Low-temperature thermal evolution of the McArthur Basin and adjacent Proterozoic orogens

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Introduction

Palaeozoic intracratonic deformation during the ca 450–300 Ma Alice Springs Orogeny presents as a highly cryptic Palaeozoic structural and thermal perturbation of central Australia, far inboard from the plate margins. Metamorphism and deformation defining the Alice Springs Orogeny has been extensively observed and studied within the Aileron Province, Irindina Province and northern Amadeus Basin (eg Bradshaw and Evans 1988, Shaw and Black 1991, Shaw *et al* 1992, Mawby *et al* 1998, **Figure 1**), with considerably less research focused on the coeval structural and thermal response of surrounding basement and basin systems. These terranes, including the Pine Creek Orogen, Warramunga Province, Murphy Province, and McArthur Basin, are situated between the Aileron Province and Amadeus Basin and an interpreted convergent margin to the present-day east of Australia, or are equidistant to this margin (**Figure 1**). However, these intermediate terranes do not exhibit high levels of deformation and metamorphism. Rather, Palaeozoic metamorphism appears to have been confined within the Aileron and Amadeus regions, with intermediate regions showing little tectonothermal response. Tectonically, this appears counterintuitive – where adjacent regions and those more proximal to the locus of convergence appear to have experienced less reworking than more distal terranes.

As the majority of both mineral and hydrocarbon resources within the North Australian Craton developed within the Proterozoic, this time period has consequently

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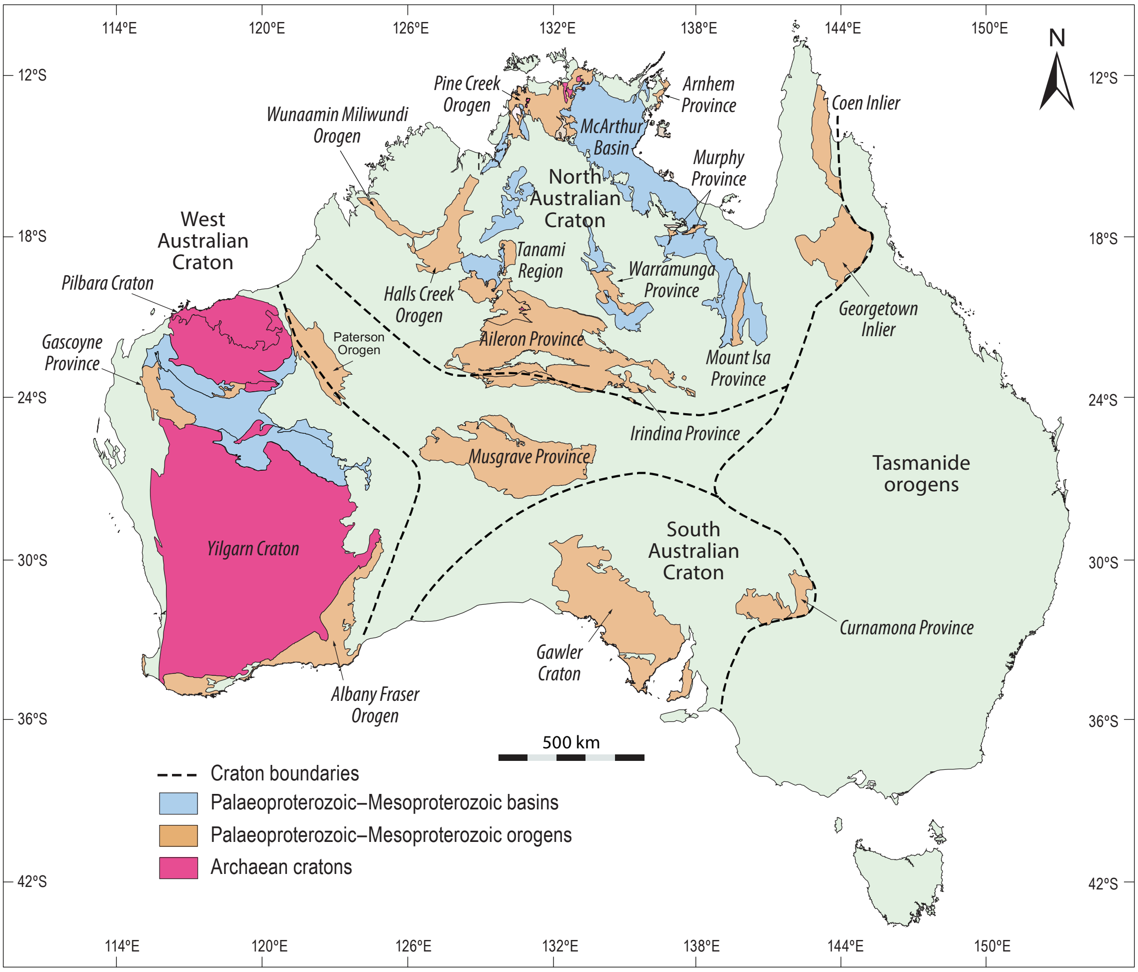

Figure 1. Simplified tectonic map of Australian Archaean and Palaeoproterozoic tectonic basement and Australian cratonic boundaries, modified from Ahmad and Scrimgeour (2013) and Cawood and Korsch (2008).

received the bulk of research endeavours. Palaeozoic evolution, including response during the Alice Springs Orogeny, is comparatively poorly constrained, yet likely plays a major role in the preservation and exhumation of resources. This work documents the low-temperature (<120°C) thermochronological reactivation history of the North Australian Craton, north of the Aileron Province, using a combination of apatite fission track and (U–Th)/He thermochronology and thermal modelling techniques. These approaches aim to establish a deformational framework for northern Australia away from the zones of tectonism at the plate boundaries, in order to provide insights into the preservation, exhumation and secondary resource generation potential across the region.

Basement deformation and thermal perturbation

Widespread structural reactivation and exhumation contemporaneous with the Ordovician–Carboniferous Alice Springs Orogeny dominates the Palaeozoic record in the North Australian Craton, with reactivation of similar ages observed more sporadically within the South Australian Craton. Deformation away from the orogenic locus of this event is largely constrained within Palaeoproterozoic crystalline basement, which hosts pre-existing structures that were reactivated in response to changing stress regimes at distant plate boundaries (Hall *et al* 2016, Nixon *et al* 2021, 2022b, c). The clearest evidence of sub-metamorphic reworking during the Alice Springs Orogeny is observed during the Pertnjara-Brewer Event (ca 390–360 Ma; Jones 1972, Bradshaw and Evans 1988), with reactivation observed in basement terrane of the Pine Creek Orogen, Tennant Region and northern Aileron Province (**Figure 2**). This broadly coincides with the major Tabberabberan Orogeny of eastern Australia (Black *et al* 2005, Rosenbaum 2018). However, considerable cooling is also observed away from highly faulted terranes throughout the duration of the Alice Springs Orogeny. In these structurally less favourable

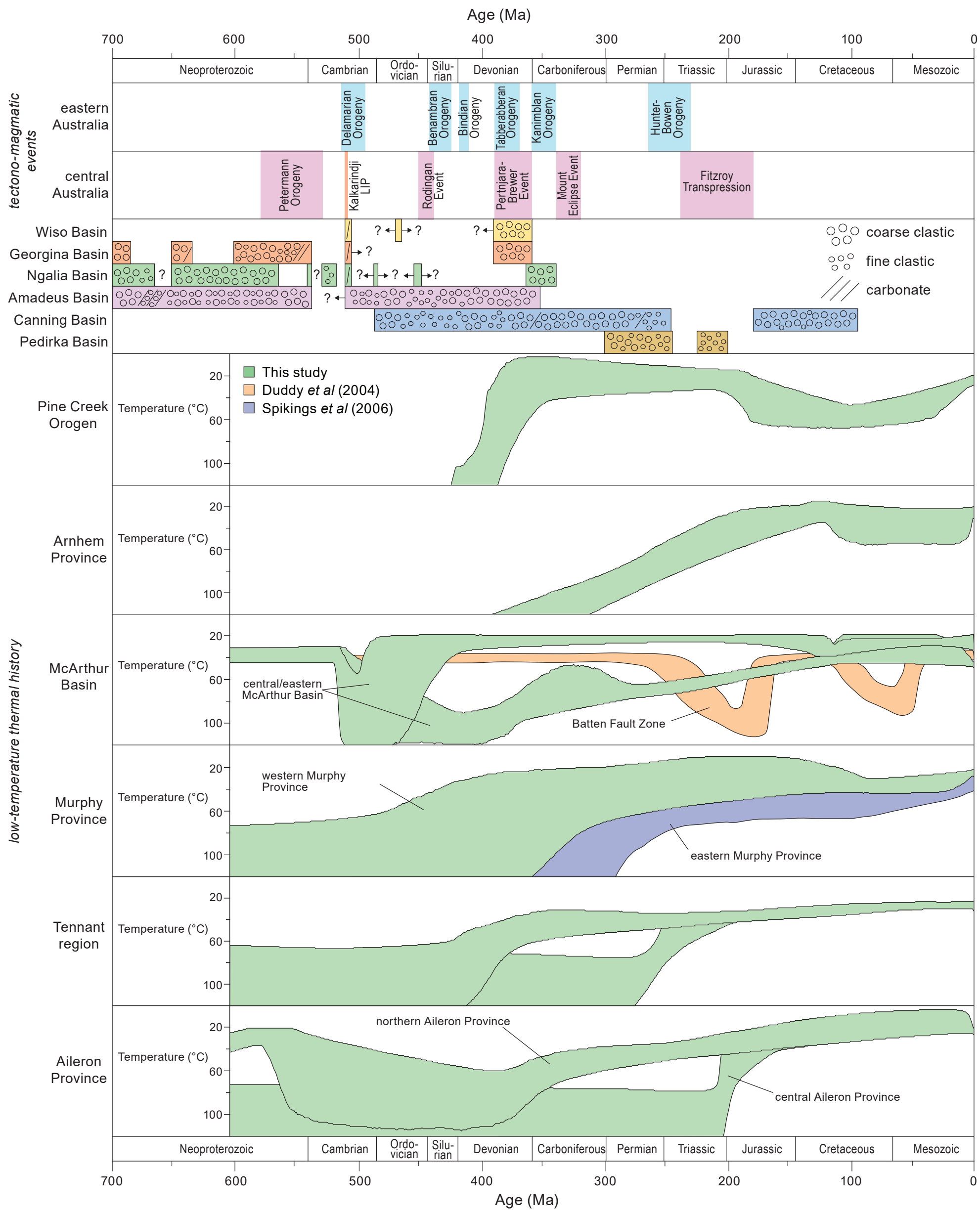

Figure 2. Time-space plot for the North Australian Craton, depicting major deformational and magmatic events, periods of sedimentation and low-temperature evolution. Generalised low-temperature thermal evolution models are from this study, supplemented by work of previous authors from the eastern Murphy Province (Spikings *et al* 2006) and Batten Fault Zone of the McArthur Basin (Duddy *et al* 2004).

regions, cooling is much slower and more long-lived in response to long wavelength exhumation. Such slow cooling during the Ordovician–Carboniferous has been observed within the Murphy Province, Arnhem Province, western Tennant Region and northern Aileron Province (**Figure 2**), where these localities lack pre-existing or favourably oriented structures for strain accommodation.

The youngest reactivation within the North Australian Craton is, somewhat counterintuitively, preserved furthest inboard from the Gondwanan plate boundary, within the central Aileron Province (**Figures 1**, **2**). Triassic deformation in this area corresponds to the timing of the late-stage Hunter-Bowen Orogeny (Rosenbaum *et al* 2012, Babaahmadi *et al* 2017, Jessop *et al* 2019). It represents the inboard propagation of strain from the eastern convergent margin that was localised in regions of thermally and metasomatically weakened crust, far from the classical accretionary terranes of the Tasmanides. This late reactivation in central Australia is confined within regions of abnormally elevated local heat production from the decay of radiogenic elements, which has thermally weakened the lithosphere and made these areas more susceptible to reworking in response to evolving far-field tectonic events at the plate margin.

Thermal response in the McArthur Basin

The McArthur Basin preserves low-temperature signatures correlating with the Alice Springs Orogeny, but also contains evidence of older thermal events within the Palaeozoic. Voluminous extrusion of basaltic lavas of the Kalkarindji Large Igneous Province across the West Australian Craton and North Australian Craton in the Cambrian (ca 510 Ma, Jourdan *et al* 2014) rapidly heated the uppermost crust. This signal represents the oldest preserved low-temperature heating event within the North Australian Craton, and only appears to be retained in the McArthur Basin (Nixon *et al* 2022c). Importantly, this short-lived event is recognised exclusively as surficial heating associated with sub-aerial lavas; the possibility of thermal resetting by comagmatic intrusive suites within the basin has been discounted by undertaking extensive U–Pb geochronology of intrusive rocks across the region that have been shown to be considerably older and part of the Mesoproterozoic Derim Derim Galiwinku/Yanliao Large Igneous Province (Yang *et al* 2020, Bodorkos *et al* 2021, Nixon *et al* 2022a,). Following initial rapid heating of the shallow sub-surface, these low-thermal-conductivity basalts effectively thermally insulated the underlying basin, invoking lower-magnitude heating for a longer time period (**Figure 2**). Erosion of portions of these lava sequences as well as basin sedimentary rocks occurred during the Devonian–Carboniferous, coeval with structural reactivation in exposed bounding basement terranes.

Conclusions

Widespread structural reactivation across the North Australian Craton is observed coeval with metamorphism and orogenic reworking in the Aileron Province and Amadeus Basin during the Alice Springs Orogeny. Localisation of strain in the Aileron Province was most likely a consequence of locally weakened crust proving to be more susceptible to deformation (Sandiford and Hand 1998, Hand and Sandiford 1999, Raimondo *et al* 2011, 2012), as a response to compressional stress likely originating at the Gondwanan plate margins. In addition to high-grade reworking in the Aileron Province, stress propagating through the continental interior was responsible for sub-metamorphic structural reactivation and exhumation within the Pine Creek Orogen, Arnhem Province, Warramunga Province, Murphy Province, Mount Isa Province and McArthur Basin. In all cases, deformation was accommodated by favourably oriented pre-existing (likely Proterozoic) structures, or as long-wave slow uplift and exhumation. Structural and compositional preconditioning for reworking appears to be the predominant factor in deformational expression during the Palaeozoic, and explains why an apparently rheologically weaker zone such as the McArthur Basin experienced only limited thermal and structural perturbation.

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