The North Australian Craton 3D Gravity and Magnetic Inversion Models - A trial for first pass modelling of the entire continent

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SUMMARY

As part of the Federal Government's Exploring for the Future program, whole-of-crust 3D gravity and magnetic inversion models have been produced for an area encompassing the North Australia Craton (NAC). These models were created to aid 3D geological mapping and identification of large-scale mineral systems such as iron oxide copper-gold (IOCG) systems.

The inversion models were derived using the University of British Columbia - Geophysical Inversion Facility (UBC-GIF) MAG3D and GRAV3D programs. We used reference models that had layers for Phanerozoic sediments, Proterozoic sediments, undifferentiated crust and the mantle. The reference model for the magnetic inversion incorporated a Curie depth surface below which magnetic susceptibility was set to zero.

To facilitate cross-referencing of the density and magnetic susceptibility models, we used identical meshes for the two inversions. The spacing of the available gravity data dictated a horizontal cell size of 1 km. We used 61 vertical layers of thickness increasing with depth. The area of interest was 2450 km by 1600 km, which meant that the mesh for the NAC models had ~240 million cells.

It was not possible to invert a model of this size. Instead, we broke the problem down into a grid of overlapping "tiles" with 8 rows and 10 columns. Each tile was independently inverted.

When the overall model was reconstructed using the core region of each tile, some low-level edge effects were observed, increasing in significance with depth. These effects were satisfactorily attenuated by applying cosine weighting from the centre of each tile out to the edge of the data-padding zone during reconstruction.

The success of the NAC modelling exercise has given us confidence that we can expand the coverage to produce coincident gravity and magnetic inversion models for the entire Australian region.

Key words: gravity; magnetics; inversion; North Australian Craton.

INTRODUCTION

The work presented here forms part of the Federal Government's Exploring for the Future (EFTF) program; an Australian Government initiative designed to assist the resource exploration industry in exploring for resources in greenfield areas of northern Australia. The initiative, led by Geoscience Australia, gathered new geoscientific data and information over a four-year period, between 2016 and 2020, to provide insight into the potential mineral, energy and groundwater resources in northern Australia.

In line with this initiative, coincident 3D gravity and magnetic inversion models were produced for an area that encompasses the North Australian Carton (NAC). The extent of the NAC and the inversion models is shown in Figure 1.

The 3D gravity and magnetic inversion models were designed to provide (1) regional-scale density and magnetic susceptibility information to assist 3D geological mapping, (2) magnetite and hematite alteration proxies for input into the IOCG mineral potential assessment of northern Australia (Murr *et al.* 2020), and (3) a trial for first pass modelling of the entire Australian continent.

METHOD AND RESULTS

The UBC-GIF programs GRAV3D v5.0 and MAG3D v5.0 were used in this study to produce coincident 3D models of density contrast and magnetic susceptibility, respectively. Details of the UBC-GIF inversion approach are documented in Li and Oldenburg (1996; 1998).

Model Dimensions

The models cover an area of 2450 km (east-west) by 1600 km (north-south) and extend to 70 km depth. This volume was discretised into a rectilinear fixed-cell mesh with identical meshes for both the gravity and the magnetic inversion models to allow for cross-referencing of the results.

A horizontal resolution of 1 km by 1 km was used to optimise the inversions in relation to the spacing of gravity data, whose average station spacing is 4 km, and be of a high enough resolution to retain regional-scale information.

A variable cell size was implemented in the vertical direction (61 cells increasing in size with depth). This incorporates detailed cells at the surface, to capture changes in topography, with increasingly coarser cells at depth to reflect how potential field data resolution decreases with distance from the source and to reduce the computation time.

This resulted in a total model volume with 239.12 million cells. This number of cells creates an inversion problem that would not converge (i.e., will not reach the target misfit) using standard methods. As a result, the total volume was divided into 80 smaller volumes (referred to as tiles; Figure 2). By dividing the total volume into tiles, the size of the problem to be solved by the inversion program is reduced significantly.

Input Data

The following data were used in the inversion modelling: (1) Australian Bathymetry and Topography Grid, June 2009 (Whiteway, 2009), (2) 2019 Complete Bouguer Anomaly Grid of Australia (series A4; Lane, *et al.* 2020), and (3) Total Magnetic Intensity Grid of Australia with Variable Reduction to Pole (VRTP) 2019 - seventh edition (Minty and Poudjom Djomani, 2019).

The potential field data were upward continued to 1 km before inversion. All datasets were resampled to 1 km cell size.

Geological Reference Model

A geological reference model was used to constrain the inversions with the following lithological volumes: (1) Phanerozoic sediments (Pryer, *et al.* 2005); (2) Proterozoic sediments (de Vries, *et al.* 2006); (3) undifferentiated crust, and (4) mantle.

The base of the undifferentiated crust is defined by AusMoho2015 for the gravity inversions (Kennett, *et al.* 2015) and by the Curie depth (Chopping and Kennett, 2015) for the magnetic inversions.

Recombining the Tiles

When the overall model was reconstructed using the core region of each tile, some low-level (~0.005 SI or 0.005 g/cm^3) edge effects were observed (Figure 3a and c), increasing in significance with depth. These differences resulted in features not being continuous across the model boundaries.

A cosine weighting function was applied to attenuate the edge effects. The cosine weighting function was applied from the centre of each tile out to the edge of the data-padding zone (a volume of overlap between tiles) during reconstruction. The weighting determines the influence each cell has on the reconstructed model and ensures that cells at the centre of each tile are retained but experience progressively greater influence from the overlapping cells of surrounding models with distance from the centre (Figure 4). The contributions from adjacent tiles are shown in Figure 5.

After applying the cosine weighting method, the continuity of features between the individual tiles is improved significantly (Figure 3b), allowing each tile to be viewed as part of a seamless collection that covers the entire NAC (Figures 6 and 7).

Future Direction

Work has begun on applying the UBC-GIF inversion approach to the whole of Australia. Using the cosine weighting function described here, 252 tiles will be recombined to create seamless 3D density and magnetic susceptibility models for the entire continent.

CONCLUSIONS

Two coincident physical property models were produced using the UBC-GIF inversion method for a volume that encompasses the NAC. These models provide information on the density and magnetic susceptibility distribution within the subsurface geology.

Due to the large number of cells being inverted, the volume was divided into 80 tiles, which were then recombined using a cosine weighting function. The cosine weighting function successfully attenuated the edge effects of each model allowing a seamless 3D model of density and magnetic susceptibility to be produced.

The success of the NAC modelling exercise has given us confidence that we can expand the coverage to produce coincident gravity and magnetic inversion models for the entire Australian region.

ACKNOWLEDGMENTS

This project was undertaken with the assistance of resources and services from the National Computational Infrastructure (NCI), which is supported by the Australian Government. The University of British Columbia – Geophysical Inversion Facility is thanked for providing use of their 3D inversion codes (GRAV3D and MAG3D) on the NCI. This record is published with permission of the CEO, Geoscience Australia.

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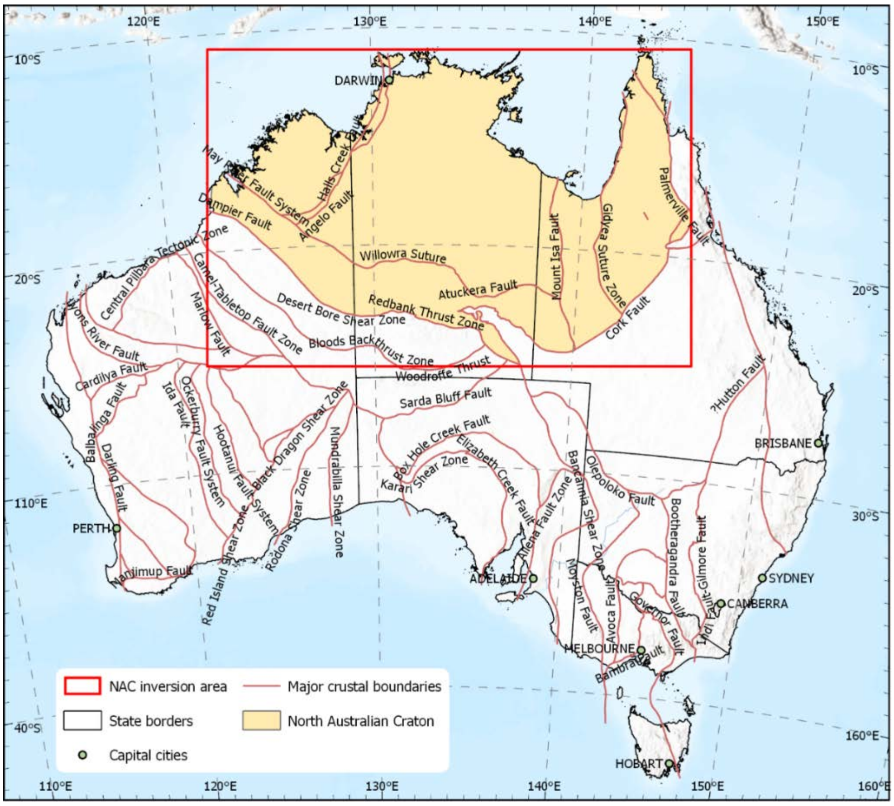

Figure 1. Extent of the 3D gravity and magnetic inversions with major crustal boundaries and a simplified NAC boundary shown. Major crustal boundaries from Korsch and Doublier (2015). Projection: Australian Albers (EPSG 3577). ArcGIS Basemap.

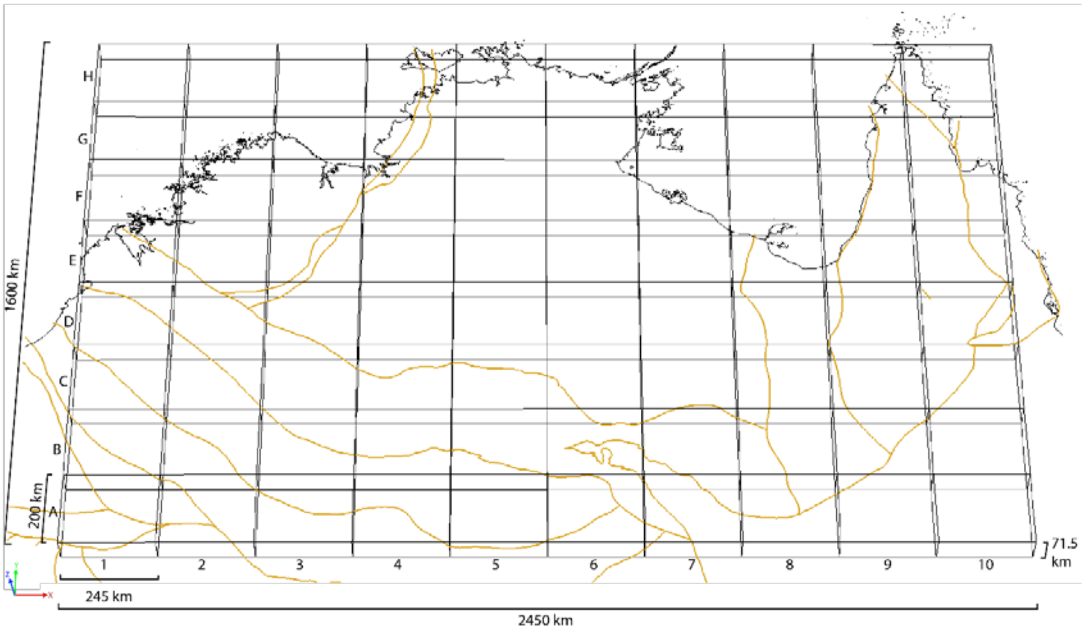

Figure 2. Perspective view of the inversion volume highlighting the location of each tile (columns labelled 1 to 10 and rows labelled A to H). Orange lines: Major crustal boundaries from Korsch and Doublier (2015).

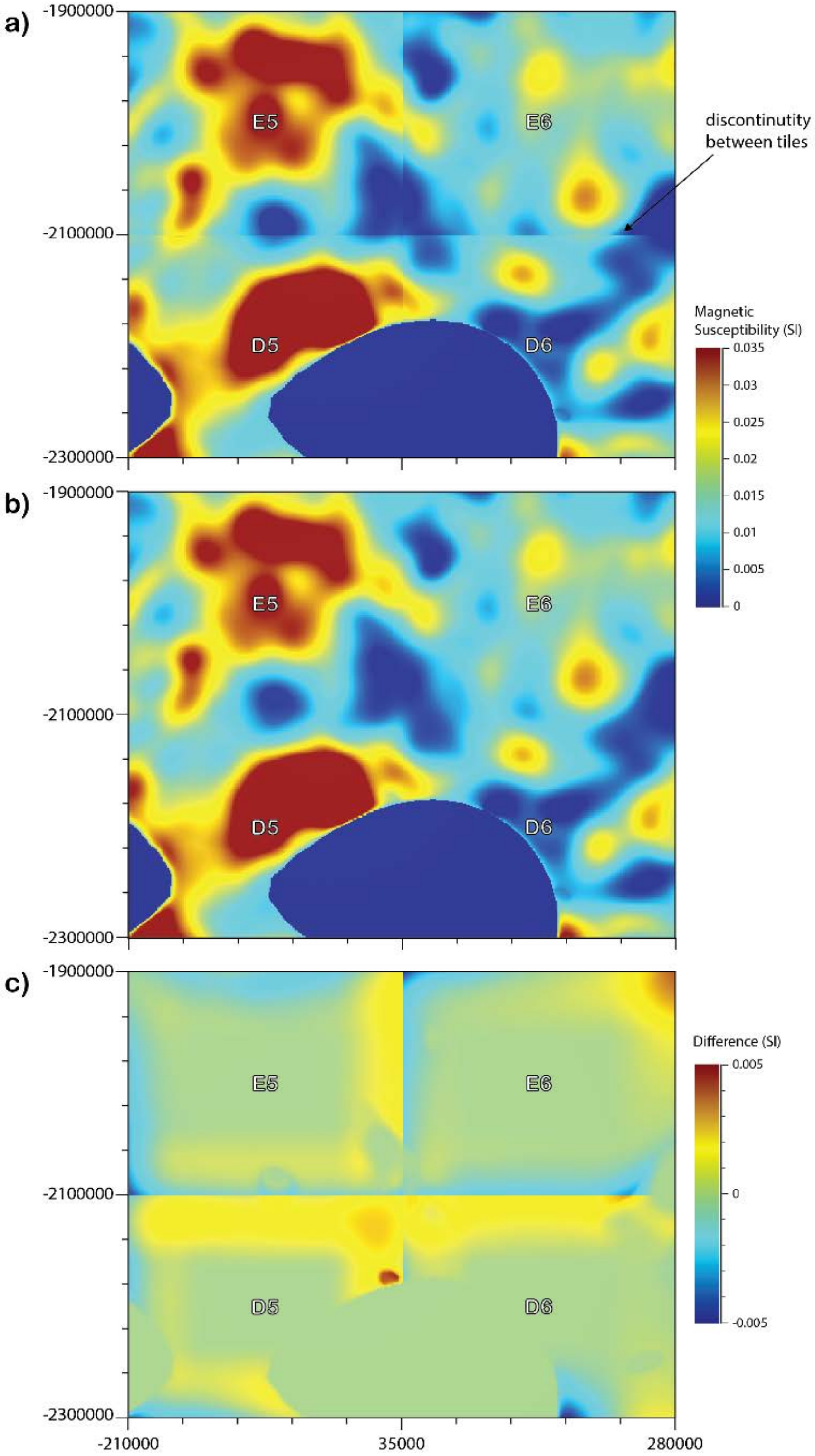

Figure 3. Map view of four adjacent magnetic inversion tiles highlighting the effect of cosine weighting. Tiles D5, D6, E5 and E6: a) without cosine weighting, b) after cosine weighting is applied, c) difference between a) and b). The horizontal slice shown is at 28 km depth for the core of each tile. Projection: Australian Albers.

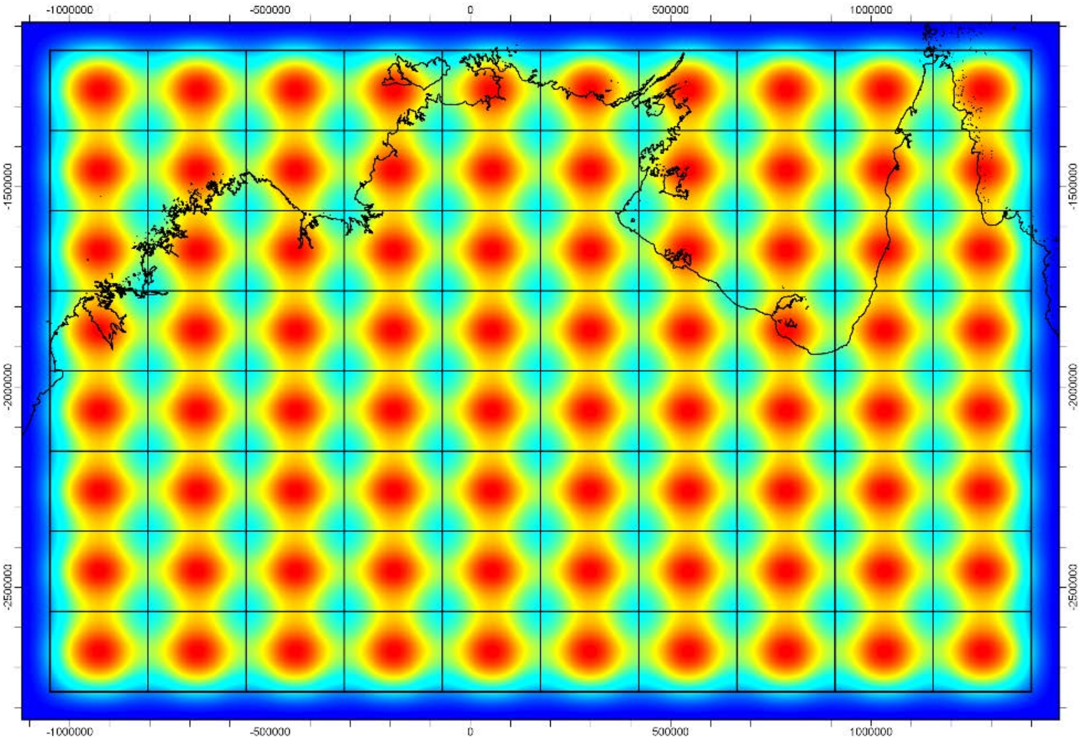

Figure 4. The cosine property weighting applied to each tile. Grading from high weighting (red) to low weighting (blue).

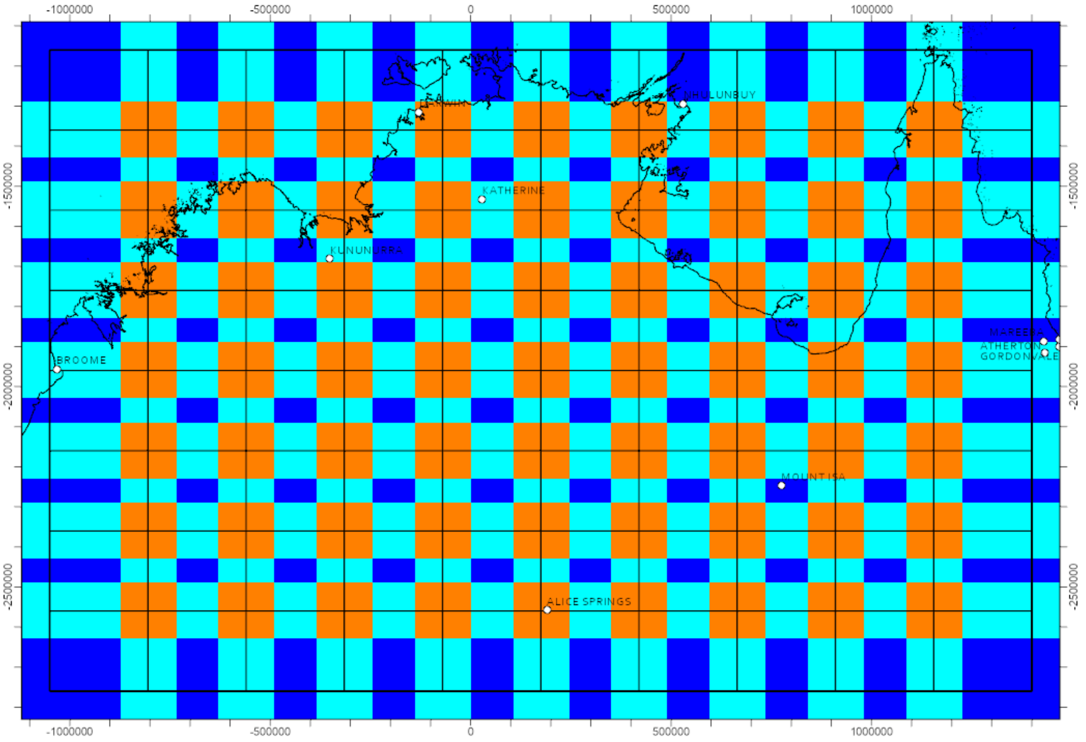

Figure 5. The cosine property contribution. Blue: contribution from centre tile only; cyan: overlapping region with contributions from 2 tiles; orange: overlapping region with contribution from 4 tiles.

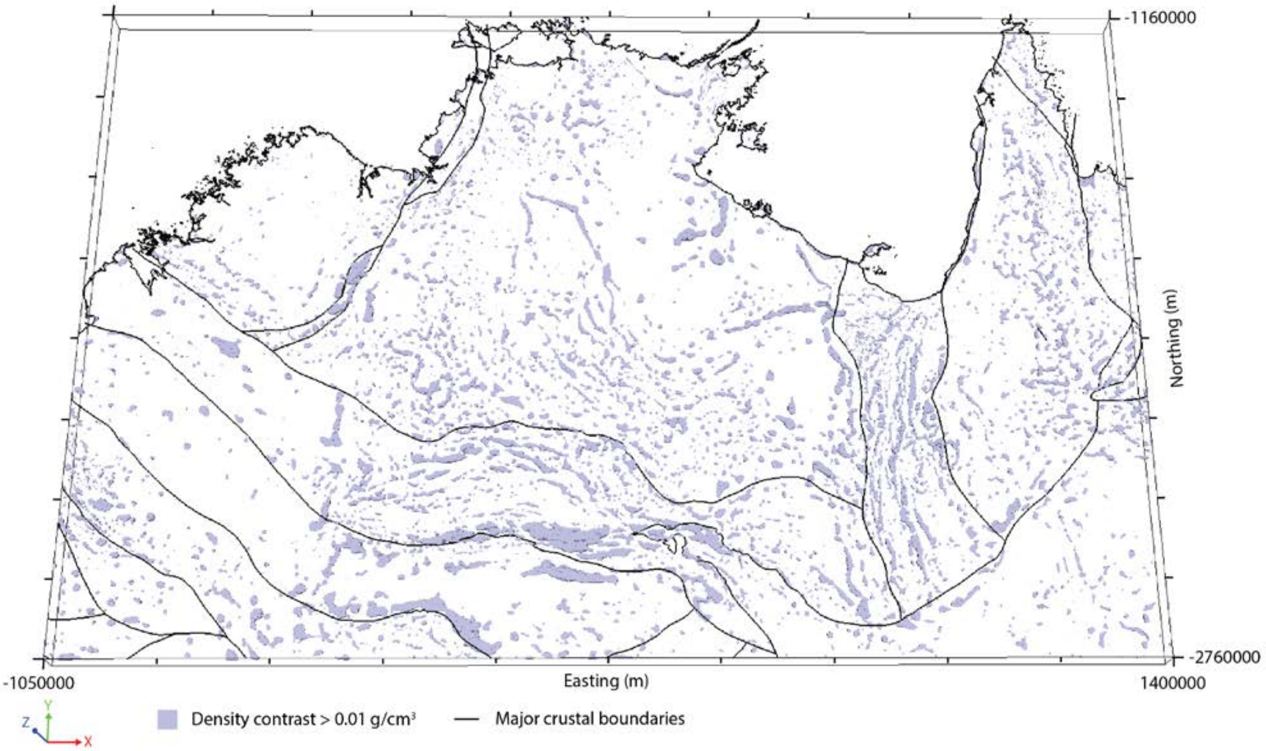

Figure 6. Recombined density model showing a volume within the undifferentiated crust with density contrast >0.01 g/cm^3. Projection: Australian Albers.

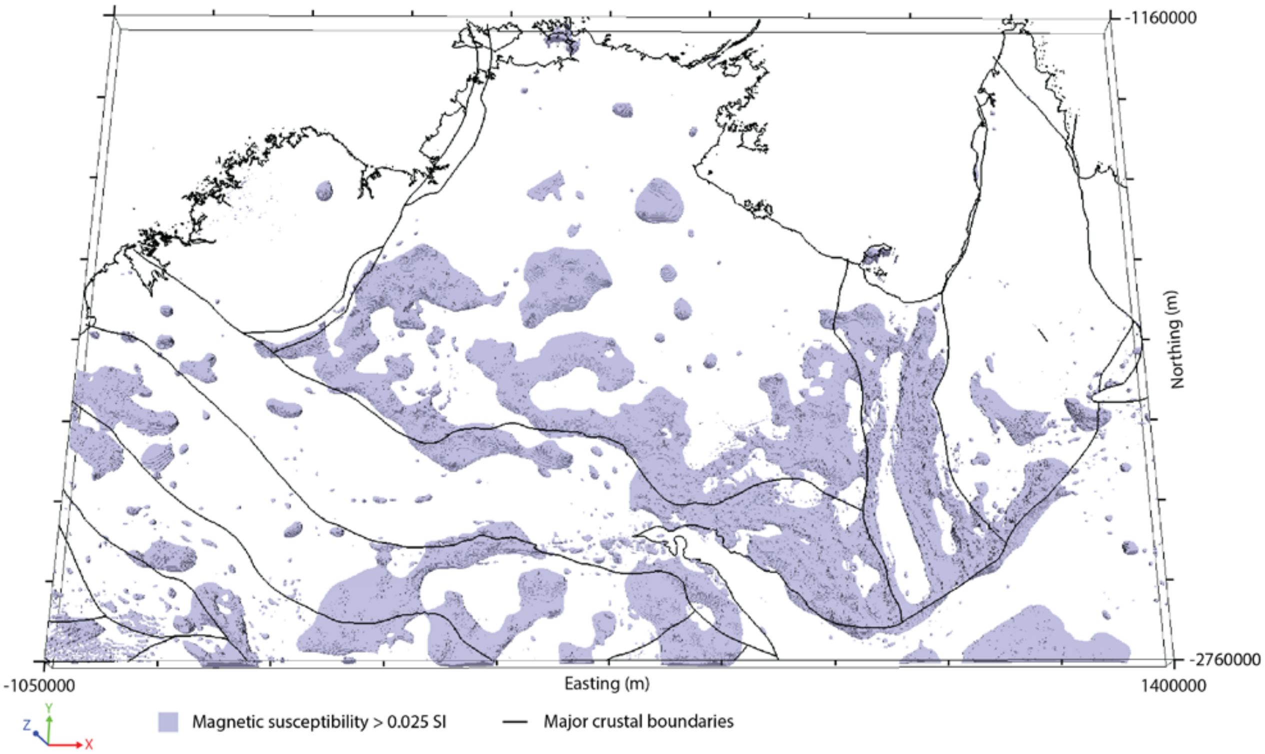

Figure 7. Recombined magnetic susceptibility model showing a volume within the undifferentiated crust with magnetic susceptibility >0.025 SI. Projection: Australian Albers.