Architecture of the Georgina Basin, Northern Territory from interpretation of new Gravity gradient data

**Introduction**

- This work provides an evaluation of newly acquired gravity data over the Georgina Basin block of tenements, and follows on from the regional scale study. As in the regional analysis, the same methodology has been employed, that is, through CSIRO’s worming and Fractore’s post-processing and interpretation of the gradients in relation to a fault framework.

- Data was collected at a ca 2km station spacing. This map shows the regional open file coverage, extracted from GADDS (February 2009), and includes the new close spaced data collected by the NTGS in the south of the tenement block. The non-public domain, 2km spaced, Mincor/JOGMEC data collected within the tenement block is shown in blue. The acquisition of close spaced high quality data in a remote region is a major contribution by the Mincor Zinc/JOGMEC JV which, in collaboration with the NTGS, surpasses many other regions of Australia.
An image of the terrain corrected Bouguer field is the main reference frame for the subsequent processing and interpretation.
Data Processing

- The positions of gradients were determined by the automated worming routine applied to the data using CSIRO’s in-house capability. This generates a 3D floating point data set in upward continued (u.c) space, with the heights of u.c. and their spacing being chosen (by CSIRO) in order to optimise the data. In this case, four different algorithms were applied (see below). The first two are the same as were used in the regional analysis, while the latter two are under development by CSIRO (freely provided to the project). The main difference is that the new processing essentially in-fills the u.c. levels at a regular spacing and results in a fuller visual effect from the worm sheets. Each gives a slightly different emphasis or perspective to the mass of gradients that are detected.
- MAX is the position of maximum gradient over successive heights of u.c., from 720m, spacing factor of ~1.2 across 16 layers.
- 1VD is the position of the first vertical derivative (spaced at same intervals as MAX). This gives better resolution of near-surface gradients.
- Linear Max is where the u.c.intervals are evenly spaced, in this instance at 500m intervals, over 31 layers, from 500m to 15500m height.
- Linear 1VD, as with the Linear MAX but with greater density of surface gradients (as per the 1VD).
- Given the 3D nature of the worm data, it is optimal to use on 3D platforms (e.g. FracSIS?, Gocad). Such data is cumbersome in a 2D GIS platform (e.g MapInfo?, Arcview). Fractore’s proprietary software (Geoscope) was used to provide a suite of images and vector lines that fast tracks the visualisation and interpretation. The lowest (near) surface worms (e.g. at 500m or 720m u.c.) were used as the template for the line interpretation, and other u.c. levels in the 3D volume were explored as a means for discriminating gradients that persist to higher levels. In particular the worm data at 2km height was used in the analysis. This is because the more fundamental (i.e deeper) features are generally better represented at higher levels of u.c., and the high frequency “noise” at lower u.c. levels can be filtered out of the analysis. Selected image outputs are contained in Appendix 1. The images are of:
  - Height (“data”) images are coloured by height value (z) of u.c, from blue (low level) to red (high level). The inference is that the higher level worm sheets (i.e. more continuous across successive u.c. levels) generally relate to deeper seated structures (such as a fault or an intrusive body). There are, naturally, exceptions to this association.
  - Amplitude images are coloured by the amplitude value (w) at each u.c height, from blue (low amplitude) to red (high amplitude). This is a measure of the contrast across the gradient.
  - Migrated images are coloured by the maximum u.c. height of worm sheets (zmax value), with the brighter coloured worms being those that are more continuous across the u.c. heights. This is achieved by using a nearest neighbour algorithm connect downwards across each level, so that the lowest u.c. level data is linked to the highest level of u.c for a particular worm. Such images can be useful in
isolating some of the more fundamental worm features and for delineating faults that break or truncate worm sheets.

- Examples of one of the data sets, using the MAX data at 720m and above, are shown here as images of u.c. height, migrated height and amplitude.

Gravity_MAX_720m+ height data
Gravity_MAX_720m+ migrated height data

Gravity_MAX_720m+ amplitude data

Interpretation
• The mass distribution appears mostly determined by basement components. High density material is characteristic of Proterozoic rocks in the Arunta block to the south, and is emphasised by an elongate NW trending ridge along the northern margins of the region. Low intensity regions immediately to the northeast and west of this ridge are interpreted as probable granites within the basement. These regions show high amplitude variations with curved worm shapes that are generally indicative of intrusive bodies. Some underlie the Georgina Basin in the southern areas of the basin. It is interesting to note a comparison with the Irish Zn province where there is an apparent association of granite-related gravity lows, situated within the basement, and mineralisation in overlying (post-granite) carbonate sediments. Other low regions within the Georgina Basin may be related to increased thickness of sedimentary successions in synclinal positions, particularly in the SW region of the basin.

• There is a broad signature change between the Arunta block basement in the south and the lower density material in the Georgina Basin to the north. This occurs across a series of NW trending gradients which are in part parallel and/or coincident with mapped faults in the region, here termed the Alice Springs Zone (ASZ). These are related to convergence during the Alice Springs Orogeny and are evident in the continental scale data (see regional report). A dominantly southerly dip of this fault system is suggested from the gravity worms.

• A second strong regional contrast is seen from east to west within the Georgina Basin and this gradient is located across the roughly north-south trending Putta-Putta Fault zone through the central parts of the tenement block. This gradient is reflected in the continental scale gravity worm data. High Bouguer gravity responses and higher magnetic intensity signatures exist to the east of the Putta-Putta compared to the west. This might suggest a thinner depth to top of basement to the east, however sediment thickness changes in the Georgina Basin indicate the basin thickening eastwards, and shoaling westwards (B. Groenewald, pers. comm.). An alternative source of the asymmetry in the mass distributions (high gravity and magnetic responses in the east) may be mafic rocks emplaced in the mid crust during Georgina Basin extension; however there is little field evidence (e.g. dyking) to support this suggestion. The Putta-Putta Fault zone is dominated by a laterally continuous, high level worm that migrates westwards across successive u.c. levels. This is interpreted as a west dipping fault. It so, the stratigraphic offset suggests it was a high angle reverse fault post-Georgina Basin. Yet, there is other evidence from within the basin fill that supports an easterly dip.

• Of particular interest are discrete amplitude domains which are elevated above the regional or background population of w values (see Appendix 1), due to the juxtaposition of rocks with contrasting properties. A corollary is that such regions have the potential for variations in strength and competency (such as a granite margin or across a fault) and hence are possible regions that are more prone to dilatant failure and provide fluid conduits during alteration and mineralising events. A further rationale for this suggestion derives from analysis of the Irish Zn
orefield where mineralised and/or altered areas appear to be associated with “warmer amplitude” gravity worms (and may relate at least in part to granites within the basement). Regions of elevated to high intensity amplitude are highlighted as broadly defined polygons. The Putte-Putta Fault zone is a particularly “warm worm” region, with a greater density of broadly coincident gravity and magnetic highs to the east. This is truncated, and rotated in a sinistrally, towards the south against the ASZ, a similarly elevated amplitude domain. Other domains of high amplitude are traced around the edges of inferred granite bodies along the southern margins of the basin. A series of high and moderate amplitude domains occur further north in the basin, mostly outside of the tenement block, associated with gravity highs (and magnetic highs) which probably reflect basement blocks. The high amplitude domains generally mirror the margins of gravity/magnetic highs (mostly basement?) and interpreted granite bodies. With such a heterogeneous basement, it may be possible that topographic effects, such as doming, may have influenced Georgina Basin sedimentation; a possible analogy may be with the MVT district in North America where the margins of uplifts and domes tend to localise ore deposition.

Gravity Domains of coherent amplitude signatures

- The main focus of the interpretation has been to extract the fault-related gradients, given that there is some fault control on mineralisation at Box Hole. Naturally, all potential field gradients are not faults, and not all faults have gradients across them. The interpretation of the fault framework is by necessity subjective, and can change accordingly to the interpreter. The benefit of using worm images is that the processing gives an unambiguous position for the gradient, and is a reference
frame for the interpreter. Importance is also placed on defining linear breaks and offsets in the worm traces as these can represent faults that lack density contrasts across them, yet are an integral part of the fault framework. A line tracing interpretation was carried on A1 size hardcopy maps at 1:400,000 scale. This was digitised and processed in a GIS platform. It is worth noting that the apparent high population of fractures/faults that derive from the worm interpretation are not unusual for a geological province and, given the fractal nature of such data (where outcrop scale patterns are mimicked at regional scales), should be expected.

Fault-related linear elements from gravity worm interpretation

- A general observation from a range of terranes containing sediment-hosted base metal deposits is that long strike length faults are an important control on deposit location, especially those that penetrate the basement. This may be because long strike length are a proxy for deeper penetrating and potentially more mineralising faults. As such, imaging the fault strike length may illuminate the more fundamental faults that have most impact on the 3D architecture and mineral prospectivity. Processing of the lineament data yields strike length images where the longer elements are represented by warmer colours. This emphasises the importance of the ASZ, as a series of NW trending fault zones which coalesce in places, and of the Putta-Putta graben (or horst) block feature. It also emphasises the NE trending system at an apparent regularly spacing across the entire region. These are also expressed in some drainage patterns (B. Groenewald, pers. comm.) and may to originate from Proterozoic age structures (as seen in the Mt Isa region). These may have undergone reactivation through the Palaeozoic, with an apparent offset of elements within the ASZ.
An analysis of interpreted fault intersections was undertaken whereby the overlaps of 1km buffers on the linears were defined, and strike length points contained with such regions were extracted and imaged. Regions were further selected on the basis of intersection intensity as possible target regions where further evaluation may be more cost effective, especially where associated with elevated amplitude regions.
In the regional scale interpretation, a coherence between the gravity and aeromagnetic gradients was highlighted through the strike length analysis. For the current interpretation, the aeromagnetic data was re-visited, this coherence was again emphasised and, rather than attempt to change the aeromagnetic linear data, it was incorporated into a new combined strike length image. This serves to emphasise an interpreted major fault pattern. Blue boxes represent potential target regions. These are defined on the basis of intersection intensity and those that lie in areas of elevated amplitude are higher ranking.
Strike length image of faults from gravity and aeromagnetic interpretations combined, and possible target regions outlined.

- Using this output in particular, and in conjunction with associated data treatments (see Appendix 1), a series of interpreted faults were traced. These represent fault structures that may be of sufficient scale to capture in a regional 3D model. The apparent dip directions are based on the geometries of related worm sheets, but this is not necessarily a diagnostic in all instances. Comparison of the newly interpreted fault frameworks shows similar patterns although differing in detail from the SEEBASE (2002) image of depth to basement.
Line tracing of major or significant fault features and interpreted dip directions, superimposed on SEEBASE depth to basement image.

- Georgina_geol_tens.png:
• Georgina_MAX_720m_data.png:

• Georgina_MAX_720m_migrated.png:
• Gravity Worm Image coloured by Amplitude, from MAX 700m+ u.c. levels:

• Interp_Signatures.png:
• Grav_Length_image.png:

• Grav_Intersection_Length.png: