Integrating Euler solutions into 3D geological models - automated mapping of depth to magnetic basement

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Summary

The Euler method of automated depth estimation from potential field data has been extended to permit solution for the structural index as part of the inversion process. Examples across several areas of Australia are discussed. A more concentrated 3D model of Broken Hill using 3DWEG also makes use of Euler.

The Euler method generates many solutions, which require culling or clustering. In some cases, depth estimates within 15% of actual source depths are achieved. It also benefits from full 3D visualization.

Introduction

A large proportion of older basement regions of the Australian continent is covered with a variable thickness of sedimentary and regolith material, which obscures most direct geological signatures of the basement architecture (Figure 1). Interpretations of magnetic and gravity potential field survey data provide an indirect insight into the underlying geology, and the continent is now well covered by such data (Milligan *et al*., 2003). Mineral exploration continues to spread from areas of outcropping and subcropping basement into areas with greater thickness of cover. One of the most useful inferences from potential field data is the depth of crystalline basement beneath the regolith. Many of the exposed/near-exposed mineral resources have probably now been found, and the next target areas are in basement regions underlying shallow cover.

Large quantities of data must now be analysed, requiring automated methods of estimating depth to basement. One popular method is Euler deconvolution (Thompson, 1982; Reid *et al*., 1990). We seek first-pass depth information from large quantities of data over large areas. We restrict our analyses to grid data.

With all methods, it is difficult to estimate the solution reliability. The Euler method, produces an oversupply of depth estimates and culling is required. Where possible, we should test depth estimates obtained against, those from different potential field depth methods, from drilling, or from seismic interpretations. We consider examples from areas across Australia, as shown in Figure 1

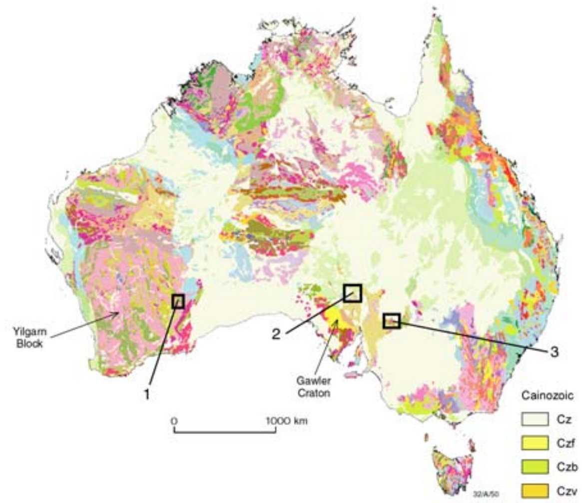

Figure 1. Geology of Australia (from Shaw *et al*. 1996). Pale yellow is Cenozoic cover. Example areas: 1. Portion of the Cundeelee 1:250 000 map sheet, 2. Olympic Cu-Au Province in the eastern Gawler Craton, 3. Broken Hill.

Analytical methods

Extended Euler deconvolution was recently implemented by Fitzgerald *et al*.(2003) following the methods of Mushayandebvu *et al.*(2001) and Nabighian and Hansen (2001). This version can estimate depth, structural index, strike and associated errors. Initial culling requires a solution vector dip greater than 20°.

<u>Cluster Analysis</u>

Many solutions remain after the initial selections, clustered around the source body singularities. Two-D binning works well for 3D or point sources. Regionally, most prominent bodies are 2D, so that clustering to lines might be optimum. Active areas of research are the analysis of such clusters (e.g. Mikhailov *et al*., 2003) and spatial sorting (e.g. Silva and Barbosa, 2003) to locate reliable solution centres.

Visualization methods

<u>3D Modelling</u>

There are several proprietary model formats. These include GO-CAD POINT format, 3DWEG Open Cascade BREP format and the SEGY format for seismic workstations. SEGY does not fit the task well, but must be supported.

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3D Rendering

Virtual Reality Markup Language (VRML) is ideal for simple 3D presentations.. There are now add-ins to support stereo viewing. It is available for free download and works in any Internet browser.

Results.

Permian basin on the Cundeelee 1:250 000 map sheet

On the Cundeelee sheet in the southeastern Eastern Goldfields a graben-like structure is seen in Fugro multiclient aeromagnetic data (A. Whitaker, pers. comm.). It is elongated and open to the northeast, >75 km long, 10 - 15 km wide, and provides a near-perfect test case for automated depth analysis.

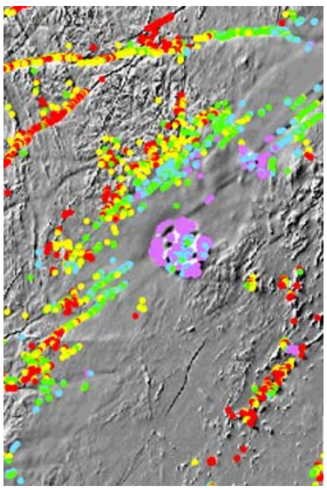

Figure 4. RTP Total magnetic intensity for a portion of the Cundeelee 1:250 000 map sheet area. NW sunshading. Symbols show Euler depths, from near surface (red) to 600 m (magenta). For location, see Figure 1.

The graben is clearly visible as a change in spatial wavelength (figure 4). The Euler solutions trend from near-surface outcrop (red) to deepest (magenta) near the basin centre. The “blob” is the “Cundeelee Intrusive”, mapped at 560 m deep, agreeing with the Euler solutions.

Olympic Cu-Au Province of the eastern Gawler Craton.

Basement in the Olympic Dam region of the eastern Gawler Craton lies beneath several hundred metres of regolith cover, a major impediment to exploration.

The Gawler Mineral Promotion Project of Geoscience Australia has produced a detailed grid of aeromagnetic data. Direen and Lyons (2002) have published an interpretation of the, magnetic and gravity data.

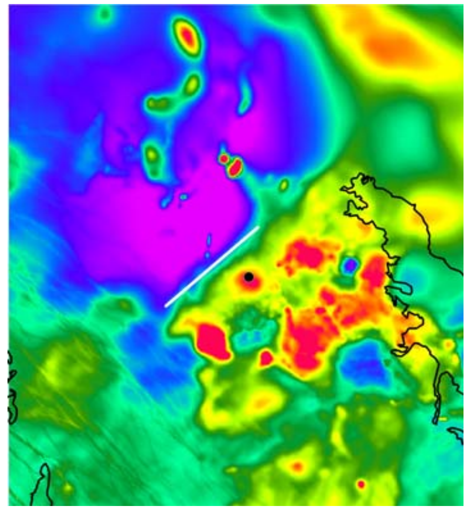

Figure 5. Image of TMI, RTP for the Olympic Dam region. Red (high) to magenta (low), linear colour stretch. Solid dot is Olympic Dam mine. White line shows the Todd Dam fault. For location see Figure 1. Image width is 134 km.

The NW-SE-trending linear anomalies in the SW are the Gairdner Dyke swarm (Figure 5).

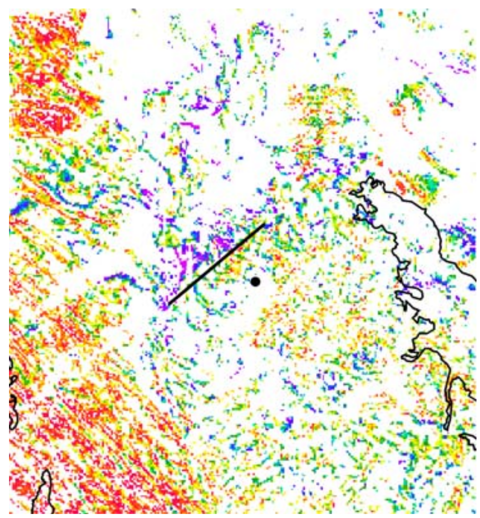

Figure 6. Euler depth image for the area shown in Figure 5. Shallow depths (-40 m) in red to deep (-6 km) (magenta).

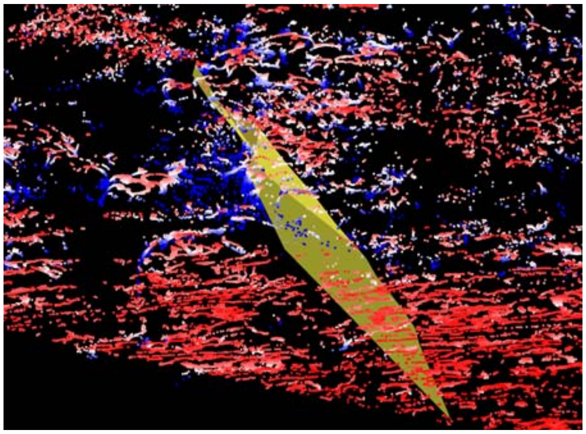

Figure 7. Visualising solutions in 3D, seen from the NW. The plane shows the Todd Dam fault, with deeper solutions to the north (left) of the fault as blue. Shallow (red), intermediate (white), deep (blue). The shallow Gairdner Dyke Swarm shows as red in the foreground.

Binned Euler depths (Figure 6) are within 15% of drilled depths (where available). The depth contrast across the Todd Dam fault is clearly visible, and the dyke swarm is imaged as a region of elongate shallow depths. The solutions are better visualised in 3D environment (figure 7).

<u>The Broken Hill District Regional Model Using 3DWEG</u>

Geological context

We present the results of a real litho-inversion applied to Broken Hill where there is a complex interplay between stratigraphy, alteration, granitic and mafic intrusions, metamorphism, and structure. The stratigraphic pile is based on the GSNSW synthesis (Willis, 1989).

3DWEG, (Guillen et. al. 2004) allows the rapid construction and editing of a family of 3D geological models. The digitized geological map (after Willis, 1989) is a primary input along with regional-scale geological cross-sections used to constrain the 3D model (Figure 8).

Geophysics

The seismic section (Figure 9), has been used as a backdrop for an interpreted section in the model. The aeromagnetic data for Broken Hill made a contribution in the creation of the 3D model. The Euler deconvolution was used to generate depth to the tops of magnetic body units. These mostly pick up the Redan and Ednas Gneisses (south-east of the project area) and iron formations (Figure 10).

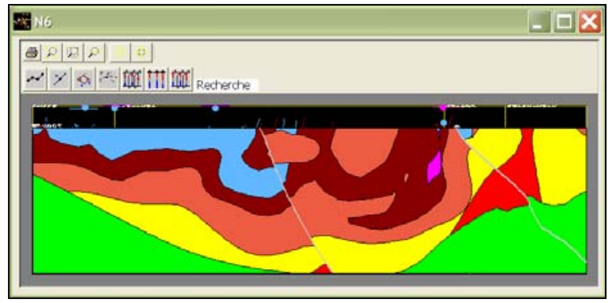

Figure 8. Section N5 in the 3D model.

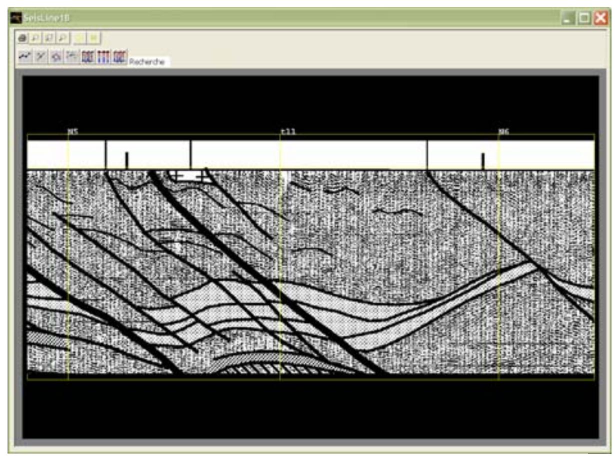

Figure 9. Seismic section with interpretation.

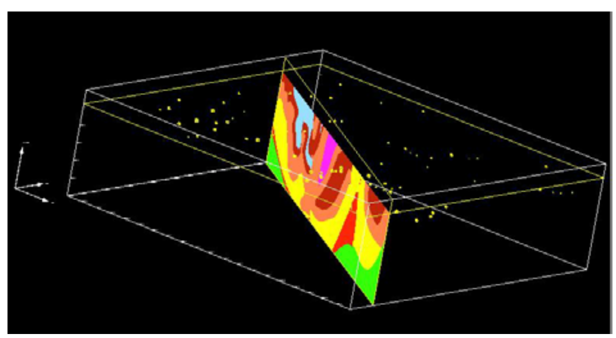

Figure 10. Using Euler Clustered depths from the magnetics to help define tops of magnetic units in Broken Hill region.

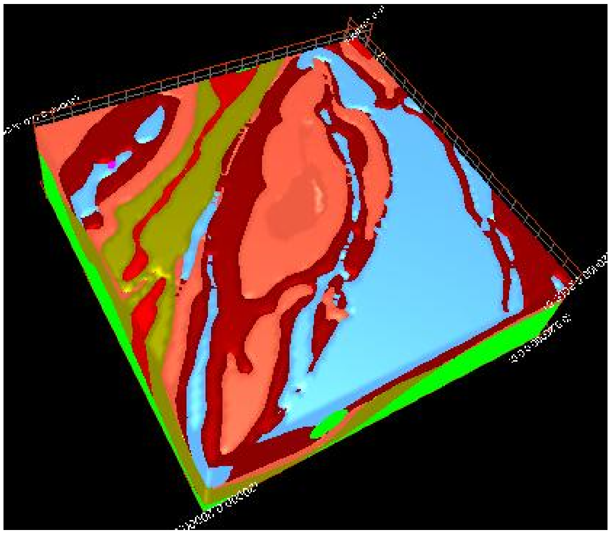

Figure 11. Perspective view of solid 3D geological model of Broken Hill.

Conclusions

The Euler method provides rapid depth estimates from potential field data. Recent improvements, together with modern visualisation, provide a quick insight into regional depth-to-basement variations. Improved accuracy will be achieved with careful attention to detail, calibration using other methods and use of clustering and spatial sorting. In some cases, depth solutions within ±15% of those observed by the Naudy method are achieved and within ±15% of true basement depth where this is known from drilling. Euler results may be used to constrain sophisticated 3D geological modelling

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Acknowledgements

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