Not-so-suspect terranes of the Rudall Province

by

CL Kirkland, SP Johnson, RH Smithies, JA Hollis, MTD Wingate, AH Hickman, IM Tyler, SG Tessalina, JB Cliff, EA Belousova, and R Murphy

Time-constrained isotopic data permit the evaluation of tectonic processes, including continental collision, rifting, and the origin of terrane fragments. The Rudall Province, in the Paterson Orogen, is part of the West Australian Craton (WAC) and now lies to the east of the Archean Pilbara Craton and overlying Fortescue and Hamersley Basins (Fig. 1). Within the region, a range of mineral systems exists, including Au–Cu (Telfer), Zn–Pb (Warrabarty), Cu (Maroochydore) and U (Kintyre). Thus, constraints on basement geology from this area have important implications for understanding mineralizing systems. The Rudall Province is divided into three lithotectonic elements, known as the Talbot, Connaughton, and Tabletop Terranes. The southern two terranes (Talbot and Connaughton) were affected by magmatism related to the 1800–1765 Ma Yapungku Orogeny.

In the Rudall Province, deformation, metamorphism, and magmatism during the Yapungku Orogeny have been interpreted as responses to Paleoproterozoic collision between the Pilbara Craton and a continent of unknown origin to the northeast (Hickman et al., 1994). In this scenario, the c. 1.8 Ga metasedimentary succession of the Rudall Province was deposited on the eastern margin of the Pilbara Craton. This interpretation was subsequently modified to suggest collision and amalgamation of the North and West Australian Cratons (Bagas and Smithies, 1997; Tyler, 2000; Li et al., 2008) during the Yapungku Orogeny. Alternatively, the event has been interpreted as a consequence of accretional processes that sutured exotic terranes to the Pilbara Craton margin (Bagas, 2004). This contribution presents time-constrained Sm–Nd, Lu–Hf, and oxygen isotope analyses to evaluate whether terranes within the Rudall Province are:

1. (para)autochthonous and related to the thickening of a Proterozoic margin of the Pilbara Craton, or
2. exotic entities that:
   a) formed part of the opposing North Australian Craton (NAC) margin, being juxtaposed with the WAC during collisional orogenesis, or
   b) have an entirely exotic source (e.g. the northern Gawler and Musgrave regions) and were juxtaposed against the WAC margin during accretionary or collisional orogenesis.

Isotopic signature of the Talbot and Connaughton Terranes

The Talbot Terrane occupies the northern and western parts of the Rudall Province, and consists of multiple deformed and metamorphosed supracrustal and felsic intrusive rocks (Bagas and Smithies, 1997; Hickman and Bagas, 1999b; 1999a). The depositional setting of the siliciclastic rocks has been interpreted as a deltaic to moderately deepwater marine basin on the southeastern margin of the Pilbara Craton (Hickman et al., 1994). The Connaughton Terrane, within the southeastern part of the province, comprises a series of poorly dated metavolcanic and metasedimentary rocks, and contains a significantly higher proportion of amphibolite than the Talbot Terrane (Bagas and Smithies, 1998). The amphibolite is interlayered with banded iron-formation, quartzite, pelitic metasedimentary rocks, chert, and ultramafic rocks (Hickman et al., 1994). In a situation similar to the Talbot Terrane, basement rocks are not exposed. Importantly, all rocks within the Connaughton Terrane were metamorphosed at upper amphibolite to granulite facies conditions during the Yapungku Orogeny (Smithies and Bagas, 1997).

The Talbot and Connaughton Terranes are dominated by granitic rocks of the 1800–1765 Ma Kalkan Supersuite (Fig. 2). In the Talbot Terrane, magmatic zircons from these granites show a range of isotopically evolved compositions, with Hf model ages (TDM2) between 3.6 and 2.6 Ga (Fig. 2). Inherited zircons in the Talbot Terrane and magmatic zircons in the Connaughton Terrane indicate crustal residence ages of 2.8 – 2.4 Ga, with strong isotopic and, in the case of inheritance, temporal affinity to detritus that originated from Capricorn Orogen basement sources (e.g. 2005–1970 Ma Dalgaringa Supersuite of the Glenburgh Terrane). Furthermore, the most evolved magmatic zircons (those with $\varepsilon Hf < -17$), from the Talbot Terrane, are also comparable with the isotopic composition of the East Pilbara Terrane, including granitic rocks of the Bridget Suite, which has a clear association with the Pilbara Craton (Fig. 3). The c. 1800 Ma Bridget Suite consists of calc-alkaline, lamprophyric syenite to monzodiorite (Budd et al., 2002), forming a north-northwest-trending belt within the East Pilbara Terrane, adjacent and subparallel to the Paterson Orogen.

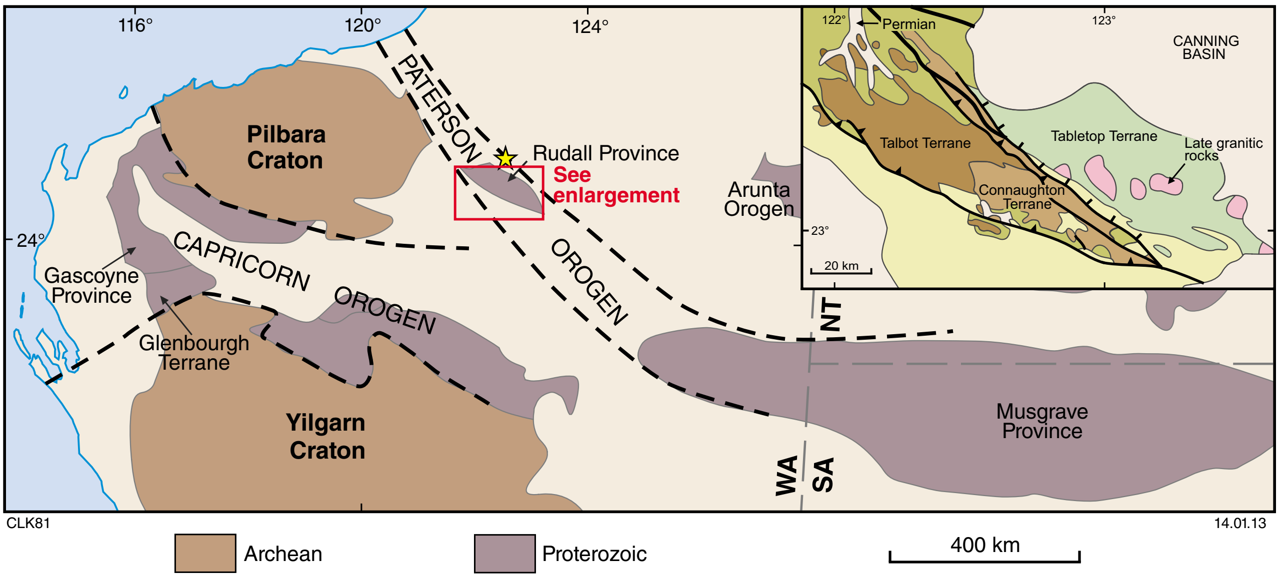

Figure 1. Location of the Rudall Province relative to Proterozoic orogens and Archean cratons in west-central Australia (modified after Bagas and Smithies, 1997; Smithies and Bagas, 1997). The inset shows the location of the three terranes of the Rudall Province. The yellow star is the Telfer gold deposit.

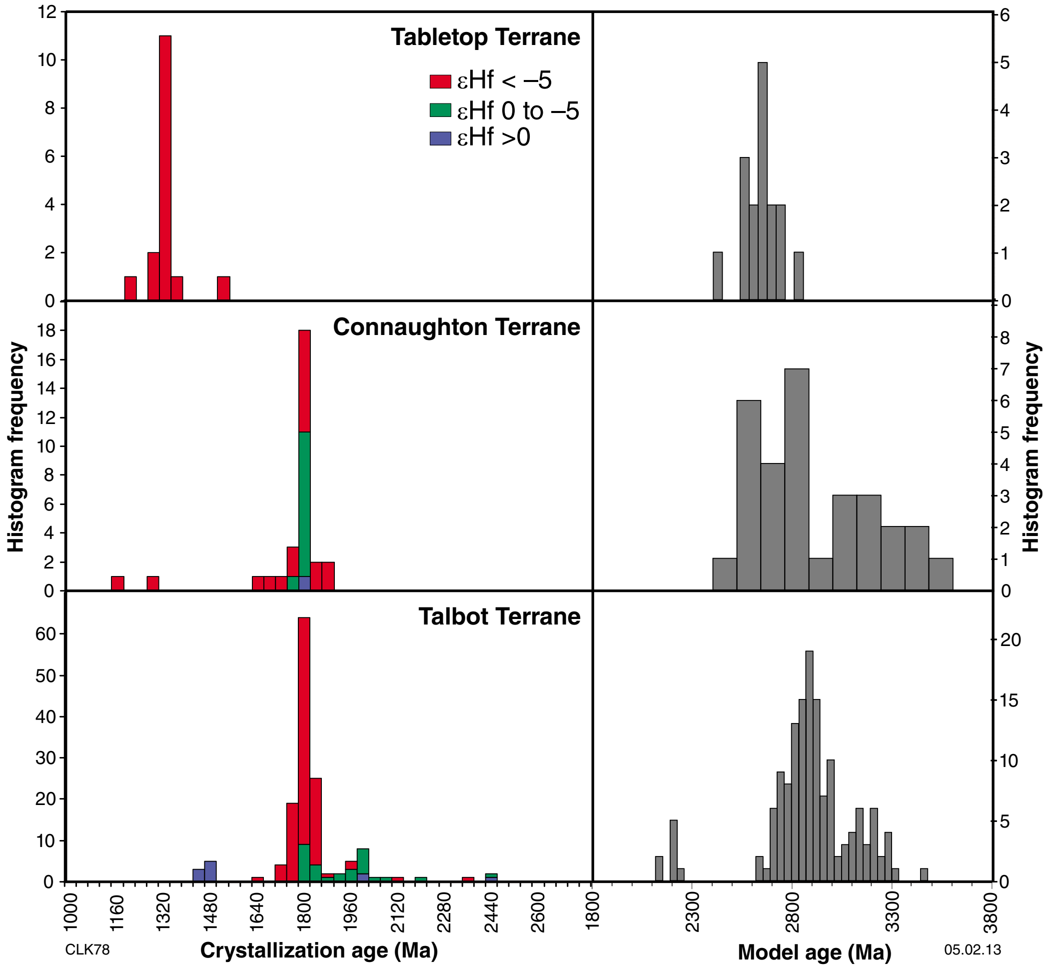

Figure 2. U–Pb magmatic crystallization ages (left) and two-stage Hf model ages (right) for zircons from Rudall Province magmatic rocks. Crystallization age data are colour-coded according to epsilon-Hf value. Although the timing of magmatism in the Tabletop Terrane is different to that in the Connaughton and Talbot Terranes, the Hf isotopic signatures of all three are broadly similar, implying that each originated from the same, or a similar, crustal source.

In the Connaughton Terrane, magmatic zircons of the Kalkan Supersuite granites are, on average, less evolved than those in the Talbot Terrane, and lie entirely within the isotopic envelope of the Glenburgh Terrane of the Capricorn Orogen. This implies less influence of a highly evolved basement (i.e. an East Pilbara Terrane component), indicating that East Pilbara Terrane basement is thinner in the Connaughton Terrane.

The broad similarity in isotopic composition and age of inherited zircons within granitic rocks of the Kalkan Supersuite in both Talbot and Connaughton Terranes, with detrital zircons in sedimentary rocks in the Capricorn Orogen, suggest that the Kalkan Supersuite granites assimilated variable degrees of sedimentary material similar to that in the Capricorn Orogen during emplacement into the upper crust (Fig. 3). Furthermore, sedimentary rocks of the eastern association of the Talbot Terrane were deposited at c. 1800 Ma during the same time as those in the Capricorn Orogen (e.g. Ashburton and Blair Basins), implying the development of a single large basin — or series of smaller, linked basins — around the southern and eastern margins of the Pilbara Craton during the late Paleoproterozoic.

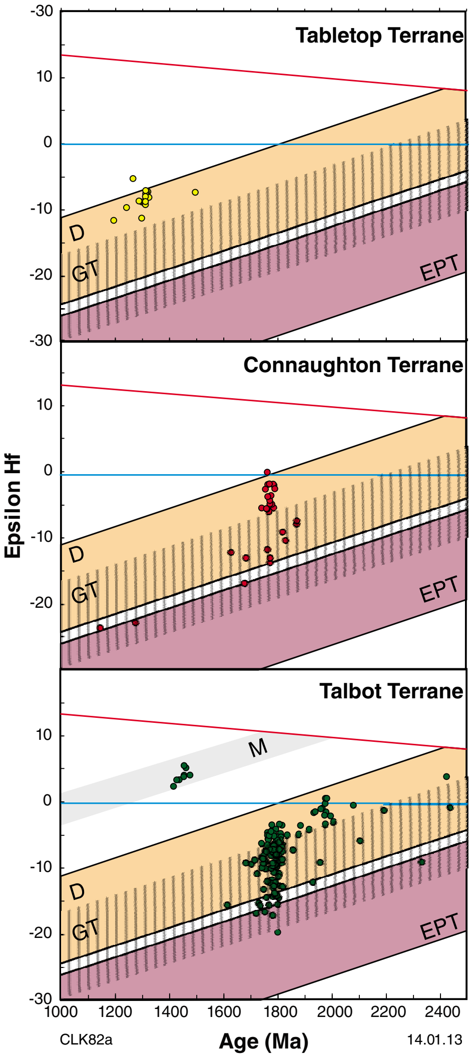

Figure 3. **Epsilon-Hf evolution diagrams for Rudall Province samples compared to potential source regions. Shaded fields illustrate normal crustal evolution of Hf along a $^{176}Lu/^{177}Hf$ slope of 0.015. Abbreviations used: EPT — East Pilbara Terrane; M — Musgrave Province c. 1.9 Ga source; GT — Glenburgh Terrane (Capricorn Orogen basement); and D — Dalgaringa Supersuite intrusive rocks. The red line is the depleted mantle model and the blue line is the CHUR (chondritic uniform reservoir) model.**

Isotopic signature of the Tabletop Terrane

The Tabletop Terrane has traditionally been regarded as a far-travelled block with crust unique to the other components of the Rudall Province. This inference was based on the similar age of magmatism in this terrane to that in the northern Gawler and Musgrave regions. U–Pb geochronology in this terrane indicates magmatism at 1590–1550 Ma (Maidment et al., in prep.) and at c. 1300 Ma. The magmatic zircons from a c. 1300 Ma granite of the Tabletop Terrane are dominated by mildly evolved compositions with model ages of 2.6 Ga (Fig. 3), that are isotopically similar to the other Rudall Terranes. The similarity of source compositions throughout all three terranes of the Rudall Province implies that the Tabletop Terrane was derived from crust of similar composition to the Connaughton Terrane and the supracrustal components of the Talbot Terrane (Fig. 2).

Crust formation and underplating at 1.9 Ga

A c. 1450 Ma metamonzogranite in the Talbot Terrane contains zircons with the least evolved Hf isotopic signature in the Rudall Province (Fig. 2). The Hf isotope data indicate either extraction from the mantle at c. 1.9 Ga, or a homogenized mix of sources with a component younger than c. 1.9 Ga. However, oxygen isotopes can be used to determine whether the granitic magma within which each zircon grew contained a contribution from near-surface rocks (e.g. those with $\delta^{18}O_{VSMOW}$ >6.3 ‰). This approach provides a means to screen the corresponding Hf model age to identify model ages that represent discrete crust-forming episodes rather than mixtures of source materials and contamination by supracrustal material. Oxygen isotope values for all zircons from this sample are within the mantle zircon field ($\delta^{18}O$ = 5.3 – 0.6 ‰). Hence, the c. 1.9 Ga model age likely reflects a crust-forming fractionation event in the lithosphere.

There is only limited additional evidence for crust formation at c. 1.9 Ga in the WAC and its marginal terranes. Magmatic and metasedimentary rocks of the Musgrave Province are dominated by two major Proterozoic juvenile crust-formation events: one at 1.6 Ga and a more significant event at c. 1.9 Ga (Kirkland et al., 2012).

Whole-rock Nd isotopes

Whole-rock Nd isotopes from the Kalkan granites imply that three source components contributed to the magmas. An evolved component with moderate Nd content is consistent with the incorporation of variable amounts of Archean Pilbara crust. A low-Nd radiogenic component is likely a reflection of new juvenile mantle addition. A third high-Nd, moderately radiogenic, component appears isotopically similar to a putative (but unexposed) c. 1.9 Ga source in the Musgrave Province that also appears to be a source for voluminous mafic sills of the c. 1465 Ma Narimbunna Dolerite that intruded the intracratonic Edmund Basin, located between the Pilbara and Yilgarn Cratons.

Summary

The broad similarity in crustal residence ages for all terranes in the Rudall Province indicates that the terranes have a common heritage, although Mesoproterozoic reworking (infracrustal magmatism) apparently occurred only in the Tabletop Terrane. Sources for all isotopic compositions preserved within the Rudall Province can be found within the proximal WAC. There is no necessity to invoke transfer of exotic NAC lithotectonic units to the WAC margin or to suggest an accretionary style of orogenesis for the Rudall Province. The Rudall sedimentary successions are autochthonous with respect to the eastern Pilbara Craton margin. This conclusion is consistent with the view presented by Reading et al. (2012), that thinned and extended Pilbara Craton crust occurs as basement beneath the Talbot Terrane. The Hf isotopic evolution of inherited and magmatic zircons within Kalkan Supersuite granites are largely influenced by a variety of autochthonous source regions, including the sedimentary successions into which they were intruded. A phase of crust formation at 1.9 Ga is indicated by Hf isotopes in a c. 1450 Ma monzogranite in the Talbot Terrane. This isotope signature appears to be similar to a dominant basement component in the Musgrave Province and in the deep crust beneath the Edmund Basin. This may support the idea of west-directed subduction and underplating beneath the WAC (or its Archean constituent blocks) as early as c. 1.9 Ga.

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