Crustal evolution of the Murchison Domain and implications for whole-of-Yilgarn tectonic models

by

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Outcrop, geochemical, and isotopic data from the northeastern Murchison Domain of the Yilgarn Craton have been compiled to develop a model of autochthonous crustal growth between 2.96 and 2.60 Ga (Fig. 1; Van Kranendonk and Ivanic, 2009). Greenstones are assigned to the Murchison Supergroup, which is divided into four autochthonous groups, separated by unconformities: 1) the 2960–2930 Ma Mount Gibson Group of mafic and felsic volcanic and volcaniclastic rocks; 2) the widespread 2825–2805 Ma Norie Group of mafic volcanic rocks, felsic volcaniclastic sandstones, and banded iron-formation; 3) the 2800–2735 Ma Polelle Group of mafic–ultramafic volcanic rocks, intermediate to felsic volcanic and volcaniclastic sedimentary rocks, and banded iron-formation; and 4) the 2735–2700 Ma Glen Group of coarse clastic sedimentary rocks, komatiitic basalt, and minor rhyolite. 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.

Deposition of the Mount Gibson, Polelle, and Glen Groups was accompanied by widespread intrusion of syn-volcanic plutons, and followed by 120 Ma of widespread and voluminous granitic magmatism from 2720 to 2600 Ma. The similarity of c. 2950 Ma inherited zircons within these granites to detrital zircon age populations in 2820 to 2720 Ma greenstones, together with Hf isotope data on zircons from dated granites, indicate autochthonous granite generation within an older crust that was extracted from a mantle source around 3 Ga.

In the Polelle Group, initial mafic–ultramafic volcanism, which was derived from deep mantle (plume) melting, changes to andesitic and then dacitic–rhyolitic volcanism between 2760 and 2740 Ma, coeval with sodic granitic plutons (tonalite–trondhjemite–granodiorite (TTG), or high-Ca granites, Champion and Cassidy, 2002). Geochemical data indicate the intermediate to felsic volcanic rocks derive from a variety of sources. Hf isotopic data ($\varepsilon Hf_{2750\ Ma}$ = -1 to -10) indicate that some of these magmas derive from, or include components of, a much older evolved (unradiogenic) crustal source, with residence in the crust since 3.8 Ga. A subduction origin for the andesites is possible, and may have included a component of entrained sediment derived from a much older source than is currently exposed in the Murchison Domain. In order to test this hypothesis, oxygen isotope data were obtained from zircons from the same dated granites that returned unradiogenic εHf values. However, the oxygen isotope results indicate values within uncertainty of mantle (e.g. $\delta^{18}O \approx 5.6$ ‰). Thus, an allochthonous input of older sedimentary material is not supported. Rather, geochemical modelling shows that c. 2760 Ma andesites can be explained by mixing of mantle-derived basaltic and crust-derived granitic magmas, a suggestion bolstered by field observations of magma mixing within sodic granitic rocks of this age (Fig. 2). Furthermore, the c. 2760 Ma age of onset of intermediate–felsic magmatism corresponds well with the calculated time lag of conductive heating of the crust following the onset of plume-derived magmatism (e.g. 30 Ma; Sandiford et al., 2004). Thus, we interpret the 2760 Ma calc-alkaline volcanic and contemporaneous TTG granitic event in the Murchison Domain as the result of widespread partial melting of a horizontally layered, stagnant older crust in response to a major mantle-plume event at 2820 Ma, including an older, lower crustal component isolated from near-surface processes. This lower crustal component was sampled only during extreme melting events.

Much of the late Archean history of the Murchison Domain, from 2720 to 2630 Ma, is similar to, and broadly contemporaneous with, events within the Eastern Goldfields Superterrane. Specifically, we note coeval komatiitic–basaltic volcanism at c. 2720 Ma, followed by widespread felsic magmatism (2690–2660 Ma), early deformation at 2675 Ma, shear-hosted gold mineralization at 2660–2630 Ma, and post-tectonic granites at c. 2630 Ma. These findings, together with the overall low metamorphic grade of the crust (prehnite–pumpellyite to upper greenschist facies), and a lack of evidence for significant thrusting and for passive margin/foreland basin/accretionary prism successions, suggest that a re-evaluation of popular subduction–accretion tectonic models for craton development (e.g. Barley et al., 1989, 2008), is warranted.

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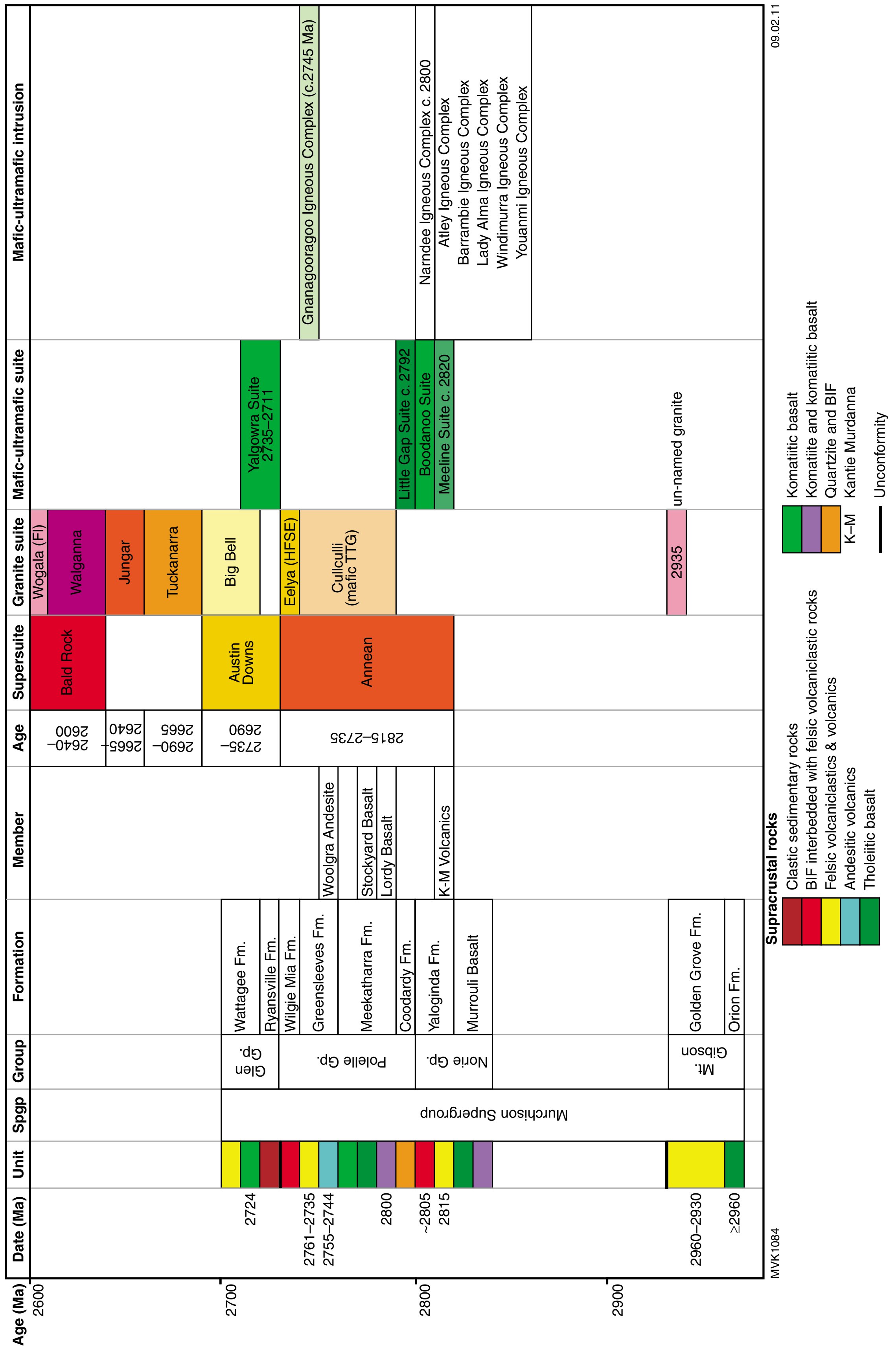

Figure 1. Stratigraphic scheme for the Murchison Domain, divided into three main columns for supracrustal rocks, granitic rocks, and mafic–ultramafic intrusive rocks (updated from Van Kranendonk and Ivanic, 2009)

Figure 2. Outcrop view of scattered, tectonically strained mafic inclusions in a c. 2750 Ma sodic granite of the northeastern Murchison Domain, which is considered to indicate magma mingling

References

Barley, ME, Eisenlohr, BN, Groves, DI, Perring, CS and Vearncombe, JR 1989, Late Archean convergent margin tectonics and gold mineralization: a new look at the Norseman–Wiluna Belt, Western Australia: Geology, v. 17, p. 826–829.

Barley, ME, Brown, SJA, Krapez, 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.

Champion, DC and Cassidy, KC 2002, Granites of the northern Murchison Province: their distribution, age, geochemistry, petrogenesis, relationship with mineralisation, and implications for tectonic environment: AMIRA P482/MERIWA M281 – Yilgarn Granitoids, p. 5.1–5.54.

Sandiford, M, Van Kranendonk, MJ and Bodorkos, S 2004, Conductive incubation and the origin of dome-and-keel structure in Archean granite–greenstone terrains: a model based on the eastern Pilbara Craton, Western Australia: Tectonics, v. 23, TC1009, DOI: 10.1029/2002TC001452.

Van Kranendonk, MJ and Ivanic, TJ 2009, A new lithostratigraphic scheme for the northeastern Murchison Domain, Yilgarn Craton: Geological Survey of Western Australia, Annual Review 2007–08, p. 34–53.