Gondwana Research 29 (2016) 136–152

Contents lists available at ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

The Australo-Antarctic Columbia to Gondwana transition

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ARTICLE INFO

Article history:
Received 11 June 2014
Received in revised form 20 October 2014
Accepted 29 October 2014
Available online 24 December 2014

Handling Editor: M. Santosh

Keywords:
Australia
Antarctica
Columbia
Rodinia
Gondwana

ABSTRACT

From the Mesoproterozoic to Cambrian, Australo-Antarctica was characterised by tectonic reconfiguration as part of the supercontinents Columbia, Rodinia and Gondwana. New tectonic knowledge of the Wilkes Land region of Antarctica allows Australo-Antarctic tectonic linkages to be resolved through reconstruction into ca. 160 Ma Gondwana. We also resolve 330 ± 30 km of sinistral strike-slip offset on the >3000 km long Mundrabilla-Frost Shear Zone and 260 ± 20 km of dextral offset on the >1000 km long Aurora Fault to reconstruct the ca. 1150 Ma geometry of Australo-Antarctica. Using this revised geometry, we derive the first model of the Columbia to Gondwana reconfiguration process that is geometrically constrained to ~100 km scale. In this model, early Mesoproterozoic tectonics is driven by two opposing subduction systems. A dominantly west-dipping subduction zone existed at the eastern margin of Australo-Antarctica until ca. 1.55–1.50 Ga. A predominantly east-dipping subduction zone operated at the western margin of the Mawson Craton from ca. 1.70 Ga to ca. 1.42 Ga. The latter caused gradual westwards motion and clockwise rotation of the Mawson Craton relative to the West and North Australian Craton and the accretion of a series of continental ribbons now preserved in the Musgrave Province and its southern extensions. A mid-Mesoproterozoic switch to predominantly west-dipping subduction beneath the West Australian Craton brought about the final closure of the Mawson Craton with the North and West Australian Craton along the Rodona-Totten Shear Zone. Convergence was achieved prior to 1.31 Ga, but final collision may not have occurred until ca. 1.29 Ga. Post-1.29 Ga intraplate activity involved prolonged high-temperature orogenesis from 1.22 to 1.12 Ga, and significant movement on the Mundrabilla-Frost Shear Zone between 1.13 and 1.09 Ga, perhaps in response to the assembly of Rodinia at ca. 1.1 Ga. The Australo-Antarctic Craton was amalgamated with Indo-Antarctica along the Indo-Australo-Antarctic Suture (IAAS) and Kuunga Orogeny, probably in the latest Neoproterozoic to early Cambrian.

1. Introduction

A continental fragment consisting of conjoined parts of Australia and Antarctica (Australo-Antarctica) is an important component of the supercontinents Columbia (Meert, 2002; Rogers and Santosh, 2002; Meert, 2012; Nance et al., 2014), Rodinia (Dalziel, 1991; Hoffman, 1991; Moores, 1991; Karlstrom et al., 1999; Li et al., 2008), and Gondwana (Lawver and Scotese, 1987; Meert and Van Der Voo, 1997; Meert, 2003; Torsvik and Cocks, 2013). For Australo-Antarctica, the transition from a Columbia-era configuration to a Rodinia-era configuration, has been the subject of scientific debate for well over a decade. Models fall into several contrasting categories, for example, non-rotational (Myers et al., 1996) vs rotational (Giles et al., 2004), or early assembly (Wade et al., 2006) vs late assembly (Aitken and Betts, 2008; Smits et al., 2014). Recent geochronological and isotopic studies in central and western Australia (Howard et al.; Kirkland et al., 2011, 2013; Smits et al., 2014; Spaggiari et al., 2014) suggest a significantly more complicated evolution than earlier models, but the geometrical framework to understand this complexity has been lacking. The transition from Rodinia-era configuration to the Gondwana-era configuration is better resolved (Cawood, 2005; Boger, 2011), however, there still remains significant uncertainty regarding the timing and nature of events, especially in Antarctica (cf Boger, 2011; Harley et al., 2013; Aitken et al., 2014).

Geological knowledge of the Wilkes Land region of Antarctica has been largely static for the last decade (cf. Fitzsimons, 2003; Boger, 2011), and this has held back a broader understanding of these tectonic transitions. Here we present a new tectonic model which incorporates a new geometry based on aerogeophysical data from the Antarctic continental interior (Aitken et al., 2014). This new data permits reconstruction of key geometrical relationships between the terranes involved in this continental reconfiguration. Although further geological work is

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http://dx.doi.org/10.1016/j.gr.2014.10.019
1342-937X/

required on both continents to better establish the timing and nature of tectonic events, the geometry imaged in the new data provides fundamental geometrical and relative timing constraints on the Mesoproterozoic reconfiguration of the Australo-Antarctic continent, and its Neoproterozoic–Cambrian collision with Indo-Antarctica.

2. Data and data processing

We use aeromagnetic and aerogravity data collected during the 2009–2013 ICECAP field program, as described in Aitken et al. (2014). This survey covers a region from 90°E to 150°E and extends from the coast up to 1000 km into the continental interior. Magnetic intensity data were corrected for the time varying magnetic field, also removing the large-scale, long term IGRF model. For gravity, we use the isostatic residual anomaly, which accounts for topographic effects, ice sheet thickness, and also the geometry of the Moho assuming local crustal isostatic compensation of the ice-sheet, oceans and bed-relief (Aitken et al., 2014). For Australia, comparable datasets are freely available from Geoscience Australia (Milligan and Franklin, 2004; Nakamura et al., 2011).

3. Reconstruction

We apply a two-stage reconstruction process to image the ca. 1150 Ma architecture, defined by characteristic magnetic granites (Aitken and Betts, 2008). We first reconstruct our data into a Gondwana model at 160 Ma using a recent and independently derived model, the Leeuwin reconstruction (Williams et al., 2011). This model provides clear continuity of many structures between the continents (Fig. 1) and provides a robust starting point for the reconstruction of earlier supercontinental configurations. Key pierce points include the Darling-Conger Fault, the Rodona-Totten Shear Zone, the Mundrabilla-Frost Shear Zone and the Kalinjala-Mertz Shear Zone. In addition we image a chain of magnetic granites on both continents that mirrors the geometry of the margin of the Gawler/Terre Adelie Craton (Fig. 1). In Australia, these late Cambrian to early Ordovician granites (Foden et al., 2002) intrude into the Kanmantoo Group along the Coorong Shear Zone, and they may represent the structural trend of the Ross-Delamerian Orogeny.

Our reconstructed data supports the interpretation that the Mertz Glacier Shear Zone correlates to the Kalinjala Mylonite Zone (Fitzsimons, 2003), and not the Coorong Shear Zone as suggested by Gibson et al. (2013) Some geophysical discrepancies, in particular for gravity data, are seen between the continents due to differences in the evolution of the two continents during Gondwana times and since Gondwana breakup. These include intraplate orogens and basins, different crustal thinning regimes during Mesozoic rifting and, in particular, different erosion and sedimentation regimes.

From this reconstruction (Fig. 1) it is clear that, despite similar character either side, Mesoproterozoic geological provinces and structural trends do not continue across the Mundrabilla-Frost Shear Zone. In gravity and magnetic data, this shear zone can be traced for over 3000 km in length (Fig. 1), extending in the Gondwana reconstruction from at least 67°S/41°E to at least 49°S/87°E. Beyond this point, its signal in magnetic and gravity data within Australia becomes less obvious, due to the presence of overprinting tectonic events, including the Mesoproterozoic Giles Event (Aitken et al., 2013), the Neoproterozoic Centralian Superbasin (Lindsay, 2002) and Neoproterozoic to Paleozoic intraplate orogenies (Sandiford and Hand, 1998). Mesoproterozoic Fault-patterns indicate it exists beneath the west Musgrave Province (Aitken et al., 2013), but its existence is more speculative to the north (Braun et al., 1991). Nevertheless, truncated and offset magnetic and gravity anomalies may indicate a structure at depth extending as far as the Kimberley Craton (Braun et al., 1991).

At the southern margin of the continent, magnetic anomalies are clearly deformed by significant motion along the Mundrabilla Shear Zone, with an inferred bulk sinistral shear sense (Fig. 1). Recent work, including a magmatic crystallisation date of 1132 ± 9 Ma from a

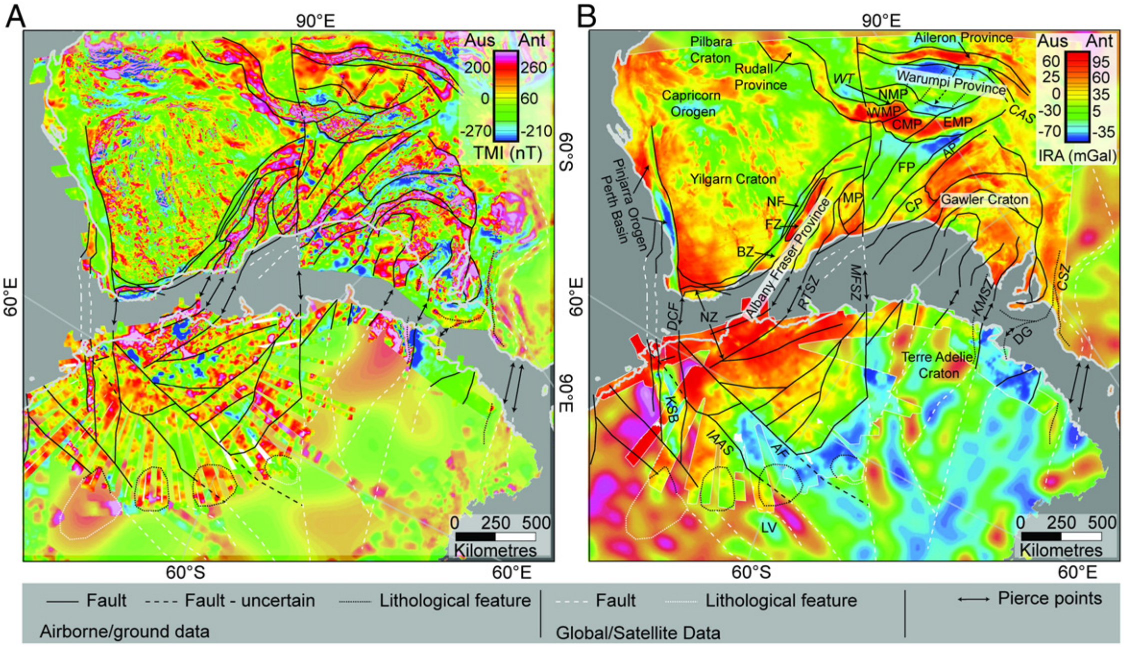

Fig. 1. Reconstruction of total magnetic intensity anomaly data (A) and isostatic residual gravity anomaly data (B) into a Gondwana fit at 160 Ma, using the Leeuwin model of Williams et al. (2011). For fair comparison the images on both continents have the same colour-stretch about the mean value for each data type. The close alignment of the major faults and shear zones between the continents suggest that this reconstruction is valid. Faults are labelled in italics and provinces in regular font where abbreviated. Abbreviations: DCF — Darling Conger Fault, KSB — Knox Subglacial Basin, RTSZ — Rodona-Totten Shear Zone, MFSZ — Mundrabilla-Frost Shear Zone, KMSZ — Kalinjala-Mertz Shear Zone, DG — Delamerian Granites, CSZ — Coorong Shear Zone, AF — Aurora Fault, IAAS — Indo-Australo Antarctic Suture, CAS — Central Australian Suture, WT — Woodroffe Thrust, NF — Northern Foreland, FZ — Fraser Zone, BZ — Biranup Zone, NZ — Nornalup Zone, MP — Madura Province, FP — Forrest Province, WMP, CMP, EMP, NMP — west, central, and east and north Musgrave Province, AP — Ammaroodinna Province, CP — Coompana Province.
Modified from Aitken et al. (2014).