Utilising potential field modelling to better inform on the 3D structural architecture in regions of excellent structural control

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SUMMARY

Information in the third dimension is intrinsic to potential-field data. Potential-field interpretations and modelling can provide crucial regional and sub-surface geological constraints in areas considered to be structurally 'well' understood. These approaches should not be restricted to regions with little to no outcrop.

The geophysical interpretation of the Leichhardt River Fault Trough provides new insight into the tectonic evolution of the region that was not apparent from the geological relationships alone. Evidence for a major inversion event over a larger region of the Western Fold Belt pre-dating ca. 1710 Ma. This requires a re-assessment of how we interpret the evolution of the eastern parts of the North Australian Craton.

In the Mt Painter Inlier, geophysical inversion modelling indicates that significant additional Ordovician aged felsic intrusions occur at depth. The intrusion of this additional material in the Palaeozoic either could be the product of; or contributed to, an increased local geotherm and heat flow in the region during the Palaeozoic. There is a potential link between these intrusives and Palaeozoic hydrothermal mineralisation in the region (e.g. Mt Gee, Yudanamutana).

Key words: potential-field modelling, integrating structural mapping with geophysics, Precambrian Australia.

INTRODUCTION

Potential field data such as aeromagnetics are often used to produce geological interpretations of regions that are poorly exposed. However, when integrated with surface mapping, potential-field data can also elucidate crucial information on the regional structural architecture and tectonic evolution of areas which are well exposed with excellent structural control.

Here we consider two regions, the Leichhardt River Fault Trough in the Mt Isa region of the North Australian Craton, and the Mount Painter Province of the South Australian Craton.

RESULTS

The Leichhardt River Fault Trough (LRFT), which is located within the western Mt Isa Inlier of northwest Queensland, Australia, is comprised of Proterozoic sedimentary and volcanic successions that formed during repeated cycles of rifting and thermal subsidence, and has undergone several basin inversion events. The region is well exposed but is also characterized by a spectacular aeromagnetic imagery, which highlights several structural features of the Mount Isa Inlier.

To better constrain the deformation history and complex overprinting relationships that formed the LRFT, aeromagnetic, gravity, and radiometric data are coupled with geological data to produce a structural interpretation map of the region (Figure 1). These data are then used to constrain 2D forwards models of the gravity and magnetic data, to better understand the 3D geometry of the folds and half-grabens within the LRFT.

Our interpretation suggests the N-S trending Leichhardt anticline formed before the development of E-W oriented normal faults bounding the half graben, which are infilled with ca. 1690-1640 Ma succession. The implication of this interpretation is that a major inversion event pre-dates the development of the ca. 1710-1690 Ma Calvert Superbasin. The implication of this interpretation is that the bulk of the crustal shortening within the LRFT pre-dates the Isan Orogeny (1620-1520 Ma). Consequently, there is a requirement to reassess the correlation of shortening events across the Mount Isa Inlier and the tectonic drivers for such a large inversion event and its implications on the tectonic evolution of the North Australia Craton.

The LRFT is characterised by large, fault-bounded north-plunging anticlines (e.g. Leichhardt anticline), which fold the ca. 1800-1750 Ma Leander Quartzite, Mount Guide Quartzites, Eastern Creek Volcanics and Lower Myally sub-group (Figure 1). A series of E-W trending half-grabens that are infilled with the ca. 1660-1650 Ma upper Myally sub-group and Calvert and Isa Superbasin sedimentary succession appear to cross-cut the north-plunging anticlines.

Understanding the relationship and timing of basin inversion events that formed the Leichhardt anticline, and subsequent extension, which formed the series of E-W oriented half-grabens, has implications for understanding the tectonic evolution of the North Australia Craton.

In the Mount Painter Province of South Australia, early Mesoproterozoic metasedimentary rocks and A-type granites are poly deformed during the ca. 1590-1550 Ma period and during the ca. 500 Ma Delamerian Orogeny (Armit et al., 2012) and the province is intruded by what appears to be a volumetrically small magmatic suite (the British Empire Granite) during the Palaeozoic.

Detailed structural and lithological mapping of the inlier (e.g. Armit et al. 2012, 2014a) cannot however explain a significant negative residual gravity anomaly (Figure 2).

A number of different 3D model scenarios were tested by inversion modelling and the best fitting model suggests that a large volume of low density material is required at the base of the model. We interpret this unit (shown in grey on Figure 2) as an extension of the Ordovician to Silurian British Empire Granite complex and may have implications for hydrothermal fluid flow during the Palaeozoic in the region (Armit et al. 2014b).

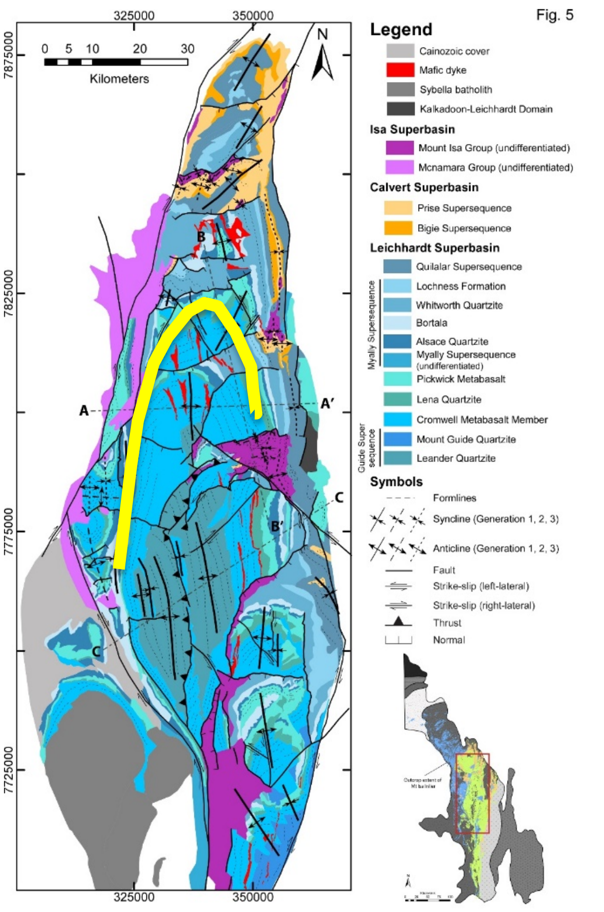

Figure 1. Interpreted geology of the LRFT after Blaikie et al. (2017) highlighting the Leichhardt orocline which must have been formed prior to the deposition of the Isa Superbasin.

CONCLUSIONS

This study has highlighted the need for a re-evaluation of the structural evolution of the eastern North Australian Craton utilising the intrinsic 3D information available from potential-field data. Insights from gravity inverse modelling on the sub-surface architecture of the Mount Painter Inlier in South Australia. These case studies highlight the importance of integrating potential field interpretations with structural mapping in regions considered to be structurally well understood.

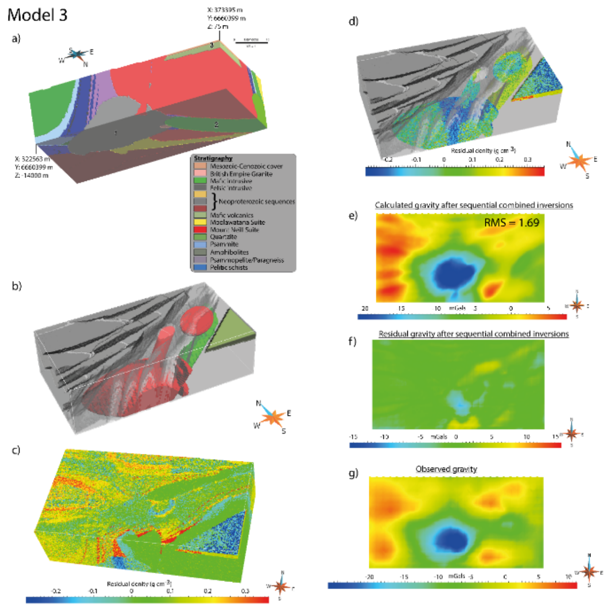

Figure 2. Reducing the 3D geophysical misfit for the Mount Painter Province (after Armit et al., 2014). The addition of a large $10^{12}m^3$ volume of felsic, low density material is required to reconcile the gravity signal of the province.

REFERENCES

Armit, R. J., Betts, P. G., Schaefer, B. F., and Ailleres, L. (2012). Constraints on long-lived Mesoproterozoic and Palaeozoic deformational events and crustal architecture in the northern Mount Painter Province, Australia. Gondwana Research, 22(1), 207-226. doi:10.1016/j.gr.2011.11.003

Armit, R. J., Betts, P. G., Schaefer, B. F., Pankhurst, M. J., and Giles, D. (2014a). Provenance of the Early Mesoproterozoic Radium Creek Group in the northern Mount Painter Inlier: Correlating isotopic signatures to inform tectonic reconstructions. Precambrian Research, 243, 63-87. doi:10.1016/j.precamres.2013.12.022

Armit, R. J., Ailleres, L., Betts, P. G., Schaefer, B. F., and Blaikie, T. N. (2014b). High-heat geodynamic setting during the Palaeozoic evolution of the Mount Painter Province, SA, Australia: Evidence from combined field structural geology and potential-field inversions. Geophysical Journal International, 199(1), 253-275. doi:10.1093/gji/ggu263

Blaikie, T. N., Betts, P. G., Armit, R. J., and Ailleres, L. (2017). The ca. 1740-1710 Ma Leichhardt Event: Inversion of a continental rift and revision of the tectonic evolution of the North Australian Craton. Precambrian Research. doi:http://dx.doi.org/10.1016/j.precamres.2017.02.003

O'Dea, M. G., and Lister, G. S. (1995). The role of ductility contrast and basement architecture in the structural evolution of the Crystal Creek block, Mount Isa Inlier, NW Queensland, Australia. Journal of Structural Geology, 17(7), 949-960. Du, B., 2000, Comparison of crosswell diffraction tomography to Kirchoff migration: Exploration Geophysics, 31, 366-371.