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Proterozoic accretionary tectonics in the east Kimberley region, Australia

Mark D. Lindsay [a,*], Sandra Occhipinti [a], Alan R.A. Aitken [a], Václav Metelka [a], Julie Hollis [b,c], Ian Tyler [b]

[a] Centre for Exploration Targeting, School of Earth and Environment, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia
[b] Department of Mines and Petroleum, Geological Survey of Western Australia, 100 Plain St, East Perth, WA 6004, Australia
[c] Department of Geology, Ministry of Mineral Resources, Government of Greenland, Imaneq 1A 201, 3900 Nuuk, Greenland

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ABSTRACT

The east Kimberley region contains well-preserved tectonic structure dating back to the Earth's most significant stage of continental growth: the assembly of the Nuna supercontinent. An integrated geological–geophysical investigation of this region has been conducted and reveals insight into its tectonic evolution, including potential influence of significant crustal-scale structures in the development of regional architecture, the emplacement of magma, and the relationship of these structures to large-scale deformation. Some newly interpreted features include a north-trending structure, and three north-west trending structures that segment the north-east trending orogen. The central segment of the orogen is a zone of higher metamorphic grade, and is host to a distinct gravity high. This gravity high can be explained by excess mass in the mid-crust. This anomaly is consistent with either a large mafic–ultramafic intrusion or a high-density crustal fragment. Possible tectonic models to explain the geophysical and metamorphic anomalies involve, in the latter case, the accretion of a crustal fragment to the Kimberley Craton prior to the 1865–1850 Ma Hooper Orogeny or, in the former case, intrusion of voluminous mafic magmas into the middle crust. Whether by igneous or structural means, we consider the development of this anomalous region to be a result of along-strike variations in subduction dynamics. These were perhaps driven by variations in slab-geometry accommodated by the orogen-normal structures we identify. The orogen-normal structures are interpreted to be crustal-scale faults, along which significant vertical displacement occurred when a crustal fragment collided with Kimberley Craton and exhumed high-grade metamorphic rocks to the surface.

1. Introduction

Paleoproterozoic orogens in Australia provide an opportunity to view the operation of plate margin processes during the assembly of the Columbia/Nuna supercontinent (Betts and Giles, 2006) hereafter referred to as Nuna (Zhao et al., 2002, 2004; Rogers and Santosh, 2002). Recent syntheses and analyses have highlighted that the Paleoproterozoic stages of Nuna amalgamation are complex and uncertain, but hold important clues processes involved (Pisarevsky et al. 2014; Betts et al., 2015). The Kimberley region in northern Australia is host to the Kimberley Craton and the Halls Creek Orogen (part of the Lamboo Province) and provides important insight into the early development of the Nuna supercontinent and Proterozoic tectonic history of Australia (Cawood and Korsch, 2008; Tyler, 2005; Tyler et al., 2012). The history of the Lamboo Province is complex and spans almost two billion years, beginning with rifting during the Paleoproterozoic along the northwestern margin of the North Australian Craton margin at 1910–1880 Ma. Plate collision with the North Australian Craton followed in the east Kimberley region with a series of events between 1865 and 1790 Ma. The South Australian Craton was sutured to the south-east of the combined Kimberley and North Australian cratons (Betts and Giles, 2006; Payne et al., 2009) to form the Diamantina Craton (Cawood and Korsch, 2008; Liang, 1996). Collision and orogenesis ceased in the Kimberley Region, and migrated to the west where the c. 1970 and 1975 Ma Yapungku Orogeny records the collision of the West Australian Craton with the Diamantina Craton (Smithies and Bagas, 1997; Bagas, 2004). Recent isotopic analyses by Kirkland et al. (2013) place the suture between the North Australian and West Australian cratons to the east of the Rudall Province. The Mawson Continent, a microcontinental ribbon that eventually forms the link between Australia and Laurentia, (Fanning et al., 1995; Betts and Giles, 2006; Betts et al., 2008; Cawood and Korsch, 2008; Payne et al., 2009; Boger, 2011) with the Australian cratons forms the proto-Nuna supercontinent of East Nuna (Pisarevski et al., 2014. The East Kimberley and Lamboo

* Corresponding author.
E-mail addresses: markdlindsay@gmail.com, mark.lindsay@uwa.edu.au (M.D. Lindsay).

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Province thus records a series of orogenic events that were important to the formation of East Nuna.

The first event we consider, the 1870–1850 Ma Hooper Orogeny resulted in the accretion of the Tickalara Arc to the Kimberley Craton (Griffin et al., 2000; Page et al., 2001; Page and Hoatson, 2000), then the North Australian Craton was sutured to the Kimberley Craton during the 1835–1805 Ma Halls Creek Orogeny (Blake et al., 2000a; Page et al., 2001; Tyler et al., 1995). Evidence of lithospheric architecture with connectivity to the mantle is interpreted from the presence of deeply-sourced and Ni–Cu–PGE prospective ultramafic–mafic rocks that intruded between 1859 and 1853 Ma. Mafic magmatism was followed by suturing to the North Australian Craton during the Halls Creek Orogeny (Sheppard et al., 1999, 2001; Tyler et al., 2012). Other deeply-sourced rocks are exemplified with the diamondiferous c. 1180 Ma Argyle lamproite pipe (Jaques et al., 1986; Luguet et al., 2009).

Clues to the tectonic processes involved in orogenesis and continental growth in the Kimberley region can be elicited by structural geophysical interpretation. Magnetic and gravity measurements, each responding to the corresponding rock properties magnetic susceptibility and density provide a means to detect and infer geological structure (Clark, 1997; Grant, 1985; Manger, 1963). The interpretation of geophysical data is most powerful when integrated with geological data. We use a combination of geological field observations, including metamorphic grade, to provide insight to Palaeoproterozoic processes considered fundamental to the tectonic evolution of the east Kimberley. We define a high metamorphic grade region and a coincident gravity high, and bounding structures. We infer these structures to be old, deep-seated and persistent features of thermomechanical contrast likely to focus and segment tectonic activity.

Two scenarios explaining the nature of the gravity anomaly have previously been suggested. Gunn and Meixner (1998) consider the modelled density of the gravity anomaly to be consistent with a large intrusion of mafic to ultramafic rocks. Shaw and Macias (2000) and Shaw et al. (2000) suggest the gravity anomaly represents a combination of mafic–ultramafic, mafic granulite and metapelitic rocks. We propose a third scenario involving the accretion and underthrusting of a >1900 Ma crustal fragment (Griffin et al., 2000) that, in combination with the newly identified cross-orogen structures, initiated differential exhumation in the centre of the orogen. We investigate the feasibility of these three models in the context of the 1870–1850 Ma Hooper and 1835–1810 Ma Halls Creek orogenies and later intraplate events.

1.1. Regional geology and tectonic setting

Our study area includes the eastern part of the Kimberley and Speewah basins and Lamboo Province (Fig. 1). The exposed Lamboo Province includes the King Leopold Orogen to the southwest of the Kimberley Craton, and the Halls Creek Orogen to the east. Both the Kimberley Basin and western portion of the Lamboo Province are underlain by the Kimberley Craton, inferred to comprise a series of NE-trending Archean and Paleoproterozoic terranes (Gunn and Meixner, 1998; Hollis et al., 2014; Lindsay et al., 2015). Fast S-wave velocities observed down to about 250 km are consistent

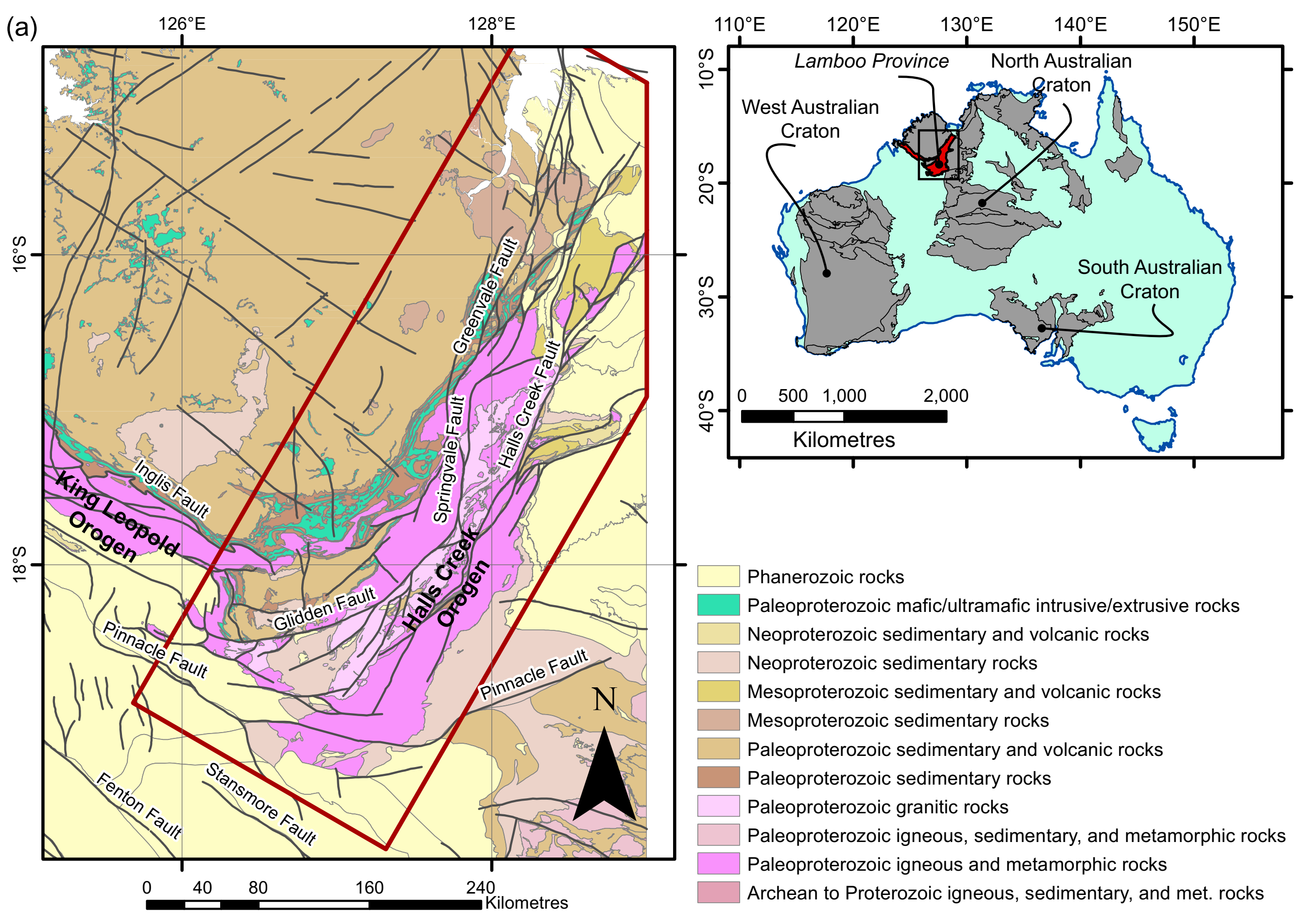

Fig. 1. Location and tectonic context of the east Kimberley: (a) Map of the east Kimberley region showing major tectonostratigraphic units of the Lamboo Province, modified after (Tyler, 2005); (b) Australia showing current configuration of cratons and location of the Lamboo Province in red. The black box indicates the view extent of (a). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)