Technical papers

The Yamarna Shear Zone: a new terrane boundary in the northeastern Yilgarn Craton?

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Abstract

The Yamarna Shear Zone is a regional-scale, north-northwesterly trending structure in the northeast corner of the Yilgarn Craton that has been interpreted as a domain boundary in the Burtville Terrane. A seismic reflection profile shows the shear zone extending through the crust.

New mapping in the northeast Yilgarn Craton has shown that the Yamarna Shear Zone is a complex structure made up of three structural zones: (i) a western zone forming the footwall, which contains upright folding and layer-parallel high-strain zones in the Mount Venn greenstone belt that formed in a compressional setting. These structures overprint earlier structures that indicate east–west directed contraction or extension; (ii) a central zone of banded and foliated granite, dated at 2662 ± 4 Ma, which has undergone dextral, strike-slip shearing; and (iii) a wide, eastern zone, composed of highly strained greenstones and metagranite that record sinistral strike-slip shearing. The strain in the structural zones is highly partitioned, with each zone preserving separate deformation events. The deformation history of the Yamarna Shear Zone can be related to events recognized in structural syntheses proposed for other parts of the Eastern Goldfields Superterrane.

An examination of greenstone and granite geochronology across the Yilgarn Craton reveals that the rocks east of the Yamarna Shear Zone are contemporaneous with those in the Kalgoorlie and Kurnalpi Terranes. In contrast, the rocks to the west of the Yamarna Shear Zone have more in common with those of the Murchison Domain of the Youanmi Terrane. These age contrasts, along with the scale and complexity of the Yamarna Shear Zone, suggest that it represents a previously unrecognized terrane boundary in the northeast Yilgarn Craton, with the Burtville Terrane now consisting of the Duketon and Merolia Domains, separated from the Yamarna Terrane to the east.

KEYWORDS: Yilgarn Craton, Yamarna Shear Zone, Burtville Terrane, Yamarna Terrane, tectonics, deformation, structural history

Introduction

The Yamarna Shear Zone is a regional-scale, north-northwesterly trending structure in the northeast part of the Yilgarn Craton (Fig. 1) that can be traced across the craton on aeromagnetic images. Based on reconnaissance-scale mapping, Gower and Boegli (1977) described the contact along the eastern side of the Yamarna greenstone belt as a 'major structural feature'. A seismic transect suggested that the Yamarna Shear Zone is a broad, crustal-scale, east-dipping, and listric structure, flooring into a detachment at a depth of 35 km (Fig. 2; Goleby et al., 2004). It is similar to the terrane-bounding Laverton shear zone and Mount George and Keith–Kilkenny shear system that have been interpreted to have complex geometries representing episodic folding and faulting (Fig. 2; Goleby et al., 2004). Recently, the Yamarna Shear Zone was described by Cassidy et al. (2006) as a domain boundary (Fig. 1) that separates the Yamarna Domain in the eastern Burtville Terrane from the Merolia Domain to the west. There is a third domain in the Burtville Terrane, the Duketon Domain, which lies to the west of the Merolia Domain (Fig. 1).

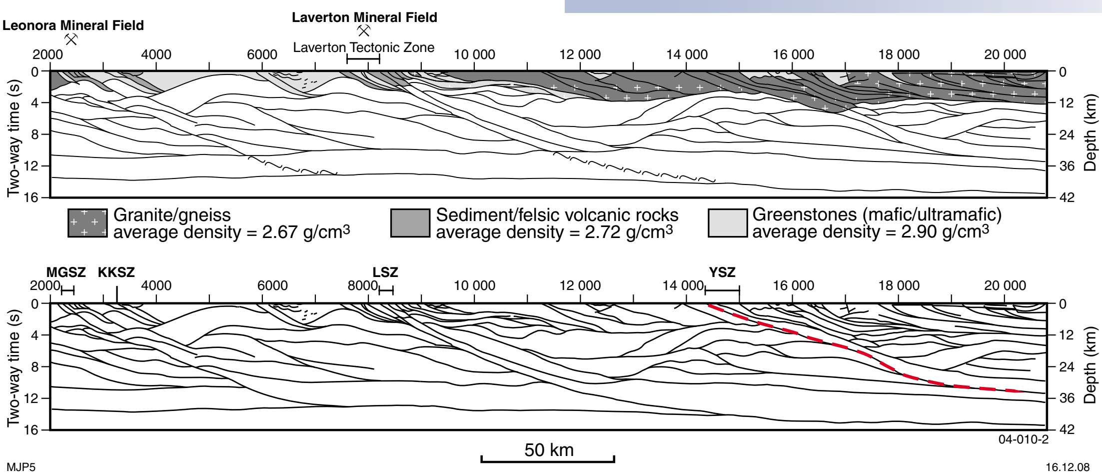

Figure 2. Seismic section showing the similarities between the Yamarna Shear Zone (YSZ) and the Laverton shear zone (LSZ) and Mount George (MGSZ) and Keith–Kilkenny shear system (KKSZ) near Leonora. The red dashed line highlights the Yamarna Shear Zone. Modified from Goleby et al. (2004)

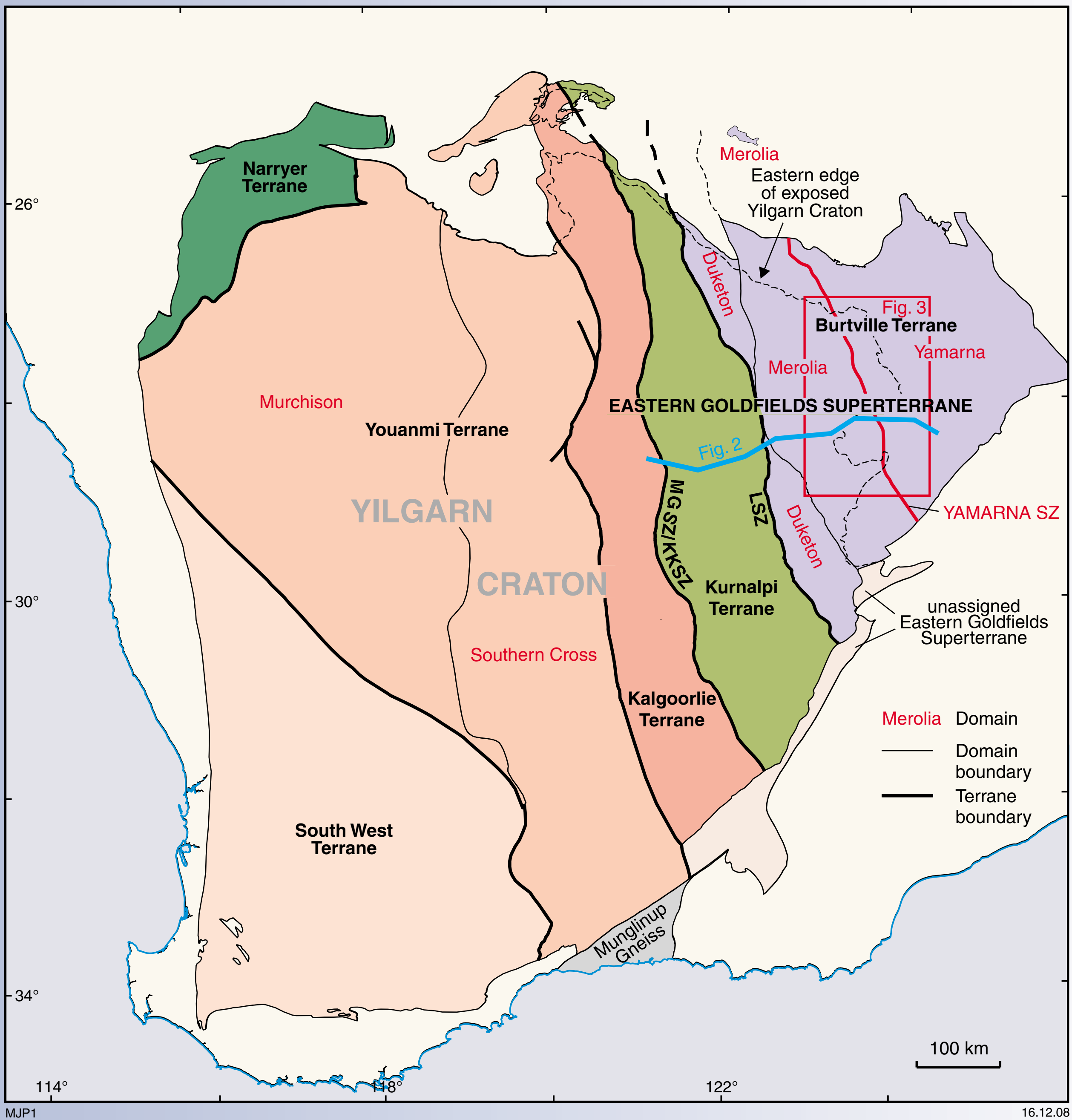

Figure 1. Tectonic subdivision of the Yilgarn Craton showing the terranes of Cassidy et al. (2006). The blue line shows the location of the seismic section shown in Figure 2. The box shows the location of Figure 3. LSZ = Laverton shear zone; MGSZ/KKSZ = Mount George and Keith–Kilkenny shear system; Yamarna SZ = Yamarna Shear Zone

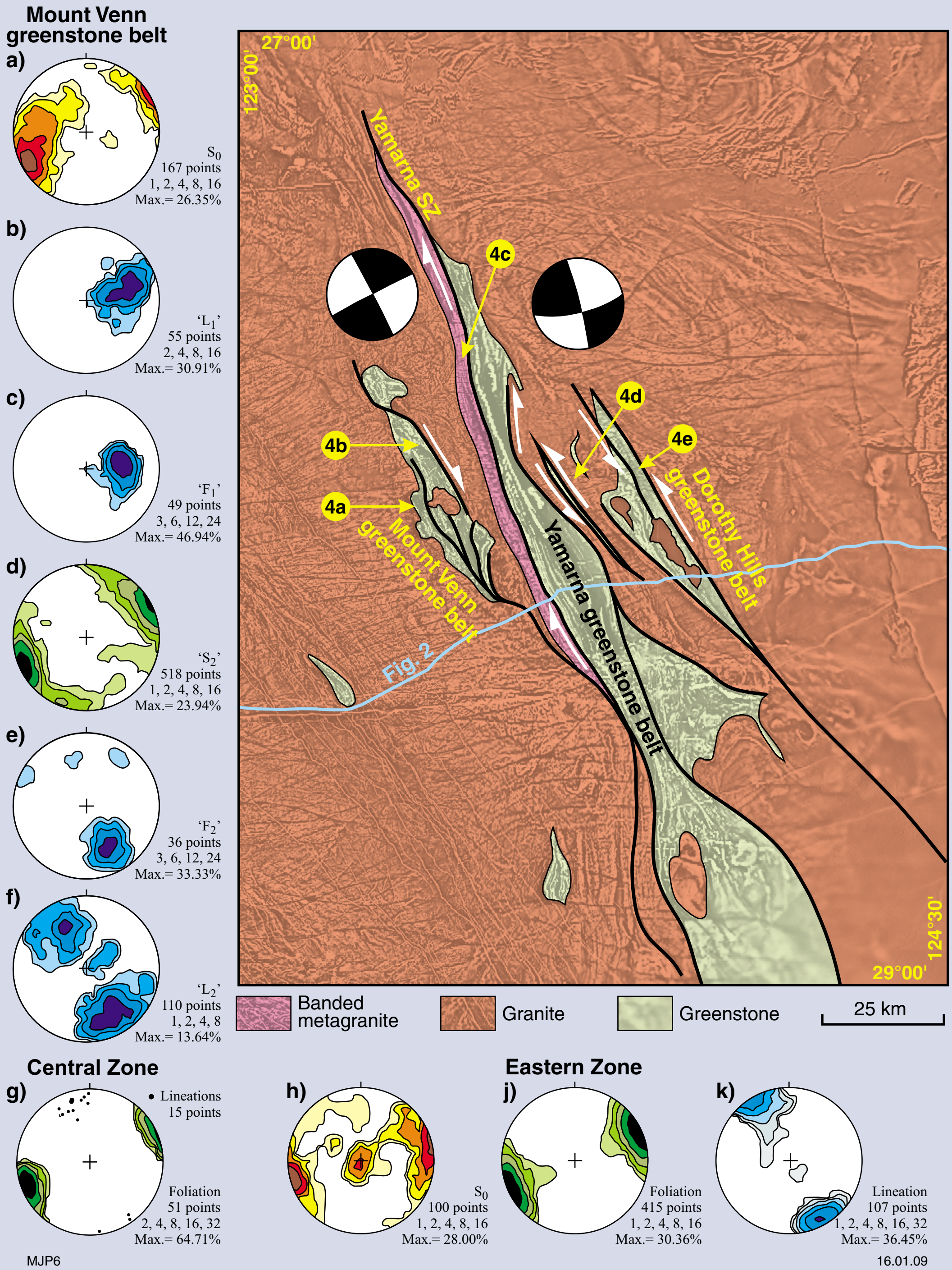

Figure 3. Simplified geology of the Yamarna Shear Zone overlain on the aeromagnetic image (1VD). The stereonets a–f are from the Mount Venn greenstone belt, g is from the central structural zone, and h–k are from the eastern structural zone. The fault solution 'balls' show the difference in stress regime between the central and eastern zones (σ_1 is located in the black quadrant). Fault solutions for the dextral and sinistral domains are based on 4 and 12 points, respectively. The numbers indicate the location of the photographs in Figure 4

New mapping in the northeast Yilgarn Craton has shown that, rather than being a simple structure, the Yamarna Shear Zone is a wide zone of deformation characterized by strain partitioning.

Structural zones and field observations

Rocks related to the Yamarna Shear Zone can be divided into three structural zones (Fig. 3):

i) The Mount Venn greenstone belt forms part of the footwall to the west of the Yamarna Shear Zone (Fig. 3), and is composed of c. 2770 Ma (GSWA samples 183118, 178122, Geological Survey of Western Australia, in prep.) ultramafic to felsic volcanic rocks, with minor sedimentary rocks near the base. This package is intruded by gabbro and dolerite sills that are up to 2 km thick (e.g. the Mount Venn and Mount Warren intrusive complexes). The greenstone belt is dominated by upright, shallowly plunging folds, with axial-planar parallel, high-strain zones with subhorizontal lineations (Figs 3a,d–f, 4a–b). These structures represent progressive folding and shearing in a compressive to possibly transpressive setting. Along the western part of the belt, a banded iron-formation (BIF) unit is characterized by S_0-parallel, down-dip sheath folds and stretching lineations that pre-date, and are overprinted by, the upright folding and shearing (Figs 3c–d, 4a). This suggests an early stage of east–west oriented, low-angle extension or thrusting: no kinematic indicators have been recognized.

ii) A central structural zone, located between the Mount Venn and Yamarna greenstone belts (Fig. 3), is composed of orthogneiss, and banded and foliated metagranites with greenstone lenses. Subhorizontal lineations, asymmetric porphyroclasts and C' planes (Figs 3g, 4c) indicate dextral strike-slip shearing within this zone. A monzogranite from this zone has a preliminary SHRIMP U–Pb zircon crystallization age of 2662 ± 4 Ma (GSWA sample 179446, GSWA, in prep.) that constrains the maximum age of dextral shearing.

iii) The eastern structural zone is composed of two main greenstone belts — the Yamarna greenstone belt to the west and the Dorothy Hills greenstone belt to the east — which are separated by a zone of sheeted and sheared metagranite and greenstones (Fig. 3). The Yamarna greenstone belt includes (from west to east) ultramafic intrusive rocks, felsic volcanic rocks, clastic sedimentary rocks, and basalts. The felsic volcanic rocks, which form a series of lenses (possibly boudins) that are distributed along the strike of the belt, have been dated at 2699 ± 5 and 2682 ± 5 Ma (Sircombe et al., 2007). Bedding in this zone shows several parallel partial girdles (Fig. 3h), which suggest that the belt contains a series of northwesterly trending folds. However, the asymmetry of the lithological assemblage across the belt suggests it does not form a simple synclinal greenstone belt. Structurally, the eastern zone is characterized by widespread, layer-parallel shear zones that have subhorizontal lineations and C–S relations that indicate a sinistral strike-slip sense of shear (Figs 3h–k, 4d–e).

Despite the difference in kinematic history, the stereonet patterns for the central and eastern zones are remarkably similar (Figs 3g, j–k). The difference between the structural zones is shown by the schematic fault solutions (Fig. 3), which can be used to show the orientation of the principal stresses for a deformation event (Blewett et al., 2004; Stüwe, 2007), with σ_1 located in the black quadrant and σ_3 in the white quadrant. The solutions indicate a major change in the stress field, resulting in the transition from sinistral to dextral shearing, with negligible change in shear plane orientation.

Structural history of the Yamarna Shear Zone

Rather than being a discrete structure, the Yamarna Shear Zone forms a broad zone of deformation, with strain partitioned into three main structural zones. The Mount Venn greenstone belt, forming the footwall to the west, preserves an early stage of approximately east–west oriented thrusting or extension. These structures were overprinted by upright folds and layer-parallel shearing, interpreted to represent a period of compressional to transpressional deformation. Based on the isolation of the fold hinges by the strike-slip shearing, it is proposed that folding and shearing in the Mount Venn greenstone belt were contemporaneous. There is no significant offset across these structures. Rather, they appear to accommodate minor layer-parallel slip in the late stage of the deformation episode, i.e. after the folds were tight to isoclinal.

The central and eastern zones are characterized by dextral and sinistral shearing, respectively. No overprinting relations have been observed for the two stages of strike-slip shearing, although Blewett and Czarnota (2007) proposed that sinistral shearing preceded dextral shearing in the Eastern Goldfields Superterrane. The age of dextral shearing in the central zone is constrained at younger than 2662 Ma.

The history presented here is consistent with that proposed for the Eastern Goldfields Superterrane by Blewett and Czarnota (2007), who recognized three early stages of deformation that involved east-northeasterly directed transport. In their interpretation, extension during D_1 was associated with deposition of the ultramafic to felsic volcanic and volcaniclastic rocks in the Kalgoorlie and Kurnalpi Terranes between c. 2720 and 2670 Ma. D_2 was a contractional deformation interpreted to result from closure of the extensional orogen at c. 2670 Ma. D_3 was a two-part extensional event associated with deposition of clastic sediments into the 'late' basins (Krapež et al., 2000) at c. 2665 Ma. No kinematic indicators have yet been found in the Mount Venn greenstone belt so it is difficult to assign the early structures in this belt. No 'late-basin' packages have been identified in the Burtville Terrane.

The transpressional deformation recorded in the Yamarna Shear Zone is also consistent with the history presented by Blewett and Czarnota (2007). Their D_4 resulted in upright, north-northwesterly trending folds followed by north-northwesterly trending sinistral shear zones at between c. 2655 and 2650 Ma. The transition from folding to strike-slip shearing was attributed to a shift in the stress axes, due to heterogeneous stress. D_5 resulted in transtensional dextral shearing, and was interpreted to result from a major rotation of the paleostress field during plate reconfiguration at c. 2635 Ma. This is consistent with the fault solutions for the central and eastern domains of the Yamarna Shear Zone (Fig. 3).

It is also possible, particularly in the absence of overprinting relations, that the three structural zones resulted from strain partitioning during a single deformation event. In this case, the dextral and sinistral strike-slip shearing would be contemporaneous and represent tectonic escape under a compressional regime (Stüwe, 2007).

Although Blewett and Czarnota (2007) provided a framework for understanding the Yamarna Shear Zone, their work was focused on the Kalgoorlie and Kurnalpi Terranes in the western Eastern Goldfields Superterrane (Fig. 1). The new mapping in the northeastern Yilgarn Craton complements this work and provides a more complete picture of the eastern Yilgarn Craton geology and the geodynamic history of the craton.

Significance of the Yamarna Shear Zone

A comparison of greenstones within and adjacent to the Yamarna Shear Zone, with those of other terranes of the Yilgarn Craton, suggests the Yamarna Shear Zone may represent a terrane boundary. Greenstones east of the Yamarna Shear Zone, in the Yamarna Domain, are lithologically similar to, and have similar ages to those in the Kalgoorlie and Kurnalpi Terranes (c. 2720 to c. 2680 Ma). In contrast, the greenstones of the Merolia and Duketon Domains have an affinity with those of the Murchison Domain in the Youanmi Terrane of the western Yilgarn Craton (Fig. 1). They include mafic and felsic volcanic rocks, minor sedimentary rocks, and mafic intrusive rocks, which have SHRIMP U–Pb zircon ages of c. 2961 Ma (GSWA sample 193363, GSWA, in prep.), c. 2805 Ma (Kositcin et al., 2008) and c. 2770 Ma (GSWA samples 183118 and 178122, GSWA, in prep.). These packages coincide with the oldest three volcanic cycles in the Meekatharra area of the Murchison Domain (fig. 1 of Van Kranendonk, 2008), which are dated at c. 2970, 2814–2799, and 2784–2755 Ma. The fourth, and youngest, package in the Meekatharra area is dated at 2719–2704 Ma, which is contemporaneous with the Kambalda sequence in the Kalgoorlie Terrane. This is only slightly older than the greenstones of the Yamarna Domain (c. 2699 to c. 2682 Ma; Sircombe et al., 2007), which have an age range similar to the Spargoville Formation and Black Flag Group (i.e. c. 2698 to c. 2666 Ma; Krapež et al., 2000) that overlie the Kambalda sequence. No greenstone rocks equivalent to the <2720 Ma package of the Yamarna Domain have been recognized in the Merolia and Duketon Domains.

Granites in the eastern Yilgarn Craton show a similar age range to the greenstone rocks. Although the granites across the Eastern Goldfields Superterrane are typically c. 2720 to c. 2620 Ma (i.e. overlapping with the greenstones of the Kalgoorlie and Kurnalpi Terranes), there are scattered 2939 ± 6 Ma and c. 2770 – c. 2755 Ma granites and gneissic protoliths in the Duketon Domain (Fletcher et al., 2001; Dunphy et al., 2003). Similar rocks of this age are also found in

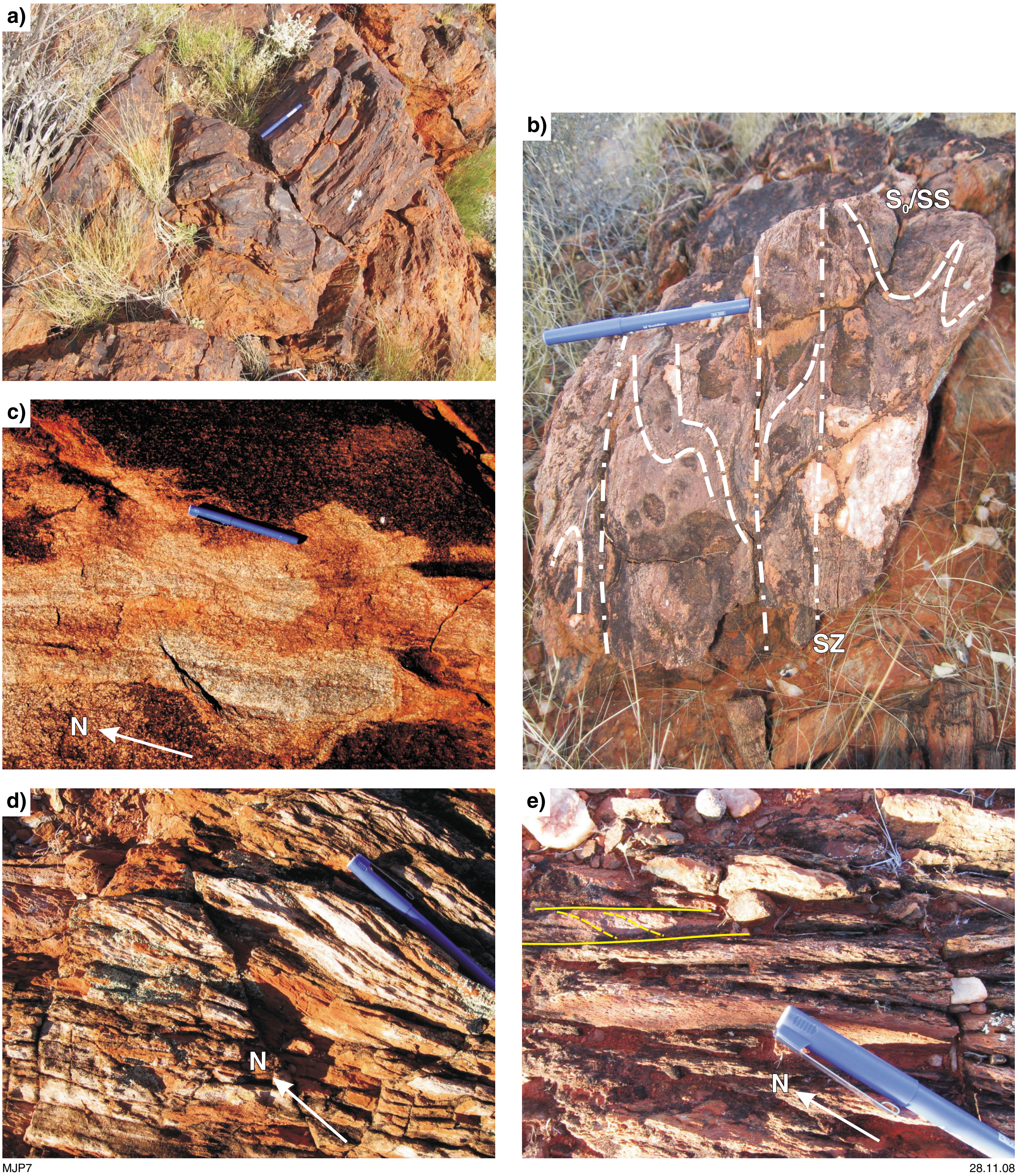

Figure 4. Photographs of structural elements from across the Yamarna Shear Zone:
a) a bedding-parallel, down-dip stretching lineation (‘L_1’; parallel to pen) is folded by upright open folds (‘F_2’) that plunge shallowly to the south (view to south); b) bedding and parallel solid-state foliation (labelled S_0/SS) is folded into shallowly plunging close to tight folds (‘F_2’) that have sheared out limbs (labelled SZ; view to south); c) dextral, melt-filled, extensional shear band in banded metagranite (pen cap is to the north); d) sinistral C–S planes in weathered granite (pen cap is to the north); and e) sinistral C–S planes in weathered basalt (pen cap is to the north). Photographs a–b are from the Mount Venn greenstone belt, c is from the central structural zone, and d–e are from the eastern zone

the Murchison Domain (Van Kranendonk, 2008). No felsic intrusive rocks of this age have yet been identified in the Yamarna Domain although there are inherited grains up to c. 2941 Ma (Black et al., in press).

It is likely that the Merolia, Duketon, and Murchison Domains share a common pre-2720 Ma history, prior to extension associated with formation of the Kalgoorlie and Kurnalpi Terranes. This older history is not preserved in the greenstones of the Yamarna Domain, nor is it observed in the Kalgoorlie and Kurnalpi Terranes other than in xenocryst zircon populations, and in isolated fragments that may represent autochthonous basement. This suggests that greenstones east of the Yamarna Shear Zone represent a younger extensional package, similar in age and character to the Kalgoorlie and Kurnalpi Terranes. Thus, the Yamarna Shear Zone likely represents a terrane boundary in the northeast Yilgarn Craton, bounding a distinct lithostratigraphic package to the east. As a consequence, the Eastern Goldfields Superterrane subdivision (Cassidy et al., 2006) should be re-evaluated. The Burtville Terrane should be removed from the Eastern Goldfields Superterrane, and divided into an older western terrane made up of the Duketon and Merolia Domains, and a younger eastern terrane corresponding to the Yamarna Domain.

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