Mapping depth to crystalline basement in South Australia

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INTRODUCTION

A long time goal of many exploration companies and Geological Surveys, has been to develop an accurate depth to economic basement map. The horizons from both drill hole basement and magnetically derived basement depths can sometimes be considered as one, however, in many cases, magnetic horizons are much more complex. This can result in depths originating higher up, as well as lower down, the geologic pile, and therefore, not coinciding with logged economic basement from drill holes.

Rather than economic basement we consider crystalline basement, which has been objectively defined for different geological regions throughout South Australia. Within the Gawler Province this is defined as Mesoproterozoic and older rocks affected by the Palaeo-Mesoproterozoic Kararan Orogeny and older events; this definition includes the Itiledoo Basin but excludes the Cariewerloo Basin. The eastern and southeastern margins of the area are placed along the eastern edges of the Torrens Hinge Zone and Stuart and Spencer Shelves and along the Kangaroo Island Shear Zone. These included areas are relatively unaffected by the Delamerian Orogeny. The Gawler Province and specifically, the Olympic Dam region, form the current focus area, however it is planned to extend this research to the entirety of the state.

The first magnetic basement contour map published by the Department over two decades ago, was a direct result from hand calculations incorporating the half slope method of Peter's. Results from this initial work are still considered to be quite accurate.

This method has been successfully incorporated into Matlab code which is currently being utilized to calculate a new set of magnetic basement depths for South Australia. Figure 1 shows a preliminary example of depths over the Gawler Province created using this code.

The slope method is applied to TMI data and due to the magnetic nature of the basement rocks in this region can be taken as a reasonable estimate of depth to crystalline basement. These depths are then constrained using drill hole information. Further work will aim to incorporate structural information such as faults and surface geological mapping to improve the depth estimation of the region.

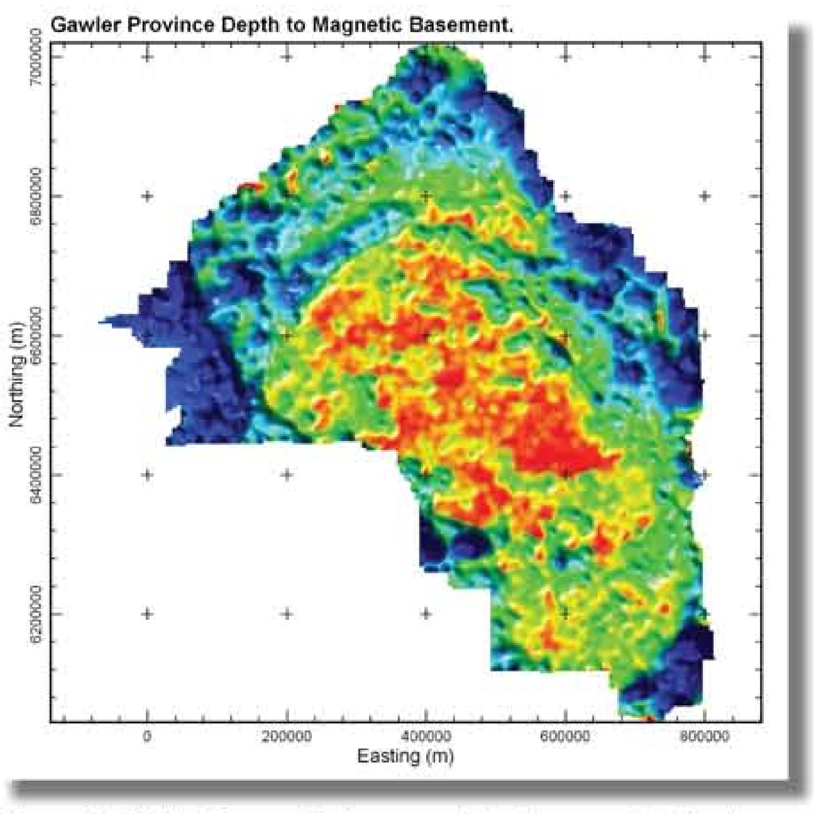

Figure 1 Grid of magnetic basement depths over the Gawler Province, South Australia, as derived from the straight slope method.

METHOD

Estimation of depth of magnetic anomaly is based on the slope of the curve created by the anomaly in a profile of magnetic data. The depth of an anomaly is related to the horizontal extent of the tangent to the maximum slope (figure 2) such that:

$h = kS$ (equation 1)

where h is the depth, S is the horizontal extent of the tangent and $1.67 \leq k \leq 2.0$ (generally k = 1.82).

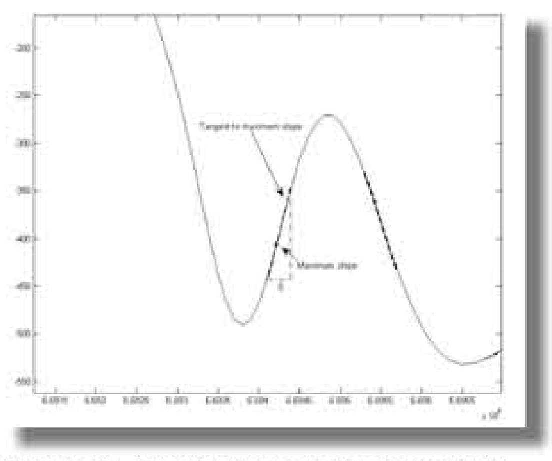

Figure 2 Depth of magnetic anomaly is related to the horizontal extent of a tangent that approximately fits the line of maximum slope.

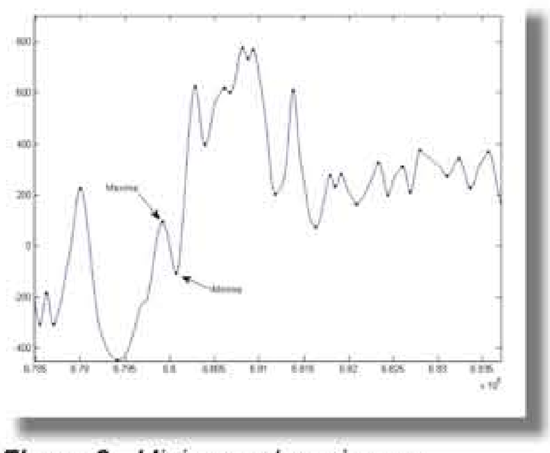

Figure 3 Minima and maxima are identified along the entire line of magnetic data (equations 2 and 3).

The manual process of assessing individual lines, selecting ideal curves and estimating the depth based on slope has been successful in the past however is extremely time consuming. In order to be successful for large scale aeromagnetic datasets the method needed to be automated. A series of functions were written in Matlab that take line data (synthesized from TMI grids) and break individual profiles into ideal curves that can then be assessed.

Individual curves lie between adjacent minima and maxima. These points are automatically located by considering whether a point is greater or less than adjacent points. Point yi is defined as a maximum if:

$y_{i-1} + \Delta y < y_i > y_{i+1} + \Delta y$ (equation 2)

And as a minimum if:

$y_{i-1} - \Delta y > y_i < y_{i+1} - \Delta y$ (equation 3)

Once maxima and minima are identified the shape of the curves lying between them can be assessed. There is a high density of curves from which depth can be estimated so only simple curves are considered; those created by interfering magnetic anomalies or small enough to be contained within noise are ignored. Curves that have too small a maximum slope (approximating flat lines – figure 4a) or cover very small x separations (spikes) are ignored. To ensure a simple shape, curves are compared with a best fit cubic polynomial and if the fit error is too great these are also ignored (figure 4b). The size of the maximum slope, the x separation and the fit error are all variables that are changed on trial lines of data in an iterative process to improve the quality of curves that are considered. These variables will change considerably across the state as the regional magnetic signatures change.

Once these settings are determined the function automatically loops through each line in the data set, determines curves along the profile and then the maximum slope for each curve is calculated and tangents fitted to these slopes (figure 5). Depths to anomalies are then estimated via equation 1.

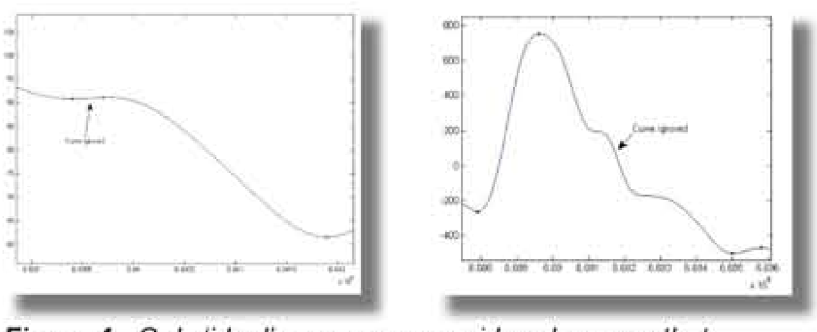

Figure 4 Only 'ideal' curves are considered, curves that approximate flat lines (a) and that are created from overlapping magnetic signatures (b) are ignored.

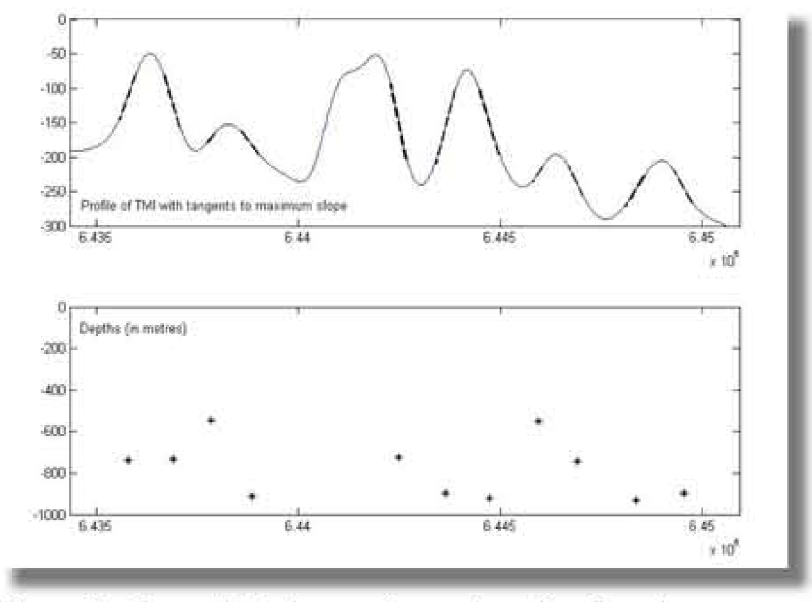

Figure 5 Tangents to the maximum slope (top figure) are fitted to individual curves along the line and a depth related to the horizontal extent of the tangent calculated (bottom figure).

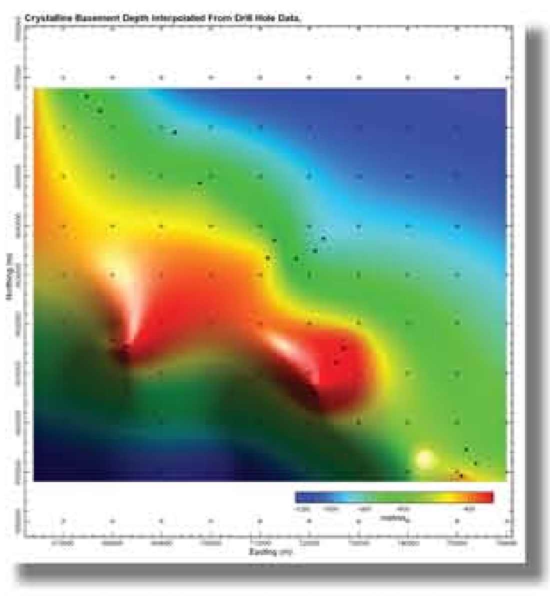

Figure 6 Drill hole depths within the Olympic Dam region. Drill hole locations are also shown.

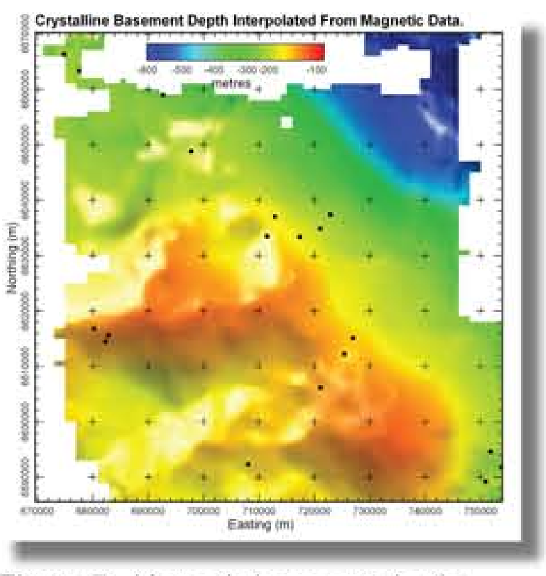

Figure 7 Magnetic basement depths gridded using the kriging algorithm, with drill hole locations.

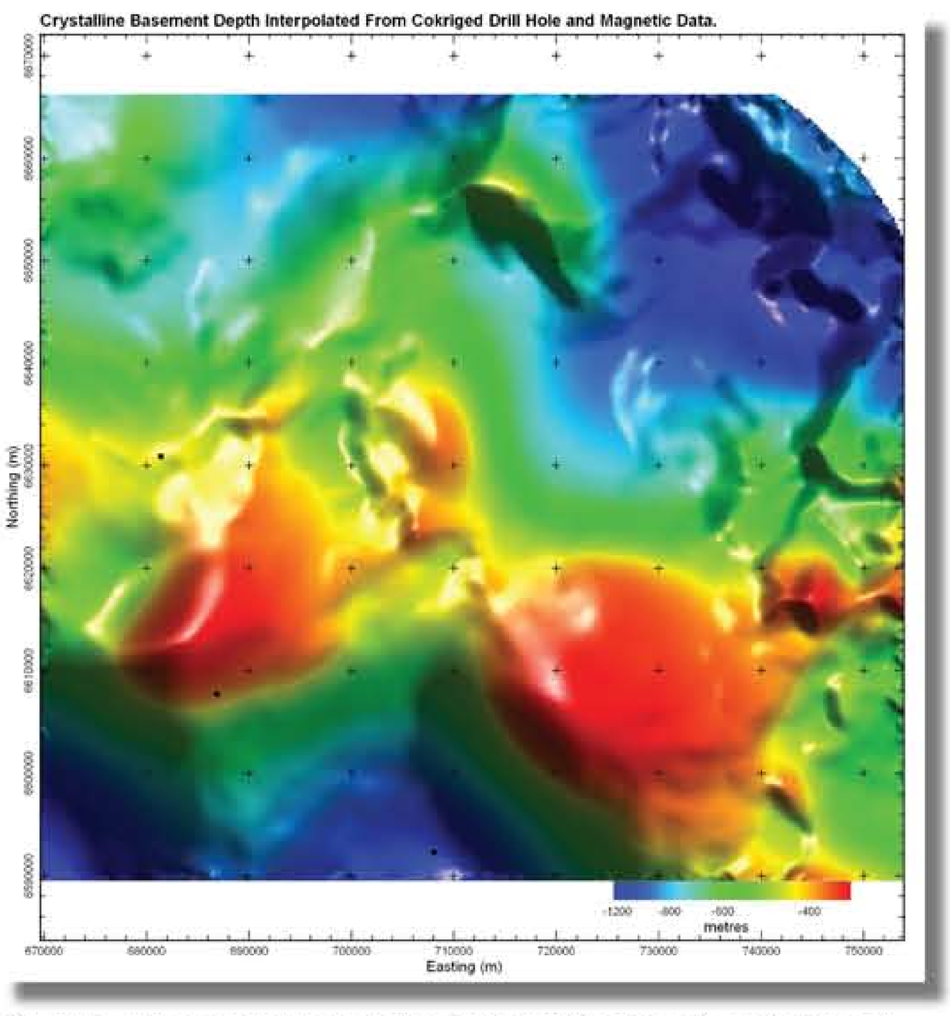

Figure 8 Final crystalline basement grid resulting from the cokriging of drill hole and magnetic basement depths derived from the slope method. IOCG locations are also shown.

DEPTH DISPLAY

Depth results from this process can be displayed as either profiles for 2D data, or point contours and grids for 3D results.

The kriging method was applied in this study and essentially uses a weighted average of neighboring points to estimate the value of an unknown point on a regular grid. Experiments showed that this method produces a cleaner result, than other gridding methods.

TOWARDS A NEW CRYSTALLINE BASEMENT DEPTH MAP

Once basement depths have been determined, the next stage is to attempt to combine these calculated depths, with measured geological depths from drill hole information into a meaningful and internally consistent basement depth product.

This can be accomplished in areas where the magnetic and geologic datasets are highly correlated and therefore likely to indicate the same horizon.

Investigations have shown the most effective method towards this aim is to incorporate the cokriging method.

Cokriging, is an enhancement of the kriging algorithm, in which the estimate of an unknown point is derived using both autocorrelation from the main variable of interest and cross-correlation from a second variable, to make better predictions.

A small area covering the Olympic Dam deposit, has been chosen to demonstrate the results. The Olympic Dam and neighboring IOCG deposits have been overlain on each figure.

The resulting grid derived entirely from the drill hole data (figure 6), exhibits similar basement trends as calculated from the magnetic data, which has been gridded using the kriging method (figure 7). There are 19 drill holes in the area of interest, creating a very smooth grid with only large scale variation in depth. Close examination of both grids, indicates a good correlation between the magnetic and drill hole datasets, however the magnetic dataset contains significantly more information. To this end the data was further cokriged to produce a final crystalline basement depth dataset that incorporates information from both the known stratigraphy and calculated magnetic basement depths. The resulting image (figure 8), stays true to the drill hole data whilst incorporates the additional information contained within the magnetic data.

THE FUTURE

This methodology will now be extended to the whole of South Australia, on an individual Craton and margin basis. A petrophysical database is currently in creation which will enable better definition of the expected geophysical anomalies associated with the crystalline basement in these regions. Final depth estimates will then be merged into a new State crystalline depth dataset.

ACKNOWLEDGEMENT

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PACE

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HOT PROSPECTS