

Crustal architecture of the Youanmi Terrane, Yilgarn Craton: preliminary data and new ideas

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The understanding of Archean geodynamics largely hinges around the long-standing debate on what tectonic styles were active on early Earth (Condie and Benn, 2006). The two end-member processes that have been proposed for Archean tectonics can be summarized as ‘horizontal tectonism’ and ‘vertical tectonism’, reflecting the view that Archean geodynamics was dominated by uniformitarian or non-uniformitarian processes, respectively (Van Kranendonk, 2004, for a review). In Western Australia, the Archean Pilbara and Yilgarn Cratons show some contrasting first-order geometric and structural features that are only partly understood, offering the opportunity for this contribution to the long-standing debate.

Geodynamic models

The Paleo- to Mesoarchean East Pilbara Terrane represents a well-documented example of crustal evolution dominated by vertical tectonics (Van Kranendonk et al., 2004), and includes a well-preserved dome-and-keel architecture, with map-view geometries characterized by circular granite–migmatite domes wrapped by greenstone envelopes displaying a well-preserved stratigraphy and lateral continuity. In contrast, the Yilgarn Craton, which is mostly Neoarchean, is dominated by craton-scale, approximately north-trending high-strain zones (Fig. 1), mostly associated with highly deformed elongate granite bodies and dismembered greenstone packages, superficially resembling Phanerozoic orogenic belts. The Yilgarn Craton is a wide hot orogen (Chardon et al., 2009) where syn-orogenic shortening was distributed over several hundreds of kilometres across strike, and deformation was assisted by long-lived magmatism (in part of juvenile nature) and HT–LP metamorphism.

Contrasting geodynamic models have been proposed to account for the structural, magmatic and metamorphic evolution of the Yilgarn Craton. Modern-style subduction–accretion models seem to adequately explain the large-scale linear structures and crustal-penetrating shear zones associated with consistently east-dipping first-order geometry (Goleby et al., 2004). In contrast, plume-dominated models may explain some features, such as a comparable craton-scale magmatic evolution throughout a large part of the Neoarchean and the apparent lack of important metamorphic gradients across the craton (Van Kranendonk et al., 2013).

The Neoarchean has been described as a period of ‘global crisis’ (Rey et al., 2003), as the intense and protracted magmatic activity led to a nearly complete reworking of the felsic continental crust. This is consistent with the observation that, across the whole craton, the base of the c. 2900–2720 Ma greenstone sequences is invariably represented by a younger intrusive contact. This observation implies that the felsic basement to the greenstones, which may be Eoarchean in places (Wyche et al., 2012), has been completely remelted and assimilated by the voluminous c. 2720–2600 Ma-old granitic plutons. However, spatial, temporal and genetic relationships between such voluminous and protracted crustal reworking and the development of the craton-scale shear zone network are mostly unclear. Given that at least some of the exposed Yilgarn shear zones are likely rooted within the lower crust (Goleby et al., 2004), relations between structures and magmatism also have significant implications for the understanding of mineral systems.

This contribution provides an overview of some case studies in progress from the Youanmi Terrane of the Yilgarn Craton. New meso- and microstructural observations, supported by recently acquired geophysical and geochemical data, are used to understand the relationships between magmatism, shearing and polyphase deformation in mineralized Neoarchean granite–greenstone systems.

Geological setting and crustal architecture of the Youanmi Terrane

The Yilgarn Craton comprises several terranes (Fig. 2), each defined as having distinct sedimentary and magmatic associations, geochemistry and ages of volcanism (Cassidy et al., 2006). The Youanmi Terrane is isotopically distinct because Sm–Nd and Lu–Hf data show several events of crustal formation and reworking between 4000 and 2600 Ma (Wyche et al., 2012). The terrane is cut by a network of late-orogenic, large-scale anastomosing shear zones more than 100 km long and about 2 to 10 km wide (Fig. 1). Several field studies indicate that most of these shear zones have a transpressional character (Zibra et al., in press).



Figure 1. Geophysical image (gravity draped over aeromagnetics) showing the trace of the terrane-scale network of late-orogenic shear zones (white) that likely controlled the rheology of the whole crustal section. The c. 2620 Ma post-kinematic plutons Garden Rock Granite (GR) and Taincrow Granite (TG), postdating the development of the shear-zone network, are marked in yellow

The dataset used for this study includes about 2000 structural observation points throughout the northern portion of the Youanmi Terrane. The points are mainly clustered along, or in the vicinity of, the recently acquired seismic traverses (Wyche et al., 2013), marked as YU1, 2, 3 on Figures 1 and 2. About 600 thin sections were studied from oriented samples, and 200 samples were also selected for quartz crystallographic preferred orientation (CPO) analysis, which is currently in progress. Structural data are combined with about 230 geochemical analyses of both granite and greenstone units and with geochronology data produced by GSWA during the routine activity of regional mapping.

For the Youanmi Terrane, the data available so far provide a structural picture that differs from the typical architecture of most Archean hot orogens (Chardon et al., 2009). One of the main peculiarities of the Youanmi Terrane (and possibly of the whole Yilgarn Craton) is represented by a marked three-dimensional asymmetry of the crustal-scale structural grain, which strikingly contrasts with the map-view apparent orthorhombic structural symmetry (Figs 1, 2). The work in progress

highlights the close relationships between transpressional deformation and magmatic processes, such as the extraction of granitic magma from its lower crustal source and the syndeformational pluton assembly in upper crustal sink regions. The geochemical evolution of some studied syntectonic plutons shows that early components of TTG affinity were followed by younger magma batches characterized by a more evolved composition (i.e. transitional to low-Ca granites).

These new data, and in particular the combined structural, geochronology and geochemical observations, suggest that geochemistry trends of Archean granites are not only a response to secular changes of Earth conditions (Martin and Moyen, 2002). Rather, at pluton to regional scale, such chemical changes within the same pluton reflect the thermal evolution of syn-magmatic, oblique-slip shear zones. In other words, such chemical trends are the result of the complex interaction between magmatism and localization of deformation within shear zones.

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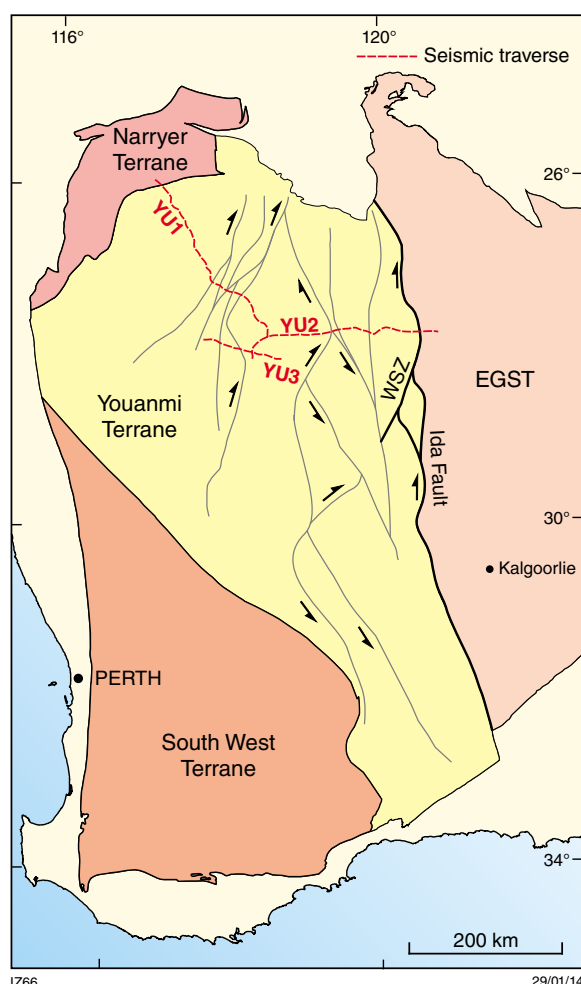


Figure 2. Geological sketch of the western portion of the Yilgarn Craton showing the location of the major terranes and the terrane-scale shear-zone network that typifies the Youanmi Terrane. Modified after Zibra et al. (in press). Abbreviations: ESGT, Eastern Goldfields Superterrane; WSZ, Waroonga Shear Zone