1 **The Australo-Antarctic Columbia to Gondwana transition**

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11 **Abstract**

12 From the Mesoproterozoic to Cambrian, Australo-Antarctica was characterised by tectonic reconfiguration as
13 part of the supercontinents Columbia, Rodinia and Gondwana. New tectonic knowledge of the Wilkes Land
14 region of Antarctica allows Australo-Antarctic tectonic linkages to be resolved through reconstruction into ca.
15 160 Ma Gondwana. We also resolve 330 ± 30 km of sinistral strike-slip offset on the > 3000 km long
16 Mundrabilla-Frost Shear Zone and 260 ± 20 km of dextral offset on the > 1000 km long Aurora Fault to
17 reconstruct the ca. 1150 Ma geometry of Australo-Antarctica. Using this revised geometry, we derive the first
18 model of the Columbia to Gondwana reconfiguration process that is geometrically constrained to ~ 100 km
19 scale. In this model, early Mesoproterozoic tectonics is driven by two opposing subduction systems. A
20 dominantly west-dipping subduction zone existed at the eastern margin of Australo-Antarctica until ca. 1.55-
21 1.50 Ga. A predominantly east-dipping subduction zone operated at the western margin of the Mawson
22 Craton from ca. 1.70 Ga to ca. 1.42 Ga. The latter caused gradual westwards motion and clockwise rotation
23 of the Mawson Craton relative to the West and North Australian Craton and the accretion of a series of
24 continental ribbons now preserved in the Musgrave Province and its southern extensions. A mid-
25 Mesoproterozoic switch to predominantly west-dipping subduction beneath the West Australian Craton
26 brought about the final closure of the Mawson Craton with the North and West Australian Craton along the
27 Rodona-Totten Shear Zone. Convergence was achieved prior to 1.31 Ga, but final collision may not have
28 occurred until ca. 1.29 Ga. Post-1.29 Ga intraplate activity involved prolonged high-temperature orogenesis
29 from 1.22-1.12 Ga, and significant movement on the Mundrabilla-Frost Shear Zone between 1.13 and 1.09
30 Ga, perhaps in response to the assembly of Rodinia at ca. 1.1 Ga. The Australo-Antarctic Craton was
31 amalgamated with Indo-Antarctica along the Indo-Australo-Antarctic Suture (IAAS) and Kuunga Orogeny,
32 probably in the latest Neoproterozoic to early Cambrian.

33 1) Introduction

34 A continental fragment consisting of conjoined parts of Australia and Antarctica (Australo-Antarctica) is an
35 important component of the supercontinents Columbia (Meert, 2002, 2012; Nance et al., 2014; Rogers and
36 Santosh, 2002), Rodinia (Dalziel, 1991; Hoffman, 1991; Karlstrom et al., 1999; Li et al., 2008; Moores,
37 1991), and Gondwana (Lawver and Scotese, 1987; Meert, 2003; Meert and Van Der Voo, 1997; Torsvik and
38 Cocks, 2013). For Australo-Antarctica, the transition from a Columbia-era configuration to a Rodinia-era
39 configuration, has been the subject of scientific debate for well over a decade. Models fall into several
40 contrasting categories, for example, non-rotational (Myers et al., 1996) vs rotational (Giles et al., 2004), or
41 early assembly (Wade et al., 2006) vs late assembly (Aitken and Betts, 2008; Smits et al., 2014). Recent
42 geochronological and isotopic studies in central and western Australia (Howard et al.; Kirkland et al., 2012;
43 Kirkland et al., 2011; Smits et al., 2014; Spaggiari et al., 2014) suggest a significantly more complicated
44 evolution than earlier models, but the geometrical framework to understand this complexity has been lacking.
45 The transition from Rodinia-era configuration to the Gondwana-era configuration is better resolved (Boger,
46 2011; Cawood, 2005), however, there still remains significant uncertainty regarding the timing and nature of
47 events, especially in Antarctica (cf Aitken et al., 2014; Boger, 2011; Harley et al., 2013).

48 Geological knowledge of the Wilkes Land region of Antarctica has been largely static for the last decade (cf.
49 Boger, 2011; Fitzsimons, 2003), and this has held back a broader understanding of these tectonic transitions.
50 Here we present a new tectonic model which incorporates a new geometry based on aerogeophysical data
51 from the Antarctic continental interior (Aitken et al., 2014). This new data permits reconstruction of key
52 geometrical relationships between the terranes involved in this continental reconfiguration. Although further
53 geological work is required on both continents to better establish the timing and nature of tectonic events, the
54 geometry imaged in the new data provides fundamental geometrical and relative timing constraints on the
55 Mesoproterozoic reconfiguration of the Australo-Antarctic continent, and its Neoproterozoic-Cambrian
56 collision with Indo-Antarctica.

57 2) Data and Data Processing

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

66 3) Reconstruction.

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

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

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

93 At the southern margin of the continent, magnetic anomalies are clearly deformed by significant motion along
94 the Mundrabilla Shear Zone, with an inferred bulk sinistral shear sense (Fig 1). Recent work, including a
95 magmatic crystallisation date of 1132 ± 9 Ma from a metagranite within the shear zone (Spaggiari et al., 2014;
96 Spaggiari et al., 2012) suggests these anomalies may be sourced in granites that belong to the ca. 1140-1130
97 Ma Esperance Supersuite. In contrast, all components of the ca. 1090-1040 Ma Giles Event and the ca. 1078-
98 1073 Ma Warakurna LIP are continuous across this fault zone in central Australia (Smithies et al., in press;
99 Wingate et al., 2004). Only minor activity has occurred on the Mundrabilla Shear Zone since the emplacement

100 of the Giles Suite intrusions at 1078-1074 Ma (Aitken et al., 2013; Evins et al., 2010). Therefore, we interpret
101 a significant late Mesoproterozoic offset on the Mundrabilla-Frost Shear Zone.

102 We reconstruct the offset by visual matching of magnetic and gravity features either side of the fault. Our
103 preferred model involves 330 ± 30 km of sinistral motion (Fig. 2). Small discrepancies in the locations of
104 matching features allow approximately 30 km of differential apparent offset. Besides the small error in
105 matching features, such correlations are non-unique, and some alternative options include dextral motion of
106 240 or 480 km and sinistral motion of 190 or 490 km (Supplementary Figures 1 through 4 respectively). The
107 preferred offset of 330 km applied to the Mundrabilla-Frost Shear Zone produces several compelling
108 connections. Firstly, the Musgrave Province is aligned with the truncated end of the Albany-Fraser Orogen,
109 providing a direct connection of these contemporaneous Mesoproterozoic orogenic belts, that have long been
110 considered co-eval (Clarke et al., 1995; White et al., 1999), but have lacked a spatial linkage. Secondly, the
111 shear zones of the western Gawler Craton are aligned with similarly oriented and equally spaced shear zones
112 within Antarctica, providing a good fit with major magnetic and gravity gradients. North of the Musgrave
113 Province, the contemporaneous Aileron Province (Arunta Orogen) and Rudall Province are brought into
114 closer agreement, removing a major kink in the geometry of this Paleoproterozoic margin.

115 Extensive Neoproterozoic to Paleozoic intraplate tectonics has occurred in central Australia. This includes the
116 formation of the Centralian Superbasin (Lindsay, 2002), associated with a large, almost circular gravity
117 low (Aitken et al., 2009b). The subsequent exhumation of east-west basement highs (the Musgrave Province
118 and Arunta Orogen) during intraplate orogenic events has formed distinctive gravity highs (Aitken et al.,
119 2009b; Sandiford and Hand, 1998). Naturally, these post-Mesoproterozoic gravity signals do not correlate in
120 our reconstruction. The natures of these intraplate events are qualitatively well known (Aitken et al., 2009a;
121 Flottmann et al., 2005; Raimondo et al., 2010), however quantitative estimates of motions are sufficiently
122 uncertain to exclude them from this reconstruction. Consequently, correlations of belts north of the Musgrave
123 Province are approximate.

124 The new Antarctic data also show that the direct continuation of the Paleozoic-Mesozoic Darling Fault, the
125 Conger Fault, is located well to the east of the traditional Denman Glacier location, and hence the Bunger
126 Hills region is located to the northwest of the Knox Subglacial Basin (Fig. 1), which is correlated to the
127 Permian-Cretaceous Perth Basin. Thus, a straightforward correlation with the Albany Fraser Orogen cannot
128 be achieved. This discrepancy can be rectified by removing a 260 ± 20 km dextral offset on the ca. 1500 km
129 long Aurora Fault, which lies parallel to the Indo-Australo-Antarctic Suture (IAAS) (Aitken et al., 2014). As
130 well as reconciling the Bunger Hills region with the Albany Fraser Orogen, this movement provides a very
131 compelling match of geophysical character and major structures within the west Mawson Craton (Fig 2). The
132 timing of movement on this fault is poorly constrained, occurring sometime between ca. 1150 Ma and the
133 formation of the Knox Subglacial Basin. The available data do not extend far enough to the south-west to
134 constrain strike slip motions on the proto-Darling-Conger Fault or IAAS.

135 **4) The Columbia to Gondwana Transition - model components**

136 From this reconstructed geometry, it is possible to infer a more fully informed model of the process of the
137 Mesoproterozoic reorganisation of the Australo-Antarctic continent. This model is necessarily speculative,
138 due to the still very limited geological knowledge within many component terranes. Here we summarise the
139 current state of knowledge for each region.

140 **4.1 Indo-Antarctica**

141 The Vestfold Terrane is defined by a highly magnetic region (Aitken et al., 2014) and runs parallel to the
142 Princess Elizabeth Land coast. This region is directly continuous with the Vestfold Hills, which preserve an
143 Archean craton(s) (3.3-2.5 Ga), reworked in the late Neoproterozoic-Cambrian and perhaps also the latest
144 Mesoproterozoic. This region has strong commonalities with eastern India (Fitzsimons, 2003; Harley et al.,
145 2013).

146 The crust immediately to the west of the Scott/Denman Glacier area is very likely of northern-Indian affinity
147 with possible links in a Gondwana reconstruction to the Central Indian Tectonic Zone (Gardner et al., in
148 press). This region lies to the southwest of the IAAS (Fig 2), and is characterised by southeast-oriented
149 magnetic features that are parallel to the suture. These features define a composite province, the Charcot and
150 Vostok terranes (Aitken et al., 2014) that are divided by the Knox Rift. The 90°E Fault separates these IAAS
151 aligned regions from a larger composite continental block that includes the Gamburtsev, Ruker and Princess
152 Elizabeth Land regions (the GRP terrane (Aitken et al., 2014)). Structural trends within the GRP terrane
153 region are highly oblique to the 90°E Fault and may be deformed by sinistral motion on the fault (Ferraccioli
154 et al., 2011). None of these regions are well known geologically, however, outcrop at Cape Charcot preserves
155 Archean orthogneiss dated at ca. 3 Ga, and a late Neoproterozoic to Cambrian thermal overprint is identified
156 there, and in outcrops to the west (Fitzsimons, 2003).

157 The Obruchev Hills represent a small and cryptic block of crust that has similarities to neither the Cape
158 Charcot Region, nor the Bunger Hills Region. It preserves an Archean Orthogneiss (2641 ± 15 Ma) reworked in
159 the late Mesoproterozoic (1040 ± 53 Ma) (Sheraton et al., 1993), but no evidence of the Neoproterozoic-
160 Cambrian reworking that has occurred to the west. The Bunger Hills region is considered part of Australo
161 Antarctica and is discussed below.

162 **4.2 The North and West Australian Craton (NAWAC) and associated orogens**

163 Paleoproterozoic orogenesis in the Rudall Province during the 1790-1760 Ma Yapungku Orogeny (Smithies
164 and Bagas, 1997) and the 1780-1770 Ma Yamba Event (Claoué-Long and Hoatson, 2005; Collins and Shaw,
165 1995) are commonly interpreted to represent the assembly of the North and West Australian Cratons into a
166 single entity (The NAWAC). The 1820-1770 Ma intraplate Capricorn Orogeny is a further response to this
167 collision (Sheppard et al., 2010). This large cratonic element forms the foundations for the Albany Fraser

168 Orogen and Arunta Orogen, which are largely thought to have developed in-situ through modification of
169 NAWAC basement (Betts et al., 2011; Kirkland et al., 2011).

170 *The West Australian Craton*

171 The West Australian Craton (WAC) consists of the Yilgarn and Pilbara Cratons, separated by the Capricorn
172 Orogen, and with the Rudall Province at its northern margin. This continental mass was assembled in two
173 stages: the ca. 2200 Ma Ophthalmian Orogeny, and the ca. 2000 Ma Glenburgh Orogeny (Johnson et al.,
174 2011a). Notwithstanding several phases of dyke/sill emplacement (Wingate, 2007), the Yilgarn and Pilbara
175 cratons were mostly stable throughout the Mesoproterozoic. The Capricorn Orogen preserves several
176 intraplate tectonic events, however. These include the high temperature, magmatism dominated, and possibly
177 extensional Mangaroon Orogeny from 1680 to 1620 Ma (Sheppard et al., 2005); the prolonged Mutherbukin
178 Tectonic Event from 1385 to 1200 Ma, characterised by shearing and metamorphism, but lacking magmatism
179 (Johnson et al., 2011b), and the relatively minor and locally restricted Edmundian Orogeny from 1040-955
180 Ma (Sheppard et al., 2007). Between these orogenic events the Capricorn Orogen saw several basin forming
181 events between 1620-1465 Ma (Edmund Basin) and ca. 1200–1070 Ma (Collier Basin) (Johnson et al.,
182 2011c).

183 *The Albany Fraser Province*

184 The Albany–Fraser Province records multiple phases of late-Paleoproterozoic and Mesoproterozoic tectonism.
185 The Albany–Fraser Province is separated into the Northern Foreland, which is the reworked component of the
186 Yilgarn Craton affected by the Proterozoic events of the Albany-Fraser Orogeny, and the Kepa Kurl Booya
187 Province. The Kepa Kurl Booya Province contains the Biranup, Fraser, and Nornalup Zones (Spaggiari et al.,
188 2009). The Biranup Zone was formed between ca. 1810 and 1650 Ma, a period which includes the 1710 -
189 1650 Ma Biranup Orogeny (Kirkland et al., 2011). Little activity has been identified in the Biranup Zone
190 preserved from Stage I of the Albany–Fraser Orogeny (AFO I) from 1345-1260 Ma, but the Biranup Zone
191 records extensive metamorphism and magmatism during Stage II of the Albany–Fraser Orogeny (AFO II)
192 from 1220-1140 Ma (Kirkland et al., 2011).

193 The Fraser Zone is composed predominantly of 1305-1290 Ma metagabbro that intruded into
194 metasedimentary rocks, possibly in the lower-crust of a back-arc or continental rift (Spaggiari et al., 2011).
195 The metasedimentary rocks, part of the Arid Basin (Spaggiari et al., 2011), contain detrital zircons with the
196 most significant populations from 1700 – 1600 Ma, and from ca. 1400 to ca. 1370 Ma (Kirkland et al., 2011;
197 Spaggiari et al., 2011), and were metamorphosed at ca. 1290 Ma (Clark et al., 2014). The Fraser Zone does
198 not preserve significant activity during AFO II.

199 The Nornalup Zone is the south-easternmost zone of the Albany Fraser Province. It is dominated by high-
200 grade metamorphism, granitic magmatism and deformation from both AFO I and AFO II (Bodorkos and
201 Clark, 2004a, b; Clark et al., 2000). The pre-1330 Ma evolution of this zone remains poorly understood,

202 however, recent work suggests similar origins to the Biranup Zone (Spaggiari et al., 2011; Spaggiari et al.,
203 2014). Detrital zircons within the Malcolm Metamorphics, also considered part of the Arid Basin, contain ca.
204 1560 to 1420 Ma ages (Nelson et al., 1995; Spaggiari et al., 2011; Spaggiari et al., 2014). 1600-1500 Ma aged
205 zircons are uncommon in the West Australian Craton, but are very common in the Musgrave Province
206 (Kirkland et al., 2012). These data can be interpreted to show that the Arid Basin was receiving detritus from
207 this terrane prior to peak metamorphism, dated at ca. 1310 Ma (Clark et al., 2000; Spaggiari et al., 2014). The
208 source of the ca. 1480-1420 Ma detritus is less certain, but the adjacent Madura Province, considered here as
209 part of the greater Mawson Craton, appears to have formed as an oceanic arc, the Loongana Arc, during this
210 time period (Spaggiari et al., 2014; Spaggiari et al., 2012).

211 In Antarctica, the Windmill Islands region preserves two major periods of orogenesis that broadly correlate to
212 AFO I and AFO II (Fitzsimons, 2003; Post et al., 1997). Pre-AFO detrital and inherited zircon populations in
213 the region carry ages of ca. 1411-1461 Ma, ca. 1533-1580 Ma, ca. 1700 Ma, ca. 1800 Ma and ca. 2360 Ma
214 (Zhang et al., 2012), and these compare relatively well with the ages in previous dating. Like those in the
215 Australian Nornalup Zone, these ages suggest a mixed provenance in the pre-AFO detrital material, including
216 components sourced from regions that experienced similar tectonic events as the Albany Fraser Province,
217 Madura Province and the Musgrave Province.

218 The Bungar Hills may also form part of the Albany Fraser Orogen (Sheraton et al., 1993), although the
219 connection is less clear than for the Windmill Islands. Reconnaissance geochronological data indicate a
220 basement of granodioritic orthogneiss, dated at 1699 ± 15 Ma and 1521 ± 29 Ma (Sheraton et al., 1992). These
221 rocks were subjected to pervasive granulite facies metamorphism, peaking at 1190 ± 15 Ma, and later
222 magmatism and syn-magmatic deformation between ca. 1170-1150 Ma (Sheraton et al., 1992; Stuwe and
223 Powell, 1989), which correlates well with events during AFO II.

224 *The Arunta Orogen*

225 The Arunta Orogen includes the Palaeoproterozoic Aileron Province and the Neoproterozoic to Palaeozoic
226 Irindina Province (Collins and Shaw, 1995). The Aileron Province has formed on the southern margin of the
227 North Australian Craton and preserves a mostly Paleoproterozoic evolution, including the 1780-1770 Ma
228 Yamba Event, which is correlated with the Yapunkgu Event of the Rudall Province (Claoué-Long and
229 Hoatson, 2005; Collins and Shaw, 1995). Subsequent events include high-grade metamorphism and granitic
230 magmatism during the 1730 – 1690 Ma Strangways Orogeny, and further high grade metamorphism during
231 the ca. 1610 – 1570 Ma Chewings Orogeny (Collins and Shaw, 1995). Prominent north-south shortening
232 within the Arunta Orogen may represent the Chewings Orogeny (Teyssier et al., 1988), although this may also
233 have happened later, at ca. 1140-1100 Ma (Morrissey et al., 2011).

234 *The Warumpi Province*

235 The Warumpi Province is a distinctly younger part of the Arunta Orogen that is separated from the Aileron
236 Province by the Central Australian Suture (Goleby et al., 1989; Selway et al., 2009). The Warumpi Province is
237 apparently continuous beneath the entire Amadeus Basin, and even into the northern Musgrave Province, with
238 no major east-west oriented geophysical discontinuities suggestive of a suture zone (Korsch et al., 1998;
239 Selway et al., 2011). The Warumpi Province has a younger protolith, and less-evolved isotopic signatures than
240 the Aileron Province (Scrimgeour et al., 2005). The earliest event preserved in the Warumpi Province is the
241 1690-1660 Ma Argilke Event, characterised by felsic magmatism (Scrimgeour et al., 2005). At ca. 1640 Ma,
242 high-grade metamorphism, deformation and magmatism occurred during the Liebig Orogeny, interpreted to
243 represent the accretion of the Warumpi Province along the Central Australian Suture (Scrimgeour et al.,
244 2005). It is possible that the Warumpi Province represents a fragment of the Aileron Province that was rifted
245 off and reattached (Betts et al., 2011).

246 The Warumpi Province also experienced two phases of Mesoproterozoic orogenesis; the Chewings Orogeny
247 (1590-1570 Ma), and Grenville-aged activity (1130-1080 Ma), including minor magmatism, intense flattening
248 and north-south shortening (Morrissey et al., 2011; Teyssier et al., 1988). Recent work suggests that the
249 Grenville-aged event is the more significant event in the eastern Warumpi Province (Morrissey et al., 2011).

250 **4.3 The Mawson Craton and associated orogens**

251 The Mawson Craton describes the part of Australo-Antarctica that has grown around the Archean to
252 Paleoproterozoic Gawler Craton and Curnamona Province. The Curnamona Province shows strong
253 commonalities with the Mt Isa region of the North Australian Craton (Giles et al., 2004), and this link forms
254 the basis of our Columbia configuration. Although distinctly younger, we also include the Mesoproterozoic
255 Musgrave Province, and more tentatively, the Madura Province, within the greater Mawson Craton, as they lie
256 eastward of Rodona-Totten Shear Zone, our inferred suture.

257 *The Gawler Craton*

258 In the period of interest, the Gawler Craton underwent a transition from a tectonically active, plate margin
259 proximal setting, to a stable craton. Most of the craton is built on the latest Archean Sleaford and Mulgathing
260 Complexes (Hand et al., 2007). From ca. 2000 Ma to ca. 1630 Ma, the tectonic setting was characterised by
261 the development of a series of basins, and an extensional environment overall (Hand et al., 2007).

262 This extension was interrupted by the craton-wide Kimban Orogeny at 1730-1690 Ma, associated with
263 widespread metamorphism, although grade varies (Howard et al., 2011b; Payne et al., 2008), granitic
264 magmatism, and shear zone activity (Hand et al., 2007; Stewart and Betts, 2010a; Stewart et al., 2009).
265 Overall shortening was approximately E-W in the eastern Gawler Craton (Hand et al., 2007). Post-Kimban
266 activity occurred in the western and northern Gawler Craton, but not the eastern Gawler Craton (Hand et al.,
267 2007). The period from 1690-1660 Ma saw the intrusion of the Tunkilia Suite granitoids, (Payne et al., 2010),

268 high to ultrahigh temperature metamorphism (Cutts et al., 2013; Howard et al., 2011a) and shearing (Stewart
269 and Betts, 2010a). The high-pressure ca. 1650 Ma Ooldean Event may represent a contractional phase in a
270 dominantly extensional post-Kimban regime (Hand et al., 2007).

271 The Central Gawler Craton is dominated by the 1630 to 1611 Ma St Peter Suite granites (Swain et al., 2008).
272 The calc-alkaline geochemistry of these rocks, and relatively juvenile Sm-Nd isotopic characteristics, point to
273 subduction-related magmatism (Betts et al., 2009; Swain et al., 2008). Subsequently, the eastern margin of the
274 central Gawler Craton records dextral-reverse, west-up motion between ca 1611 and 1592 Ma named the
275 Wartaken Event (Stewart and Betts, 2010b).

276 The craton-wide Hiltaba Event from 1595-1575 Ma represents a major thermal event, characterised by
277 voluminous magmatism, including an extraordinarily large felsic volcanic system (Hand et al., 2007). Post-
278 Hiltaba tectonic activity is limited to the northern and western Gawler Craton. Major events include the 1570-
279 1540 Ma Kararan Orogeny, characterised by high grade metamorphism (Hand et al., 2007) and overall north-
280 south shortening (Stewart and Betts, 2010a), and the Coorabie Event, involving ca 1470-1450 Ma cooling
281 (Fraser and Lyons, 2006) and dextral transpressional reactivation of shear zones (Stewart et al., 2009).

282 The Terre Adelie Craton in Antarctica is quite narrow at the coast, and occupies a ~ 100 km wide region
283 dominated by rocks with similar ages to the Sleaford Complex, and preserving metamorphic events that
284 correspond to the Sleafordian, Kimban and Wartaken Orogenies, suggesting correlation to the western Eyre
285 Peninsula region (Fitzsimons, 2003). The Mertz Glacier Shear Zone juxtaposes the Terre Adelie Craton
286 directly against ca. 500 Ma rocks (Di Vincenzo et al., 2007), and so the eastern Gawler Craton and Adelaide
287 Supergroup are apparently missing from Wilkes Land, although they may exist at depth. The Mawson Craton
288 potentially continues southwards to the Miller Range (Fitzsimons, 2003) and even the Shackleton Ranges
289 (Will et al., 2009), however, these links lack geometrical constraint.

290 *The Coompana Province*

291 The Coompana Province is entirely concealed and knowledge is extremely limited. Our data show that the
292 triangular Coompana Province is bounded by major shear zones that separate it from the western Gawler
293 Craton and the east Musgrave Province, and confine it to Australia (Fig 2.) The earliest known event in the
294 Coompana Province is relatively juvenile granitic magmatism at 1505 Ma (Wade et al., 2007), however, this
295 is younger than all the surrounding regions, indicating an undetected earlier history. The eastern boundary is
296 defined by the linear magnetic feature that includes the Ammaroodina Province (Baines et al., 2011), and
297 against which all Gawler Craton structures are truncated. This structure apparently controls continent-scale
298 topography, is associated with a major Moho gradient (Salmon et al., 2013), and possesses marked gradients
299 in seismic tomographies (Kennett and Blewett, 2012) suggesting that it represents the fundamental
300 lithospheric boundary of the Gawler Craton. For the purposes of this reconstruction, we consider the
301 Coompana Province as part of the western Gawler Craton, rather than a younger addition.

302 *Musgrave Province*

303 The Musgrave Province lies to the northwest of the Gawler Craton and preserves four Mesoproterozoic
304 domains: the north, west, central and east. These domains have a largely shared history since the ca. 1220-
305 1150 Ma Musgrave Orogeny, but differ in their early to mid-Mesoproterozoic evolution. The earliest history
306 suggested for the Musgrave Province, on the basis of Hf isotopic data, is an initial age of mantle extraction at
307 ca. 1900 Ma for zircons sourced from the west and east Musgrave Province (Kirkland et al., 2012). A
308 subsequent addition of juvenile magma at 1650-1550 Ma is indicated by Kirkland et al (2012), corroborating
309 previous work throughout the province (Camacho and Fanning, 1995; Edgoose et al., 2004; Wade et al.,
310 2006). Smits et al. (2014) interpreted a similar dataset differently, and they propose a partial Wilson cycle
311 operating from 1.7 Ga to 1.2 Ga for this region.

312 The west Musgrave Province is the most well studied of the subdivisions (Evins et al., 2010; Howard et al., in
313 press; Smithies et al., 2011). Excluding the isotopic history above, the oldest rocks in the west Musgrave
314 Province are the Papulakuntja Supersuite, granitic rocks crystallised at 1402 ± 4 Ma (Howard et al., in press).
315 The Mount West Orogeny (1345-1293 Ma (Howard et al., in press)) involved extensive granitic magmatism
316 and the deposition of the co-eval Ramarama basin (Evins et al., 2012). Dominant detrital zircon populations
317 within this basin are geographically variable. In the northeast, the dominant population peaks at 1570 ± 70 Ma,
318 with a sub-peak at ca. 1480 Ma, and relatively little post 1400 Ma detritus. Detritus in the centre of the
319 province is defined by a fairly flat-topped distribution between ca. 1570 and 1360 Ma, which contains sub-
320 peaks at 1500 and 1420 Ma. In the southwest there is only sparse evidence of pre-1410 Ma inheritance or
321 detritus (Evins et al., 2012)

322 The eastern and central Musgrave Provinces are very similar to each other, but contain significant mid-
323 Mesoproterozoic differences. Perhaps the least well understood region, the central Musgrave Province
324 preserves patchy evidence for numerous events, including juvenile, possibly oceanic, arc magmatism at ca.
325 1600 -1550 Ma (Wade et al., 2006), magmatism dated at 1502 ± 14 Ma (Maboko et al., 1991), and an inferred
326 metamorphic event dated at 1429 ± 38 Ma and 1383 ± 36 Ma (Maboko et al., 1991). 1320-1300 Ma $^{40}\text{Ar}/^{39}\text{Ar}$
327 cooling ages in hornblende (Maboko et al., 1991) may record the effects of the Mt West Orogeny in the
328 central zone.

329 Although there is abundant evidence for an early Mesoproterozoic arc (Camacho and Fanning, 1995; Edgoose
330 et al., 2004), neither the ca. 1400 Ma event nor the Mt West Orogeny is recognised in the eastern Musgrave
331 Province. Metasedimentary gneisses in the eastern Musgrave Province contain a significant population of ca.
332 1400 Ma detrital zircons, but there is no significant population of ca. 1340-1290 Ma zircons (Wade et al.,
333 2008).

334 The north Musgrave Province is separated from the east, central and west Musgrave Province by the 540 ± 10
335 Ma Woodroffe Thrust (Maboko et al., 1992). North Musgrave Province data are not included in the analysis
336 of Kirkland et al (2012) and the pre-Mesoproterozoic origins of that region remain undefined. The north

337 Musgrave Province was pervasively affected by ca. 1600-1550 Ma juvenile magmatism (Camacho and
338 Fanning, 1995; Edgoose et al., 2004). Despite reasonably detailed work (Edgoose et al., 2004), this region
339 conspicuously lacks evidence for mid-Mesoproterozoic tectonic activity between ca. 1540 Ma and 1200 Ma
340 (Edgoose et al., 2004). This suggests apparent quiescence, despite the significant events occurring in the rest
341 of the Musgrave Province. One explanation, of course, is that these events occurred but have not been
342 preserved or detected. An alternative explanation, supported by a similar period of quiescence in the Warumpi
343 Province, is that the north Musgrave Province was separate from the rest of the Musgrave Province during the
344 mid-Mesoproterozoic.

345 The ca. 1220-1120 Ma Musgrave Orogeny affected all domains, and is characterised by prolonged high and
346 ultra-high temperature, amphibolite to granulite facies metamorphism and extensive high temperature
347 magmatism, spanning the period 1220 Ma to 1150 Ma (Smithies et al., 2011; Wade et al., 2008). Following
348 the Musgrave Orogeny, the ca. 1090-1040 Ma Ngaanyatjarra Rift (Evins et al., 2010) affected the Musgrave
349 Province. This rift event is characterised by voluminous bimodal magmatism (The Giles Event) and a series of
350 deformation events of both extensional and contractional nature (Aitken et al., 2013; Evins et al., 2010).

351 *The Madura and Forrest Provinces*

352 These provinces lie in an entirely unexposed and very poorly known region to the south of the Musgrave
353 Province, to the west of the Gawler Craton and to the east of the Albany Fraser Orogen. The Madura Province
354 lies between the Rodona and Mundrabilla shear zones (Spaggiari et al., 2012). Basement to this region is
355 entirely unexposed, but U-Pb zircon dating from widely spaced drill holes that intersect basement indicate a
356 Mid-Mesoproterozoic terrane that was separate from the Albany Fraser Province until ca. 1330 Ma (Spaggiari
357 et al., 2014), but may have been connected to the West Musgrave Province. Drilling in the central Madura
358 Province has recognised a juvenile, mafic dominated suite that is dated at ca. 1410 Ma, termed the Loongana
359 Supersuite, interpreted to have formed in an oceanic arc (Spaggiari et al., 2014). Furthermore, this is the most
360 plausible source-rock for 1425-1375 Ma detritus in the Arid Basin of the Albany Fraser Province (Spaggiari et
361 al., 2014). In the western Madura Province, a more prolonged history is indicated, including an interpreted
362 metamorphic event at 1478 ± 4 Ma, and a few zircons dated at 1538 ± 17 Ma and between 2408-2293 Ma that
363 can be interpreted as either inherited or detrital (Spaggiari et al., 2012). The far south-east of this province
364 shows very different magnetic character, and, based on our reconstruction, may be more similar to the Forrest
365 Province.

366 Immediately across the Mundrabilla Shear Zone, the rocks of the Forrest Province are characterised by just
367 one drill hole which has intersected basement and provided granitic material with an interpreted igneous
368 crystallization age of 1140 ± 8 Ma, and a single zircon dated at 1598 ± 14 Ma. This older age possibly reflects a
369 component of the basement rocks, or sediment incorporated into the drillhole from the overlying basin
370 (Spaggiari et al., 2012).

4.4 The Eastern Australian Margin

The Mt Isa, MacArthur Basin and Curnamona regions preserve evidence of widespread basin formation during the latest Paleoproterozoic, including the 1730-1670 Ma Calvert Superbasin and the 1668-1590 Ma Isa Superbasin (Jackson et al., 2000). The Calvert Superbasin is interpreted to be the result of a rifting event, with northwest-southeast directed extension documented in the Mt Isa Province (O'Dea et al., 1997). In contrast, the Isa Superbasin and its correlatives in the MacArthur Basin and Curnamona Province are dominated by carbonaceous and clastic marine sediments. This basin has been interpreted to represent thermal subsidence of the lithosphere (Betts and Lister, 2001).

From ca. 1600-1500 Ma the eastern margin of Australia experienced a series of tectonic events that are characterised by poly-deformation, rapid switches between crustal shortening and extension, high temperature metamorphism, and both plate margin related and intraplate magmatism (Betts and Giles, 2006 and references therein). The complex geological evolution of the eastern Australian margin during this time likely reflects the interaction of two convergent margins (Figs. 3-4), one facing an external ocean along the southern margin of the Columbia supercontinent and the second to the east of the continent associated with the closure of a relatively small ocean separating Australia and Laurentia (Betts and Giles, 2006; Betts et al., 2008).

In the Mount Isa region, the protracted and episodic Isan Orogeny occurred from ca 1590 Ma to ca. 1490 Ma (Betts et al., 2006; Blenkinsop et al., 2008). The early stages of orogenesis involved thin-skinned thrusting and basin inversion associated with north-south to northwest directed crustal shortening, also associated with high temperature metamorphism, ca. 1590-1580 Ma (Foster and Rubenach, 2006). East-west crustal shortening at ca. 1540-1530 Ma (Betts and Giles, 2006) was followed by extensive A-type magmatism throughout the eastern Mount Isa terrane between 1540-1490 Ma (Mark, 2001).

In north-east Queensland, the Coen, Yambo, Dargalong and Georgetown Inliers record a somewhat similar evolution for this period. Between ca. 1580-1550 Ma these regions experienced ~north-south shortening, the Jana Orogeny, followed by east-west shortening, the Waruna Orogeny (Betts and Giles, 2006 and references therein). Syn-orogenic granitic magmatism between 1560-1550 Ma includes the Forest Home Supersuite, which has been interpreted to be subduction-related (Betts and Giles, 2006 and references therein).

The major events in the Curnamona Province include crustal shortening at ca 1610-1595 Ma during the Olarian Orogeny. The Olarian Orogeny followed a period of crustal extension at ca 1610 Ma (Forbes et al., 2008) and is characterised by high temperature metamorphism and thin-skinned inversion of ca 1710-1640 Ma basin systems (Forbes et al., 2005; Gibson et al., 2004). Subsequently, the Benagerie Volcanic Suite was erupted onto the Curnamona Province between 1587 to 1581 Ma (Wade et al., 2012). These volcanic rocks have similar chemistry to the Hiltaba Suite and may be related (Wade et al., 2012). The Mount Painter Inlier, at the northwest margin of the Curnamona Province, experienced a period of sedimentation (max dep. 1595±3.7 Ma), followed by deformation at mid-crustal levels and exhumation between ca 1592 Ma and 1585

405 Ma (Armit et al., 2014). Unlike the North Australian terranes, the Curnamona Province and eastern Gawler
406 Craton preserve little evidence for significant tectonic activity between ca. 1580 and 1500 Ma.

407 After 1500 Ma, $^{40}\text{Ar}/^{39}\text{Ar}$ dating suggests that both the Mount Isa Inlier and the Gawler Craton each
408 experienced a period of cooling and exhumation, until ca 1370 Ma (Betts and Giles, 2006; Foster and Ehlers,
409 1998; Fraser and Lyons, 2006; Spikings et al., 2002). This time period was also marked by the deposition of
410 intraplate sedimentary basins, including the Roper Superbasin in Northern Australia (1500-1430 Ma) and the
411 Cariewerloo Basin in Southern Australia (ca. 1450 Ma).

412 We do not have sufficient high quality Antarctic geophysical data with which to constrain the geometry and
413 nature of this margin in Antarctica. Unlike the western Gawler Craton, the eastern Gawler Craton and
414 Curnamona Province do not have an obvious correlative in Antarctica, where the region east of the Mertz
415 Glacier Fault comprises the Wilkes Subglacial Basin, and rocks of the Ross Orogen. Borg et al (1990)
416 defined the Beardmore Microcontinent on the basis of isotopic differences between Cambro-Ordovician
417 intrusions either side of the Mertz Glacier Shear Zone. Boger (2011) further suggested that the Beardmore
418 Microcontinent may represent a correlative block to the Curnamona region and easternmost Gawler Craton.

419 **5) The Columbia to Gondwana Transition**

420 **5.1 Stage 1 – Columbia margin activity (~1740 to ~1600 Ma)**

421 This stage in Australia's evolution has been the topic of several syntheses (Betts and Giles, 2006; Betts et al.,
422 2008; Cawood and Korsch, 2008; Payne et al., 2009). Although a paucity of understanding remains, it is clear
423 that Australia preserves extension, episodic orogenesis and crustal reworking at the edge(s) of Columbia
424 (Betts et al., 2011). Major orogenic episodes are the Strangways-Kimban-Nimrod Orogeny, the Biranup-
425 Argilke Orogeny, the Ooldea-Leibig Orogeny, the St Peters Suite magmatic event and the Wartaken
426 Event/Olarian Orogeny.

427 **1740-1710 Ma: Strangways-Kimban-Nimrod Orogeny (Fig 3a)**

428 Following the suturing of the West and North Australian cratons during the ca. 1800-1780 Ma Yamba and
429 Yapungku Orogenies, widespread basins developed across the Gawler Craton, Curnamona Province and
430 North Australia (Betts et al., 2008), including the Calvert Superbasin. This basin forming event is commonly
431 interpreted to have occurred in a far-field continental back-arc setting (Giles et al., 2002; Hand et al., 2007),
432 although it is not clear where the subduction zones were situated. Basin development was interrupted by the
433 Strangways-Kimban-Nimrod Orogeny between ca 1740 Ma and 1690 Ma (Betts et al., 2011). These three
434 events may represent simultaneous events along a continuous orogenic belt that extended for ~3000 km, and
435 have been interpreted to represent continent-continent collision (Boger, 2011).

436 **1710-1660 Ma: Biranup – Argilke Orogeny (Fig 3a)**

437 Following the Kimban-Strangways-Nimrod Orogeny, tectonic activity along the southern margin of the
438 Australian continent moved outboard. The Biranup Orogeny impinged upon the margin of the Yilgarn Craton
439 between ca 1710-1650 Ma, with the Biranup Zone most likely in an arc to back arc setting (Kirkland et al.,
440 2011; Spaggiari et al., 2011). The ca. 1680 to 1620 Ma Mangaroon Orogeny, within the West Australian
441 Craton (Sheppard et al., 2005) was probably triggered by this tectonic event. The partly contemporaneous ca.
442 1690-1660 Ma Argilke Event affected the Warumpi Province (Collins and Shaw, 1995). At this time, the
443 Warumpi Province was probably positioned outboard of the Australian continent (Scrimgeour et al., 2005).
444 Our new reconstruction shows the Biranup Zone and the Warumpi Province, including the North Musgrave
445 Province, to be a continuous belt extending along the margin of the NAWAC. Subduction was probably
446 northwest-dipping in the Biranup Zone, given its West Australian provenance (Kirkland et al., 2011). It is less
447 well constrained in the Warumpi Province, although north-dipping subduction is most likely.

448 The presence of post-Kimban Orogeny magmatism and high grade reworking in the western Gawler Craton
449 between ca 1695 Ma and 1660 Ma (Cutts et al., 2013; Howard et al., 2011a; Payne et al., 2010) may indicate
450 proximity to a plate margin. The location of subduction zones, if any, and their polarity is uncertain, but east-
451 dipping subduction as a continuation of the Biranup-Warumpi system (Betts et al., 2011), or west-northwest
452 dipping subduction, as a precedent to the St Peter's Suite arc in the central Gawler Craton region (Stewart and
453 Betts, 2010a) are both plausible configurations.

454 **1660-1630 Ma: Liebig Orogeny and Ooldean Event (Fig 3b)**

455 At the eastern margin of Australia, continued sedimentation into the Calvert Superbasin, suggests that this
456 region was under continued extension until 1670 Ma. Subsequently, the Isa Superbasin was deposited between
457 1668-1590 Ma. The reconstructed basin geometry of the Isa Superbasin is suggestive of thermal relaxation of
458 the lithosphere (Betts and Lister, 2001), indicating that after ca. 1670 Ma the driver of rifting ceased. Lambeck
459 et al. (2012) interpreted a change from more evolved to more juvenile sediment sources for the eastern
460 Australian basins at ca 1650 Ma.

461 The timing of this change in the basins of eastern Australia is coincident with the changing tectonics in central
462 Australia regions. In the southern Arunta Inlier, the ca. 1640 Ma Liebig Orogeny is interpreted to represent
463 south-dipping subduction culminating in the accretion of the Warumpi Province to the North Australian
464 Craton (Scrimgeour et al., 2005; Selway et al., 2009). This event may have links with the contemporaneous
465 Ooldean Event in the western Gawler Craton. Part of the episodic to ongoing post-Kimban tectonic activity
466 (Cutts et al., 2013), the Ooldean Event is a distinct high-pressure phase (Hand et al., 2007). This may indicate
467 changes in the tectonics of a nearby subduction zone, perhaps the incipient Musgrave arc to the west, which
468 may have begun retreating at this time (Smits et al., 2014), or the St Peters Suite arc to the east (Swain et al.,
469 2008).

470 **1620-1610 Ma: St Peter Suite subduction (Fig 3b)**

471 The St Peter Suite in the central Gawler Craton has been interpreted to represent magmatism above a north-
472 dipping subduction zone between ca 1620-1610 Ma (Swain et al., 2008). The final closure of this ocean may
473 have caused the ca 1610 Ma to 1590 Ma Wartaken Orogeny (Stewart and Betts, 2010b) and the intraplate
474 Olarian Orogeny (1610-1600 Ma) in the Curnamona Province (Forbes et al., 2008).

475 **5.2 Stage 2 – Reorganisation and movement (~1600 to ~1350 Ma)**

476 This stage involved reconfiguration of Australia and the relevant part of Antarctica from a Columbia
477 configuration to something approaching the Rodinia configuration shown in Figure 2. This process involves
478 relative motion between the Mawson Craton and the North and West Australian Craton.

479 It is not our purpose to describe this large-scale motion in detail, as current paleogeographic constraints do not
480 improve greatly on the model of Giles et al (2004). However, our newly imaged geometry, by moving the
481 Mawson Craton ~330 km to the south, solves a significant space problem present in the Giles et al (2004)
482 model. The new configuration requires a certain degree of relative rotation (at least 30 degrees), to provide
483 plausible early Mesoproterozoic ocean geometry in central Australia. In addition, the Mawson Craton must
484 first move south relative to the NAWAC and then to the north-west to avoid premature "pinching" against the
485 North Musgrave Province.

486 **1600-1540 Ma: Eastern Australia and Musgrave subduction, Hiltaba Event and widespread intraplate** 487 **orogenesis (Fig 4a)**

488 Following the Wartaken Event, plate margin activity ceased in the central Gawler Craton, and tectonic activity
489 moved west and also east. The north, east and central Musgrave Province, and the unexposed Forrest
490 Province to the south, all preserve evidence for juvenile magmatism, interpreted to be arc-related, throughout
491 the period 1600 to 1540 Ma (Camacho and Fanning, 1995; Kirkland et al., 2012; Spaggiari et al., 2012; Wade
492 et al., 2006). This arc however, may have an earlier history stretching back to 1.7 Ga (Smits et al., 2014). The
493 west Musgrave Province also experienced a juvenile magmatic addition at this time (Kirkland et al., 2012).
494 To accommodate this activity within a single arc, and to accommodate later events in the West Musgrave
495 Province, we rotate the West Musgrave Province into a position along strike from the central Musgrave
496 Province, occupying a large gap to the south of the North Musgrave Province (Fig 4a). Although it is very
497 sparsely sampled, there is currently no evidence for ca. 1600-1550 Ma juvenile magmatism in the Madura
498 Province, and its inclusion in this orogenic belt is highly speculative. A more conservative alternative is to
499 position this tectonic element outboard of the central Musgrave Province. This requires an additional
500 subduction zone beneath the West Musgrave Province (Fig 4a).

501 Juvenile magmatism in the Musgrave Province is contemporaneous with the Hiltaba magmatic event in the
502 Gawler Craton, which is a craton-wide thermal event characterised by A-type granitic magmatism and
503 voluminous volcanism (Hand et al., 2007). The Benagerie Volcanic Suite are also A-type in composition, and
504 were erupted onto the Curnamona Province between 1587 to 1581 Ma (Wade et al., 2012). The cause of this
505 event is uncertain and the potential involvement of a mantle plume remains under debate (Betts et al., 2009).

Other contemporaneous events include orogenic events in the Arunta Inlier (Chewings Orogeny), the western Curnamona Province (Painter Orogeny), the western Gawler Craton (Kararan Orogeny), the Mount Isa Inlier (Isan Orogeny), and in northeast Queensland (Jana and Waruna Orogenies) (Betts and Giles, 2006). Together, these events indicate widespread shortening, generally perpendicular to the inferred subduction zones to the east and southwest (Fig 4a).

1540-1420 Ma (Fig. 4b)

Possible arc magmatism (Forest Home Suite) preserved in northeast Queensland (Betts and Giles, 2006 and references therein) suggests that the ocean between Australia and Laurentia still existed at ca 1550 Ma. The final consumption of this ocean is interpreted to have occurred between ca 1550 Ma and 1500 Ma, which is recorded by upright north-south oriented folding and wrench faulting associated with the Isan Orogeny (Betts and Giles, 2006).

The Mount Isa region experienced cooling and exhumation between ca. 1440-1390 Ma (Spikings et al., 2002), and at a similar time, the Coorabie event occurred in the western and northern Gawler Craton (Fraser and Lyons, 2006). The Coorabie Event is associated with northwest-southeast (present orientation) shortening (Stewart et al., 2009), parallel to the Musgrave plate margin. Both northern and southern Australia possess sedimentary basins from this period. The Roper Superbasin was deposited on the North Australian Craton between 1540-1430 Ma, and the 1450±21 Ma (Fanning et al., 1983) Cariewerloo Basin was deposited on the eastern and central Gawler Craton.

This time period also saw the deposition of the Belt-Purcell Supergroup in Laurentia (1470-1400 Ma) and the existence of ca. 1580 Ma detritus in these basins, thought to be Australian-sourced, has been inferred to support proximity of eastern Australia and Laurentia (Ross et al., 1992). This interpretation implies that Australia's eastern margin underwent uplift and erosion under the process of rifting from Laurentia, contributing material to a rift-basin forming to the east (Fig 4b).

Activity at the southern margin is less well established because actual rocks from this period are essentially lacking in the Musgrave Province, except for a magmatic zircon population inferred from an early dataset in the central Musgrave Province (Maboko et al., 1991). However, the Ramarama Basin (Evins et al., 2012) of the west Musgrave Province, an unnamed basin in the east Musgrave Province (Evins et al., 2012; Wade et al., 2008) and the Arid Basin of the Albany Fraser Province (Clark et al., 2000; Spaggiari et al., 2011; Spaggiari et al., 2012) all preserve significant proportions of detrital zircons dated between ca. 1540 and 1420 Ma. These data suggest ongoing zircon-forming events, but perhaps less intense or more spatially restricted, in central Australia, although distal detritus sources cannot be excluded. In accordance with the model of Smits et al (2014), the Musgrave subduction zone is interpreted to have remained active during this period, with activity focused in the central Musgrave Province.

1420-1400 Ma: West Musgrave & Madura Province subduction (Fig 4c)

Here, we interpret the ca. 1415-1400 Ma magmatism in the West Musgrave Province and the Madura Province to be indicative of subduction. The Papulankutja Supersuite has arc-like calc-alkaline geochemistry, but an isotopically evolved source (Kirkland et al., 2012). As noted by Kirkland et al (2012) this may represent an arc environment in which continental lower crust is thrust beneath the arc, and is not unusual for a continental arc setting. Hf isotopic compositions from the ca. 1400 Ma Loongana Supersuite are juvenile, and approach mantle-like values, suggesting an oceanic-arc like environment, with little continental contribution (Spaggiari et al., 2014).

The polarity of this subduction zone(s) is not known, but with our revised continental geometry, anticlockwise rotation of the west Musgrave Province and Madura Province during this period is necessary to accommodate both prior and later events. Short segments of subduction zones such as this are prone to rapid rollback at their edges (Schellart et al., 2007), and differential rollback of the subduction zone, pinned in the east but free to move in the west, may have generated this rotation (Fig 4c).

This period of tectonic activity may have ceased as a result of the docking of the west Musgrave Province with the central Musgrave Province (Fig 4c). On very limited evidence, this may have resulted in ca. 1400 Ma metamorphism in the central Musgrave Province (Maboko et al., 1991). Further evidence for ca. 1400 Ma docking of these terranes may be found in mid-Mesoproterozoic basins of the east Musgrave Province, which have apparently sampled abundant ca. 1600-1400 Ma aged rocks, but not rocks of the Mt West Orogeny (Evins et al., 2012; Wade et al., 2008). Later docking, during the Mount West Orogeny, is also permissible, but sediment transport must have been directed elsewhere.

5.3 Stage 3 – Suturing and Collision (1400 – 1250 Ma)

This stage involved the suturing of the Mawson and West Australian Cratons, ultimately resulting in Stage I of the Albany Fraser Orogeny (Clark et al., 2000) and the Mt West Orogeny (Howard et al., in press; White et al., 1999). These events are often considered along-strike equivalents, and most interpretations invoke continental collision during this period, although this is yet to be unequivocally demonstrated. The North Australian Craton, including the North Musgrave Province, preserves no record of these events despite reasonably detailed work (Edgoose et al., 2004). This lack of evidence is not definitive, but is plausibly explained by isolation from this process.

1400-1350 Ma (Fig 5a):

Limited evidence for ca. 1370 Ma magmatism is preserved, derived from inherited and detrital zircon populations in the Windmill Islands region (Zhang et al., 2012) and the Musgrave Province (Evins et al., 2012; Kirkland et al., 2012; Smits et al., 2014). In addition, the earliest stages of the Mutherbukin Orogeny commenced within the West Australian Craton at ca. 1385 Ma, after 250 Ma of quiescence (Johnson et al., 2011b). These very limited data could be interpreted to suggest the rejuvenation of a west dipping subduction system, as a precursor to the Albany Fraser and Mt West Orogenies.

574 **1350-1290 Ma: Convergence and soft collision (Fig 5a)**

575 The Albany Fraser Orogeny Stage I started between 1345 and 1330 Ma (Kirkland et al., 2011). Ca. 1480-
576 1400 and 1550-1600 Ma detrital zircon populations within Arid Basin metasedimentary rocks (Clark et al.,
577 2000; Spaggiari et al., 2011; Spaggiari et al., 2014) were received prior to metamorphism, which is dated at
578 1311 ± 4 Ma in the Malcolm Metamorphics (Clark et al., 2000). The Arid Basin in the Fraser Zone was
579 receiving similarly aged detritus prior to the 1305-1290 Ma emplacement of metagabbro (Kirkland et al.,
580 2011; Spaggiari et al., 2011). The Windmill Islands (Zhang et al., 2012) also contains detrital zircon
581 populations of this age.

582 The most likely source of this detritus is the west Mawson Craton, i.e. the Madura Province Forrest Province
583 and Musgrave Province which suggests that convergence was achieved prior to ca. 1310 Ma, perhaps in a soft
584 collision. The apparent lack of AFO I aged rocks in the Madura Province suggests west-dipping subduction,
585 with the west Mawson Craton ultimately being thrust over the Albany Fraser Province on the Rodona Shear
586 Zone (Clark et al., 2000; Spaggiari et al., 2014).

587 At the same time, the Mount West Orogeny was active in the west Musgrave Province. A plate-margin
588 environment is suggested for this event based on geochemical and isotopic signatures (Howard et al., in press;
589 Kirkland et al., 2012). North-dipping subduction has been previously suggested (Evins et al., 2012).
590 However, with north-dipping subduction, the superposition of the Mount West Orogeny on the 1400 Ma
591 Papulankutja Supersuite, but not on 1400 Ma rocks of the Madura Province, requires that these terranes were
592 separate. A simpler explanation may involve southeast dipping subduction beneath the northern part, but not
593 the southern part, of the Loongana-Papulankatja arc previously docked with the eastern and central Musgrave
594 province at ca. 1400 Ma (Fig 5a).

595 **1290-1250 Ma: Hard collision (Fig 5b)**

596 At approximately 1290 Ma, the tectonics of the continent was significantly modified. The last recorded
597 magmatism in the Mt West Orogeny was at 1293 Ma (Howard et al., in press), suggesting the end of
598 subduction. Mafic magmatism in the Fraser Zone of the Albany Fraser Orogen also ceased at 1290 Ma
599 (Spaggiari et al., 2011), suggesting that extension ceased. The intraplate Mutherbukin Orogeny in the
600 Capricorn Orogen intensifies significantly at ca. 1280 Ma (Johnson et al., 2011b). We interpret this change in
601 tectonic regime to represent the hard collision of the Mawson Craton with the NAWAC at ca. 1290 Ma, in
602 agreement with previous interpretations (Bodorkos and Clark, 2004b; Clark et al., 2000).

603 **5.4 Stage 4 – Intraplate orogenesis and shearing (1250 – 1090 Ma)**

604 This stage involves widespread and pervasive high grade metamorphism and magmatism involving most of
605 the component terranes amalgamated during stages 2 and 3 (Aitken and Betts, 2008), including their
606 extensions into Antarctica. The tectonic setting of this major event has been the subject of some recent
607 debate, with an intraplate setting currently favoured by many (e.g. Smithies et al., 2011; Wade et al., 2008).

608 At the end of this stage, continent-scale shearing on the Mundrabilla Shear Zone significantly altered the
609 tectonic architecture of the region.

610 **1250-1140 Ma (Fig 6a)**

611 The main period of magmatism and metamorphism in AFO II and the Musgrave Orogeny began at ca. 1220-
612 1215 Ma (Kirkland et al., 2012; Smithies et al., 2011). The Musgrave Orogeny peaked between ca. 1200-1180
613 Ma, during which period magmatic and metamorphic isotopic ages are abundant (Kirkland et al., 2012;
614 Smithies et al., 2011), and after which the rate of zircon-formation reduced (Smithies et al., 2011). This is
615 taken as a proxy for the reducing intensity of tectonic activity, although UHT conditions persisted until 1120
616 Ma (Smithies et al., 2011). AFO II also preserves an apparent peak in zircon-forming tectonic activity at
617 1200-1180 Ma, although with less data, this is less well defined (Kirkland et al., 2011). The West Australian
618 Craton continued to record contemporaneous intraplate activity, as the Mutherbukin Orogeny persisted until
619 ca. 1200 Ma (Johnson et al., 2011c), and ca. 1210 Ma dyke swarms were intruded around the margins of the
620 Yilgarn Craton (Wingate, 2007).

621 Widespread magmatism continued until at least 1150-1140 Ma, at which time the orogenic province was at its
622 broadest, with an area encompassing the eastern Warumpi Province (Collins and Shaw, 1995; Morrissey et al.,
623 2011), the Bungar Hills (Sheraton et al., 1992), and the southern Forrest Province (Spaggiari et al., 2012) (Fig
624 6a). $^{40}\text{K}/^{40}\text{Ar}$ cooling ages of 1185 Ma on hornblende and 1159 Ma on biotite (Flint and Daly, 1993) indicate
625 that the Coompana Province was being exhumed at this time, however the Gawler Craton in general preserves
626 little evidence of this event.

627 **1140-1090 Ma (Fig 6b)**

628 This age bracket includes as its defining feature the occurrence of 200 to 300 km of offset on the Mundrabilla-
629 Frost Shear Zone. There is little direct evidence for tectonic activity south of the Musgrave Province after
630 1130 Ma, but the Warumpi Province preserves significant tectonic activity between 1140 and 1080 Ma
631 (Morrissey et al., 2011). Monazite dating indicates flat-lying fabric development between 1140 and 1109 Ma,
632 and subsequent east-trending folds that are in turn cut by the undeformed Stuart Dyke Swarm, dated at ca.
633 1080 Ma (Zhao and McCulloch, 1993). The east-west trending folding event in the Warumpi Province is
634 consistent with both the kinematics and timing of our proposed sinistral offset on the Mundrabilla Shear Zone.

635 North of the Warumpi Province the offset may be significantly less. The Paleoproterozoic Halls-Creek
636 Orogen at the eastern margin of the Kimberley Craton, preserves an apparent sinistral offset of ~80-100 km
637 located at the northern end of the Mundrabilla-Frost Shear Zone (Fig 6b). Northeast and north oriented
638 sinistral shear zones have been recognised previously in the Halls Creek Orogen (Tyler and Griffin, 1990) but
639 their timing is very ill constrained. Shearing may have occurred during the late Mesoproterozoic Yampi
640 Orogeny or the late Neoproterozoic King Leopold Orogeny.

641 Currently, there is no known driver for this continent-scale strike-slip motion. Paleomagnetic data suggest that
642 a coherent Rodinia supercontinent was not developed until ca. 1.1 Ga (Pisarevsky et al., 2014), and if this is
643 the case, then this large scale intraplate movement may reflect the response of Australo-Antarctica to Rodinia
644 Assembly. The motion direction is consistent with a maximum horizontal stress aligned perpendicular to the
645 main Grenville front in most Rodinia reconstructions (Burrett and Berry, 2000; Hoffman, 1991; Li et al.,
646 2008; Moores, 1991). Moreover, the timing of motion is consistent with the transition, in Laurentia, from the
647 1190-1140 Ma Shawinigan Orogeny to the 1090-1020 Ma Ottawan phase of the Grenville Orogeny, perhaps
648 representative of a change from accretionary to collisional tectonics (Rivers, 2008).

649 The Pinjarra Orogen occupies the western margin of the Australian continent, largely beneath the Perth Basin
650 (Fitzsimons, 2003). Although the ca. 1090-1050 Ma Pinjarra Orogeny (Fitzsimons, 2003), is close by, it is
651 limited in extent and intensity, and mostly post-dates the movement on the Mundrabilla-Frost Shear Zone.
652 We consider the (Mesoproterozoic) Pinjarra Orogeny more likely to represent a simultaneous intraplate
653 response to a larger-scale driver than the driver of such a large movement.

654 **5.5 Stage 5 –Rodinia to Gondwana (1090 Ma – Permian?)**

655 The ca. 1078-1073 Ma Warakurna LIP (Fig. 7) crosses all central and western Australian terranes, including
656 the Capricorn Orogen, Yilgarn Craton, Musgrave Province and Arunta Province (Wingate et al., 2004). The
657 Mundrabilla Shear Zone may have exerted an influence in focusing magmatism within the west Musgrave
658 Province during the 1090 – 1040 Ma Giles Event (Smithies et al.), but activity on the Mundrabilla Shear Zone
659 during this event involves only km-scale offsets on minor north-oriented faults that were active at ca. 1067 ± 8
660 Ma (Aitken et al., 2013).

661 The Neoproterozoic to early Paleozoic Centralian Superbasin is also continuous and uninterrupted over the
662 Mundrabilla-Frost Shear Zone (Lindsay, 2002). Central Australia also experienced several significant
663 intraplate reworking events, most notably the ca. 600- 550 Ma Paterson-Petermann and ca. 450-350 Ma Alice
664 Springs orogenies (Sandiford and Hand, 1998). These intraplate orogenies have accommodated significant
665 vertical crustal motions, and the formation of deep foreland basins, causing a distinctive gravity signal of
666 narrow highs within a broad low (Aitken et al., 2009b), as well as coincident magnetic signals. Each orogeny
667 involved 50-100 km of ~N-S shortening, at least east of the Mundrabilla-Frost Shear Zone (Flottmann et al.,
668 2005). It is likely that the Mundrabilla-Frost Shear Zone played a role in partitioning strain during these
669 events, including also the formation of the Canning Basin (Braun et al., 1991). Quantitative estimates of
670 shortening/extension do not exist west of the Mundrabilla-Frost Shear Zone.

671 In Gondwana assembly, the spatial and temporal relationships of the major orogenic belts within Antarctica
672 are of key importance, but are poorly imaged. Two near-orthogonal trends intersect near the Denman Glacier
673 region, where late Neoproterozoic to Cambrian tectonic activity is commonly recorded (Fitzsimons, 2003).
674 The Kuunga Orogeny (Meert, 2003), including the (Neoproterozoic) Pinjarra Orogeny and Vestfold Terrane,
675 extends along the coast, and the almost orthogonal region between the IAAS and the 90°E Fault (including the

676 Charcot and Vostok Terranes), extends inland (Aitken et al., 2014). Similarly-aged tectonic activity has
677 recently been recorded from the Gulden Draak Knoll, which was probably adjacent at the time (Gardner et al.,
678 in press) and the Leeuwin Complex in south-west Western Australia preserves ca. 520 Ma granitic
679 magmatism (Collins, 2003).

680 On the basis of current data (Fig. 1), the Denman Glacier region lies well to the south of the Vestfold Terrane,
681 and by extension the Kuunga Orogeny. The region is located along-strike from, and may be underlain by the
682 IAAS (Aitken et al., 2014). The outcrops west of the Denman and Scott Glaciers preserve Neoproterozoic-
683 Cambrian granitic magmatism and metamorphism, whereas the Bunger Hills region does not (Sheraton et al.,
684 1993). Furthermore, structure within the Charcot and Vostok terranes is IAAS-parallel (Aitken et al., 2014;
685 Studinger et al., 2003), whereas structures in the western Mawson Craton are at a high angle to the IAAS (Fig
686 1). This suggests southwest-dipping subduction with a relatively rigid downgoing plate thrusting beneath a
687 relatively weak upper plate.

688 The 260 km of dextral motion on the Aurora Fault was potentially caused by north-south-directed collision
689 along the IAAS. Alternatively, east-west extension, perhaps during the Paleozoic to early Mesozoic, is a
690 possibility. Similarly oriented dextral shear zones are common in south-western Australia (Fig 7). These have
691 played an important role in controlling the formation of the Perth Basin, but the timing of their early
692 movements is not known (Song and Cawood, 2000). Incorporating this offset on the Aurora Fault (Fig 2, Fig
693 7b), also places the Leeuwin Complex approximately along strike from the Vestfold Terrane, along the
694 Kuunga trend (Fig 7b).

695 Identifying the relative timing of these orthogonal events is problematic, as the geochronological data from all
696 regions return contemporaneous dates between 550 and 500 Ma. Although the magnetic data is very broadly
697 spaced at the intersection location, we infer that the 90°E Fault is truncated by the Vestfold terrane (Fig 1).
698 Thus we tentatively suggest a late-Neoproterozoic-Cambrian collision along the IAAS, followed shortly after
699 by a second collision along the Kuunga Orogeny trend.

700 The eastern margin of Australo-Antarctica preserves two main phases of post-Mesoproterozoic activity.
701 Firstly, the Australian margin was subjected to lithospheric extension at ca. 830-750 Ma, resulting in the
702 deposition of the Adelaide Rift Complex and also the Gairdner-Amata dykes swarm, interpreted to represent
703 an aulacogen (Zhao et al., 1994), and the onset of the Centralian Superbasin (Lindsay, 2002). This may
704 represent the rifting of Australo-Antarctica's Rodinian neighbour, possibly Laurentia (Burrett and Berry,
705 2000; Dalziel, 1991; Karlstrom et al., 1999; Moores, 1991) or South China (Li et al., 2008). Evidence for
706 comparable activity in East Antarctica is limited, but the Neoproterozoic Koettlitz, Skelton and Beardmore
707 Groups in the TAM may be equivalents of the Adelaide Rift Complex (Boger, 2011). The second major
708 phase involves the accretionary orogenesis of the Terra-ustralis Orogen from the Cambrian to the late
709 Carboniferous (Cawood, 2005). This orogen involves a highly complex and prolonged series of tectonic
710 events, however, our interpreted architecture for its early stages follows Aitken et al (2014) in suggesting a

link between the Wilkes Subglacial Basin and the early Cambrian Kanmantoo Group, with the Ross Dleamrian Orogeny to the east.

6) Conclusion

The geometry we image for the Australo-Antarctic continent at ca. 1150 Ma, and its later juncture with Indo-Antarctica, allows for a significantly revised model of the Mesoproterozoic reconfiguration of the Australo-Antarctic continent. Unlike previous models, which have involved very simple geometries, and often single events in this tectonic transition, this new model suggests a near continuum of activity through the Mesoproterozoic, driven by several subduction systems. This model has more in common with models of the long-lived, active convergent margin systems from the Phanerozoic, such as the Tasmanides (Cawood, 2005; Collins and Vernon, 1994) and Sundaland (Metcalf, 2011). In particular, the western Musgrave Province and Madura Province region in the period of ca. 1430 Ma to 1290 Ma may have resembled the Mesozoic to present Mediterranean region in tectonic complexity. Needless to say, we cannot pretend that the full complexity of this system is resolved from the current data, and significant additional work is needed to more accurately define the details, and test this model.

The model we propose for the Mesoproterozoic consists of two contemporaneous subduction systems. A west-dipping system at Australo-Antarctica's eastern margin was active between 1.7-1.55 Ga, and brought Australia and Laurentia together in their Columbia configuration. This convergent zone was later rifted during ca. 1.5-1.3 Ga reorganisation of Australo-Antarctica from a Columbia into a Rodinia configuration.

The second subduction system existed at the continent's southern margin, and was predominantly north and east dipping, later west-dipping. This system was continually active between ca. 1710 Ma and ca. 1290 Ma, although the locus of activity changed, and several apparent hiatuses exist. These hiatuses may reflect insufficient geological data coverage and tectonic overprinting, or interplays with the contemporaneous system at the eastern margin of the continent, causing reduced activity.

Through predominantly east-directed subduction, a series of continental ribbons were accreted onto the western margin of the East Mawson Craton, forming the West Mawson Craton (including the Musgrave Province, Forrest province and Madura Province, and the relevant parts of Antarctica). West-directed subduction became dominant after ca. 1420 Ma, resulting in the closure of the remaining ocean during AFO I and the Mt West Orogeny. The Rodona-Totten Shear Zone is defined as the suture between the Mawson Craton and the North and West Australian Craton.

The late Mesoproterozoic to Neoproterozoic evolution of Australo-Antarctica is dominantly intraplate, but far from static, involving significant magmatic and metamorphic events as well as hundreds of kilometres of offset on the supercontinent-scale Mundrabilla-Frost Shear Zone. The largest motion may be a result of the assembly of Rodinia, and is contemporaneous with the onset of collisional tectonics at the Grenville-Front

(Rivers, 2008). The end of Rodinia is marked by extension in the Adelaide Rift Complex and intraplate basin formation in central Australia (Zhao et al., 1994).

Gondwana assembly is marked by the collision of the Mawson Craton with Indo-Antarctica, which occurred along the NW-trending Indo-Australo-Antarctic Suture, probably in the late Neoproterozoic to early Cambrian, with a somewhat later collision along the Kuunga Suture to the north and west. This may have caused further strike-slip motion within the Mawson Craton along the Aurora Fault. The Terra-Australis orogeny and its intraplate effects dominate Australo-Antarctica from the Cambrian to late Carboniferous (Cawood, 2005).

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136 136 **Figure Captions**

1137 **Figure 1** – Reconstruction of total magnetic intensity anomaly data (a) and isostatic residual gravity
 1138 anomaly data (b) into a Gondwana fit at 160 Ma, using the Leeuwin model of Williams et al. (2011). For
 1139 fair comparison the images on both continents have the same colour-stretch about the mean value for each
 1140 data type. The close alignment of the major faults and shear zones between the continents suggest that this
 1141 reconstruction is valid. Faults are labelled in *italics* and provinces in regular font where abbreviated.

1142 Abbreviations: DCF- Darling Conger Fault, KSB – Knox Subglacial Basin, RTSZ – Rodona-Totten Shear
 1143 Zone, MFSZ – Mundrabilla-Frost Shear Zone, KMSZ – Kalinjala-Mertz Shear Zone, DG- Delamerian
 1144 Granites, CSZ – Coorong Shear Zone, AF – Aurora Fault, IAAS – Indo-Australo Antarctic Suture, CAS -
 1145 Central Australian Suture, WT – Woodroffe Thrust, NF – Northern Foreland, FZ – Fraser Zone, BZ –
 1146 Biranup Zone, NZ – Nornalup Zone, MP –Madura Province, FP - Forrest Province, WMP, CMP, EMP,
 1147 NMP – West, central, and east and north Musgrave Province, AP – Ammaroodinna Province, CP -
 1148 Coompana Province. Modified from Aitken et al (2014).

1149 **Figure 2** - Preferred reconstruction of the Rodinia configuration at ca. 1150 Ma following retro-
 1150 deformation of ca. 330 km of sinistral offset on the Mundrabilla-Frost Shear Zone and 260 km of
 1151 dextral offset on the Aurora Fault. The close alignment of several correlated provinces and ca. 1150
 1152 Ma magmatic belts defined by magnetic trends provides a compelling image of the geometry of the
 1153 system. This reconstruction does not take account of post-Mesoproterozoic intraplate events in central
 1154 Australia. These dominate the gravity signal, and also strongly influence magnetic trends. Furthermore,
 1155 they also involved large horizontal motions (50-100 km) that render correlation of prior architecture
 1156 approximate north of the Musgrave Province. Note the revised position of the Bunger Hills (BH), now
 1157 located at the margin of the Albany Fraser Province, despite being located to the west of the Conger
 1158 Fault. Abbreviations as in Figure 1.

1159 **Figure 3** - Stage 1 of our reconstruction, showing the 1740-1660 Ma configuration (a) and the 1660-
 1160 1600 Ma configuration (b). For the purposes of visualisation we include in this reconstruction the

1161 shortening estimates of Flottmann et al. (2005) for the Petermann (100 km) and Alice Springs orogenies
1162 (50 km) east of the Mundrabilla-Frost Shear Zone. We note that these estimates are far from certain,
1163 and may not be representative of orogeny-wide shortening. Relative motions to the west of the
1164 Mundrabilla-Frost Shear Zone from the Paterson Orogeny and the opening of the Canning Basin may
1165 be equally significant but remain unconstrained, and are NOT included. 1740-1660 Ma activity (a) is
1166 characterised firstly by the formation of basins across North Australia and the Gawler Craton, and the
1167 Strangways-Kimban-Nimrod Orogeny. Subsequently the Biranup Orogeny and Argilke Event affected
1168 the southern margin, also including the Tunkilia Suite in the western Gawler Craton. 1660-1640 Ma
1169 activity (b) is characterised by a change in the system, with the Liebig Orogeny and Ooldean event on
1170 the southern margin and a change in sedimentary environment in northern Australia. Later on, the St
1171 Peters Suite arc developed in the central Gawler Craton, followed by the Wartaken Event and Olarian
1172 Orogeny at 1620-1600 Ma.

1173 **Figure 4** - Stage 2: showing the 1600-1550 Ma configuration (a), the 1550-1420 Ma configuration
1174 (b) and the 1420-1400 Ma configuration (c). The earliest of these is characterised by an east dipping
1175 arc-system west of the Gawler Craton, and a west-dipping system at the eastern margin. As a result of
1176 the first, the juvenile Musgrave Province was formed upon ca. 1900 Ma lithosphere (Kirkland et al.,
1177 2012). The intraplate effects of these arc systems are significant, and may include the Chewings, Isan
1178 and Kararan orogenies, and probably the Hiltaba Magmatic Event and Benagerie Volcanics (BV).
1179 After 1550 Ma tectonics at the eastern margin changed, perhaps due to collision of Laurentia, and the
1180 onset of extension by 1470 Ma. Activity at the southern margin likely continued with little change
1181 through to at least 1450 Ma (Smits et al., 2014). At ca. 1420 Ma subduction beneath the Loongana-
1182 Papulankutja (Loo-Pa) arc commenced, probably with west-dipping subduction. Symbology is as per
1183 Figure 3.

1184 **Figure 5** - Stage 3: showing the 1400-1290 Ma configuration (a) and the 1290-1260 Ma configuration
1185 (b). Evidence for tectonic activity between 1400 Ma and 1345 Ma is limited, but may have involved
1186 the docking of the Loo-Pa arc with the central Musgrave Province, and incipient subduction beneath the
1187 NAWAC. A major west-dipping subduction system was active outboard of the NAWAC from 1345
1188 Ma to ca. 1290 Ma. By ca. 1310 Ma sediments from regions similar to the west Mawson Craton were
1189 being deposited within the Arid Basin. Simultaneously the Mt West Orogeny was active for which we
1190 infer a south dipping subduction zone. At ca 1290 Ma we infer the hard collision of these cratons (b).
1191 Symbology is as per Figure 3.

1192 **Figure 6** - Stage 4: showing the 1260-1130 Ma configuration (a) and the 1130-1090 Ma
1193 configuration (b). The earlier part is characterised by a major intraplate orogeny (AFO II, Musgrave
1194 Orogeny) characterised by HT to UHT metamorphism, magmatism, mid-crustal flattening and
1195 northeast-southwest shortening in the Albany Fraser Province (Bodorkos and Clark, 2004a, b; Clark et

1196 al., 2000) and eastern Musgrave province (Aitken and Betts, 2009). This orogeny ceased at ca. 1130
1197 Ma, and at some stage prior to 1090 Ma, ~200-300 km of sinistral offset occurred on the Mundrabilla-
1198 Frost Shear Zone, causing north-south shortening in the Warumpi Province (Morrissey et al., 2011),
1199 and perhaps also at the Kimberley Craton margins. The early stages of the Pinjarra Orogeny may have
1200 occurred synchronous with this movement. Symbology is as per Figure 3. HCSZ – Heywood Cheyne
1201 Shear Zone.

1202 **Figure 7** - Stage 5: showing the 1090-750 Ma configuration (a) and the 650-350 Ma configuration
1203 (b). At 1080 Ma, the Warakurna LIP is continuous and undisturbed across the Mundrabilla Shear Zone,
1204 and the Pinjarra Orogeny is active to the west. Subsequently, rifting along Australo-Antarctica's
1205 eastern margin and the Centralian Superbasin and dyke swarms within central Australia commenced ca
1206 830-800 Ma. Central Australia later experienced intraplate contractional orogenesis at ca. 650-550 Ma
1207 (Paterson-Petermann Orogeny) and also ca. 450-350 Ma (Alice Springs Orogeny). Some ~150 km of
1208 north-south shortening has been estimated east of the Mundrabilla-Frost Shear Zone during these events
1209 (Flottmann et al., 2005). North-directed suturing of Indo-Antarctica with the Mawson Craton occurred
1210 along the IAAS, probably in the early Cambrian, ca. 530-510 Ma (Gardner et al., in press). The ~260
1211 km dextral offset on the Aurora Fault may have happened as a result of this collision. The kinematics of
1212 fault motion also allow for east-west extension, possibly during the Paleozoic-Mesozoic, but prior to
1213 the development of the Knox Subglacial Basin. The onset of the Cambrian to Carboniferous Terra-
1214 Australis Orogeny, may have caused extension forming the Wilkes Subglacial Basin and the
1215 Kanmantoo Group (ca. 530 Ma). Symbology is as per Figure 3. KSB - Koeetlitz, Skelton and
1216 Beardmore Groups

Figure 2

Figure 3
Geological Provinces

Tectonic Elements

Figure 4

Figure 5

Figure 6

Figure 7