Depth to Basement calculation in Southern Thomson, QLD.

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SUMMARY

The southern extension of the Thomson Orogen near the New South Wales border in southern Queensland is an underexplored greenfields area with mineral potential. The uncertainty surrounding cover thicknesses in the area leads to increased exploration risk. Calculation of a depth to basement surface lowers risk for greenfields explorers and is a valuable contribution to regional geological understanding.

Available drillholes show basement depths vary from about 100m to over 3km in the study area but data is too sparse to create a reliable surface. A combination of different automatic depth to basement techniques, including Euler deconvolution and Naudy, were used to create a depth to basement surface. These techniques were preferred due to a regionally extensive high frequency, low amplitude magnetic signature attributed to shallow sources in one of the cover sequences in the study region.

A combination of Geosoft's Located Euler and standard Euler Deconvolution were used to calculate depth to basement solutions. Naudy depths were also compared to the Euler solutions, particularly in areas where the drill holes indicated the basement was relatively shallow (where smoothing associated with gridding can cause overestimation of source depths) or dyke-like features were present.

Seismic data available in the north of the study area was interpreted and used as a secondary quality control check (along with the drill hole data) on the basement surface. The final depth to basement surface defines an area of shallow basement in the south-west of the study area.

Key words: Depth to basement, Euler, Naudy, Southern Thomson.

INTRODUCTION

Depth to crystalline basement is a major consideration when conducting minerals exploration. The thickness of sedimentary cover concealing mineralised basement rock is a primary factor in determining whether economic greenfields exploration is viable. In areas of intensive exploration and drilling, a reasonably accurate depth to basement surface can be created using drilling intercepts. However large areas of Queensland, which are potentially prospective, do not have the benefit of extensive exploration to define the depth to basement. In these areas other methods must be used to estimate the depths.

There are many depth estimation methods which use magnetic data. These methods include: Naudy, Werner Deconvolution, analytic signal, Euler Deconvolution, Euler Deconvolution of the analytic signal, source parameter imaging, and continuous wavelet transform (Li, 2003). Each method has individual strengths and weaknesses which must be assessed in relation to the data quality and purpose of the depth estimation. For example, some depth estimation techniques use higher order

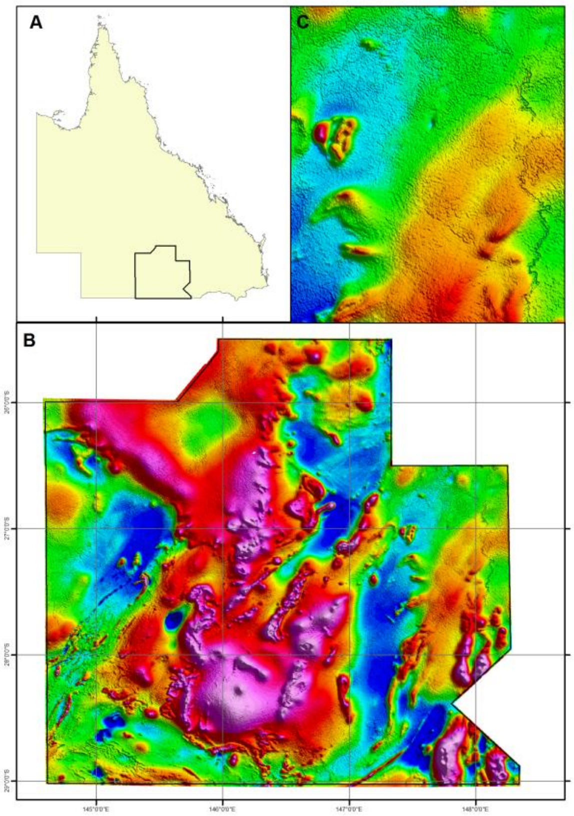

Figure 1. A. Location of the depth to basement study. B. Airborne magnetic data from the Thomson and Thomson Extension surveys conducted on behalf the Geological Survey of Queensland in 2011-12. Data was collected on 400m spaced E-W lines at a nominal height of 80m. C. Detailed image of the high frequency signal which covers the project area. Note the apparent fluvial features and also the extensive nature and low amplitude of the signal.

(2^{nd} order and above) vertical derivatives which accentuate noise and shallow sources in the data. It is good practice to use more than one method to obtain more accurate depth estimates (Li, 2003; FitzGerald, 2004).

The area selected for this study in central southern Queensland has limited drilling data and the current depth to basement surface contains large areas which are unconstrained due to the absence of drill holes (Brown *et al*., 2012). Basement in the study area is defined as the mildly metamorphosed sediments, volcanics and intrusives of the Thomson Orogen. Basement surface exposure is confined to very small areas in the south west of the study area, indicating at least the local presence of cover shallow enough for economic exploration. This area is potentially prospective for orogenic gold (Purdy et al., 2013), but remains largely unexplored partly due to the uncertain extent of shallow cover over mineralised basement rocks.

Using magnetic data from the new Thomson and Thomson Extension airborne surveys (Figure 1) a depth to basement surface was created. This depth to basement surface contains much greater detail and is significantly more robust than earlier surfaces created using the sparse drill hole data available for the region.

SELECTION OF TECHNIQUES

As mentioned previously it is important to select appropriate depth to basement estimation techniques. It is also important to assess whether the underlying principles of the depth estimation techniques are applicable to the study area.

All of the conventional depth estimation techniques use depth to magnetic source as a proxy for depth to basement and assume that there are no significant magnetic sources in the cover sequences. The other key assumption of automated depth to basement calculations is that the magnetic sources are located at the top of the basement interface, rather than below it. Based on magnetic susceptibility data collected from drill core in the study area this appears to be a valid assumption. However, visual inspection of the data shows a very short wavelength magnetic response covering the entire survey area (Figure 1). This signal has the same characteristics in areas where drilling shows basement at over 1km depth, as it does in areas where the basement is only 100m deep, suggesting that it is unrelated to the basement depth. The very short wavelengths suggest that the sources of the anomalies are shallow and in some areas the signal appears to define fluvial channels, although its widespread nature indicates its origins are not restricted to fluvial processes. This short wavelength signal has a significant impact on the selection of an appropriate depth estimation technique.

Initial modelling conducted as part of this project suggested that the depth of source for this short wavelength anomaly is up to 250 m deep. These modelled depths were deeper than expected so an inspection of the top 300 m of drill core from GSQ Mitchell 1 and GSQ Quilpie 1 was conducted.

GSQ Mitchell 1 did not have any elevated magnetic susceptibility values. GSQ Quilpie 1 had an area of anomalous magnetic susceptibility values at depths between 96.5 and 120.5 metres. The core in this section is a silty sandstone with minor carbonates and has been interpreted as part of the Mackunda Formation (John, 1987). There was little or no visible magnetite present in the core, but magnetite grains were recovered from crumbled core using a magnet. The magnetic susceptibility values, measured with KT-9 magnetometer, for the anomalous section were generally between 0.3×10^{-3} and 0.5×10^{-3} SI. The susceptibility was not evenly distributed with localised values of up to 6.4×10^{-3} SI measured. The average values are at least an order of magnitude higher than would be expected for sandstone. It is likely that this section of core is the cause of the high frequency signal displayed in the magnetic data.

The impact this signal has on depth to basement calculation is significant, particularly for techniques which use vertical derivatives. The signal could not be easily filtered out of the data as the frequency is of a similar magnitude to the response of the shallow basement in the south west of the study area.

Careful selection and use of depth to basement techniques was the key to dealing with the high frequency signal. The two techniques which were chosen were Naudy and the Euler deconvolution technique.

AUTOMATED SOLUTIONS

Two main automated depth to basement techniques, Naudy and Euler, were used in the study area. Both techniques were applied selectively and the solutions were analysed thoroughly to ensure that the solutions generated were plausible. The solutions for each technique were compared to the known depths from drill holes (Figure 2). If the solutions near drill holes agreed with the basement depths from drilling the set of solutions was considered to be reasonably accurate.

Several settings in the Naudy technique were altered in order to nullify the effect of the high frequency signal previously mentioned. While the high frequency signal had a similar frequency to the shallow basement in the area, the amplitude of this signal was very small compared to the basement. Naudy solutions were calculated where the minimum anomaly was greater than 3nT, which suppressed the influence of the high frequency signal. The Naudy algorithm was allowed to generate solutions with negative susceptibilities as there are clearly areas of remanent magnetisation in parts of the study area.

Use of Euler Deconvolution to calculate reasonable depth to basement solutions was more challenging than the use of Naudy. Euler relies on the correct selection of window size and structural index in order to calculate meaningful solutions. These were selected based on analysis of the magnetic data. During this study it quickly became evident that the standard Euler Deconvolution was being severely effected by the presence of the high frequency signal. Geosoft’s Located Euler Deconvolution was used to minimise the effects of the high frequency signal. This method is calculated using the analytic signal grid. The software uses an algorithm to automatically calculate the location and size of the anomalies in the analytic signal grid. The Located Euler then calculates Euler solutions at each of the locations with optimised window size based on the size of the anomaly. As with traditional Euler Deconvolution an appropriate structural index must be chosen to create meaningful solutions (Reid *et al.*, 1990; Saleh and Pasteka, 2012). The high frequency signal was present in the analytic signal grid but had a very low amplitude response. Settings in the Located Euler enabled solutions to be calculated based on amplitude, allowing the effects of high frequency signals to be mitigated.

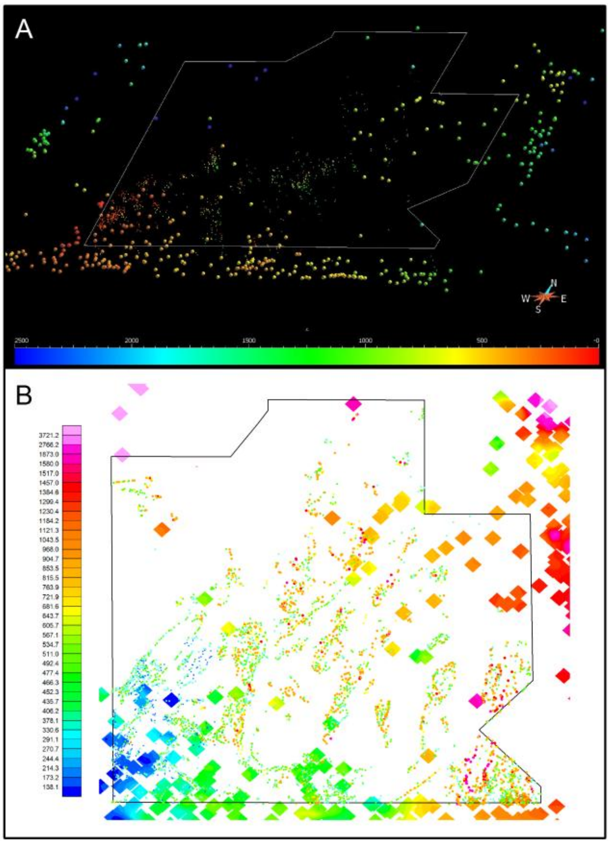

Figure 2. Solutions from Naudy and Euler Deconvolution were assessed for accuracy in 2D and 3D. In each situation the same colour stretch applied to the solutions and the drillholes for easy comparison. A. Drillhole locations (spheres) and Naudy solutions (points) in 3D visualisation package. B. Located Euler SI=0.5 solutions (points) viewed with the gridded drillhole data.

MANUAL MODELLING

Some areas in the study did not produce any reasonable solutions using automated depth estimation techniques. This occurred in 2 main areas, the southeast and the northwest. In the northwest seismic data was available to constrain the depth to basement, but no seismic data was available in the southeast. In this area manual modelling was undertaken, with forward modelling of magnetic profiles used to provide depth to basement estimates.

SEISMIC DATA

Using RMS velocities from seismic sections in the area, depths to acoustically different layers were calculated. This enabled depth curves to be constructed which were subsequently brought into 3D visualisation software in an attempt to match reflecting interfaces with the surface created by Naudy and Located Euler solutions. This provides the ability to match the interface to the appropriate unit boundaries using nearby drill holes. This interface would be invaluable if it could be identified in sections across the whole area where drill holes are limited.

COMBINING SOLUTIONS

The depth to basement estimates from the various techniques and data sources were combined into a single surface. This was done in stages using 3D software. The solutions from the various techniques were ranked in terms of reliability. Drillholes were the most reliable, followed by seismic interpretation, manual modelling and finally the automated solutions as the lowest reliability. The solutions were combined so that in any given area the most reliable type of depth information was used to constrain the depth to basement surface. Solutions from all methods were analysed to assess their agreement. Lower reliability solutions were not used to constrain the surface where more reliable options were available.

The geological character of the basement was a prime consideration when determining the appropriate use of the Euler and Naudy techniques for assessment of basement depths. In the south west of the study area where basement is shallowest, the magnetic data show a series of linear magnetic and remanent magnetised anomalies which appear to be dyke-like features. In this area the Naudy depth solutions were preferred as they are calculated from the line data rather than from the gridded data as used for the Euler solutions. This allows accurate calculation of shallower solutions. Naudy solutions outside this southwest area were considered to be less accurate as there are no obvious dyke structures in the magnetic data. Outside this area the located Euler solutions were used as the major constraint on the depth to basement surface.

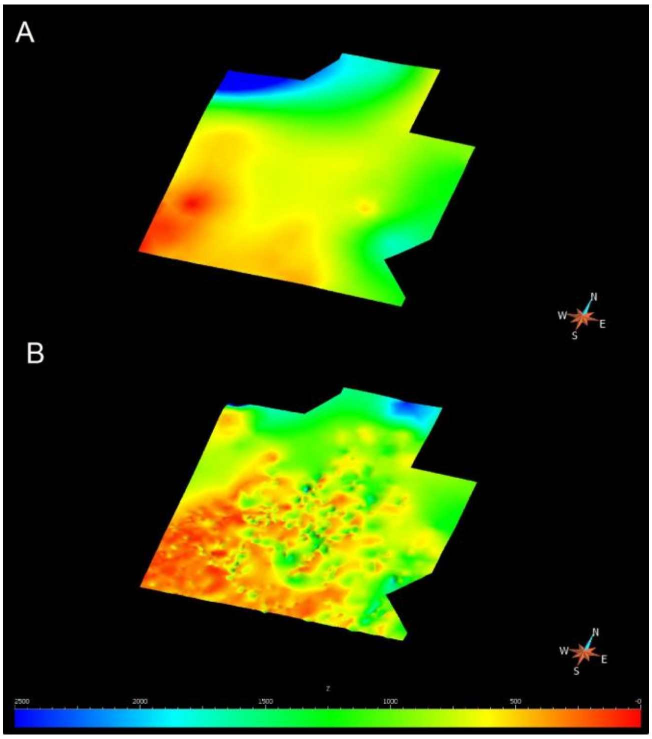

Figure 3. Colour scale indicates cover thickness (0m to 2500m (red to blue)). A. Initial depth to basement surface constructed from drillhole intercepts. B. Final depth to basement surface incorporating all available depth information.

CONCLUSIONS

The final basement surface (Figure 3) shows a sizable area of reasonably shallow cover in the southwest of the project area. The addition of automated depth to basement estimation techniques provided a valuable contribution to understanding cover thicknesses in the Southern Thomson area. The presence of a reasonable number of drill holes was essential to identifying valid solution sets produced by either Naudy or Euler techniques. Overall the combination of drill holes, seismic data, manual modelling and automated modelling provided a more robust and detailed surface than the use of any dataset in isolation. Careful consideration should be used when applying this technique to areas with severely limited drillhole information.

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