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High grade metamorphism of sedimentary rocks during Palaeozoic rift basin formation in central Australia

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ABSTRACT

Exhumation of middle and lower crustal rocks during the 450–320 Ma intraplate Alice Springs Orogeny in central Australia provides an opportunity to examine the deep burial of sedimentary successions leading to regional high-grade metamorphism. SIMS zircon U–Pb geochronology shows that high-grade metasedimentary units recording lower crustal pressures share a depositional history with unmetamorphosed sedimentary successions in surrounding sedimentary basins. These surrounding basins constitute parts of a large and formerly contiguous intraplate basin that covered much of Neoproterozoic to early Palaeozoic Australia. Within the highly metamorphosed Harts Range Group, metamorphic zircon growth at 480–460 Ma records mid-to-lower crustal (~0.9–1.0 GPa) metamorphism. Similarities in detrital zircon age spectra between the Harts Range Group and Late Neoproterozoic–Cambrian sequences in the surrounding Amadeus and Georgina basins imply that the Harts Range Group is a highly metamorphosed equivalent of the same successions. Maximum depositional ages for parts of the Harts Range Group are as low as ~520–500 Ma indicating that burial to depths approaching 30 km occurred ~20–40 Ma after deposition. Palaeogeographic reconstructions based on well-preserved sedimentary records indicate that throughout the Cambro–Ordovician central Australia was covered by a shallow, gently subsiding epicratonic marine basin, and provide a context for the deep burial of the Harts Range Group. Sedimentation and burial coincided with voluminous mafic magmatism that is absent from the surrounding unmetamorphosed basinal successions, suggesting that the Harts Range Group accumulated in a localised sub-basin associated with sufficient lithospheric extension to generate mantle partial melting. The presently preserved axial extent of this sub-basin is >200 km. Its width has been modified by subsequent shortening associated with the Alice Springs Orogeny, but must have been >80 km. Seismic reflection data suggest that the Harts Range Group is preserved within an inverted crustal-scale half graben structure, lending further support to the notion that it accumulated in a discrete sub-basin. Based on palaeogeographic constraints we suggest that burial of the Harts Range Group to lower crustal depths occurred primarily via sediment loading in an exceptionally deep Late Cambrian to Early Ordovician intraplate rift basin. High-temperature Ordovician deformation within the Harts Range Group formed a regional low angle foliation associated with ongoing mafic magmatism that was coeval with deepening of the overlying marine basin, suggesting that metamorphism of the Harts Range Group was associated with ongoing extension. The resulting lower crustal metamorphic terrain is therefore interpreted to represent high-temperature deformation in the lower levels of a deep sedimentary basin during continued basin development. If this model is correct, it indicates that regional-scale moderate- to high-pressure metamorphism of supracrustal rocks need not necessarily reflect compressional thickening of the crust, an assumption commonly made in studies of many metamorphic terrains that lack a palaeogeographic context.

1. Introduction

The burial of sedimentary successions to lower crustal depths (>25–30 km) and their subsequent regional high-grade metamorphism are generally regarded as reflecting compressional tectonic regimes (e.g. Vance et al., 1998; Brown, 2001; Lee and Cho, 2003; Scrimgeour et al., 2005). This notion is consistent with contractional style structures that are observed in many metamorphic terrains, as well as thermomechanical modelling which shows that large-scale contractional deformation is an efficient way to bury supracrustal rocks (e.g. Jamieson et al., 2002). In metamorphic terrains that lack a well defined palaeogeographic or palaeotectonic context, metamorphic style is often used as a primary constraint on the potential tectonic setting (e.g. Vance et al., 1998; Scrimgeour et al., 2005). This is

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particularly the case in terrains that are poorly preserved due to overprinting by later events (e.g. Cutts et al., 2010). Despite the general notion that deep burial of sedimentary successions reflects compressional processes, however, there are a number of examples where burial to depths in excess of 20 km is associated with the formation of crustal-scale rift basins (Allen et al., 1995; Ojakangas et al., 2001; Baldwin et al., 2003; Maystrenko et al., 2003). The preservation of these basins, allowing their thickness to be directly measured, means that their keels are still deeply buried, precluding direct examination of the thermal character of the basal rift successions. Deep rift basins, however, are commonly associated with mafic magmatism and high basal heat flows (e.g. Ruppel, 1995), making them a logical setting for regional high-grade metamorphism if rifting and magmatism were maintained for a sufficient period of time (e.g. Wickham and Oxburgh, 1985; Aitken et al., 2012). Therefore we should expect that deeply inverted crustal-scale rift basins might expose highly metamorphosed sequences that were deposited, buried and metamorphosed within the evolving rift.

Central Australia contains a remarkable record of intraplate deformation expressed by the formation of a Neoproterozoic to mid-Palaeozoic continental-scale intraplate basin, the Centralian Superbasin (Fig. 1), and its modification during rifting events and intraplate orogeny (Lindsay and Korsch, 1991; Walter et al., 1995; Camacho et al., 1997; Hand and Sandiford, 1999; Mawby et al., 1999; Scrimgeour and Close, 1999; Camacho and McDougall, 2000; Haines et al., 2001; Wade et al., 2008a; Raimondo et al., 2009). The superbasin was initiated at about 830 Ma as a broad, shallow sag coeval with rifting along the now eastern margin of Proterozoic Australia (Lindsay et al., 1987; Lindsay, 2002). Basin development for about the next 250 Ma was maintained by small rift systems linked to on-going extension along the eastern Australian margin (Lindsay et al., 1987; Walter et al., 1995). The basin underwent two periods of orogenic-scale intraplate inversion (Sandiford and Hand, 1998; Hand and Sandiford, 1999; Sandiford et al., 2001) that divided it into a series of structural remnants, the Amadeus, Georgina, Officer and Ngalia basins (Fig. 1). The first inversion event was the Petermann Orogeny between 580 and 530 Ma, which exhumed Mesoproterozoic basement from depths of up to 50 km (Scrimgeour and Close, 1999; Camacho et al., 1997; Wade et al., 2005, 2006; Raimondo et al., 2009). The second was the Alice Springs Orogeny between 450 and 320 Ma, which exhumed middle and lower crustal rocks from depths of up to 30 km (Collins and Teyssier, 1989a,b; Dunlap and Teyssier, 1995; Dunlap et al., 1995; Mawby et al., 1999). Between these two intraplate orogenic events, shallow marine epicontinental sedimentation was maintained across much of central Australia.

Until recently, all models for the intraplate evolution of central Australia considered that the mid- and lower-crustal rocks exhumed during the Alice Springs Orogeny formed part of the Palaeoproterozoic basement to the Centralian Superbasin (Stewart et al., 1984; Ding and James, 1985; James and Ding, 1988; Collins and Teyssier, 1989a,b; Dunlap and Teyssier, 1995; Braun and Shaw, 1998). However, SIMS (sensitive high resolution ion microprobe (SHRIMP)) zircon U–Pb dating of metasedimentary rocks from the Harts Range Group in the Harts Range

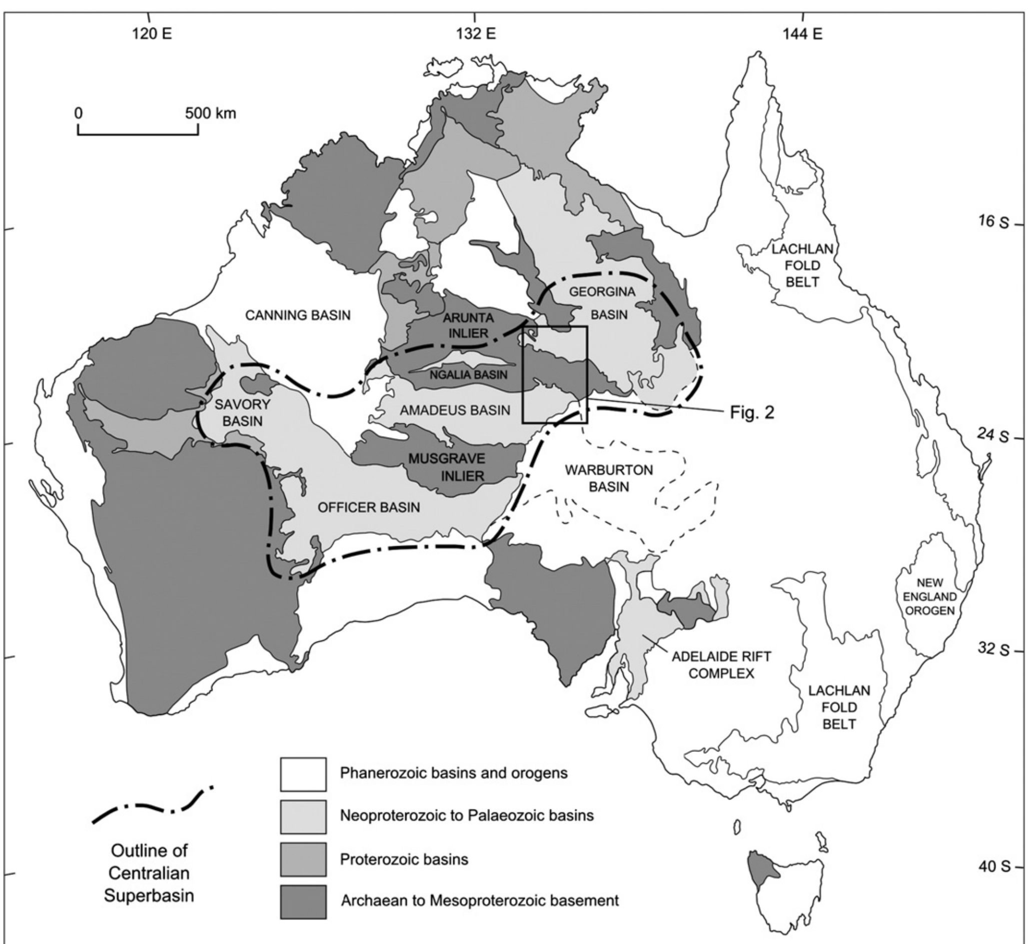

Fig. 1. Map of Australia showing the major basement and basin domains. The outline of the formerly contiguous Centralian Superbasin (Walter et al., 1995) is shown. The basin is now a series of structural remnants (Officer-Savory, Amadeus, Georgina and Ngalia) which were formed during the 580–530 Ma Petermann and the 450–320 Ma Alice Springs intracratonic orogenies which dismembered the basin (Sandiford and Hand, 1998).