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New constraints on the origin and evolution of the Thomson Orogen and links with central Australia from isotopic studies of detrital zircons

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ABSTRACT

Interpretation of the Thomson Orogen and its context within the Tasmanides of eastern Australia is hampered by vast areas of deep sedimentary cover which also mask potential relationships between central and eastern Australia. Within covered areas, basement drill cores offer the only direct geological information. This study presents new detrital zircon isotopic data from these drill cores and poorly understood outcropping units to provide new age and provenance information for sedimentary rocks from the Thomson Orogen. Two distinct detrital zircon signatures are revealed. One is dominated by Grenvillian-aged (1300–900 Ma) zircons with a significant peak at ~1180 Ma and lesser peak at ~1070 Ma. These age peaks, along with Lu–Hf isotopic compositions (median $\varepsilon Hf(t) = +1.5$), dominantly mantle-like $\delta^{18}O$ values (median = 5.53‰) and model ages of ~1.89 Ga, support a Musgrave Province (central Australia) source. The dominance of Grenvillian-aged material additionally points to deposition during the Petermann Orogeny (570–530 Ma) when the Musgrave Province was uplifted, shedding abundant material to the Centralian Superbasin. Comparable age spectra suggest that parts of the Thomson Orogen were connected to the Centralian Superbasin during this period. We use the term 'Syn-Petermann' to describe this signature which is observed in two drill cores adjacent to the North Australian Craton and scattered units in the outcropping Thomson Orogen. The second signature marks a significant provenance shift and is remarkably consistent throughout the Thomson Orogen. Age spectra exhibit dominant peaks at 600–560 Ma, lesser 1300–900 Ma populations and maximum depositional ages of ~495 Ma. This pattern is termed the 'Pacific Gondwana' detrital zircon signature and is recognised throughout eastern Australia, Antarctica and central Australia. Lu–Hf isotope data for Thomson Orogen rocks with this signature are highly variable with $\varepsilon Hf(t)$ values between -49 and +10 and dominantly supracrustal $\delta^{18}O$ values suggesting input from different and more diverse source regions relative to those exhibiting the Syn-Petermann signature.

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1. Introduction

The Neoproterozoic to Palaeozoic Thomson Orogen is a major component of the Tasmanides of eastern Australia, which also includes the Delamerian, Lachlan, Mossman and New England Orogens (Fig. 1). Together, these tectonic elements record the growth of orogenic belts along the eastern Gondwana margin following the break-up of Rodinia.

The Thomson Orogen occupies a large and important portion of the Tasmanides between the North Australian Craton to the west, New England Orogen to the east and Lachlan Orogen to the south but outcrop is sparse. Current models for the tectonic evolution of the Thomson Orogen and its context relative to surrounding crustal elements focus on small exposures, scattered drill cores and interpretation of geophysical data in northwest New South Wales (Burton, 2010; Glen et al., 2010; Greenfield et al., 2010; Glen et al., 2013), or the structure and geochronology of exposed areas in north Queensland (e.g. Fergusson et al., 2007a; Henderson et al., 2011). Research in the north-west New South Wales portion (sometimes referred to as the southern Thomson Orogen) has aimed at defining the location and nature of the southern margin and is the subject of recent debate (e.g. Burton, 2010; Glen et al., 2013).

Work at the northern end of the Thomson Orogen in the Anakie, Charters Towers, and Greenvale Provinces of central-north Queensland (e.g. Withnall et al., 1995; Fergusson et al., 2001, 2007a, 2007b, 2007c; Henderson et al., 2011) provides valuable geochronology, geochemistry and structural data. This reveals a complex thermal and structural history with major tectonic events tentatively correlated with those in southern Australia (e.g. late Neoproterozoic rifting, and deformation during the Delamerian and Benambran Orogenies). One major hypothesis from this work is that the Grenvillian-aged (1300–900 Ma)

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Musgrave Province of central Australia extends eastward forming an unexposed belt below the Thomson Orogen and adjacent to the North Australian Craton (see Fergusson et al., 2007a, figure 7). This has major implications for reconstructions of the supercontinent Rodinia which partly rely on re-joining orogenic belts of this age (Cawood, 2005; Li et al., 2008; Fergusson and Henderson, 2015).

All tectonic models for the Thomson Orogen and Tasmanides are hampered by the vast area of relatively unknown geology in central and southwest Queensland where Devonian to Cretaceous cover basins are up to ~4 km thick. This has also contributed to a poor understanding of how tectonic events in central Australia (e.g. Petermann Orogeny) and sedimentation in central Australian basins may relate to eastern Australia. The undercover Thomson Orogen is a key area to investigate potential links and is the focus of this study.

Glimpses of the undercover Thomson Orogen are revealed in deep basement intersections of petroleum and stratigraphic drill holes. These are dominated by low grade metasedimentary rocks (dominantly turbidites) with minor volcanic rocks and granites (Fig. 1) (Brown et al., 2012). Here we present the results of an isotopic study of detrital zircons from throughout the undercover Thomson Orogen and poorly understood outcropping units to show regional correlations and highlight strong links between central Australian Basins (Centralian Superbasin) and the Thomson Orogen.

2. Background geology

2.1. Outcropping Thomson Orogen

The majority of Thomson Orogen outcrop occurs in the Anakie, Charters Towers and Greenvale Provinces of central-north Queensland

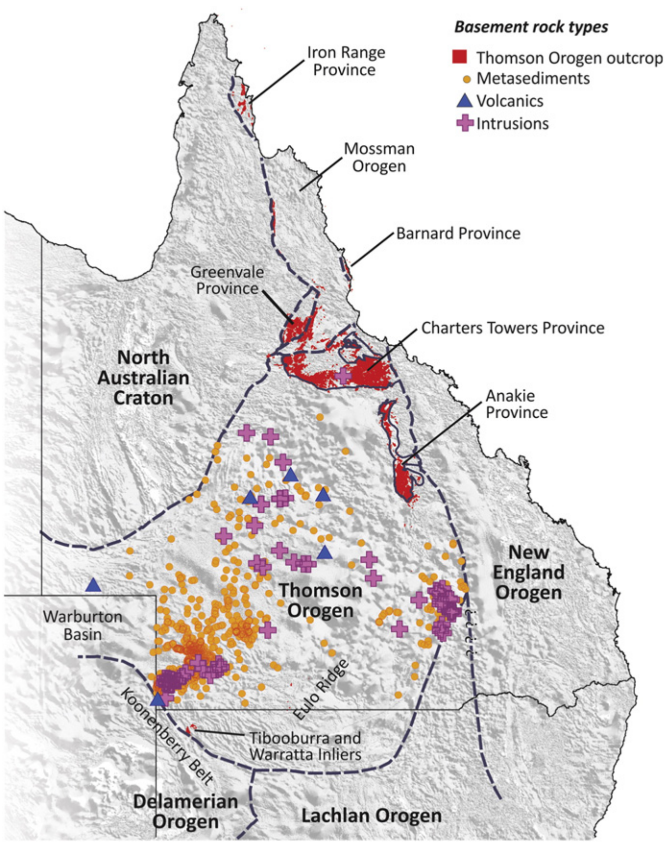

Fig. 1. Location of the Thomson Orogen relative to major tectonic elements of northeast Australia. The majority of outcrop occurs in the Anakie, Charters Towers and Greenvale Provinces. Information about the geology in the vast covered areas through central and southwest Queensland is from basement intersections of petroleum and stratigraphic drill holes. These are dominated by low-grade siliciclastic metasediments.

(Fig. 1). Small granitoid exposures also occur in southern Queensland and represent the surface expression of a broad basement high (Eulo Ridge). In New South Wales, exposure is restricted to inliers of granodiorite and metasedimentary rocks near Tibooburra and along the southern margin near Louth (Greenfield et al., 2010; Glen et al., 2013).

The stratigraphy of the outcropping Thomson Orogen broadly comprises a lower package of metasedimentary and minor mafic metavolcanic rocks inferred to be Neoproterozoic to Cambrian in age overlain by Cambrian to Ordovician felsic metavolcanic and metasedimentary units (Fig. 2).

2.1.1. Neoproterozoic to Cambrian

Two metasedimentary-dominated successions inferred to be Neoproterozoic to Cambrian in age were recognised by Fergusson et al. (2001, 2007a) based on detrital zircon and monazite U–Pb geochronology and structural studies. The lower (older) succession is characterised by abundant late Mesoproterozoic (Grenvillian) aged grains and maximum depositional ages of ~580 Ma or older (Fig. 3a). This succession comprises the Cape River Metamorphics, lower parts of the Argentine Metamorphics and possibly the Running River Metamorphics in the Charters Towers Province, and lower parts of the Anakie Metamorphic Group (Bathampton Metamorphics) in the Anakie Province (Fig. 2). The Halls Reward Metamorphics in the Greenvale Province were formerly considered part of this succession but are now known to be younger (Kositcin et al., 2015b). This Neoproterozoic to Cambrian succession is interpreted to represent part of a passive margin associated with continental rifting with the dominant 'Grenvillian' (1300–900 Ma) zircons derived from a now concealed extension of the Musgrave Province into eastern Australia (Fergusson et al., 2007a).

The upper succession has younger maximum depositional ages of 495–511 Ma, abundant zircons in the 650–500 Ma age range and subordinate populations between 1300 and 900 Ma (Fig. 3b) (Fergusson et al., 2007a). This succession comprises upper parts of the Anakie Metamorphic Group (Wynyard Metamorphics), lower grade parts of the Argentine Metamorphics and the Charters Towers Metamorphics (Fig. 2). This succession is interpreted as being associated with the active Gondwana margin which developed on the former passive margin with 650–500 Ma zircons sourced from rift-related and back-arc volcanism (Fergusson et al., 2007a).

A minimum of three deformations are observed within the Neoproterozoic to Cambrian units (Withnall et al., 1995; Fergusson et al., 2005a, 2007b, 2007c). The main early deformation and metamorphism is correlated with the Delamerian Orogeny in southern Australia.

2.1.2. Cambrian to Ordovician

Overlying Cambrian to Ordovician units lack the early regional deformation attributed to the Delamerian Orogeny. These probably experienced peak metamorphic conditions in the late Ordovician to early Silurian related to the Benambran Orogeny (Ali, 2010; Greenfield, 2010a).

In Queensland, Cambrian to Ordovician units host VMS mineralisation (e.g. Thalanga, Balcooma, Dry River, Surveyor) and are dominated by felsic metavolcanic and metasedimentary sequences interpreted to represent deposition in a back arc basin (Henderson, 1986; Fergusson et al., 2007a, 2007b). In the north these comprise the Balcooma Metavolcanic Group and Lucky Creek Metamorphic Group (Greenvale Province) and the Seventy Mile Range Group (Charters Towers Province) (Fig. 2). Possible equivalents crop out to the south in the Anakie Province as monotonous sequences of quartzose to feldspathic sandstone and mudstone in Les Jumelles Beds.

Contemporaneous units in northwest New South Wales form the Warratta Group and crop out in the Tibooburra (Easter Monday Formation) and Warratta (Jeffreys Flat Formation) inliers (Fig. 1) and as recessive outcrops at Yancannia (Yancannia Formation). They

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