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Early history of the Amadeus Basin: Implications for the existence and geometry of the Centralian Superbasin

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ABSTRACT

The Centralian Superbasin is a concept connecting Neoproterozoic successions that presently occur in separate structural basins in central Australia into a once-continuous depositional system. The superbasin is thought to have been initiated ~830 Ma, coevally with the breakup of Rodinia, by a mantle plume centred under the central Adelaide Geosyncline, South Australia. The superbasin is thought to deepen towards the south with the basal sediments mainly sourced from the Arunta Region in the north, and blanketing the crystalline Musgrave Block to the south. Our results suggest that deposition in the Amadeus Basin, the most studied of these intraplate basins that made up the superbasin, began ~1040 Ma ago (assembly of Rodinia; about 200 Ma earlier than previously suggested) in association with a mantle plume that formed the Warakurna large igneous province. Moreover, we argue for a two stage opening of the Amadeus Basin, one starting at ~1040 and the other at ~800 Ma, and a long stratigraphic break(s) within Supersequence 1. The basal units of Supersequence 1 in the southern Amadeus Basin yield detrital zircon U–Pb age populations consistent with derivation from the Musgrave Block, which must have been emergent at the time. Our data support the correlation between the basal Neoproterozoic units of the Amadeus Basin (Heavitree Quartzite and Bitter Springs Formation) and the Succession B in western North America, consistent with paleogeographical reconstructions placing Australia to the west of North America after the assembly of Rodinia and before its breakup. Furthermore, our study brings into question the existence of the Centralian Superbasin because Supersequence 1 sedimentary rocks do not belong to a single depositional system.

1. Introduction

In Australia, the onset of Rodinia break-up is thought to be related to a mantle plume event with a head centred under the central Adelaide Geosyncline, South Australia (Fig. 1; von der Borch, 1980; Zhao et al., 1994). Thermal subsidence after plume activity is interpreted to have formed the large intraplate sedimentary basins (Officer, Amadeus, Ngalia and Georgina Basins) of central Australia (Zhao et al., 1994). The Neoproterozoic sedimentary rocks of these separate basins are thought to constitute remnants of the once-continuous Centralian Superbasin (Fig. 1; Walter et al., 1995). Studies of the sedimentary successions of the Amadeus Basin have influenced the thinking about global environmental changes in the Neoproterozoic, such as secular variations in carbon isotope composition of seawater (e.g., Halverson et al., 2005), long-term oscillations in the chemical composition of seawater between aragonite and calcite seas as seen in the Phanerozoic (Kovalevych et al., 2006), debate regarding the synchronicity of Snowball Earth glaciations (Kendall et al., 2006), and evolution of life (e.g., Schopf, 1992). The existence and geometry of this superbasin also has direct implications for models that explain intraplate deformation in central Australia (e.g., Sandiford and Hand, 1998).

The timing of initiation of the Centralian Superbasin is not well determined, but it is widely held that deposition started at ~830 Ma (Hand and Sandiford, 1999; Li and Powell, 2001; Lindsay, 2002; Walter and Veevers, 1997; Walter et al., 1995; Zhao et al., 1994). Basaltic flows in the Amadeus Basin, correlated with the ~830 Ma Gairdner-Amata dyke swarm (Zhao et al., 1994; Wingate et al., 1998; Glikson et al., 1996), are only found in sedimentary rocks that formed well after the sag phase was initiated (Southgate, 1991), suggesting that the underlying, rift-phase units are significantly older. Volcanism at ~1070 Ma (Close et al., 2003;

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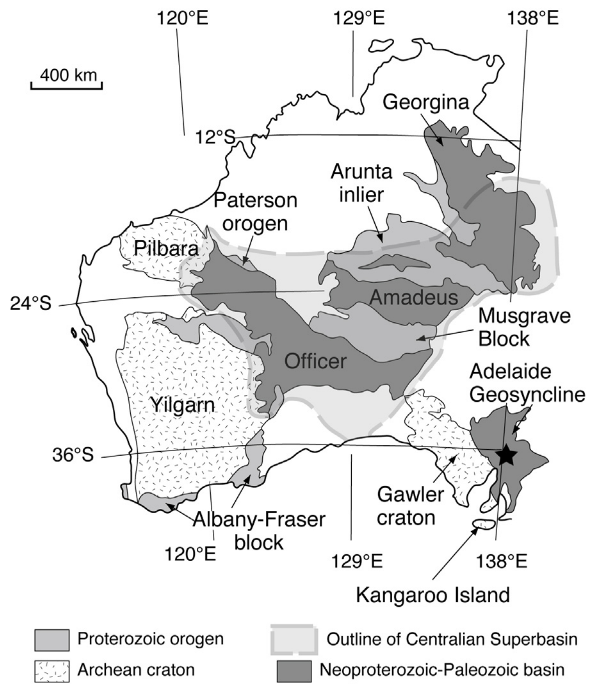

Fig. 1. Distribution of Proterozic-Paleozoic basins in relation to basement blocks and regions in Australia (modified after Shaw, 1991). Outline of the Centralian Superbasin is from Walter et al. (1995). Filled black star represents the approximate location of the plume centre (von der Borch, 1980; Zhao et al., 1994).

Scrimgeour and Close, 1999; Stevens and Apak, 1999), previously related to tectonic subsidence in the early stages of basin development (Forman, 1966; Korsch and Lindsay, 1989; Lindsay, 1989; Lindsay and Korsch, 1989; Lindsay and Korsch, 1991; Wells et al., 1966), has been largely ignored because it is considered to be too old for the initiation of the basin (Shaw, 1991; Zhao et al., 1994). In addition, Walter and Veevers (1997) considered the Arunta Region, north of the Amadeus Basin (Fig. 1), to be the dominant source of the sediment for the basal units, with little or no contribution from the other basement terranes. However, Zhao et al. (1992) and Maidment et al. (2007) inferred that sedimentary rocks of the Amadeus Basin were sourced from the Musgrave Block as well as the Arunta Region using Sm–Nd and U–Pb isotopes, respectively. Many interpretations of the superbasin have been influenced by long-distance comparisons with other basins, in particular the Adelaide Geosyncline, and by the notion that basin formation was related to the break-up of Rodinia (Lindsay, 2002; Walter and Veevers, 1997; Walter et al., 1995; Zhao et al., 1994).

Because of these inconsistencies, we have revisited the assumption that the formation of the superbasin was linked with a plume at ~830 Ma in South Australia. We do this by examining the provenance of zircons from the basal rift-related units of the south-western Amadeus Basin. In addition, we document and assess the extent of ~1070 Ma magmatism associated with the Warakurna large igneous province (Wingate et al., 2004) in central Australia. We argue that the data support an alternative interpretation, where basin formation in central Australia was initiated much earlier than is widely accepted, during widespread extension at ~1070 Ma, probably in a plume setting contemporaneous with Rodinia assembly, with the plume head centred in central Australia (Wingate et al., 2004). The basin appears to have had a period (~200 Ma) of quiescence until ~800 Ma when extension associated with the initial stages of Rodinia breakup caused further subsidence in the basin.

2. Regional setting

The east-west trending Musgrave Block is a Meso-Neoproterozoic mobile zone consisting of high-grade metamorphic and intrusive rocks covering an area of about 120,000 km^2 in the centre of the Australian continent (Fig. 1). The rocks of the Musgrave Block preserve two contrasting styles of orogenesis. Igneous and high temperature metamorphic episodes at ~1600 Ma, ~1300 Ma and ~1200 Ma were followed by high-strain deformation during the Petermann Orogeny at ~550 Ma (e.g., Camacho and McDougall, 2000). Widespread emplacement of granitoids occurred in three thermal episodes at ~1300 Ma, ~1150 Ma and ~1050 Ma (Camacho, 1997; Camacho and Fanning, 1995; Gray and Compston, 1978; Maboko et al., 1991; Smithies et al., 2008; Smithies et al., 2011; Sun and Sheraton, 1992; White et al., 1999). Mafic magmatism appears to be confined to two distinct episodes (Major, 1973; Sheraton and Sun, 1997; Zhao and McCulloch, 1993). The Giles Complex layered intrusion and the Alcurra Dyke Swarm, intruded at ~1070 Ma, represent the older generation (Camacho et al., 1991; Edgoose et al., 1993; Glikson et al., 1995; Schmidt et al., 2006; Sheraton and Sun, 1997; Zhao and McCulloch, 1993). They belong to the Warakurna large igneous province (Wingate et al., 2004) and appear to be related to the Ngaanyatjarra Rift (Evins et al., 2010). The younger Amata Suite dykes were emplaced at about 830 Ma and form part of the Gairdner-Amata dyke swarm in South Australia (Glikson et al., 1996; Sun and Sheraton, 1992; Wingate et al., 1998; Zhao and McCulloch, 1993).

The Musgrave Block is unconformably overlain by the basal strata of the Amadeus Basin, an asymmetric, east–west trending intraplate depression that covers an area of ~160,000 km^2 of central Australia, and separates the Arunta Region from the Musgrave Block (Fig. 2). Up to 14 km of sedimentary rock, ranging in age from the Mesoproterozoic to the Late Devonian, is preserved within the basin. The sedimentary succession was deposited in mainly shallow-marine and terrestrial environments, and records two episodes of basin restriction leading to deposition of Neoproterozoic and Early Cambrian evaporites, and late Neoproterozoic glacial activity. In the northern part of the basin, the present-day basin architecture defines three sub-basins with a central ridge on their southern margins (Lindsay and Korsch 1991). In contrast, the southern part of the basin is characterized by thin and discontinuous sequences (Lindsay and Korsch, 1989).

The contact between the southern Amadeus Basin and Musgrave Block has been described by Close et al. (2003), Edgoose et al. (1993), Scrimgeour et al. (1999), and Young et al. (2002) from which much of the following description of the units is derived. A sequence of interbedded siliciclastic sedimentary rocks (e.g., Karukali Quartzite, Bloods Range Formation), basalts (Tjuninanta Formation, Mount Harris Basalt) and rhyolites (Puntitjata Rhyolite; Fig. 3) is restricted to the southwestern margin of the basin, and unconformably overlies the ~1150 Ma Pottoyu granite suite. These rocks, collectively assigned to the Tjauwata Group (Close et al., 2003), have been interpreted as a rift sequence (bimodal volcanics and coarse-grained siliciclastic rocks including conglomerates) that underlies the more extensive Amadeus Basin succession related to thermal subsidence at the sag-stage of basin development (Fig. 3; Close et al., 2003; Lindsay and Korsch, 1991). A minimum age for the Mt. Harris Basalt is provided by the 1084 ± 9 Ma age of high level granites that intrude it (U–Pb on zircon; Close et al., 2003). The Puntitjata Rhyolite (1075.0 ± 2.5 Ma; Close et al., 2003) is overlain by the Wankari Volcanics (SHRIMP U–Pb age of 1051 ± 22 Ma; Scrimgeour et al., 1999), which are interpreted conformably to underlie quartz-rich sediments of the Bloods Range Formation. All these ages are within error of the extensive ca. 1070 Ma Stuart and Alcurra mafic dyke swarms in the Arunta Region and Musgrave Block, respectively (Camacho et al., 1991; Edgoose et al., 1993;