Thermobarometric evolution of subdomains within the western Yilgarn Craton

by

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Introduction

The western Yilgarn Craton (Fig. 1) preserves a long and complex metamorphic history, having >12 distinct periods of metamorphic paragenesis growth extending from the Paleoarchean to the Neoarchean. The dominant regional Neoarchean events are shared with the eastern Yilgarn Craton (Goscombe et al., 2007, 2009), although these events occurred in different tectonic settings and resulted in different metamorphic conditions. In addition, the northern, western, and southern margins of the craton have been variably reworked (regionally pervasive reworking) and reactivated (i.e. shear zones) as part of >10 distinct orogenic events from Paleoproterozoic to Cambrian in age, producing a wide range of metamorphic parageneses. The peak metamorphic conditions attained in key domains of the western Yilgarn Craton are summarized below. The peak conditions presented here are based on the pooling of pressure–temperature (P–T) calculations with self-similar results from small geographical subdomains. Pooled errors are ignored for clarity, but are typically ±10–30ºC and ±0.5 – 1.0 kb. The metamorphic constraints presented are preliminary and, at least at this stage in the research program, are not discussed within a chronologic, structural, and tectonic context.

Youanmi Terrane

Southern Cross Domain, north

The Edale Shear Zone, southeast of Sandstone in the north of the Southern Cross Domain of the Youanmi Terrane, experienced a wide range of low-pressure peak conditions — 524–607ºC, 2.2 – 4.5 kb, and temperature-over-depth ratios of 39–72ºC/km (n=14) — with clockwise P–T paths.

Along strike, the Illaara greenstone belt experienced peak conditions of 596ºC and 5.1 kb, with a temperature-over-depth ratio of 35ºC/km (n=2). Further along strike, the Ida greenstone belt experienced moderate-pressure peak conditions of 583–635ºC and 4.2 – 6.2 kb, temperature-over-depth ratios of 29–43ºC/km (n=3), and clockwise P–T paths.

The Marymia Inlier experienced low-pressure metamorphism in the east, and higher-pressure conditions in the west. Peak conditions in the east were approximately 561ºC and 3.0 kb, with a temperature-over-depth ratio of 53ºC/km (n=1); in the west, the conditions were 600ºC, 8.0 kb, and 21ºC/km (Gazley et al., 2011).

A single sample from the Atley greenstone belt experienced peak conditions of 450ºC and 4.2 kb, with a temperature-over-depth ratio of 31ºC/km. The Gum Creek greenstone belt experienced a moderate range of pressures: in lower-grade rocks, the peak conditions were 550ºC and 4.0 kb, with a temperature-over-depth ratio of 39ºC/km (n=1); higher-grade samples experienced higher-pressure peak conditions of 621ºC and 6.7 kb, with a temperature-over-depth ratio of 27ºC/km (n=2) and anticlockwise P–T paths. Granitoids in the Gum Creek area crystallized under very low pressures, at 1.2 kb. The Joyners Find, Red Handed Bore, Youanmi, and Poison Hills greenstone belts experienced similar peak conditions of 588–640ºC and 4.0 – 4.6 kb, with temperature-over-depth ratios of 38–44ºC/km (n=6); the Poison Hills greenstone belt has mineral parageneses indicating two metamorphic events. Lower-grade conditions in the Agnew–Wiluna greenstone belt were 517ºC, 3.8 kb, and 39ºC/km.

Southern Cross Domain, south

The Forrestania greenstone belt preserves evidence for events with a moderate range of pressures. Peak conditions in lower-pressure rocks were 503–661ºC and 2.8 – 5.2 kb, with temperature-over-depth ratios of 28–57ºC/km (n=18); however, a number of samples experienced higher-pressure peak conditions of 579–676ºC and 6.3 – 7.0 kb, with temperature-over-depth ratios of 24–31ºC/km (n=2), and clockwise and isothermal decompression P–T paths.

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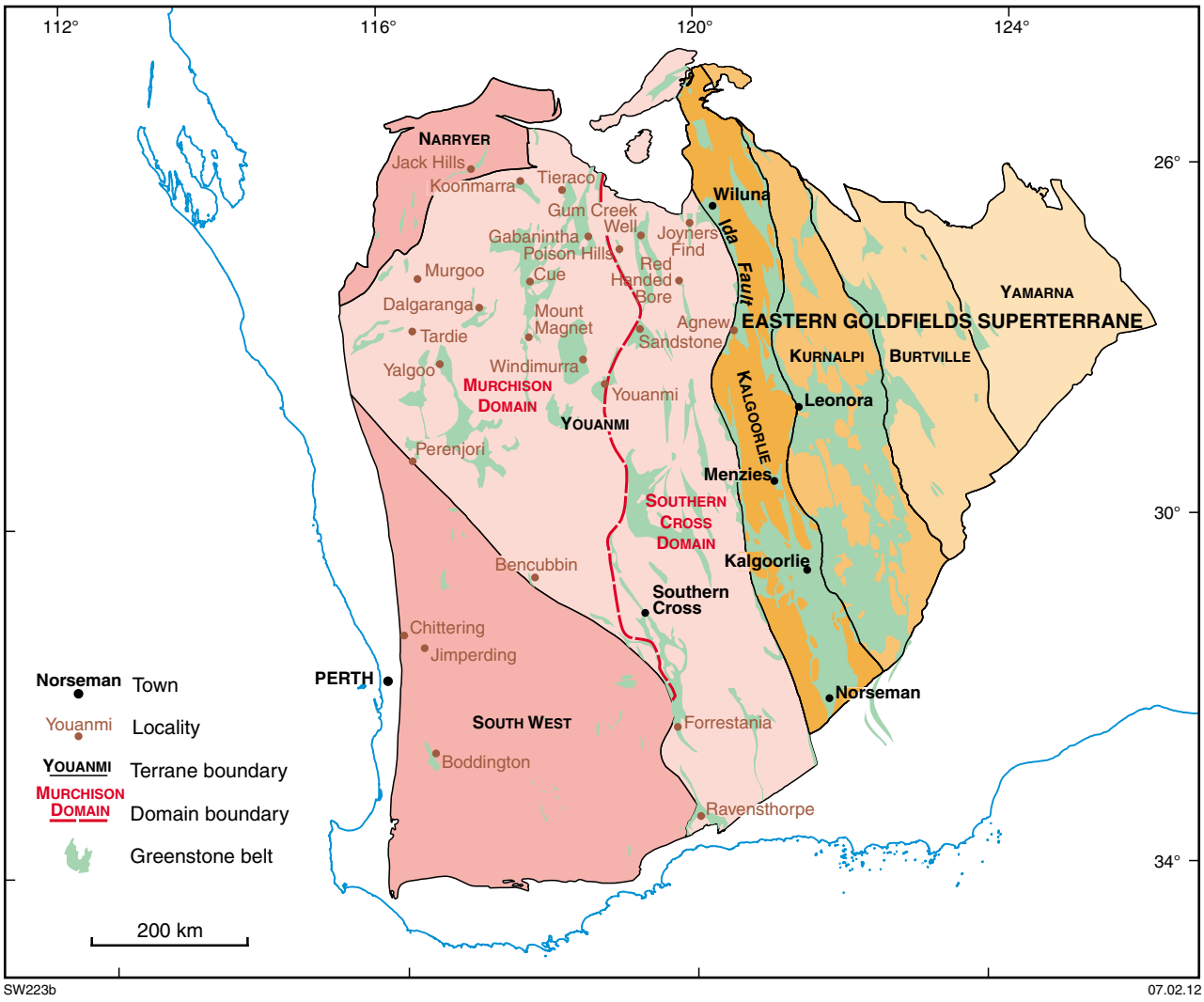

Figure 1. Terrane subdivision of the Yilgarn Craton, showing localities mentioned in the text

Ravensthorpe greenstone belt

The 'Carlingup Terrane' of Witt (1999), in the eastern part of the Ravensthorpe greenstone belt, experienced peak conditions of 566–580ºC and 4.5 – 5.0 kb, with temperature-over-depth ratios of 32–38ºC/km (n=10). Mineral parageneses indicate early anticlockwise P–T paths, followed by probable late clockwise P–T paths and secondary chloritoid growth, which may have been due to the loading of the Yilgarn margin during the Proterozoic Albany–Fraser events. A smaller number of samples experienced low-pressure peak conditions of 525–548ºC and 2.2 – 4.0 kb, with temperature-over-depth ratios of 38–71ºC/km (n=5), and clockwise P–T paths indicating isothermal decompression. The 'Cocanarup Terrane' of Witt (1999), on the western margin of the Ravensthorpe greenstone belt, experienced clockwise P–T paths with isothermal decompression, and peak conditions of 547–584ºC and 3.2 kb, with temperature-over-depth ratios of 49–52ºC/km (n=4). A few samples experienced higher-pressure peak conditions of 558–620ºC and 5.9 – 6.0 kb, with temperature-over-depth ratios of 27–30ºC km (n=2). The 'Ravensthorpe Terrane' of Witt (1999), in the central region of the greenstone belt, experienced peak conditions of 559–562ºC and 3.7 – 4.1 kb, with temperature-over-depth ratios of 39–43ºC/km (n=8). A few samples experienced higher-pressure peak conditions of 572–590ºC and 5.9 kb, with temperature-over-depth ratios of 28–29ºC/km (n=3). Both groupings experienced predominantly clockwise P–T paths with isothermal decompression, although a few samples have parageneses indicative of anticlockwise paths. The Manyutup Tonalite in the central 'Ravensthorpe Terrane' crystallized at low pressures — 3.0 – 5.1 kb (n=6) — and was subsequently buried and metamorphosed at 614–639ºC, 6.6 – 7.0 kb, and 26–27ºC/km (n=10).

Murchison Domain

Greenstones in the Murchison Domain of the Youanmi Terrane experienced a wide range of peak temperature conditions, all at low pressures. The lowest-grade conditions were 499ºC and 1.7 kb, with a temperature-over-depth ratio of 86ºC/km (n=4), and isothermal loading and anticlockwise P–T paths. Regional metamorphic peak conditions were 590–593ºC, 3.0 – 3.1 kb, and 55–56ºC km (n=3). The highest-grade peak conditions were 679ºC, 4.0 kb, and 51ºC/km (n=3).

The Koonmarra greenstone belt experienced peak conditions of 600ºC, 3.1 kb, and 55ºC/km (n=2), with decompressive cooling P–T paths. Greenstones around Murgoo, Tardie, and Tieraco had similar peak conditions, ranging 560–584ºC, 4.6 – 5.1 kb, and 33–35ºC/kb. Those around Perenjori and Bencubbin experienced higher grades but at similar pressures, with peak conditions of 631–632ºC, 4.1 – 4.7 kb, and 38–59ºC/kb.

The greenstones around Cue and Mount Magnet experienced at least two metamorphic events. Metamorphism associated with mineralization at Big Bell experienced a wide range in peak conditions — 543–648ºC and 4.6 – 4.9 kb, with temperature-over-depth ratios of 35–38ºC/km (n=9). Regional metamorphism elsewhere in the Cue region had typical peak conditions of 504–528ºC, 3.0 – 4.9 kb, and 30–45ºC/km (n=7), with isobaric cooling P–T paths, although a single sample has higher-pressure peak conditions of 575ºC, 6.4 kb, and 26ºC/km. Granitoids in this region crystallized under low-pressure conditions, at 1.9 kb (n=5).

The Dalgaranga greenstone belt experienced a wide range of peak temperature conditions, all at low pressures. The lowest-grade conditions detected were 494ºC and 2.0 kb, with a temperature-over-depth ratio of 76ºC/km (n=6), and ambiguous clockwise or anticlockwise P–T paths. Regional metamorphic peak conditions were 535–566ºC, 3.0 – 3.3 kb, and 51–53ºC/km (n=6), with clockwise and isothermal decompression P–T paths. Early gneissic metamorphism on the dome margins experienced peak conditions of 624ºC, 4.0 kb, and 45ºC/km (n=4).

The Yalgoo greenstone belt experienced a wide range in peak temperature conditions, all at low pressures. The lowest-grade conditions were 469ºC and 2.9 kb, with a temperature-over-depth ratio of 51ºC/km (n=4), and isobaric heating and isobaric cooling paths. Peak conditions were 552ºC, 3.3 kb, and 50ºC/km (n=4), with decompressive cooling P–T paths. Early gneissic metamorphism on the dome margins experienced peak conditions of 624ºC, 4.0 kb, and 45ºC/km (n=4).

Contact aureoles on the margins of mafic–ultramafic intrusive complexes, such as the Windimurra Igneous Complex, preserve the earliest and lowest-pressure metamorphic parageneses in the Youanmi Terrane. Windimurra contact aureoles preserve very low pressure conditions, ranging from 515ºC, 1.0 kb, and 147ºC/kb, to low-pressure granulites of 709ºC, 0.2 kb, and 844ºC km within a raft on the upper surface. The Gabanintha contact aureole, as elsewhere in the Murchison Domain, experienced peak temperatures, estimated in the literature, of 720–860ºC at unknown pressures (n=13).

Narryer Terrane

Narryer granulites preserve three distinct peak metamorphic conditions. Most P–T calculations for the subdomains have peak conditions in the range 665–681ºC and 4.1 – 4.5 kb, and temperature-over-depth ratios of 43–48ºC/km (n=10), with clockwise P–T paths. Higher-temperature peak conditions in some subdomains were 759–770ºC, 5.0 – 5.2 kb, and 42–43ºC/km (n=6), with clockwise P–T paths. An amphibolite-facies subdomain has peak conditions of 610ºC, 4.5 kb, and 39ºC/km (n=2), and a clockwise P–T path. Granitoids in the Narryer Terrane crystallized at pressures of 5.3 kb.

Retrograde shear zones are interpreted to have Proterozoic mineral parageneses. In the granulite terrane, these retrograde shear zones had metamorphic conditions ranging between 621ºC, 5.7 kb, and 31ºC/km (n=3), and 500ºC, 3.6 kb, and 40ºC/km (n=1). The Jack Hills greenstone belt is also interpreted to have Proterozoic mineral parageneses, with peak metamorphic conditions in different parts of the Jack Hills greenstone belt being 498–549ºC and 2.5 – 4.3 kb, with temperature-over-depth ratios of 36–61ºC/km (n=6), and clockwise P–T paths.

Transitional margins of the South West Terrane

Amphibolite-grade gneisses within the eastern transitional margin of the South West Terrane have peak conditions of 610–675ºC and 3.5 – 5.5 kb, with temperature-over-depth ratios of 34–50ºC/km (n=4). The northern transitional margin experienced both amphibolite- and granulite-facies metamorphism: granulite subdomains, including the Westonia greenstone belt, experienced peak conditions of 760–800ºC and 2.2 and 4.7 kb, with temperature-over-depth ratios of 103 and 46–49ºC/km (n=3). Amphibolite-grade gneisses also demonstrate a large range in pressures, with peak conditions of 536–615 and 630ºC, and 3.6 – 4.4 and 7.4 kb, with temperature-over-depth ratios of 34–43 and 24ºC/km (n=26).

South West Terrane

Granulite

Granulites in the eastern parts of the South West Terrane experienced peak conditions of 712–784ºC and 4.2 – 5.3 kb, with temperature-over-depth ratios of 44–52ºC/km (n=16), and isobaric cooling P–T paths. Granulites and granitoids in the western parts of the Southwest Terrane crystallized at 700–730ºC and 4.2 kb, with temperature-over-depth ratios of 48ºC/km (n=7). Mineral parageneses are ambiguous, but may indicate anticlockwise P–T paths. The Boddington greenstone belt experienced peak conditions of 500–600ºC, 2.0 –3.0 kb, and 57–71ºC/km (n=2).

Granulites from the ‘Lake Grace Terrane’ of Wilde (2001) preserve at least four distinct clusters of peak metamorphic conditions. The highest-pressure subdomain experienced peak conditions of 798ºC, 8.5 kb, and 27ºC/km (n=1),

with clockwise and isothermal decompression P–T paths. The highest-temperature subdomains experienced peak conditions of 754–852ºC, 5.4 – 6.9 kb, and 31–44ºC/km (n=8), with clockwise and isothermal decompression P–T paths. The lowest-pressure subdomains experienced peak conditions of 771–831ºC, 3.1 – 4.8 kb, and 50–71ºC/km (n=2), with ambiguous cooling paths. Finally, the lowest grade amphibolite-facies subdomains experienced peak conditions of 645–707ºC, 4.1 – 6.7 kb, and 28–49ºC/km (n=9), with isobaric cooling P–T path.

Granulites from the Jimperding greenstone belt also preserve at least four distinct clusters of peak metamorphic conditions. The highest-grade subdomains experienced peak conditions of 798–883ºC, 7.1 – 8.1 kb, and 30–35ºC/km (n=4), with clockwise P–T paths. Other subdomains with clockwise P–T paths experienced peak conditions of 810–826ºC, 5.8 kb, and 40–42ºC/km (n=6). The lowest-grade subdomains experienced peak conditions of 625–684ºC, 4.3–6.4 kb, and 31–42ºC/km (n=2), with isobaric cooling paths. Finally, subdomains with anticlockwise P–T paths experienced peak conditions of 713–807ºC, 3.6 – 5.0 kb, and 45–59ºC/km (n=8).

Chittering greenstone belt

Barrovian metapelite schists within the Chittering greenstone belt are interpreted to have Proterozoic or Cambrian metamorphic parageneses; there is currently no empirical evidence for earlier Archean parageneses or protoliths for these rocks. Nevertheless, the Barrovian-series main foliation envelops large, early garnet porphyroclasts, which are tentatively interpreted as relict Archean parageneses. Compositional isopleths from these garnet cores indicate low-pressure conditions of 549–560ºC, 4.8 – 4.9 kb, and 33ºC/km (n=7). Conversely, the main-foliation parageneses experienced high-pressure peak conditions of 565–572ºC, 8.0 – 10.6 kb, and 16–20ºC/km (n=9). P–T paths show isothermal loading, and very tight anticlockwise turn-around, followed by isothermal decompression.

‘Balingup Terrane’

Some rocks in the ‘Balingup Terrane’ of Wilde (2001) are strongly sheared and almost totally reworked to form Proterozoic metamorphic parageneses. Relict primary mineral grains within the mylonites and parageneses in the unsheared rocks are interpreted to be of Archean age. Archean assemblages preserve two peak metamorphic groupings: 1) conditions of 610–635ºC, 3.0 – 3.9 kb, and 45–60ºC/km (n=5), and 2) higher-pressure conditions of 592, 683, and 718ºC, 6.1 – 6.8 kb, and 28–31ºC/kb (n=8). Proterozoic mylonite assemblages in this terrane preserve peak metamorphic conditions of 597–670ºC, 5.7 – 6.9 kb, and 23–31ºC/km (n=38). Proterozoic P–T paths typically involved near-isothermal loading and a tight clockwise turn-around, followed by isothermal decompression.

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