Three-dimensional extension of the Hill End Trough based on the modelling of the regional gravity data

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SUMMARY

Computer modelling was used to establish basement architecture of an inverted sedimentary basin using regional gravity and interpreted geology. The gravity data reflect the response of the Ordovician volcanic basement of the Hill End Trough. The three-dimensional model of basin opening indicates "*chocolate-tablet*" type extension in response to opening of the trough along a small circle about a pole of rotation to the northwest. There is a strong correlation between the basement architecture and plunge changes in surface folds and also with mineral deposits in the Silurian-Early Devonian fill of the Hill End Trough.

Key words: gravity, modelling, basement architecture, mineral deposits.

INTRODUCTION

The mid-Silurian to Early Devonian Hill End Trough, as defined in this paper, is bounded to the south by the Carboniferous Bathurst Batholith and the Lachlan Transverse Zone (Glen & Walshe 1999) and to the east and west by Ordovician volcanics that are overlain by thin Silurian-Early Devonian rocks and intruded in part by Carboniferous granites (Figure 1). The trough is one of several back arc basins developed in the Eastern Lachlan Orogen in central New South Wales (Glen 1992) and was deformed in the Middle Devonian (Glen & Watkins 1999, Packham 1999) and probably also in the Carboniferous (Glen & Watkins 1999). Flanking Ordovician volcanics show strong positive anomalies in the regional gravity field. The trough itself is associated with a lower gravity signature decreasing from north (and northeast) to the south: the lowest gravity values (~700 gu) are associated with the WNW trending granites of the Carboniferous Bathurst Batholith (Figure 2). Glen and Walshe (1999) suggested that this north-to-south gravity gradient reflected the southward thickening of Silurian and Devonian sedimentary fill of the Hill End Trough and thus deepening of basement. This interpretation has been updated by new modelling of gravity data reported here which has led to new ideas about basement architecture and trough formation.

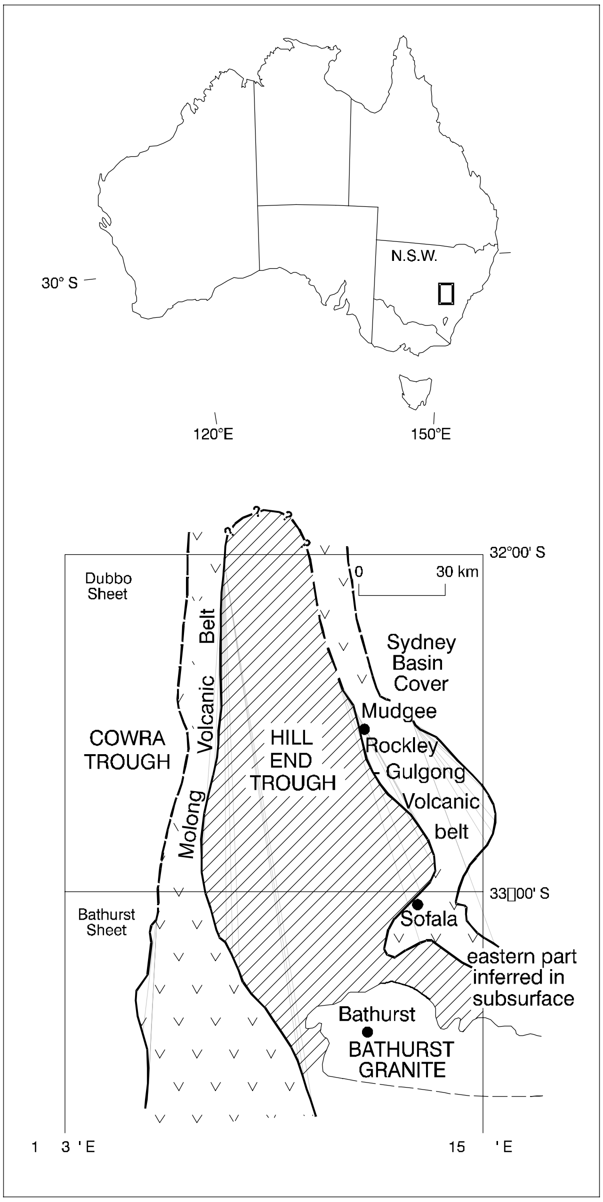

Figure 1. Generalised outline of the Hill End Trough.

GRAVITY INTERPRETATION AND MODELLING

Computer modelling has been performed using *ModelVision*™ software and qualitative interpretation has been carried out on contoured gravity data (Figure 2). Three E-W and two NNW-SSE sections were modelled to assist the interpretation. In order to simplify the modelling, lithologies were divided into four groups of similar petrophysical properties. The first group, Ordovician volcanics, consist of mafic and intermediate volcanics (gabbro, basalt, andesite, monzonite) and mafic volcaniclastics with a density range of 2.80 – 2.88 T/m^3. Ordovician volcanics crop out on the eastern and western trough margins and are inferred to underlie the Hill End Trough. The second group consists of Ordovician quartz - rich turbidites, with an assumed density of 2.72 T/m^3 on the eastern side of the Rockley - Gulgong volcanic belt. The third group is the Silurian- Early Devonian basin fill, comprising interbedded slightly metamorphosed volcaniclastic sandstone-siltstone-shale (referred to as slate) with lesser felsic volcanics with densities in a range from 2.64 to 2.72 T/m^3. Fourthly, Carboniferous porphyritic to equigranular biotite granites that intruded basement and basin sequences have a large range of densities 2.59 – 2.74 T/m^3 due to a variable silica content. Density values are about 10% higher than those used by Direen et al. (2001). Modelling of the five cross-sections led to inferences about thickness of mid Silurian–Early Devonian basin fill, depth to Ordovician basement and basement architecture.

INTERPRETATION OF GRAVITY DATA

High gravity values flanking the Hill End Trough coincide with Ordovician volcanics and converge to the north (Figure 2), indicating that the Hill End Trough narrows to the north. These volcanics and overlying Silurian-Early Devonian cover, are partly intruded by Carboniferous granites (Figure 3). The Rockley-Gulgong Volcanic Belt east of the Hill End Trough is juxtaposed to the east against mapped and inferred Ordovician turbidites (Adaminaby Group). A northwest belt of gravity highs in the northeastern part of the area (Figure 3) is interpreted as a third belt of Ordovician volcanics below the thin cover of the Sydney Basin.

The relative gravity low between the flanking highs over Ordovician volcanics coincides broadly with the Hill End Trough. However, superimposing geology on top of the gravity shows that there is little correlation between gravity data and the geometry of regional units filling the trough, especially in the north. This led to the suggestion that the gravity values over the trough are largely a response to deeper Ordovician volcanic basement (Glen & Walshe 1999). The stepwise reduction of this gravity low from north to south was interpreted by them as a reflection of Ordovician basement deepening to the south, a consequence of the thickening of trough fill from north to south during rifting.

This interpretation is now being updated. Contoured gravity data displays blocks of low-gradient Bouguer gravity separated by high gradient zones (Figures 2 and 3). The low gradient blocks display progressively lower gravity values from north to south and from east to west. There are two orientations of steep gradient zones: one set trends NE, while the other set swings from NW in the south to NNW and N tends in the north of the basin (Figure 3).

BASEMENT ARCHITECTURE

The distribution of high (steep) and low (flat) gravity gradient zones have been used to develop a three-dimensional model of the basement architecture of the Hill End Trough. Potential field modelling software used imposes constraints on visualisation: the central parts of zones of steep gradient are represented only by discrete vertical surfaces (Figure 3); and it has not been possible to subdivide the high-strain zone along the western edge of the trough.

Gravity modelling also indicates that the deepest part of the basin (> 7 km) occurs on the western side and it is interpreted to be an early depocentre of the trough, shallowing to the east and north. This depocentre is largely overlain by the Cunningham Formation, which comprises the youngest stratigraphic unit in the trough. Gravity modelling indicates that the low-gradient zones are the tops of tilt blocks of basement Ordovician volcanics and the zones of steep gravity gradient are steeply dipping normal faults. The three dimensional array of steep gradients suggests normal faults throwing down both to the south and west as well as to the east (Figure 3). Modelling also suggests that the Carboniferous granites are strongly controlled by the intersection of NE-trending cross structures with NW to NNW trending structures, implying some reactivation on these features during the Carboniferous. Modelling of gravity and magnetic data in *ModelVision*™ (supported by *QuickMag*™ modelling) suggests that the interpreted Carboniferous granites were emplaced at depths of 5 – 10 km and also increase in size with increasing depth.

BASIN EXTENSION MODEL

Because the gravity data reflect the present-day distribution of the inverted basement blocks, they postdate the inversion of the Hill End Trough. While it is interpreted that the architecture was inherited from rifting during formation of the Hill End Trough, at this stage it is unclear how much of the basement architecture was modified by subsequent contractional deformation. If basement blocks were bypassed during the contraction, with a decollement at the base of the basin fill, there would have been little reactivation of normal faults at the level of basement and little internal shortening of basement blocks themselves. Alternatively, if the basement blocks were fully involved in the contraction, allowance for this needs to be made in the interpretation of rift geometry. The east-west composite deep seismic reflection line across the Molong Volcanic Belt and into the western part of the Hill End Trough provides some controls. Interpretation of this line by Glen et al. (2002), suggests that while there was probably partial reverse reactivation of extensional faults at the level of Ordovician basement, complete reverse reactivation only occurred along one fault at this stratigraphic level.

With this caveat, it is suggested that two sets of normal faults can be interpreted from the contoured gravity data. This implies that the Hill End Trough opened in two directions:

one direction oriented NW-SE, predominantly in the south, and the other direction rotating from NE-SW in the south to E-W in the north. It is inferred that both sets of extensional faults were coeval, in "*chocolate-tablet"* type extension, although there may have been local switching between sets, with one set acting as accommodation zones during any one increment of extension. The presence of complex directions of extension is consistent with the trough closing the north, implying opening occurred along an approximate small circle about a pole of rotation to the northwest.

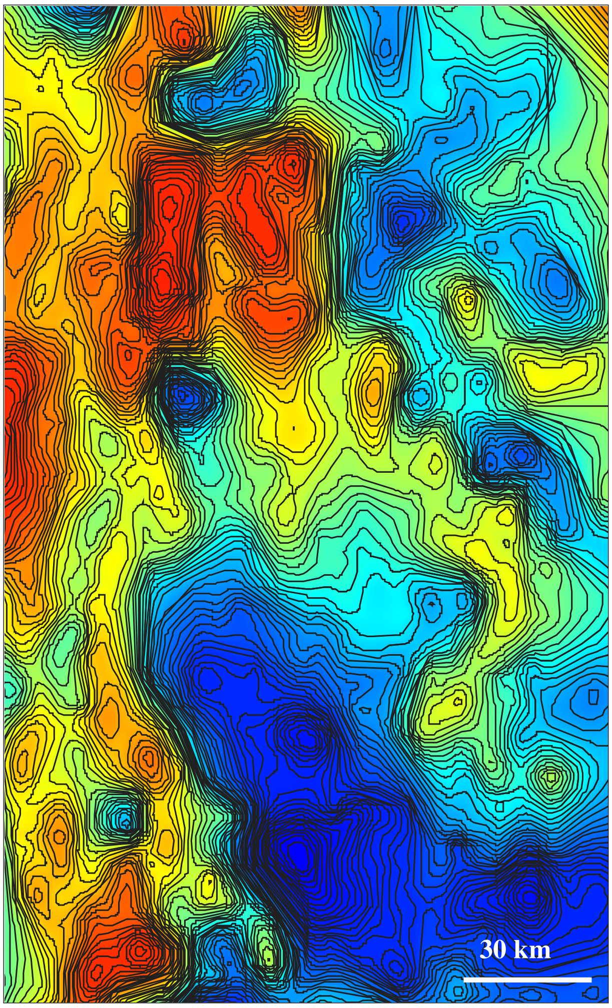

Figure 2. Regional gravity image (4 x 5 km grid) with contours above the Hill End Trough.

EFFECT OF BASEMENT ARCHITECTURE ON DEFORMATION OF TROUGH

There is a strong correlation between plunge changes in folds in fill of the Hill End Trough and the location of NW trending normal faults (albeit only shown to date in the modelling as vertical traces) in the underlying Ordovician basement. The suggestion that these plunge changes reflect subtle reactivation of basement blocks during basin inversion provides an explanation of the transverse zones inferred by Glen (1999).

There also appears to be a significant link between interpreted basement architecture and the location of major mineral deposits. For example, the Stuart Town goldfield is clustered above the intersection of a NE trending structure and nw structure. The Hargraves and Windeyer goldfields lie above one rectangular block oriented northwest. The Hill End goldfield lies above a corner zone between two intersecting faults. It thus appears that basement fault zones acted as efficient pathways in transferring metals and solutions from Ordovician basement into suitable traps in the fill of the Hill End Trough.

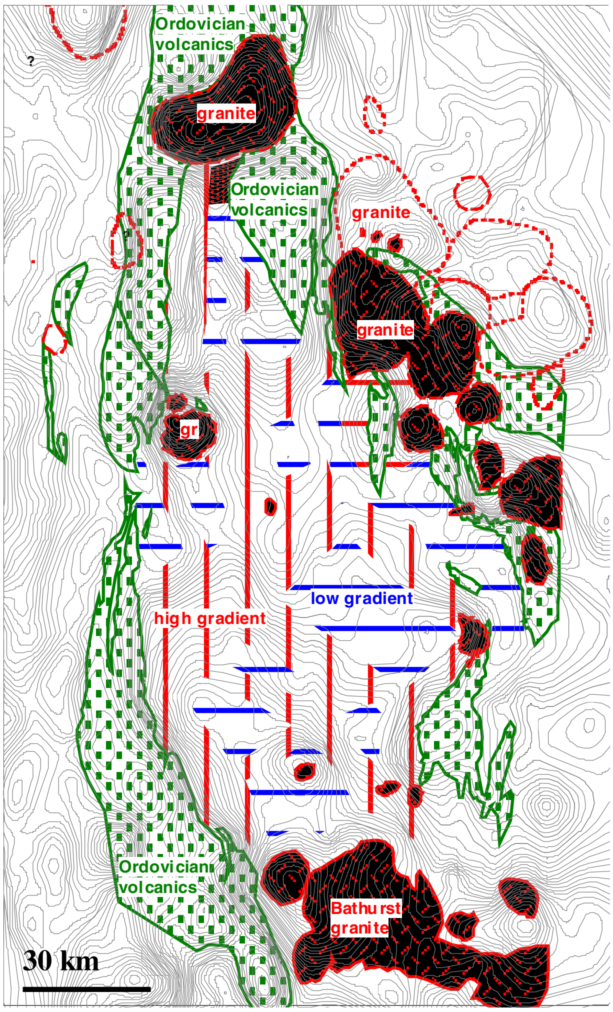

Figure 3. Subdivision of gravity contours with high gradient high (steep) zones (red vertical lines) and low gradient low (flat) zone (blue horizontal lines). Red circular features define outcropping and interpreted granites and green outlines outcropping Ordovician volcanics.

CONCLUSIONS

Modelling of regional gravity data collected from the Hill End Trough has led to the following interpretations:

- The Hill End Trough coincides with a zone of low gravity response underlain by Ordovician volcanics.
- The low gravity response reflects dense basement Ordovician volcanics and volcaniclastic rocks buried by Silurian-Early Devonian fill of the trough.
- Gradients in the contoured gravity data are interpreted to be the effects of Silurian-Early Devonian extension in

Ordovician basement below the Hill End Trough. The inferred presence of two (NE and NW-N tending) sets of extensional faults separating tilt blocks suggests the trough opened by three-dimensional "*chocolate-tablet*" type extension.

- The maximum thickness of the Silurian-Early Devonian sediments exceeds 7 km on the western side, thinning across partially reactivated extensional faults to the east and north.
- Partial reactivation of basement faults has produced changes in plunge of regional Silurian-Early Devonian trough fill.
- Basement faults acted as efficient plumbing systems during mineralisation.

ACKNOWLEDGEMENTS

Published with the permission of the Director-General of the New South Wales Department of Mineral Resources. We thank Jeff Vassallo for comments on the manuscript. We also thank our colleagues for support during this project.

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