Gondwana Research 28 (2015) 1019–1031

Contents lists available at ScienceDirect

Gondwana Research

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

Discovery of a microcontinent (Gulden Draak Knoll) offshore Western Australia: Implications for East Gondwana reconstructions

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ARTICLE INFO

Article history:
Received 17 May 2014
Received in revised form 7 August 2014
Accepted 11 August 2014
Available online 19 September 2014

Handling Editor: A.R.A. Aitken

Keywords:
Gondwana
East Antarctica
Kuunga Orogen
Zircon age
Hf-isotopes
Reconstruction

ABSTRACT

Analysis of dredged samples from the Gulden Draak Knoll demonstrates that it is a submarine rifted continental fragment that lies at the boundary between the western Perth Abyssal Plain and Wharton Basin, Indian Ocean. The Knoll comprises a granulite facies basement, including pelitic paragneiss and mafic orthogneiss, with a Cambrian granite inferred to intrude the other rocks. Boulders and cobbles of felsic gneiss with Mesoproterozoic and Cambrian protolith ages were also sampled likely reflecting a complex basement to variable sedimentary and volcanic rocks. The U–Pb isotopic system in the Archean and Mesoproterozoic zircon is significantly disturbed, reflecting Cambrian orogenesis that affected all samples. The protolith to garnet–sillimanite–biotite paragneiss has a maximum deposition age of 1163 ± 24 Ma and includes older detrital zircon grains with populations at c. 2.65 Ga and between 1.4 and 1.1 Ga. A younger population in this sample is interpreted as a mix of newly grown metamorphic zircon and isotopically reset zircon, implying that the granulite facies metamorphism occurred at c. 511 ± 5 Ma. Protracted Cambrian orogenesis is indicated by a metamorphic age in the mafic orthogneiss of 530 ± 6 Ma and isotopic disturbance shortly following emplacement of granite (c. 540 Ma with zircon ages disturbed to 509 ± 7 Ma) and the protolith to the felsic orthogneiss (c. 528 Ma with zircon ages disturbed to 510 ± 3 Ma). Xenocrystic zircon grains in the Cambrian rocks include Archean (c. 2839 ± 9 Ma) and Mesoproterozoic (1230–1370 Ma) populations also isotopically disturbed during Cambrian orogenesis. Igneous Cambrian zircon grains have less radiogenic Hf-isotope compositions (Hf_i = 0.281821–0.281367) than Mesoproterozoic xenocrysts (Hf_i = 0.282267–0.281993), indicating limited involvement of the Mesoproterozoic crust in granite production. A more likely source includes Archean crust represented by xenocrysts with Hf_i = 0.281399–0.280863. The Gulden Draak Knoll is reconstructed in Gondwana ('Leeuwin' full-fit model) along strike of a major structure termed the Indo–Australo–Antarctic Suture (IAAS), recently mapped from geophysical interpretations in Wilkes Land, Antarctica. New isotopic data suggest that basement rocks from the Gulden Draak Knoll have affinity to crust exposed either side of the IAAS. Determining if this structure is a suture zone sensu stricto remains to be tested.

1. Introduction

Comparison of the geology of conjugate continental margins provides an observational basis to test plate tectonic reconstructions (e.g., Gibson et al., 2011; Torsvik and Cocks, 2013). Some rifted margins involve numerous microcontinents (e.g., east coast of Australia, Gaina et al., 1998) that affect the reconstructed fit of continents and must be considered in testing full-fit reconstructions of complex ocean basins. The seafloor offshore Western Australia records the spreading history between Greater India and Australia–Antarctica during the Cretaceous breakup of Gondwana (Markl, 1974; Gibbons et al., 2012; Williams et al., 2013a). Reconstruction of the early evolution of the Indian Ocean is hampered by: (1) the unknown origin of several major plateaus and ridges, (2) the controversial age of the ocean floor, a significant proportion of which formed during the Cretaceous Normal Superchron, and (3) the lack of the conjugate margin (Greater India), which has been lost due to the processes of subduction and collision. During a recent research cruise across the Perth Abyssal Plain (PAP) aboard the *RV Southern Surveyor* (SS2011-v06), we retrieved the first dredge samples from known bathymetric highs, Gulden Draak and Batavia knolls. Seafloor mapping and dredging indicate that these features have relatively smooth surfaces, comprising common continental rocks and delineate two microcontinents stranded at the boundary between the western Perth Abyssal Plain (W-PAP) and Wharton Basin (WB; Fig. 1a). Continental rocks also

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http://dx.doi.org/10.1016/j.gr.2014.08.013
1342-937X/

comprise the basement to the southern Naturaliste Plateau (NP; Fig. 1a; Halpin et al., 2008).

The difficulties in reconstructing India into Gondwana listed above are compounded by the limited outcrop in Antarctica (e.g., Boger, 2011) and controversy surrounding full-fit reconstructions of the simpler conjugate Australian and Antarctic margins due to problems in reconciling geological and geophysical constraints (e.g., Williams et al., 2011, 2012; White et al., 2013; Aitken et al., 2014). A southern

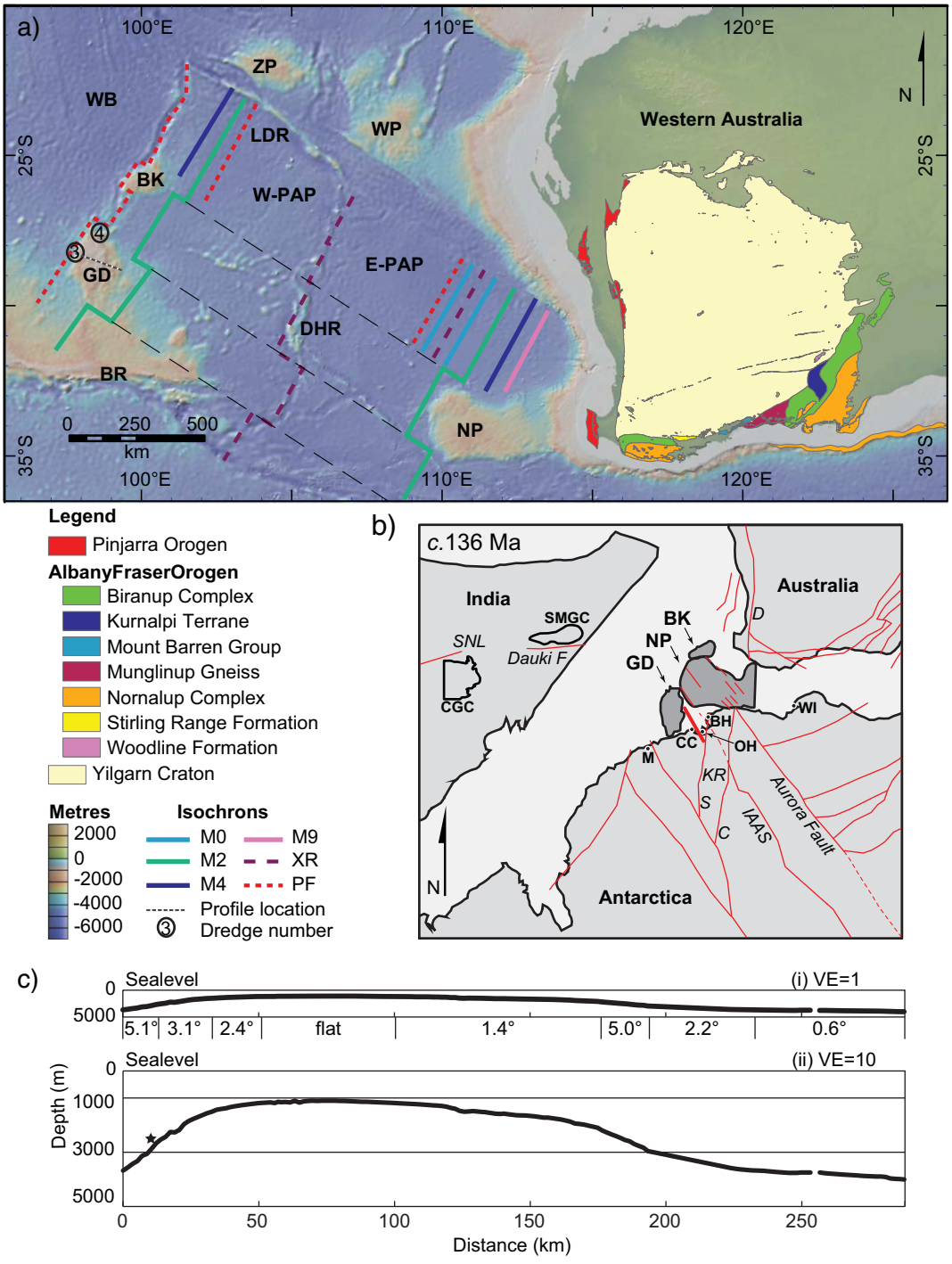

Fig. 1. (a) Gulden Draak (GD) Knoll location map showing profile (dashed line) and dredge locations (numbers in circles), based on GeoMapApp (http:www.geomapapp.org) Global Multi-Resolution Topography Synthesis (Ryan et al., 2009) overlaid with extinct ridge (XR), pseudofault (PF) and isochrons (M0, M2, M4, M9) from Gibbons et al. (2012) and Western Australian geology of the Yilgarn Craton, the Albany Fraser Orogen and the Pinjarra Orogen from the Department of Mines and Petroleum Western Australia (2010). Abbreviations are Batavia Knoll (BK), Broken Ridge (BR), Dirk Hartog Ridge (DHR), eastern Perth Abyssal Plain (E-PAP), Lost Dutchman Ridge (LDR), Naturaliste Plateau (NP), Wallaby Plateau (WP), western Perth Abyssal Plain (W-PAP) Wharton Basin (WB) and Zenith Plateau (ZP). (b) Tectonic reconstruction of East Gondwana c. 136 Ma after Gibbons et al. (2012) showing the relative locations of Gulden Draak Knoll (GD), Batavia Knoll (BK) and Naturaliste Plateau (NP) with respect to India, Australia and Antarctica. Structure noted in Australia and Antarctica (light lines) is from Aitken et al. (2014). Structure noted on the Naturaliste Plateau (light lines) is from Hall et al. (2013). The adjusted location of the IAAS proposed in this study by closing the Knox Rift (KR) is shown as a bold line. Abbreviations are Bunger Hills (BH), Conger Fault (C), Cape Charcot (CC), Chotanagpur Gneissic Complex (CGC), Darling Fault (D), Indo–Australo–Antarctic Suture (IAAS), Knox Rift (KR), Mirny (M), Obruchev Hills (OH), Scott Fault (S), Shillong–Meghalaya Gneissic Complex (SMGC), Son–Narmada Lineament (SNL) and Windmill Islands (WI). (c) Profile of Gulden Draak Knoll with (i) 1× and (ii) 10× vertical exaggeration. Location shown in Fig. 1 from west to east. The average slope angles are noted for segments of the profile.