Tectonophysics 483 (2010) 151–177

Contents lists available at ScienceDirect

Tectonophysics

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

Implications for Proterozoic plate margin evolution from geophysical analysis and crustal-scale modeling within the western Gawler Craton, Australia

John R. Stewart *, Peter G. Betts

School of Geosciences, Monash University, Clayton, Victoria 3800, Australia

ARTICLE INFO

Article history:
Received 2 February 2009
Received in revised form 19 November 2009
Accepted 20 November 2009
Available online 3 December 2009

Keywords:
Forward modeling
Gawler Craton
Kimban Orogeny
Potential field geophysics
Proterozoic
Shear zone

ABSTRACT

Complexly deformed late Archean to Mesoproterozoic rocks of the western Gawler Craton are poorly exposed, thus reducing the ability to extract meaningful geological, structural and tectonic information. This study focuses on shear zone analysis via a constrained integration of qualitative aeromagnetic and Bouguer gravity data interpretation with quantitative two-dimensional forward modeling. This integration provides a means to interpret the crustal architecture as well as constrain a sequence of events, which aid the interpretation of a tectonic history for the western Gawler Craton. Results indicate a polyphase shearing history dominated by a crustal-scale array of predominantly west-dipping shear zones. The initiation of ~east–west trending SZ_1 structures was likely coincident with ca. 1750–1720 Ma crustal extension, high heat flow and deposition on thinned areas of Archean crust with the development of a dense, possibly underplated lower crustal component. $SZ_{1\text{-}R2}$ dextral transpressional movements reactivated SZ_1 during the ca. 1720–1670 Ma Kimban Orogeny, which is interpreted to record collision between the Gawler Craton and the North Australian Craton. During this event basins marginal to, and in the interior of the Archean crustal block of the western Gawler Craton were inverted and the dense lower crust was vertically offset, causing some of the long wavelength (~30–50 km) Bouguer gravity anomalies presently observed. Shear zone activity is constrained until ca. 1680 Ma during which time subduction rollback established a new arc position at the southern margin of the Archean crust with magmatism persisting until ca. 1670 Ma. SZ_3 structures overprint and offset the interpreted axis of the Kimban Orogeny within the Archean crust. These structures record a major phase of crustal-scale sinistral strike-slip movement associated with ~north–south shortening between ca. 1630 and 1540 Ma prior to their reactivation at ca. 1450 Ma. This $SZ_{3\text{-}R4}$ reactivation is interpreted to cause southwest-directed crustal transport, which was focused as west-side-up movements internal to the Archean continent, whereas dextral strike-slip was focused at a major rheological boundary between thick Archean crust to the south and thick Paleoproterozoic basins to the north.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Archean–Proterozoic terranes often record a cryptic tectonic signature due to polydeformation, reworking, reactivation, and the obscurity of “basement” by younger sedimentary cover (e.g. Holdsworth et al., 2001; Butler et al., 2006; Direen et al., 2005; Stewart et al., 2009). Reworking is particularly complicated in areas affected by plate margin processes due to focused deformation episodes over protracted time-scales (e.g. Vauchez et al., 1997; Murphy et al., 1999; Tikoff et al., 2001). By systematically addressing these complexities and constructing geological evolutions and tectonic histories for these terranes insight into crustal and plate margin processes can be determined. This can provide constraint for continental evolution and global correlations within supercontinent cycles (e.g. Moores, 1991; Karlstrom et al., 2001; Betts et al., 2008).

Solving Precambrian tectonic problems involves holistic assessments of the geological record. These generally rely on the integration of outcropping geology and structural relationships with established geochemical determinations and absolute geochronology to unravel the tectonic evolution and setting. A major drawback in studies of many Precambrian terranes is a lack of exposure, limiting the amount of attainable geological data, and hampering the assessment of geological and structural evolution, kinematic analyses and overprinting relationships.

Traditionally, understanding geological processes has been limited to the shallowest parts of the crust through the construction of cross-sections, which are based on the analysis of rock distributions, geometries and overprinting relationships (Fig. 1). This method is limited by the amount and position of outcropping geology, and major assumptions include: (1) the surface geology is representative of geology at depth; (2) dip information at the surface can be confidently

---

* Corresponding author. Tel.: +61 9905 4348; fax: +61 9905 4903.
E-mail addresses: john.stewart@sci.monash.edu.au (J.R. Stewart), Peter.betts@sci.monash.edu.au (P.G. Betts).

0040-1951/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2009.11.016

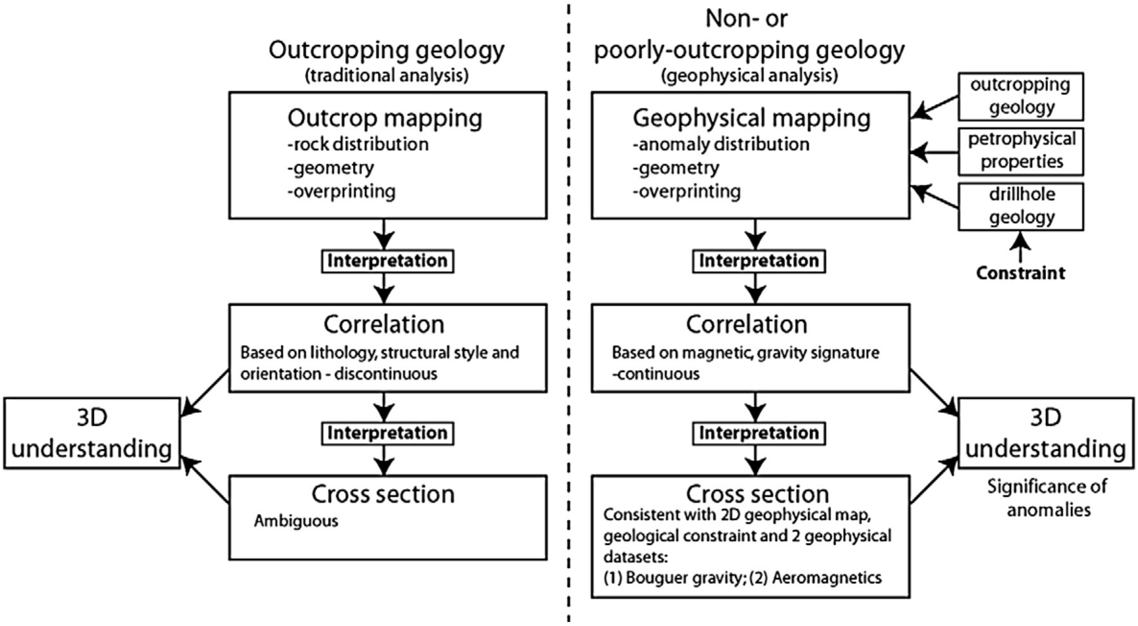

Fig. 1. Flow chart comparing traditional geological analysis with geophysical analysis performed in the present study. Traditional analyses are based on observations made from outcropping geology. The methodology used in this study can be applied to areas with little or no outcropping geology via the integration of Bouguer gravity and aeromagnetic data with geological constraint, which can be used to develop a three-dimensional understanding.

extrapolated with depth; and (3) information at discrete outcrops can be confidently interpolated. These assumptions all require a degree of interpretation and thus any solution is ambiguous.

Our approach follows a similar workflow to traditional geological analyses (Fig. 1), although the emphasis is on the use of potential field geophysical datasets (Bouguer gravity and aeromagnetic data). The application of potential field data is limited by its own ambiguity (i.e. an infinite of possible interpretations for any given dataset), however, this can be significantly reduced when geological constraints such as drillhole, outcrop mapping and structure, and petrophysical property data is added. Potential field interpretation allows for the interpretation of continuous bodies in areas of discontinuous outcrop; provides overprinting relationships where there is no outcrop; gives the ability to constrain the crustal architecture at depth; and allows the interpretation of three-dimensional relationships at multiple crustal levels (Direen et al., 2005; Williams et al., 2009; Aitken and Betts, 2009; Stewart et al., 2009). Interpretation occurs when geological meaning and significance are prescribed to potential field signatures (Fig. 1) such that these data allow the production of geological maps in the same manner as traditional studies (e.g. Whiting, 1986; Betts et al., 2003) and provide constraint for interpretation into two-dimensional cross-sections and three-dimensional blocks. Once the interpretive aspects have been addressed the methodology for producing a geological interpretation is no less valid than other interpretive mapping techniques. The major benefit is that potential field interpretations contribute toward determining geological constraints in areas of poor or negligible outcrop where traditional mapping techniques inherently fail.

The location chosen for the present study comprises the western Gawler Craton, which is an area of very limited exposure (<1%) (Fig. 2). Geochemical analysis of sparse outcrop suggest that this terrane is located proximal to a plate margin (Teasdale, 1997; Ferris, 2001; Swain et al., 2008), which has led many researchers to extend their tectonic models from the Gawler Craton across the entire eastern Australian Proterozoic continent. This Proterozoic plate margin has been interpreted to record the processes of accretion and deformation associated with subduction and convergence over ~1000 m.y. (e.g. Betts et al., 2003; Betts and Giles, 2006; Wade et al., 2006; Swain et al., 2008; Betts et al., 2009; Payne et al., 2009). This area is thus of extreme importance as many continental reconstructions rely on the sequence of events in this area to constrain their models (e.g. Betts and Giles, 2006; Payne et al., 2009). In this study we apply the mapping techniques outlined above to existing potential field data to gain a greater understanding of the evolution of the plate margin. We integrate these results into the established absolute geochronology and geochemistry of the region to determine a coherent tectonic evolution, constrained by outcrop and drillhole observations, as well as previous studies (e.g. Teasdale, 1997; McLean and Betts, 2003; Direen et al., 2005; Thomas et al., 2008; Stewart et al., 2009). We present forward models of the potential field data which are primarily constrained by the geophysical interpretations in the same way that geologists construct sections using outcrop geology; however, they allow interpretation to much greater depths. Forward modeling allows the validity of the geophysical map to be tested as their construction is constrained by: (1) the geophysical interpretation (and the constraint inherent in its production); (2) known petrophysical properties of rock units interpreted to lie within the section; (3) the Bouguer gravity data; (4) the aeromagnetic data; (5) published constraints on lithospheric architecture (e.g. interpretation of seismic data; Collins, 1991; Clitheroe et al., 2000). We provide a sensitivity analysis of our resulting sections to address the ambiguity of the forward modeling procedure.

This study demonstrates a sophisticated methodology that extends the validity of potential field data for geological analysis, and particularly structural and kinematic analysis. This analysis can be applied to the continental scale allowing the constrained interpretation of large-scale geodynamic processes within poorly exposed Precambrian areas.

2. Geological setting of the western Gawler Craton

The present understanding of the tectonic history of the western Gawler Craton is based on evidence from <1% outcrop, sparse drillholes and largely unconstrained regional-scale geophysical interpretations. The rock record is strongly biased toward magmatic rocks, which preferentially outcrop preserving limited structural information. The record of highly deformed sedimentary rocks is mainly from drillholes, the sparse distribution of which makes them ill-suited for

Download English Version:

https://daneshyari.com/en/article/4693706

Download Persian Version:

https://daneshyari.com/article/4693706

Daneshyari.com