The tectono-magmatic evolution of the Yilgarn orogen: in search of a model

by

I Zibra

Secular changes in fundamental physical parameters, such as mantle temperature and density (Labrosse and Jaupart, 2007), imply that the mechanical behaviour of the continental lithosphere has changed through time. Since the geological record becomes progressively more fragmented as we go back in time, there is a general lack of consensus about Archean geodynamics (van Hunen and Moyen, 2012). Moreover, given that the association of granites with volcano-sedimentary supracrustal sequences has no clear Phanerozoic counterparts, the tectonic setting of Archean granite–greenstone terranes is highly debated (Bédard, 2010). The two end-member processes that have been proposed for Archean tectonics are generally referred to as 'horizontal tectonism' and 'vertical tectonism', reflecting the view that Archean geodynamics was dominated by uniformitarian (i.e. plate tectonics-like) or non-uniformitarian processes, respectively (e.g. Van Kranendonk et al., 2004). Although some plate tectonic features (such as subduction–accretion) probably occurred sporadically in the Mesoarchean geological record (e.g. Smithies et al., 2005), several lines of evidence indicate that the transition from episodic-overturn/stagnant-lid regime (a form of vertical tectonism) to modern-style plate tectonics occurred progressively throughout Neoarchean times. The Neoarchean transition in global geodynamics primarily reflects a significant increase in recycling of crustal material into the mantle, and is therefore interpreted as evidence for the widespread occurrence of complete Wilson cycles.

The Neoarchean Yilgarn orogen of Western Australia (Fig. 1; Zibra et al., 2017a) contains many typical traits of ancient-type orogens, such as negligible topography and the occurrence of long-lasting and widespread synorogenic magmatism (Van Kranendonk et al., 2013), features that are generally thought characteristic of hot Precambrian orogens. However, the Yilgarn orogen contains regional-scale synorogenic clastic deposits (Figs 1b, 2) that developed during major tectonic episodes of crustal shortening, at the onset of the orogeny (Zibra et al., 2017a), and the late-orogenic, orogen-wide transpressional event associated with the exhumation of high-grade greenstones (Zibra et al., 2017b). These features imply that the Neoarchean Yilgarn orogenic lithosphere was stiff enough to allow tectonic processes analogous to those that dominate modern-style orogenic belts, such as strain localization, development of significant regional topography and, consequently, focused erosion. Such tectonic styles might represent an intermediate stage between Archean-type and modern-type orogens.

The bulk east–west horizontal shortening recorded during most of the tectonic evolution of the Yilgarn Orogen is commonly ascribed to a series of accretion episodes that led to amalgamation of the Eastern Goldfields Superterrane (EGST), and the Narryer and South West Terranes, onto an older foreland represented by the Youanmi Terrane (Myers, 1995; Wilde et al., 1996; Krapež and Barley, 2008). The Ida Fault is regarded as the suture between the EGST and the Youanmi Terrane (Myers, 1995), a scenario that is consistent with the existence of a 2736–2724 Ma volcanic arc setting now preserved in the hangingwall of the Ida Fault (de Joux et al., 2014), together with the occurrence of high-grade greenstones along this major structure (Zibra et al., 2017b). Alternatively, the various terranes could have once been part of a Mesoarchean 'proto-Yilgarn' continent, subsequently rifted into a series of ribbon continents during possible extensional events within the 2960–2750 Ma time slice, and in turn amalgamated again by inversion tectonics during the Neoarchean Yilgarn Orogeny (autochthonous models; Czarnota et al., 2010; Pawley et al., 2012; Van Kranendonk et al., 2013). Autochthonous models mainly hinge on the geochronological and isotopic evidence of broadly contemporaneous crust-forming events throughout the various terranes from at least c. 3100 Ma (Wyche et al., 2012; Mole et al., 2015). However, given that the Precambrian Earth recorded a series of global tectono-magmatic events, broadly contemporaneous crust-forming events would also be expected if the terranes now assembled into the Yilgarn Craton were not in physical contact. In summary, available datasets allow for both end-member geodynamic models (accretion of an allochthonous EGST or inversion of an autochthonous ensialic rift) and both models may account for the tectono-magmatic and sedimentary evolution of the Yilgarn continent. Thus, many of the fundamental questions about Archean tectonics that have been raised since the 1970s (e.g. van Hunen and Moyen, 2012) remain unanswered.

Recent structural work has documented that several of the transpressional, crustal-scale shear zones exposed in the Yilgarn Craton accommodated the synorogenic emplacement of syntectonic plutons (Zibra et al., 2014). Shearing along these major structures was intimately connected with the development of syntectonic clastic deposits and with exhumation of high-grade greenstones along the Ida Fault (Zibra et al., 2017b). Structural and geochronological evidence indicate that each episode of pluton emplacement induced a deformation event that

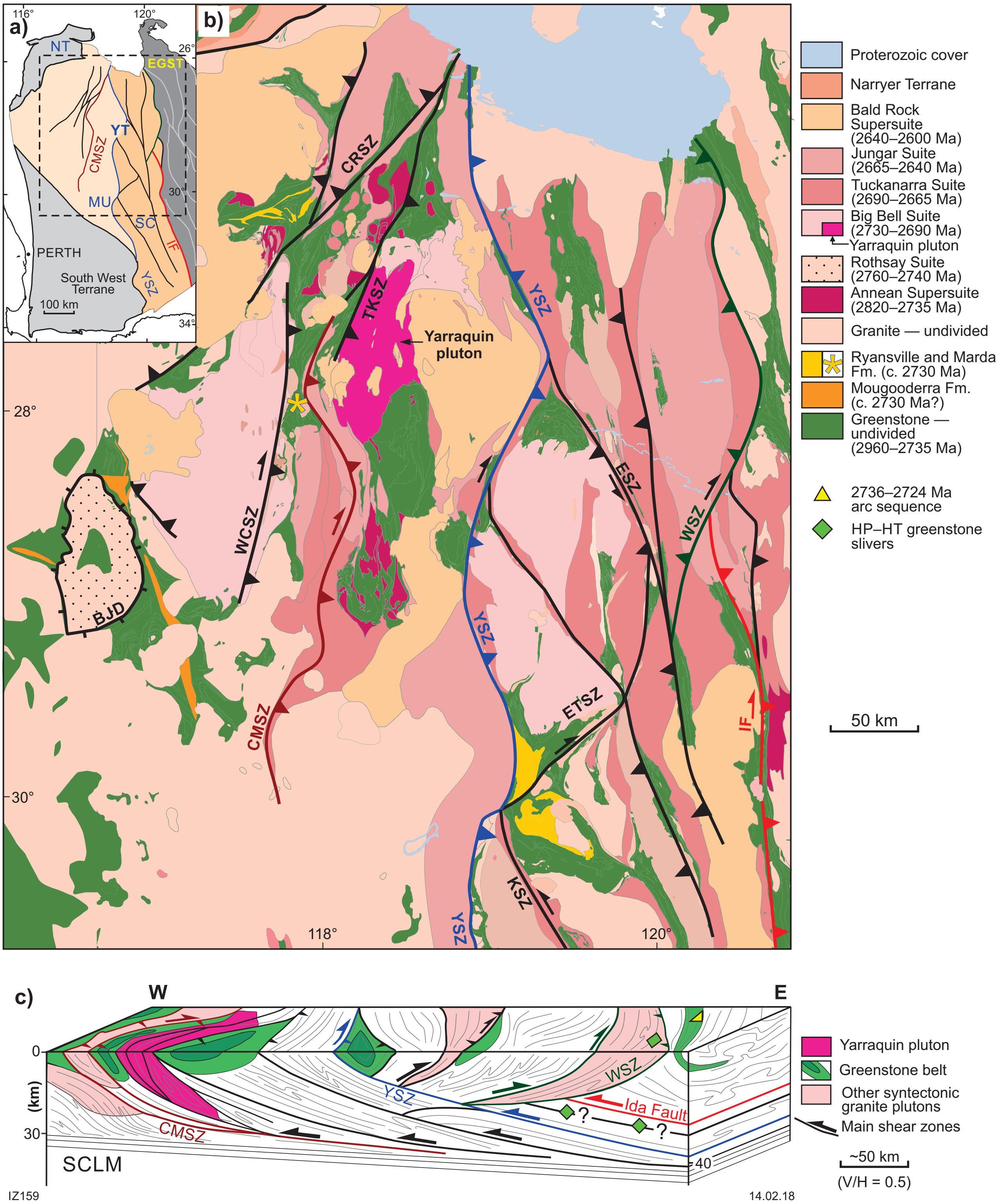

Figure 1. a) Simplified map of the main geological subdivisions and shear zones of the western portion of the Yilgarn Craton, showing the main terranes and the network of craton-scale shear zones. EGST, Eastern Goldfields Superterrane; NT, Narryer Terrane. In the western half of the craton, the Youanmi Terrane (YT) is subdivided into Murchison (MU) and Southern Cross (SC) domains. Main shear zones are colour-coded: IF, Ida Fault; YSZ, Youanmi Shear Zone; CMSZ, Cundimurra Shear Zone. Rectangle shows the location of (b); b) interpreted geological map of the central portion of the Youanmi Terrane. Abbreviations for the shear zones not shown in (a): CRSZ, Chunderloo Shear Zone; ESZ, Edale Shear Zone; ETSZ, Evanston Shear Zone; KSZ, Koolyanobbing Shear Zone; TKSZ, Tuckabianna Shear Zone; WSZ, Waroonga Shear Zone; WCSZ, Wattle Creek Shear Zone; BJD, Badja Decollement. Location of HP–HT greenstone slivers and the 2736–2724 Ma arc sequence are from (Zibra et al., 2017b) and de Joux et al. (2014), respectively; c) block diagram summarizing the crustal architecture of the western portion of the Yilgarn Craton, as reconstructed by merging the results of seismic traverses. The Moho discontinuity and the highly reflective middle to lower crust overlie a seismically transparent subcontinental lithospheric mantle (SCLM)

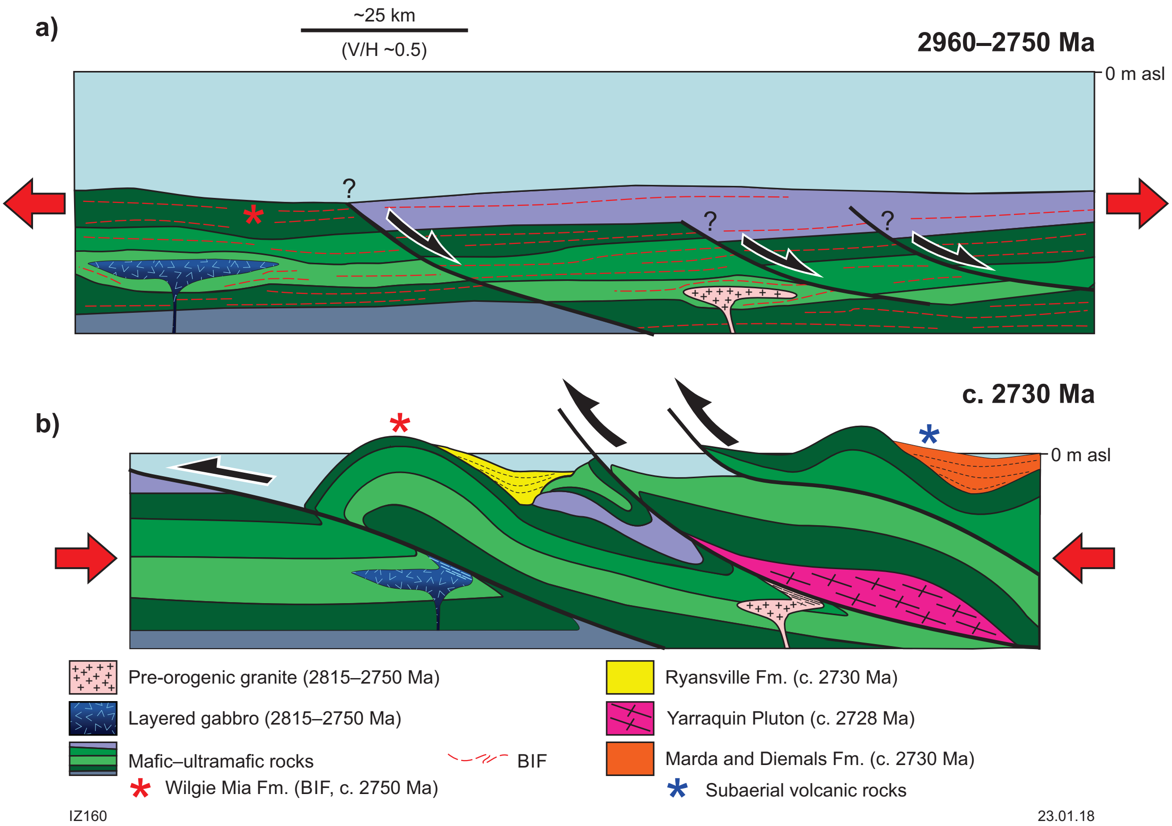

Figure 2. Cartoon outlining the pre- to early-orogenic evolution of the western part of the Yilgarn orogen: a) 2960–2750 Ma accumulation of a thick greenstone pile dominated by mafic–ultramafic volcanic rocks interlayered with BIF, the latter devoid of any clastic input. It is likely that events of lithospheric extension during this period were accommodated by large-scale shear zones with normal kinematics; b) at c. 2730 Ma, the onset of the Neoarchean orogeny is marked by shearing along large-scale, E-dipping contractional structures, exhumation of the 2960–2750 Ma succession to subaerial conditions, and proximal, high-energy sedimentary basins developed above a regional unconformity. At the same time, the Yarraquin pluton was emplaced along part of the wide network of east-dipping, contractional shear zones

was mostly localized within the pluton itself and within the crustal-scale channel that allowed its emplacement, leaving only a minor structural signature in the adjacent areas. The overall orogenic cycle produced adjacent high-strain belts showing comparable geometry and kinematics, but whose ages span from c. 2730 to 2660 Ma, covering most of the duration of the Neoarchean Yilgarn Orogeny. These results indicate that the concept of regional deformation in Archean granite–greenstone systems needs to be reassessed.

One way to investigate the tectonic evolution of the Yilgarn Orogen is to compare the tectono-magmatic evolution of the two main terranes juxtaposed by the Ida Fault. This approach focuses on two historically contentious issues: 1) the nature of the greenstone basement (oceanic vs continental?), and 2) the significance of terrane boundaries (sutures vs intracontinental weaknesses?). A synthesis of recently published work and in-progress data indicates that greenstones belonging to both the Youanmi Terrane and the EGST developed on older sialic crust, and therefore the nature of the Archean oceanic crust remains elusive. In fact, the 2820–2800 Ma time slice is characterized, in the Youanmi Terrane, by the development of a thick greenstone sequence developed in a distal, deep-marine environment, far from any detrital source. This sequence developed above >3000 Ma felsic basement that, at the currently exposed crustal level, is now preserved only as an isotopic signature, and as detrital and inherited zircons in younger granitic and sedimentary rocks (Wyche et al., 2012). At the same time, in the western portion of the EGST, the Kalgoorlie Terrane records the development of a >300 km-wide segment of granitic crust that later became the basement of the 2730–2660 Ma komatiite-bearing greenstone sequence that characterizes this terrane. Overall, the available data suggest that the Ida Fault represents a long-lived structure that accommodated large displacements during the orogeny, juxtaposing crustal domains characterized by contrasting pre- and syn-orogenic tectono-magmatic evolution. Data discussed here have significant implications for our understanding of Archean orogenic processes.

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