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Long-lived, autochthonous development of the Archean Murchison Domain, and implications for Yilgarn Craton tectonics

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ABSTRACT

Map, geochemical, and geochronological data are used to develop a new stratigraphic scheme and unravel the Archean tectonic evolution of the Murchison Domain of the Yilgarn Craton. Greenstones are divided into four groups: (1) c. 2960–2935 Ma Mount Gibson Group of mafic and felsic volcanic and volcaniclastic rocks, in the southern part of the domain; (2) the widespread 2825–2805 Ma Norie Group of mafic volcanic rocks, felsic volcaniclastic sandstones and banded iron-formation; (3) 2800–2735 Ma Polelle Group of mafic-ultramafic volcanic rocks, intermediate to felsic volcanic and volcaniclastic sedimentary rocks, and banded iron-formation; (4) the 2735–2700 Ma Glen Group of coarse clastic sedimentary rocks, komatiitic basalt, and minor rhyolite. Younger groups each have an unconformable relationship with older, underlying, greenstones, whereas the base of the Mount Gibson Group is intruded by younger granites. Very large layered mafic–ultramafic complexes of the Meeline and Boodanoo suites (e.g. Windimurra Igneous Complex) accompanied eruption of the Norie Group during crustal extension at 2825–2805 Ma. Less voluminous mafic-ultramafic intrusive suites accompanied eruption of the Polelle and Glen groups. Common c. 2950 Ma xenocrystic zircons in these rocks, combined with similar-age detrital zircons in 2820–2720 Ma greenstones, implies autochthonous development of post 2820 Ma greenstones on older crust.

Greenstone belt volcanism was accompanied by widespread intrusion of syn-volcanic plutons and outlasted by 110 Ma of widespread and voluminous granitic magmatism, from 2720 to 2600 Ma, including 2640–2600 Ma post-tectonic granites. All granites are crustal melts, indicating an extremely long period of crustal melting and thus an external thermal input, with or without the effects of thermal blanketing from newly erupted greenstones.

Deformation consists of four events, including two early periods of greenstone tilting (D_1 = 2930–2825 Ma; D_2 = 2735 Ma) – possibly associated with crustal extension – and two later (c. 2680–2640 Ma) periods of deformation resulting in tight to isoclinal folding of greenstones. D_3 structures include steeply-plunging, east–west trending folds of greenstones and open domes of granitic rocks, which formed during a period of inferred partial convective overturn of dense greenstone upper crust and partially molten granitic middle crust at c. 2675 Ma. Overprinting D_4 structures developed in response to strong east–west compression, resulting in broad, splayed, north-northeast striking dextral shear zones, upright, north- to north-northeast trending folds, and minor north-northwest striking sinistral shear zones. Gold mineralization tends to be focussed in regions of D_4 dextral shear and/or low-pressure domains in fold interference structures.

Much of the late history of the domain, from 2720 to 2630 Ma, is similar and contemporaneous with events that also affected the Eastern Goldfield Superterrane (EGS) of the craton. Shared events include komatiitic-basaltic volcanism at c. 2720 Ma, followed by widespread felsic magmatism (2690–2660 Ma), early deformation at 2675 Ma, shear-hosted gold mineralisation at 2660–2630 Ma, and post-tectonic granites at c. 2630 Ma. In addition, the whole craton experienced a period of mafic-ultramafic magmatism (komatiitic–basaltic volcanic rocks, layered mafic-ultramafic complexes, and gabbros) at c. 2810 Ma, indicating a shared early history. These findings, together with the low overall metamorphic grade (prehnite-pumpellyite to upper greenschist facies), lack of evidence for significant thrusting, and lack of passive margin/foreland basin/accretionary prism successions suggest that a re-evaluation of subduction-accretion tectonic models for craton development is warranted.

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1. Introduction

Archean tectonics remains one of the most controversial issues in the Earth Sciences, in part due to the great age and poor preservation of many rocks, but also due to a paucity of constraints in some cratons, particularly regarding plate configuration and tectonic context. The Archean Yilgarn Craton of Western Australia is one craton for which the tectonic model of formation has continued to rage (Campbell and Hill, 1988; Czarnota et al., 2010). Partly this debate stems from poor outcrop across much of the craton, but it also stems from poor data coverage for those less-mineralised parts outside of the well-known Eastern Goldfields Superterrane (EGS).

Most current thinking divides the Yilgarn Craton into a number of terranes based on distinct crustal histories and geochemical features of volcanic rocks (Fig. 1: Cassidy et al., 2006; Czarnota et al., 2010). The craton is widely considered to have evolved through Neoarchean subduction, arc magmatism, and accretion of outboard terranes (Narryer Terrane, Eastern Goldfields Superterrane and potentially a number of distinct terranes in the Southwest Terrane) onto an older nucleus (tectonic foreland) represented by the Youanmi Terrane (Barley et al., 1990, 2008; Wilde et al., 1996; Swager, 1997; Swager et al., 1997; Champion and Cassidy, 2007; Kositcin et al., 2008; Krapez and Barley, 2008; Standing, 2008).

However, a number of features of the geology of the craton are at odds with an arc-accretion model: (1) komatiitic and basaltic rocks are contemporaneous and derive from a common, plume-related source across all terranes of the Eastern Goldfields Superterrane (Campbell et al., 1989; Barnes et al., 2012); (2) xenocrystic and detrital Hadean zircon grains, thought to be uniquely characteristic of the Narryer Terrane, have been found in the Youanmi Terrane (Nelson et al., 2000; Wyche, 2007), suggesting a link between these crustal elements; (3) granitic magmatism commenced simultaneously across the whole of the craton, (2690 Ma), well *prior to* the inferred age of terrane accretion (2660 Ma); (4) inferred subduction-related magmatism 2690–2660 Ma occurs simultaneously across the whole of the craton (1000 km) (e.g. Czarnota et al., 2010), inconsistent with the geometry of modern arcs.

In order to further constrain the possible tectonic framework of the craton, we here investigate the hitherto poorly known Murchison Domain of the Youanmi Terrane, the proposed foreland to the orogen, drawing on results from recent mapping by the Geological Survey of Western Australia (GSWA), previous and new U–Pb zircon and baddeleyite SHRIMP geochronology, and structural analysis. The results outline a 350 Ma history of autochthonous crustal development from 2950 Ma to 2600 Ma, and show that, although the northern Murchison Domain does indeed preserve an older crustal history than the EGS, it also contains a remarkably similar, and contemporaneous Neoarchean history to the terranes of the EGS, including eruption of mafic to felsic volcanic rocks, widespread and long-lived emplacement of granitic rocks, ductile strike-slip shearing, and gold mineralisation. These results are used to suggest that the Youanmi Terrane and Eastern Goldfields Superterrane of the Yilgarn Craton evolved together as a single crustal element affected by Neoarchean plume-related magmatism and rifting.

1.1. Regional geology

The ~300,000 km^2 Youanmi Terrane forms the western half of the Archean Yilgarn Craton (Fig. 1: terrane nomenclature after Cassidy et al., 2006) and is recognised as distinct from the EGS in the eastern half of the craton on the basis of its higher metamorphic grade, older and more dismembered greenstones, and the widespread presence of banded iron-formation. The well-preserved, older, geological history of the Youanmi Terrane is recorded in greenstones (2.95 Ga) and granitic rocks (3.2 Ga, with xenocrystic zircons up to 4.0 Ga), 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; Pidgeon and Hallberg, 2000; Champion and Cassidy, 2007).

The Youanmi Terrane is subdivided into the Murchison and Southern Cross domains on the basis of distinct lithostratigraphic assemblages in greenstone belts (Fig. 1: Cassidy et al., 2006). The Southern Cross Domain consists of undated, dominantly mafic, volcanic rocks that are unconformably overlain by c. 2730 Ma calc-alkaline felsic volcanic rocks and associated subvolcanic intrusions of the Marda Complex, and these are in turn unconformably overlain by a succession of clastic sedimentary rocks (Chen et al., 2003). The boundary between the Southern Cross and Murchison domains is a late-tectonic, anastomosing, strike-slip shear zone.

To the east, the Youanmi Terrane is in fault contact against the EGS along the north–south striking, long-lived, Ida Fault. The Youanmi Terrane is also fault-bounded against the Narryer Terrane in the northwest (famous for its Hadean detrital zircons and Paleoarchean crustal remnants: Nutman et al., 1993; Wilde et al., 2001), and against the South West Terrane, which has a long and complex Meso- to Neoarchean history (Wilde et al., 1996; Wilde, 2001).

The EGS is characterised by greenstones deposited between 2720 Ma and 2660 Ma, and voluminous granitic rocks emplaced in the range 2720–2620 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). Late clastic basins deposited at ca. 2655 Ma (Krapez et al., 2000; Krapez and Barley, 2008) are another distinct feature of the EGS compared with Youanmi Terrane, which lack such deposits. Deformation of the EGS included alternating periods of extension and compression from c. 2705 Ma to 2630 Ma, with gold mineralisation largely accompanying the development of anastomosing north-northwest to north-northeast striking brittle-ductile shear zones from 2660 to 2630 Ma (Bateman and Hagemann, 2004; Blewett and Czarnota, 2007).

1.2. Previous interpretations of Murchison Domain

Supracrustal assemblages in the 'Murchison Province' and 'Southern Cross Province' of the western Yilgarn Craton were initially subdivided into four lithological associations (Hallberg et al., 1976a; Muhling and Low, 1977; Baxter, 1982; Elias, 1982; Baxter et al., 1983; Lipple et al., 1983; Baxter and Lipple, 1985). They comprise an upper felsic–sedimentary association, an upper mafic association, a lower felsic–sedimentary association, and a lower mafic association.

Subsequently, Watkins and Hickman (1990) introduced a stratigraphic scheme for the 'Murchison Supergroup', which comprised the older Luke Creek Group and a younger Mount Farmer Group, based on regional mapping but with very little isotopic dating. The Porlell and Yalgoo Subgroups, as well as seventeen individual formations from parts of dismembered greenstone belts, were also defined within the Mount Farmer Group. These authors provided a wealth of geochemical data on the volcanic stratigraphy.

Subsequent high-precision U–Pb zircon geochronology on rocks from the northeastern 'Murchison Terrane' by Pidgeon and Hallberg (2000) showed several inconsistencies with the lithostratigraphic scheme of Watkins and Hickman (1990). As a result, Pidgeon and Hallberg (2000) introduced an informal subdivision of supracrustal greenstone lithologies into five 'assemblages' and concluded that it was not possible to erect a formalised stratigraphic scheme for the greenstones of the Murchison region.

Gneissic and plutonic granitic rocks of the Murchison Domain were subdivided by Watkins and Hickman (1990) into three main