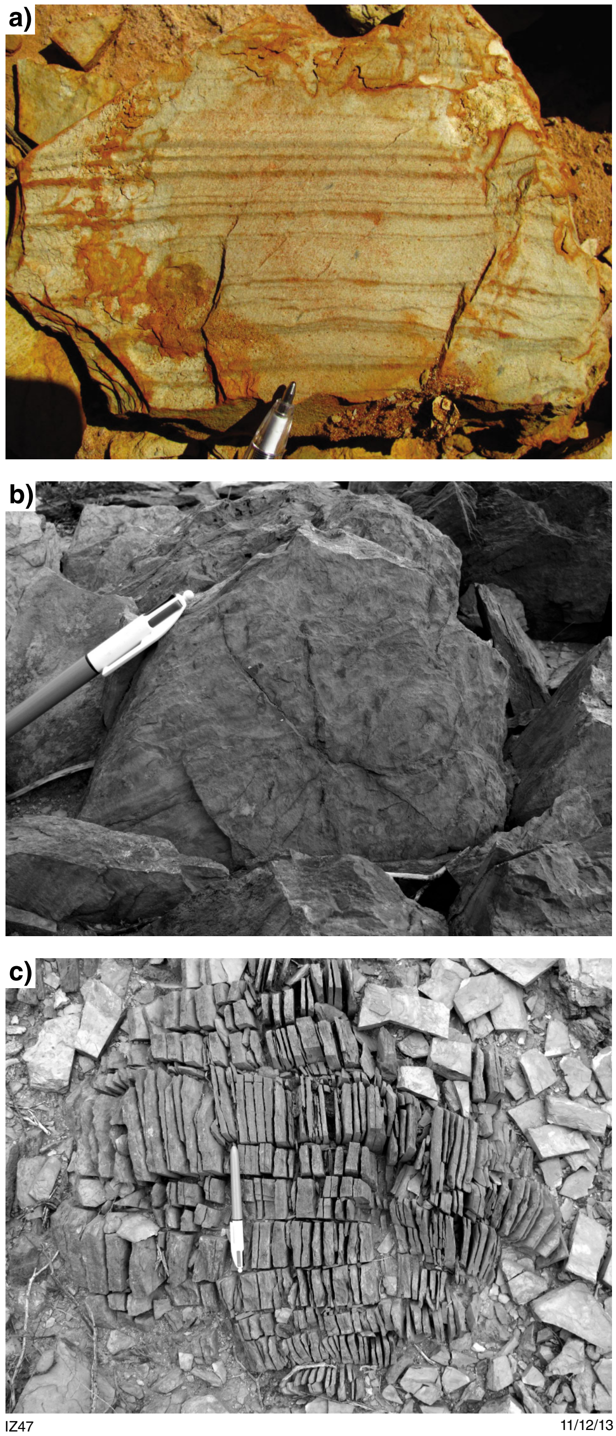


Figure 23. **Felsic volcanic rocks in the Tuckabianna Syncline: a) detail from felsic volcanic rocks showing the well-preserved primary bedding; b) detail (facing west) from the felsic volcanic unit exposed in the hinge of the Tuckabianna Syncline. The intersection lineation (parallel to the pen) is generated by the intersection of the northeasterly trending, steep foliation and the moderately (~45°) south-dipping primary bedding; c) steep north-northeasterly striking foliation in metamorphosed felsic volcanics overprinted by an easterly striking, spaced cleavage. In this area, the later overprint is typically not visible in the more competent lithologies.**

At this locality, the typical solid-state fabric in the Cundimurra Granite is mainly represented by sheared porphyritic granite. This locality provides the northernmost exposure of this ~150 km long pluton. On the subhorizontal pavements, the steep, north-northeasterly striking mylonitic foliation contains a subhorizontal stretching lineation (030°/75° and 04°/200°, respectively) defined by recrystallized quartzofeldspathic aggregates. On these surfaces, dextral shear sense is provided by S–C fabric and C' shear band (Fig. 25a). Microstructures are characterized by feldspar deformation in the 'low plasticity field', with grain-scale brittle fracturing and albite neo-crystallization, while quartz aggregates show evidence of dominant subgrain-rotation recrystallization (Fig. 25b).

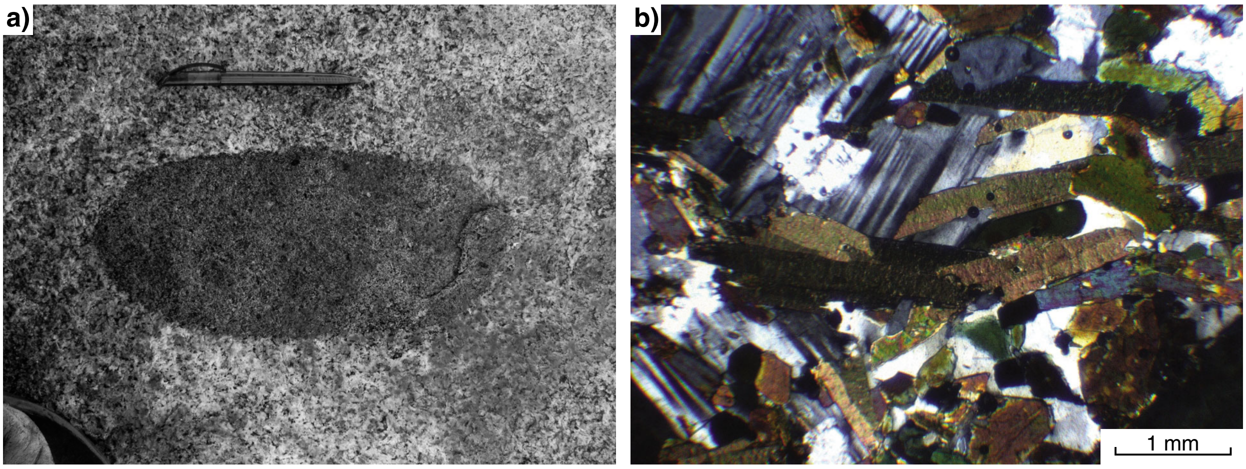
Locality 4.3: Cundimurra Granite: relationships between the pluton and country rocks along the eastern pluton aureole

From locality 4.2, drive westward along Pinnacles Road to the Great Northern Highway. Drive south for 30 km and stop on the eastern side of the road at MGA Zone 50 590796E 6925066N.

This locality offers a natural cross-section through the country rocks preserved along the eastern side of the Cundimurra Granite (Fig. 26). From the highway, walk east through an amphibolite derived from amygdaloidal basalt, which is intruded by garnet-bearing, sheared micro-leucogranite dykes. Farther east, a thin layer of andalusite-bearing mica schist (Fig. 27a) associated with garnet-bearing ferruginous quartzite is followed by a thin peridotite sill which grades eastward into gabbro. All lithologies (except the peridotite) show a pervasive northerly trending tectonic foliation associated with a steeply plunging mineral lineation (340°/60° and 85°/070°, respectively). Differentiation trends in mafic intrusive rocks suggest an eastward younging direction. Mica schists contain synkinematic andalusite, cordierite and staurolite porphyroblasts that likely developed during pluton emplacement. There is also evidence that the development of andalusite porphyroblasts postdated a crenulation cleavage (Fig. 27b, c). A spaced crenulation cleavage, which post-dates the main fabric, is detectable at thin-section scale (Fig. 23d), and is locally visible at outcrop scale. This later fabric reflects the syndeformational cooling down to greenschist facies conditions. This location is highly significant for the understanding of the P–T–t evolution of the granite aureole system.

Locality 4.4: Cundimurra Granite — primary magmatic features

From locality 4.3, drive 14 km southward along the Great Northern Highway, to an east-branching track (MGA Zone 50 585183E 6914433N), then turn left and take the track to the east-southeast. Drive for 400 m and, after the bore,



IZ48 12/06/14

Figure 24. Garden Rock Monzogranite: a) subhorizontal pavement showing rounded hornblende-bearing mafic microgranular enclaves, elongated parallel to the easterly striking magmatic foliation in the Garden Rock Monzogranite; b) thin section from the contact between mafic microgranular enclaves and host granite, with hornblende and biotite grains surrounded by the undeformed late-magmatic quartz and K-feldspar

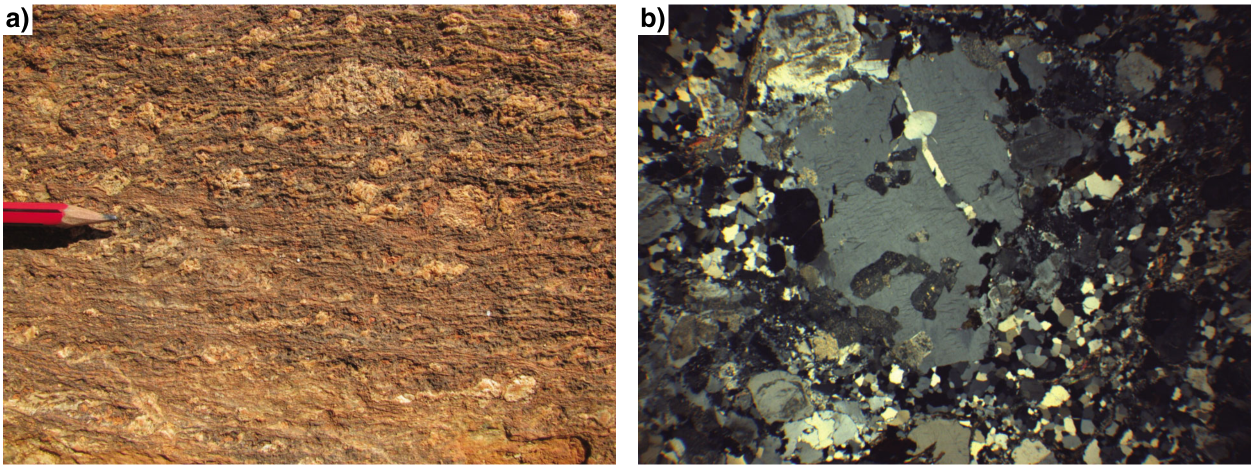


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Figure 25. Cundimurra Granite: a) horizontal pavement of sheared porphyritic granite. S–C fabric and C' shear bands, readily detectable on weathered surfaces, suggest dextral shear sense; b) typical microfabric from the sheared Cundimurra Granite, with dilatant microfractures in K-feldspar porphyroclasts and recrystallized quartz aggregates associated with biotite and muscovite synkinematic aggregates. Crossed polars, base of photo 9 mm

turn right following the south-directed track. Follow this track for 2 km, then turn right and proceed west-southwest for 700 m to a group of small granite domes at MGA Zone 50 585225E 6911748N.

At this locality (Fig. 28), an equigranular, medium-grained biotite-bearing granodiorite to tonalite is mainly mesocratic and compositionally homogeneous. Steeply plunging magmatic foliation (350°/80°) is well developed and highlighted by aligned feldspars and biotite flakes. Thin-section analysis indicates that the main anisotropy is indeed a magmatic to submagmatic foliation and that a very limited crystal-plastic deformation took place at a temperature close to granite solidus, likely during magma crystallization. The main foliation is post-dated by thin (~1–15 cm thick), undeformed biotite-rich microdiorite to microtonalite veins emplaced along a fracture network (Fig. 29). Even this younger intrusion displays a nearly pristine magmatic microfabric without any detectable solid-state overprint.

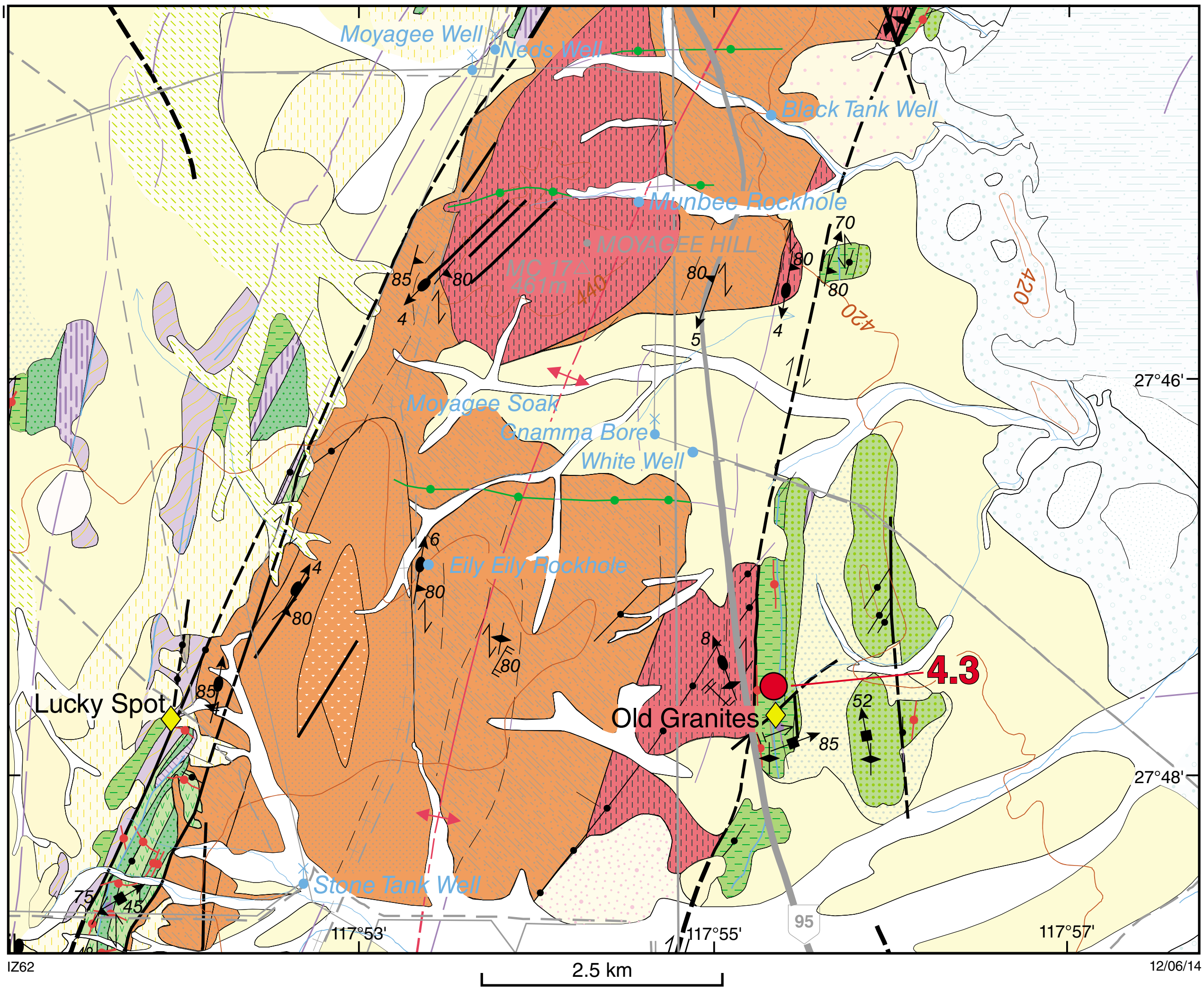


Figure 26. Extract from Austin 1:100 000 geological map (Zibra, 2011), showing surface geology and the excursion locality

Locality 4.5: Cundimurra Granite — relationships between magmatism and shearing

From the previous locality, proceed 850 m west across the open bushland to MGA Zone 50 584381E 6911763N.

Here, the main rock type is a tonalitic orthogneiss with a steep, northwesterly striking gneissic foliation with a shallowly plunging mineral lineation (335°/72° and 14°/330°, respectively). A prevailing dextral shear sense is visible on subhorizontal exposures. Typical microstructures show evidence of coarse-grained quartz recrystallization and fully plastic deformation in plagioclase, suggesting mid-amphibolite facies conditions as a minimum (Fig. 30a). This is consistent with the occurrence, just a few hundred metres to the west, of melt segregation structures (Weinberg, 2006) overprinting the gneissic foliation (Fig. 30b), suggesting that the latter developed when some residual melt was still present in the deforming aggregate. Together, these observations suggest that strike–slip shearing was active during the emplacement of the Cundimurra Granite. The main foliation is post-dated by thin (1–5 cm) biotite-rich tonalite veins emplaced along a fracture network (Fig. 30c), similar to the veins observed at locality 4.4. Primary fabric in some veins is overprinted by a cataclastic foliation. These veins are cut by a ~20 cm thick mylonite (likely greenschist facies), which nucleated along a quartz-rich leucogranitic dyke (Fig. 30d). This southeasterly striking shear zone (140°/65° and 30°/150°) shows a sinistral shear sense (Fig. 30d).

Intertectonic plutons

Intertectonic plutons are typically circular to ovoid in map view, ranging in composition from tonalite to monzogranite. They mostly show a weak magmatic fabric, roughly concordant to pluton margins and, in places, record some localized solid-state overprint (generally concordant to regional-scale structures and unrelated to emplacement processes) along the contacts with the surrounding country rocks (greenstone successions).

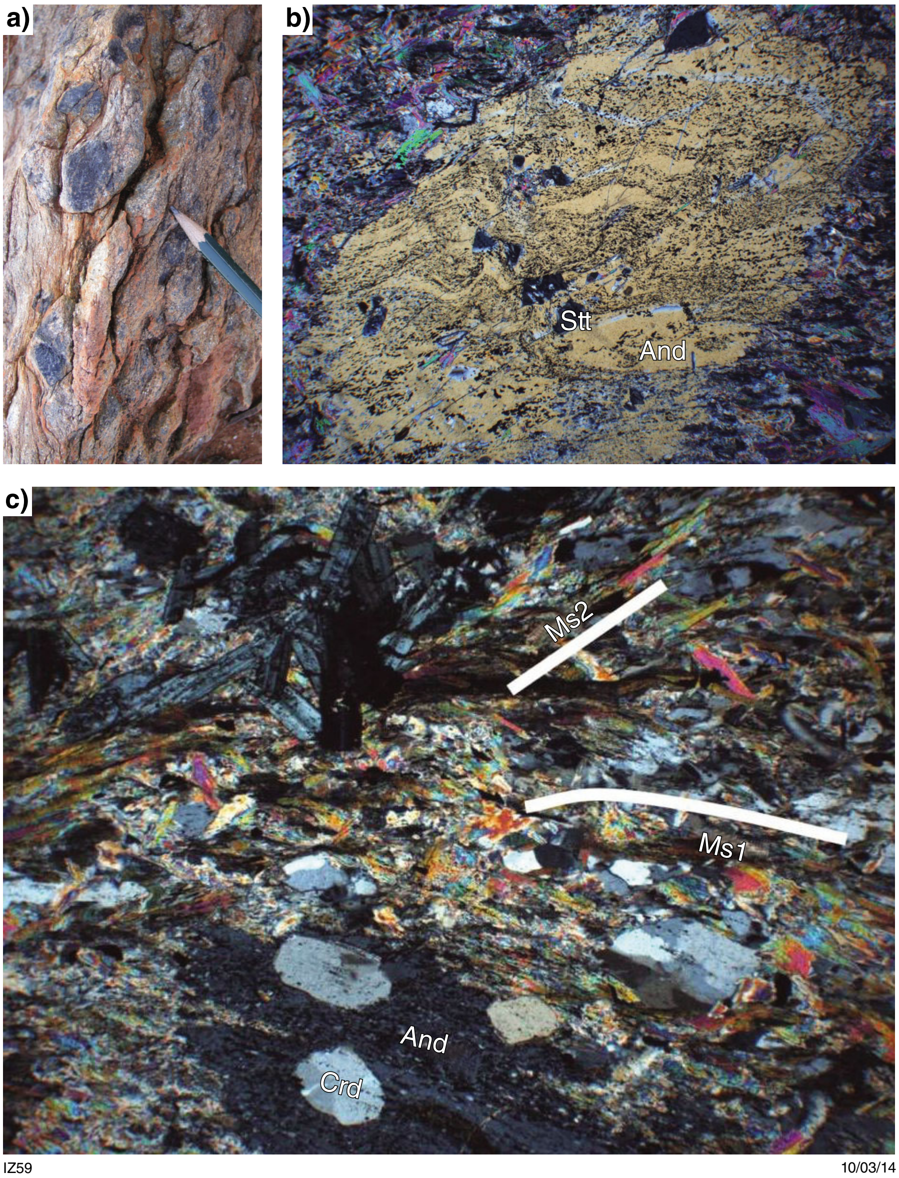


Figure 27. Andalusite-bearing mica schist: a) typical outcrop-scale appearance. Observations along XZ sections (facing south here) suggest greenstone-down shear sense; b) andalusite porphyroblast including small staurolite remnants (dark grey) and postdating a crenulation cleavage in mica schist; c) spaced crenulation cleavage in mica schist, with synkinematic muscovite2 and chloritoid overprinting an earlier microfabric including andalusite, cordierite, staurolite and muscovite1

A good example of an intertectonic pluton is the elliptical ‘Wheel of Fortune’ Pluton, a small (10 × 5 km) pluton, which is exposed northeast of Mount Magnet. Because it is largely undeformed, this pluton was considered to be post-tectonic (e.g. Watkins and Hickman, 1990). However, the 2702 ± 6 Ma emplacement age determined by Schiøtte and Campbell (1996) indicates that it is older than the adjacent Cundimurra Granite. During the new mapping, the discovery of sheared pluton margins along the Cuddingwarra Shear Zone (Fig. 5; see also Zibra, 2011) fits with the geochronological data and suggest that the Wheel of Fortune Pluton should be regarded as intertectonic.

Locality 5.1: ‘The Granites’ locality

From the town of Mount Magnet, drive north for 7 km along the Great Northern Highway and then turn right into the track that leads to the numerous granitic domes exposed on the eastern side of the highway. Stop at MGA Zone 50 583772E 6902751N.

At this locality, pristine primary magmatic fabric in medium- to coarse-grained granites range in composition from tonalite to monzogranite. The magmatic foliation is locally defined by aligned feldspar phenocrysts and biotite flakes (Fig. 31a) but is quite weak and without a

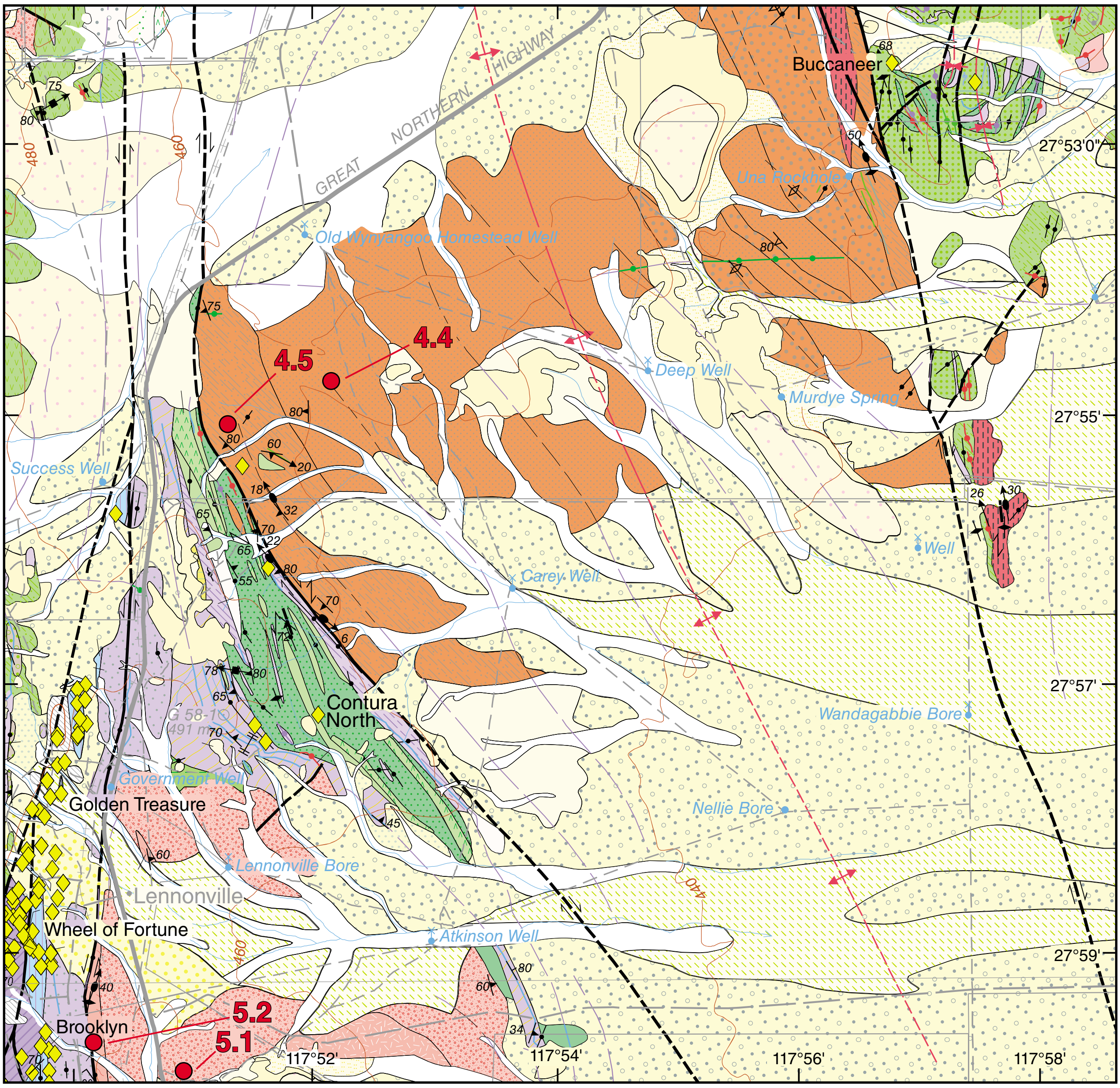
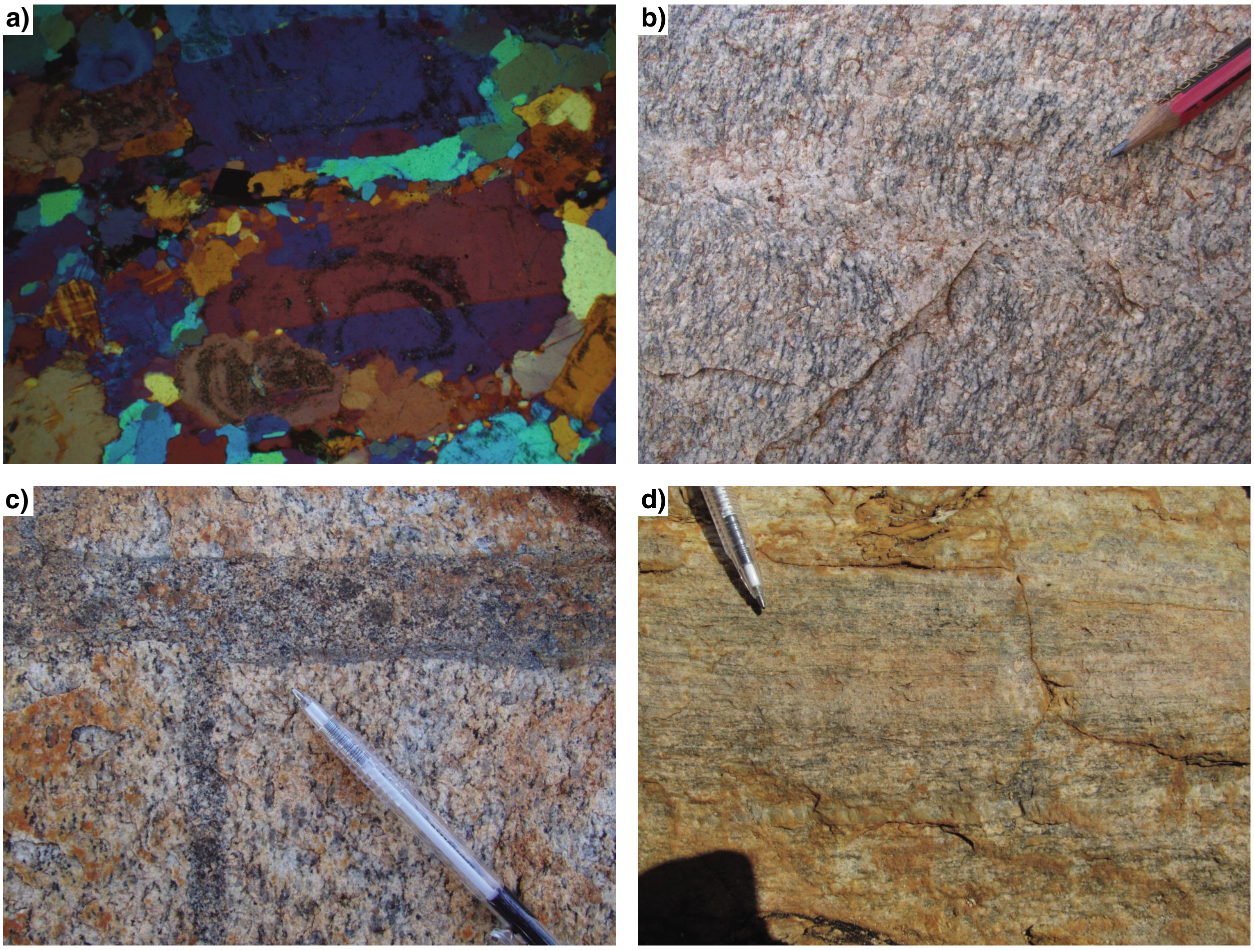


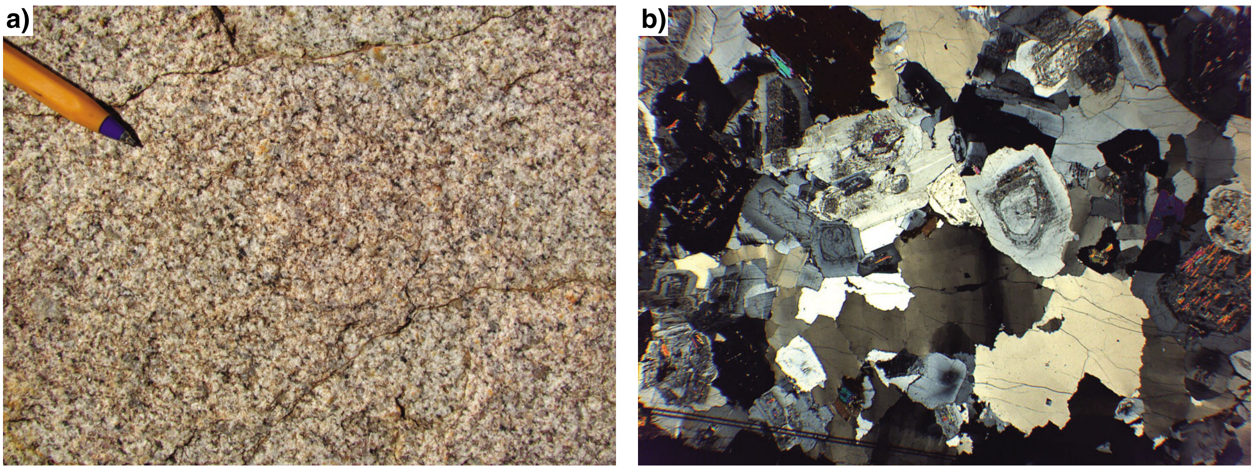
Figure 28. Extract from AUSTIN 1:100 000 geological map (Zibra, 2011), showing surface geology and excursion localities

Figure 29. Microdiorite dyke network injected into host granodiorite showing a northerly trending magmatic foliation (subparallel to the hammer handle) highlighted by aligned biotite flakes



IZ49 11/12/13

Figure 30. Cundimurra Granite: a) microstructures from the host metatonalite, with core-and-mantle microstructure in plagioclase and coarse-grained quartz recrystallization. Crossed polars, gypsum plate inserted, base of photo 2.5 mm; b) melt segregation structure represented by an irregular pocket of undeformed leucogranitic melt, postdating (or coeval with?) the development of the gneissic foliation in the host tonalitic gneiss; c) microdiorite dyke network preferentially injected parallel and perpendicular to the gneissic foliation in host tonalite; d) high-strain zone mainly localized within a leucogranitic dyke, and post-dating the injection of microdioritic veins. S–C fabric and shear bands indicate sinistral shear sense.



IZ51 11/12/13

Figure 31. Wheel of Fortune pluton: a) typical outcrop-scale appearance of tonalite displaying magmatic foliation (subparallel to the pen) defined by aligned plagioclase grains and biotite flakes; b) typical microfabric from undeformed tonalite at locality 5.1. Zoned, euhedral plagioclase grains are surrounded by interstitial quartz grains and biotite flakes. Chessboard subgrain boundary pattern in quartz reflects minimal deformation recorded during tonalite crystallization.

consistent orientation at pluton scale. Thin-section analysis confirms that the primary magmatic fabric is completely undeformed, with undulose extinction in quartz being the only visible evidence of crystal-plastic deformation (Fig. 31b).

Locality 5.2: The sheared pluton boundary

From locality 5.1, drive back to the Great Northern Highway and drive north for 2.5 km. Turn left at MGA Zone 50 582592E 6905289N and then left again along a wide gravel road parallel to the Great Northern Highway. Drive south for 1.6 km to the pluton margin that is exposed 300 m east of the gravel road (MGA Zone 50 582194E 6903738N).

In this area, the marginal facies of the Wheel of Fortune Pluton is largely composed of sheared pegmatites and aplites associated with the host granodiorite. The steep, northerly striking mylonitic foliation (350°/80°) parallel to the pluton margin bears a moderately southerly plunging stretching lineation (10°–30°/170°). Sinistral shear sense is defined by S–C fabric, C' shear bands (Fig. 32a) and locally by drag folds developed within sheared felsic veins. Microstructures are characterized by S–C foliation defined by quartz ribbons and feldspar aggregates truncated by C' shear bands associated with extreme grain size reduction (Fig. 32b). As a whole, they are indicative of deformation under mid-greenschist facies conditions. The country rocks are poorly exposed here, but well exposed along the southern continuation of this contact. They are mainly represented by mafic to ultramafic schists showing a foliation parallel to the gneissic foliation in the metagranite, and a steeply southerly plunging mineral lineation marked by oriented amphibole and chlorite crystals (Fig. 32c).

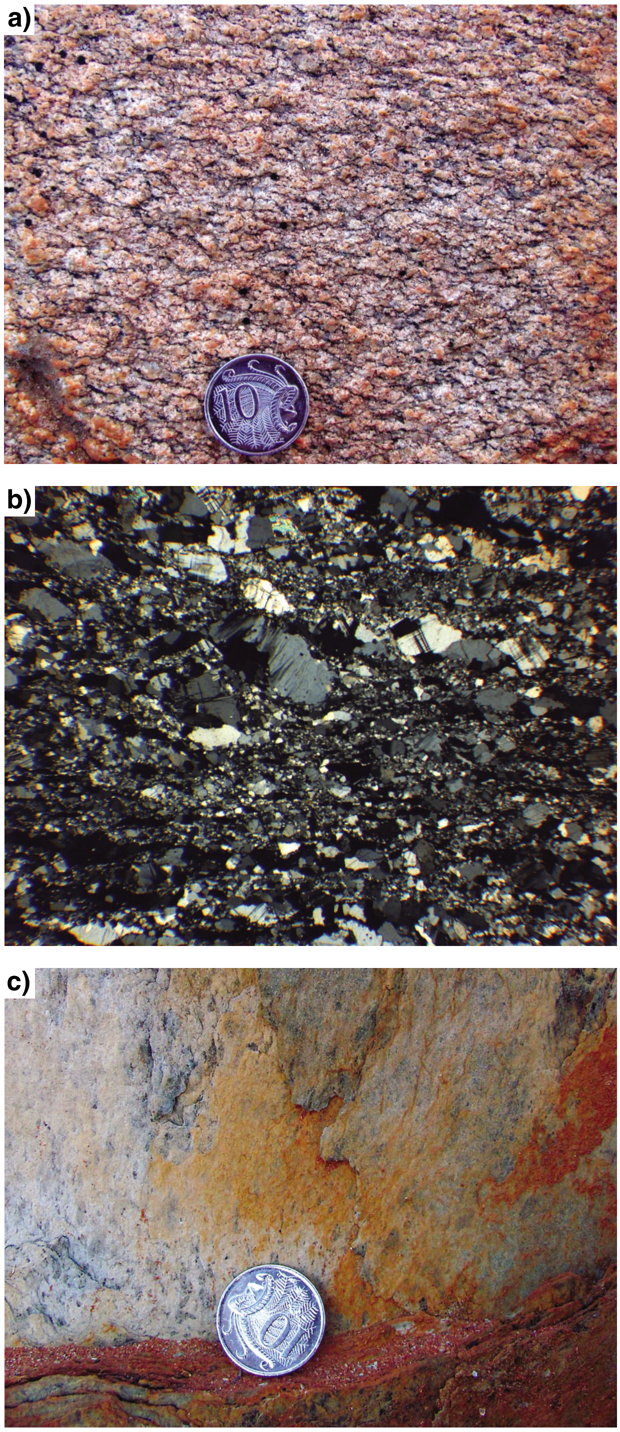


Figure 32. Wheel of Fortune pluton marginal facies: a) subhorizontal exposure from the sheared granodiorite exposed near the western pluton margin. S–C fabric and C' shear bands suggest sinistral shear sense; b) microstructures from the sheared pluton boundary with S–C foliation defined by quartz ribbons and feldspar aggregates truncated by C' shear bands associated with extreme grain size reduction; c) ultramafic schists showing the northerly striking, subvertical foliation associated with a steeply southerly plunging mineral lineation highlighted by chlorite and amphibole crystals

The Lakeside Pluton

The Lakeside Pluton is interpreted as one of the large-scale, high-temperature shear zones mentioned in the introduction. The pluton lies between the northerly trending sinistral Cuddingwarra Shear Zone (CDSZ; Fig. 5) and the northeasterly trending dextral Chunderloo Shear Zone. Here, granitic rocks occupy a lozenge-shaped area centred along the core of the north-northeasterly trending Big Bell antiform (BBA, Fig. 5). These granites are mostly unaffected by the greenschist facies shearing event that gave rise to the regional shear zones, allowing the study of syn-emplacement and syn-crystallization structures. In this area, the dominant granitic type is represented by mesocratic, porphyritic to equigranular, biotite tonalite to monzogranite. These rocks are intruded by medium-grained leucogranite and meso- to leucocratic microgranite dykes. Monzogranites include metre- to kilometre-scale xenoliths mainly represented by tonalitic to granodioritic migmatite gneiss. In the Cue area (some 60 km north of these excursion localities), these high-grade tonalite–trondhjemite–granodiorite (TTG) gneisses provided an emplacement age of c. 2720 Ma. Along the transect described here, the structures developed during syndeformational pluton crystallization and the structural relationships with the adjacent Mount Magnet greenstone belt are well displayed. The transect crosses the kilometre-scale Wattle Creek Shear Zone (Fig. 33) that was active during and after pluton crystallization at about 2700 Ma (Zibra, 2012).

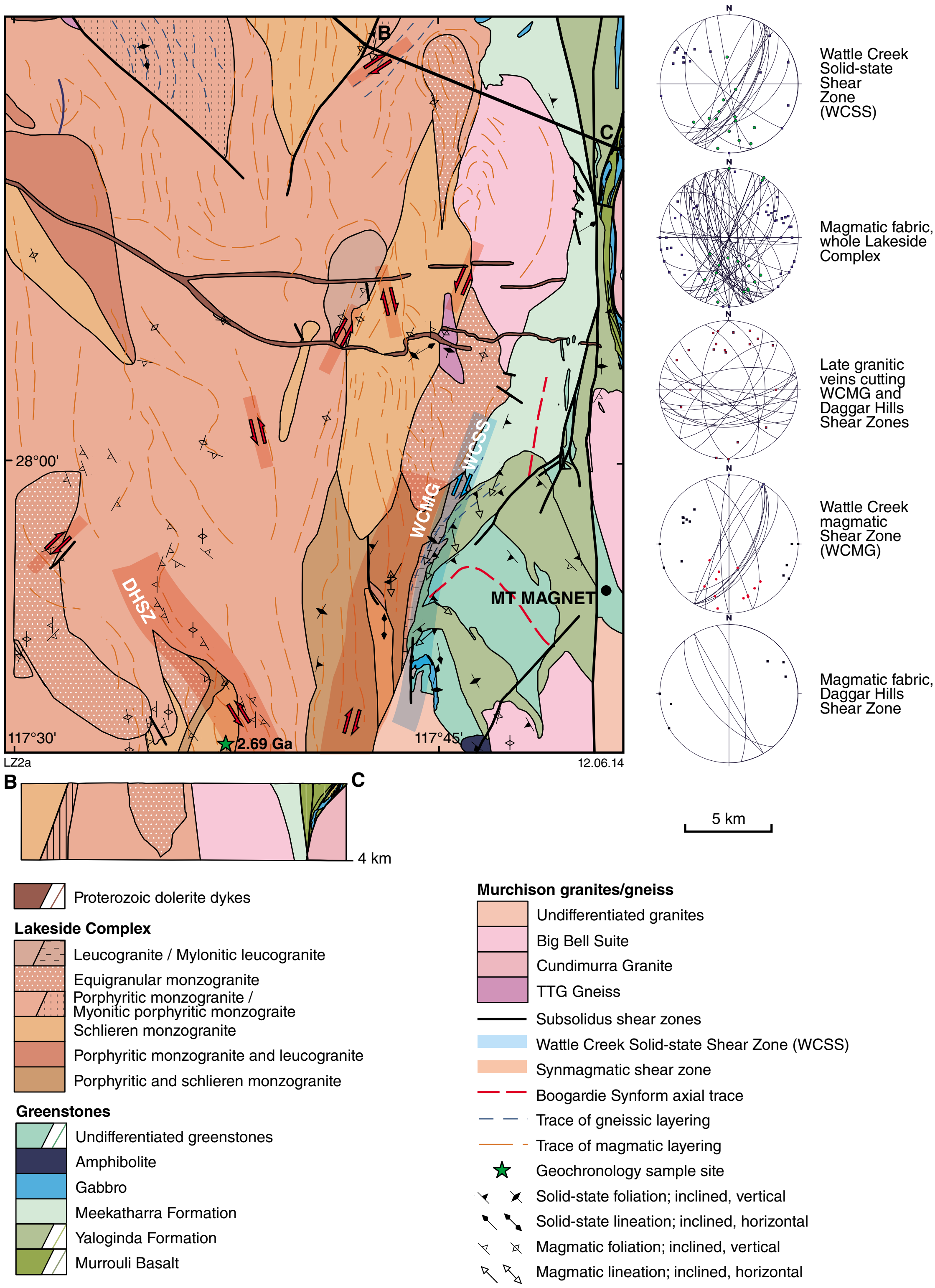


Figure 33. Interpreted geological map of the area around Mount Magnet, showing available geochronological data. DHSZ: Daggar Hills Shear Zone; WCMG: Wattle Creek Magmatic Shear Zone; WCSS: Wattle Creek Solid-State Shear Zone, developed along the eastern pluton boundary. In the stereonets, circles: magmatic and solid-state lineation; black squares: poles to foliation. After Zibra (2012)

Locality 6.1

From the town of Mount Magnet, drive for 14 km east along the Mount Magnet – Palmer Well road towards Boogardie Station. Stop on the southern side of the road at MGA Zone 50 569817E 6897730N. Proceed south-southeast for 700 m, following the creek bed, to MGA Zone 50 570178E 6897139N.

This locality displays the structural relationship between a kilometre-sized, TTG-like, layered migmatitic orthogneiss and its host porphyritic granite. The dominant structural style in the layered orthogneiss is characterized by the occurrence of a fairly regular network of melt-bearing shear bands cutting the high-temperature layering. These shear bands show a consistent geometry (010°–035°/60°), are associated with injection of leucogranitic melt, and invariably indicate dextral shear sense as suggested by drag-fold geometry in the host-layered gneiss (Fig. 34a). Their orientation is subparallel to the map-scale Wattle Creek Shear Zone and to the eastern pluton boundary with the Mount Magnet greenstone belt. Consistent with outcrop-scale structures, microstructures show that the TTG gneiss retained some residual melt during the development of the main gneissic fabric (Fig. 34b). Several other structures related to the deformation of the partially molten gneiss are present in this wide pavement exposure and can be examined in relation to the magmatic to high-temperature solid-state fabric seen in the adjacent porphyritic granite (Fig. 34c). This main fabric is post-dated by east-striking, late-magmatic granitic dykes. Geochronology investigations are currently in progress on this outcrop locality, in both the dykes and host granite-migmatite system. Preliminary results suggest an emplacement age of c. 2700 Ma for the host porphyritic granite, confirming previous investigations. In contrast, the easterly trending leucogranite dyke sampled here returned a main population magmatic zircon grains clustering around 2730 Ma. Preliminary interpretation suggests that the analysed zircons are inherited, likely representing the age of the mid-crustal dyke protolith.

Locality 6.2

From the locality 6.1, drive back to the main Mount Magnet – Palmer Well road and then towards Mount Magnet for about 3 km and stop just west of the breakaway at MGA Zone 50 572821E 6898021N.

At this locality, the sheared intrusive contact between the Lakeside Pluton and the country rocks, here represented by the Mount Magnet greenstone belt, is exposed. Through a ~1 km cross section (from west to east), the transition from a granodiorite associated with numerous leucogranitic veins and including numerous amphibolite xenoliths to a metabasalt intruded by numerous granitic veins of various sizes and orientations is well exposed. The northeasterly trending contact, subparallel to the gneissic foliation in both granite and mafic rocks (030°/65°), is associated with a well-developed mineral and stretching lineation (55°/200°) and dextral shear sense. Microstructural analysis and the occurrence of garnet–pyroxene skarns in this contact aureole (these rocks are exposed along strike about 3 km northeast of this locality) suggest that the main fabric developed under mid-amphibolite facies conditions (Zibra, 2012).

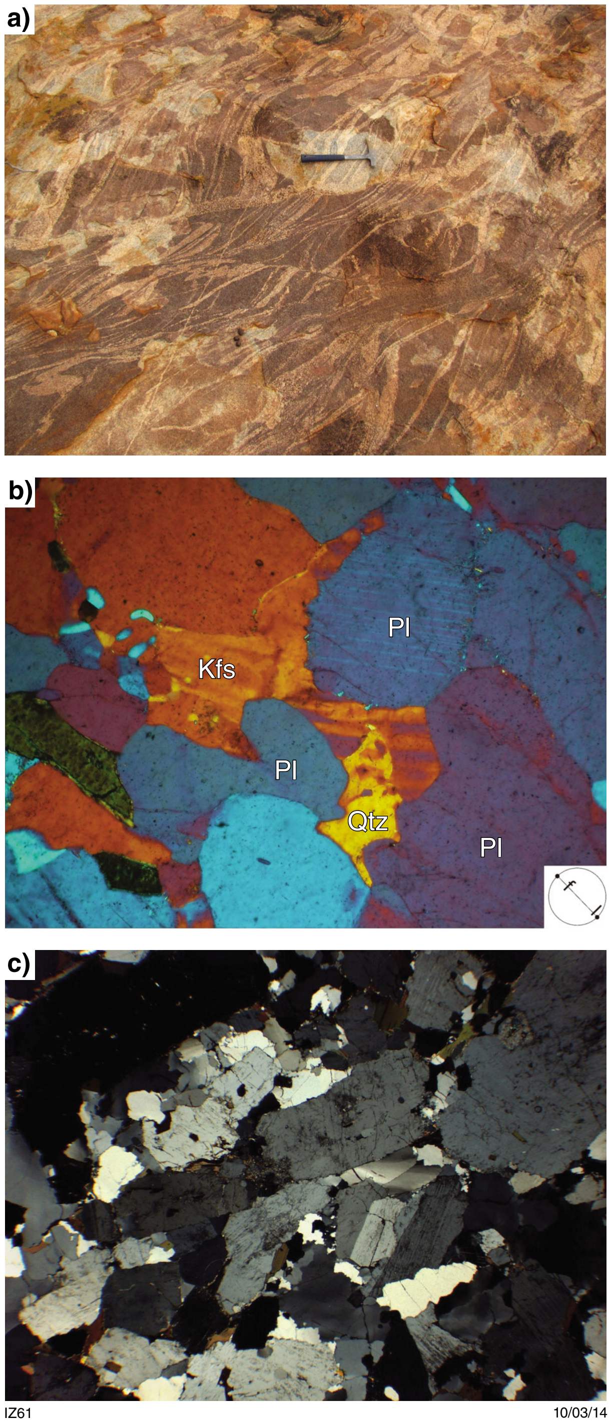


Figure 34. The Lakeside Pluton: a) migmatitic TTG gneiss with layering cut by dextral, melt-filled shear bands; b) typical microfabric from the tonalitic component of the layered TTG gneiss, with lobate quartz–plagioclase phase boundaries. Interstitial K-feldspar occurs as seams preferentially aligned along quartz–plagioclase phase boundaries oriented subperpendicular to the foliation. Base of photo 1 mm. Crossed polars, gypsum plate inserted. Inset at lower right shows orientation with respect to foliation and lineation. After Zibra (2012); c) submagmatic foliation in porphyritic granite at locality 6.1, displaying aligned euhedral feldspars and quartz aggregates recrystallized in the high-quartz field. This fabric likely reflects syn-emplacement deformation at T> ~650°C.

References

Anderson, JL, Barth, AP, Wooden, JL and Mazdab, F 2008, Thermometers and thermobarometers in granitic systems: Reviews in Mineralogy and Geochemistry, v. 69, p. 121–142.

Barley, ME, Brown, SJA, Krapež, B and Kositcin, N 2008, Physical volcanology and geochemistry of a Late Archaean volcanic arc: Kurnalpi and Gindalbie Terranes, Eastern Goldfields Superterrane, Western Australia: Precambrian Research, v. 161, p. 53–76.

Barnes, SJ, Lesher, CM and Sproule, RA 2007, Geochemistry of komatiites in the Eastern Goldfields Superterrane, Western Australia, and the Abitibi greenstone belt, Canada, and implications for the distribution of associated Ni–Cu–PGE deposits: Applied Earth Science, v. 116, p. 167–187.

Bateman, R and Hagemann, S 2004, Gold mineralisation throughout about 45 Ma of Archaean orogenesis: protracted flux of gold in the Golden Mile, Yilgarn Craton, Western Australia: Mineralium Deposita, v. 39, no. 5–6, p. 536–559.

Beardsmore, TJ 2002, The geology, tectonic evolution and gold mineralization of the Lawlers region: a synopsis of present knowledge: Barrick Gold of Australia Ltd, Confidential Technical Report 1026, 279p.

Blewett, RS and Czarnota, K 2007, Diversity of structurally controlled gold through time and space of the central Eastern Goldfields Superterrane — a field guide: Geological Survey of Western Australia, Record 2007/19, 65p.

Blewett, RS, Czarnota, K and Henson, PA 2010, Structural-event framework for the eastern Yilgarn Craton, Western Australia, and its implications for orogenic gold: Precambrian Research, v. 183, p. 203–209.

Bodorkos, S and Wingate, MTD 2007, Compilation of geochronology data, 2007 update, data package.

Broome, J, Journeaux, T, Simpson, C, Dodunski, N, Hosken, J, De Vitry, C and Pilapil, L 1998, Agnew gold deposits, *in* Geology of Australian and Papua New Guinean Mineral Deposits *edited by* D Berkman and DH Mackenzie: The Australasian Institute of Mining and Metallurgy, Melbourne, Australia, p. 161–166.

Cassidy, KF, Champion, DC, Krapež, B, Barley, ME, Brown, SJA, Blewett, RS, Groenewald, PB and Tyler, IM 2006, A revised geological framework for the Yilgarn Craton, Western Australia: Geological Survey of Western Australia, Record 2006/8, 8p.

Champion, DC and Cassidy, KF 2007, An overview of the Yilgarn and its crustal evolution, *in* Proceedings *edited by* FP Bierlein and CM Knox-Robinson: Geoscience Australia; Geoconferences (WA) Inc. Kalgoorlie '07, Kalgoorlie, Western Australia, 25 September 2007; Record 2007/14, p. 8–13.

Champion, DC and Sheraton, JW 1997, Geochemistry and Nd isotope systematics of Archaean granites of the Eastern Goldfields, Yilgarn Craton, Australia: implications for crustal growth processes: Precambrian Research, v. 83, p. 109–132.

Chen, SF, Libby, JW, Greenfield, JE, Wyche, S and Riganti, A 2001, Geometry and kinematics of large arcuate structures formed by impingement of rigid granitoids into greenstone belts during progressive shortening: Geology, v. 29, no. 3, p. 283–286.

Czarnota, K, Champion, DC, Goscombe, B, Blewett, RS, Cassidy, KF, Henson, PA and Groenewald, PB 2010, Geodynamics of the eastern Yilgarn Craton: Precambrian Research, v. 183, p. 175–202.

Dewey, JE, Holdsworth, RE and Strachan, RA 1998, Transpression and transtension zones, *in* Continental transpressional and transtensional tectonics *edited by* R Holdsworth, RA Strachan and JE Dewey: Geological Society, London, Special Publications 135, p. 1–14.

Dunphy, JM, Fletcher, IR, Cassidy, KF and Champion, DC 2003, Compilation of SHRIMP U–Pb geochronological data, Yilgarn Craton, Western Australia, 2001–2002: Geoscience Australia, Geoscience Australia Record 2003/15, 139p.

Duuring, P, Bleeker, W, Beresford, SW, Fiorentini, ML and Rosengren, NM 2012, Structural evolution of the Agnew–Wiluna greenstone belt, eastern Yilgarn Craton and implications for komatiite-hosted Ni sulfide exploration: Australian Journal of Earth Sciences, v. 59, no. 5, p. 765–791.

Eisenlohr, BN, Groves, DI, Libby, J and Vearncombe, JR 1993, The nature of large-scale shear zones and their relevance to gold mineralization, Yilgarn Block: Mineral and Energy Research Institute of Western Australia, Report 122, 161p.

Fossen, H and Tikoff, B 1998, Extended models of transpression and transtension, and application to tectonic settings, *in* Continental transpressional and transtensional tectonics *edited by* RE Holdsworth, RA Strachan and JF Dewey: The Geological Society, London, Special Publications 135, p. 15–33.

Gee, RD, Baxter, JL, Wilde, SA and Williams, IR 1981, Crustal development in the Yilgarn Block, *in* Archaean Geology *edited by* JE Glover and DI Groves: Geological Society of Australia; Second International Archaean Symposium, Perth, Western Australia, Special Publication 7, p. 43–56.

Goscombe, B, Blewett, RS, Czarnota, K, Groenewald, B and Maas, R 2009, Metamorphic evolution and integrated terrane analysis of the Eastern Yilgarn Craton: Rationale, methods, outcomes and interpretation: Geoscience Australia, Record 2009/23, 270p.

Ivanic, TJ, Wingate, MTD, Kirkland, CL, Van Kranendonk, MJ and Wyche, S 2010, Age and significance of voluminous mafic–ultramafic magmatic events in the Murchison Domain, Yilgarn Craton: Australian Journal of Earth Sciences, v. 57, no. 5, p. 597–614.

Kositcin, N, Brown, SJA, Barley, ME, Krapež, B, Cassidy, KF and Champion, DC 2008, SHRIMP U–Pb zircon age constraints on the Late Archaean tectonostratigraphic architecture of the Eastern Goldfields Superterrane, Yilgarn Craton, Western Australia: Precambrian Research, v. 161, p. 5–33.

Krapež, B and Barley, ME 2008, Late Archaean synorogenic basins of the Eastern Goldfields Superterrane, Yilgarn Craton, Western Australia: Part III. Signatures of tectonic escape in an arc–continent collision zone: Precambrian Research, v. 161, no. 1–2, p. 183–199.

Krapež, B, Barley, ME and Brown, SJA 2008, Late Archaean synorogenic basins of the Eastern Goldfields Superterrane, Yilgarn Craton, Western Australia, Part I. Kalgoorlie and Gindalbie Terranes: Precambrian Research, v. 161, p. 135–153.

Krapež, B, Brown, SJA, Hand, J, Barley, ME and Cas, RAF 2000, Age constraints of recycled crustal and supracrustal sources of Archaean metasedimentary sequences, Eastern Goldfields Province, Western Australia: evidence from SHRIMP zircon dating: Tectonophysics, v. 332, no. 1–2, p. 89–133.

Morris, PA, Riganti, A and Chen, SF 2007, Evaluating the provenance of Archean sedimentary rocks of the Diemals Formation (central Yilgarn Craton) using whole-rock chemistry and precise U–Pb zircon chronology: Australian Journal of Earth Sciences, v. 54, no. 8, p. 1123–1136, doi:10.1080/08120090701615758.

Morris, PA and Witt, WK 1997, Geochemistry and tectonic setting of two contrasting Archaean felisc volcanic associations in the Eastern Goldfields, Western Australia: Precambrian Research, v. 83, p. 83–107.

Mueller, AG, Campbell, IH, Schiøtte, L, Sevigny, JH and Layer, PW 1996, Constraints on the age of granitoid emplacement, metamorphism, gold mineralization, and subsequent cooling of the Archean greenstone terrane at Big Bell, Western Australia: Economic Geology, v. 91, p. 896–915.

Myers, JS and Swager, C 1997, The Yilgarn Craton, in Greenstone belts edited by M de Wit and LD Ashwal: Clarendon Press, Oxford, UK, p. 640–656.

Nelson, DR 2004, Compilation of geochronology data, 1994–2001: Geological Survey of Western Australia, Record data package 2003/2.

Nelson, DR, Robinson, BW and Myers, JS 2000, Complex geological histories extending for >4.0 Ga deciphered from xenocryst zircon microstructures: Earth and Planetary Science Letters, v. 181, p. 89–102.

Nutman, AP, Bennett, VC, Kinny, PD and Price, R 1993, Large-scale crustal structure of the northwestern Yilgarn Craton, Western Australia: evidence from Nd isotopic data and zircon geochronology: Tectonics, v. 12, p. 971–981.

Pawley, MJ, Wingate, MTD, Kirkland, CL, Wyche, S, Hall, CE, Romano, SS and Doublier, MP 2012, Adding pieces to the puzzle: episodic crustal growth and a new terrane in the northeast Yilgarn Craton, Western Australia: Australian Journal of Earth Sciences, v. 59, no. 5, p. 603–623, doi:10.1080.08120099.2012.696555.

Pidgeon, RT and Wilde, SA 1990, The distribution of 3.0 Ga and 2.7 Ga volcanic episodes in the Yilgarn Craton of Western Australia: Precambrian Research, v. 48, p. 309–325.

Platt, JP, Allchurch, PD and Rutland, RWR 1978, Archaean tectonics in the Agnew supracrustal belt, Western Australia: Precambrian Research, v. 7, p. 3–30.

Rey, PF, Philippot, P and Thébaud, N 2003, Contribution of mantle plumes, crustal thickening and greenstone blanketing to the 2.75–2.65 Ga global crisis: Precambrian Research, v. 127, p. 43–60.

Schiøtte, L and Campbell, IH 1996, Chronology of the Mount Magnet granite–greenstone terrain, Yilgarn Craton, Western Australia: implications for field based predictions of the relative timing of granitoid emplacement: Precambrian Research, v. 78, p. 237–260.

Stewart, AJ, Williams, IR and Elias, M (compilers) 1983, Youanmi, Western Australia: Geological Survey of Western Australia, 1:250 000 Geological Series Explanatory Notes, 58p.

Tullis, J and Yund, RA 1987, Transition from cataclistic flow to dislocation creep of feldspar: mechanisms and microstructures: Geology, v. 15, p. 606–609.

Van Kranendonk, MJ, Ivanic, TJ, Wingate, MT, Kirkland, CL and Wyche, S 2013, Long-lived, autochthonous development of the Archean Murchison Domain, and implications for Yilgarn Craton tectonics: Precambrian Research, v. 229, p. 49–92.

Wang, Q 1995, New geochronological data for granitoid intrusions in the Reedy area, Murchison province, Western Australia: constraints on genesis of gold mineralization: Australian conference on geochronology and isotope geoscience, November 9–10, 1995, Curtin University of Technology, Perth.

Wang, Q 1998, Geochronology of the granite–greenstone terranes in the Murchison and Southern Cross Provinces of the Yilgarn Craton, PhD thesis: Australian National University, Canberra, 186p.

Watkins, KP, Fletcher, IR and De Laeter, JR 1991, Crustal evolution of Archaean granitoids in the Murchison Province, Western Australia: Precambrian Research, v. 50, p. 311–336.

Watkins, KP and Hickman, AH 1990, Geological evolution and mineralization of the Murchison Province, Western Australia: Geological Survey of Western Australia, Bulletin 137, 267p.

Weinberg, RF 2006, Melt extraction structures in granitic plutons: Geology, v. 34, p. 305–308.

Wiedenbeck, M and Watkins, KP 1993, A timescale for granitoid emplacement in the Archean Murchison Province, Western Australia, by single zircon geochronology: Precambrian Research, v. 61, p. 1–26.

Wilde, SA 2001, Jimperding and Chittering metamorphic belts, Western Australia – a field guide: Geological Survey of Western Australia, Record 2001/12, 24p.

Wilde, SA, Middleton, MF and Evans, BJ 1996, Terrane accretion in the southwestern Yilgarn Craton: evidence from a deep seismic crustal profile: Precambrian Research, v. 78, p. 179–196.

Wilde, SA, Valley, JW, Peck, WH and Graham, CM 2001, Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago: Nature, v. 409, p. 175–178.

Wingate, MTD, Kirkland, CL and Ivanic, TJ 2012, 193972: metarhyolite clast in volcaniclastic breccia, Weld Range; Geochronology Record 1011: Geological Survey of Western Australia, 4p.

Wyche, S, Ivanic, T and Zibra, I (compilers) 2013, Youanmi and southern Carnarvon seismic and magnetotelluric (MT) workshop (preliminary edition): Geological Survey of Western Australia, Record 2013/6, 171p.

Wyche, S, Kirkland, CL, Riganti, A, Pawley, MJ, Belousova, E and Wingate, MTD 2012, Isotopic constraints on stratigraphy in the central and eastern Yilgarn Craton, Western Australia: Australian Journal of Earth Sciences, v. 59, no. 5 (Archean evolution — Yilgarn Craton), p. 657–670, doi:10.1080/08120099.2012.697677.

Yeats, CJ, McNaughton, NJ and Groves, DI 1996, SHRIMP U–Pb geochronological constraints on Archean volcanic-hosted massive sulfide and lode gold mineralization at Mount Gibson, Yilgarn Craton, Western Australia: Economic Geology, v. 91, p. 1354–1371.

Zibra, I 2011, Austin, WA Sheet 2442: Geological Survey of Western Australia, 1:100 000 Geological Series.

Zibra, I 2012, Syndeformational granite crystallization along the Mount Magnet greenstone belt, Yilgarn Craton: evidence of large-scale magma-driven strain localization during Neoarchean time: Australian Journal of Earth Sciences, v. 59, no. 5, p. 793–806.

Zibra, I 2013, Wynyangoo, WA Sheet 2542: Geological Survey of Western Australia, 1:100 000 geological series.

Zibra, I, Kruhl, JH, Montanini, A and Tribuzio, R 2012, Shearing of magma along a high-grade shear zone: evolution of microstructures during the transition from magmatic to solid-state flow: Journal of Structural Geology, v. 37, p. 150–160.

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