

**POTENTIAL FIELD MODELLING
OF GEOLOGICAL CROSS-SECTIONS
DUCHESS- URANDANGI REGION
MT ISA BASIN
PRELIMINARY REPORT**

SUBMITTED BY:

SUBMITTED TO:

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BACKGROUND

Five transects of approximately 50km length have been put together by Kathy McKeagney covering strategic components of the southern portion of the Mt Isa Eastern Succession ([Figure 1](#)). The sections have little if no depth constraints other than dip information contained within the published geological maps.

The purpose behind the following potential field modelling exercise was to test and as far as possible, control structural boundaries to depth. Armed with only a high resolution magnetic survey, regional gravity and a scattered petrophysics sampling, it was hoped that developing a consistent geometry between the 5 parallel cross-sections would help constrain modelling at depth. Any improvement to modelling beyond simply a mass and magnetisation balance to the observed data, would help in the understanding and development of regional architecture

The following report presents the final albeit non-unique model developed from the potential field (PF) data. Constraints, process weaknesses and recommendations on future work are also documented.

PETROPHYSICS

On a regional basis, the Mt Isa petrophysics database available for the above exercise is relatively comprehensive (Appendix I) and with few analogues in Australia. There are some notable sampling exceptions particularly for lower Proterozoic rocks and basement, and the intra-population sampling very limited.

Nevertheless, in the absence of anything better, the dataset has provided benchmarks for density and magnetic values for most of the units covered by the cross-sections. Additional comments are as follows:

1. Granite susceptibility and density are as varied as their compositions within the region. Many of the granites are extremely magnetic; often in excess of 10000×10^{-6} SI. According to Rubenach M. (2003, pers.comm. – see [Appendix II](#)), some of these granites are more magnetic than their mafic counterparts; a consequence of their relative abundance and mixing with granodiorite and diorite. Mafic mixing is also responsible for the relatively high density for some of these granites - 2.65 to 2.7g/cc.

Whilst not mentioned by Rubenach, but nevertheless implied, is the possibility of intra-batholith variability particularly in respect to magnetisation

2. Densities of most of the sediments are high compared to normal text-book ranges (2.6-2.7). This is no doubt partially a function of age and regional metamorphism. It is felt that little distinction can

be made between the various sedimentary units (metamorphosed or otherwise) on the basis of sampled density alone. None of these sedimentary units are magnetic

3. The densest rock units are volcanic flows within the Malbon Group (Marraba volcanics) and Soldiers Cap Group (Toole Creek Volcanics) with densities in the range of 2.8 – 3.0g/cc. Both are also highly magnetic; often in excess of 10000×10^{-6} SI.
4. Dolerite dykes (mapped in dark purple) of high density (2.8g/cc) and high susceptibility ($\sim 10000 \times 10^{-6}$ SI) are extremely pervasive throughout the entire Proterozoic.
5. A basement rock is hard to define as such, but is assumed to be represented by the Tewinga Group; amphibolites, gneisses and metavolcanics with an average density of 2.7-2.8g/cc and low to moderately magnetic ($1000 - 3000 \times 10^{-6}$ SI).

MODELLING ASSUMPTIONS & CONSTRAINTS

With the exception of surface control, the modelling is geometrically unconstrained and relies on known density and susceptibility contrasts to force dip directions and depth extents (for mass at least). This is an extremely non-rigorous approach to building subsurface geometry and certainly, negates PF modelling being used as a validation process (a system used to build a model cannot also validate it).

To assist in modelling, some additional constraints have been emplaced, notably:

1. Minimise the number of PF annihilators within the depth section. An annihilator being a compensatory magnetic or mass-body at depth that simply cancels out the effect of a shallower source.
2. Despite the potential and propensity for intra-granite & sediment variability, maintain as far as possible the same density and magnetisation for each unit
3. Limit the basement types employed across all sections
4. As far as possible, make the model consistent between sections. This simplifies overall geometry; an approach that is necessary in any PF modelling exercise (that is, the simpler the model, the more reliable).
5. Change rock densities or susceptibilities in preference to changing rock type to make a fit.
6. Respect surface dips where possible and avoid fanning out of units from surface expression.

7. For magnetic units, remanence has been ignored. While this can lead to erroneous assumptions of dip, general opinion is that where it exists in the Mt Isa Basin, it is near parallel to the earth's current field. Therefore, if it is present and overlooked, it will simply lead to an underestimation of the total response.

Where there are clear breaches of the above, the 'conflict' will be documented.

POTENTIAL FIELD DATA SETS AND REGIONAL FIELD CONSIDERATIONS

Prior to presenting results, some discussion of the datasets is warranted, particularly in regard to sampling and regional-field issues.

MAGNETICS

Data has been extracted from the 1990s MIM airborne survey, flown on east-west profiles at 150-200m intervals, 7m stations and 70m mean terrain clearance.

With unit thicknesses of thousands of metres, this sampling is more than adequate for both detection and resolution where magnetic contrast exists. Some of the thinner dolerite dykes and east-west structuring may be poorly delineated however, particularly in the process of re-sampling the data to 100m for the forward modelling exercise.

The regional field (that component in the data considered to be too long to fit within the depth extent of the modelling window) has usually been fitted with a DC shift, with minimal consequence to the overall baseline and 'shape' of the data.

GRAVITY

Data has been extracted from Geoscience Australia's gravity database and incorporates a variety of regional and detailed datasets. [Figure 2](#) shows pertinent station positions with a nominal spacing of 10-20km.

Clearly such a dataset precludes resolution of some individual sedimentary packages and the fitted response must be viewed in the context of:

- Allowance for high frequency misfit to the observed profile
- A large lateral tolerance on body boundaries where density contrast is the only constraint

In this case, regional fitting is more complex as there is clearly a long-wavelength feature to many of the cross-sections.

Rather than simply fit polynomials to the long-wavelength and subtract it from the total response, the regional has been left in the model as form of basement structure. This is significant in it self, and will be discussed as part of the general interpretation.

RESULTS – SECTION BY SECTION MODELLING

The five traverses were modelled concurrently to a depth of approximately 10km using Modelvision. Kathy's interpretations were embedded into the cross-sections to provide surface-geology input and pivot points for unit and fault dips. Colour coding for lithologies is standardised and shown in [Appendix III](#) along with **nominal** (starting) densities and magnetic susceptibilities.

Note that the term basement is used loosely, and refers to any dense/low to moderate magnetic material below Malbon Group.

Modelled sections using backgrounds of 2.68g/cc (Bouguer Gravity) and 0SI (magnetics) at 1 to 1 scale are shown in the accompanying figures. Comments are as follows:

KURIDALA 37 ([Figure 3](#))

1. Densities of the SCG cannot explain the steep gravity gradient rising up towards the east. A basement ramp has been invoked, shallowing rapidly under cover to compensate for the mass deficit.
2. Granites are recorded in the central portion of the cross-section and it assumed that these make up the bulk of material in profile lows.
3. The gravity high under steeply dipping Malbon members, cannot be easily explained by the density contrast against bordering granites. Instead, shallow basement or a thickening section of Marraba Volcanics is required
4. Likewise, an even shallower section of dense/magnetic basement-like rocks is required underneath the Staveley Formation near Agate Downs. Descriptions of Staveley on the Duchess sheet refers mainly to arenite, siltstone and phyllite and a local basement high is required for both the gravity high and the magnetic signature

Additional details and dip tests within the modelling are highlighted in a separate report, included as [Appendix IV](#).

KURIDALA 50 ([Figure 4](#))

1. Bouguer gravity shows a similar trend as for 37 but with a slightly more gradual ramp up of basement rocks from west to east.
2. A local gravity high at 435800E suggests that the small outcrop of Marraba Volcanics is more extensive at depth. The location is also marked by a rapid change in magnetic gradient, implying a steep dip to the east and possibly representing a southern continuation of the Martin Creek Fault.

3. An embayment in the main NS band of Wimberu granite occurs between 434000E and 441000E on more or less the cross-section 765000N. Since granite is still mapped in outcrop across this section, it is assumed that it is relatively thin here, with the east-west boundary probably fault controlled (given the dramatic change). The replacement material is unknown, but given the requirement for low density, low magnetisation and the stratigraphic position, arenites of the Argylla Formation are assumed.
4. At 44600E a steep easterly dipping dyke marks the edge of Mary Kathleen / Kuridala Formations. Numerous dykes and repeated stratigraphy blur individual units for the data resolution.
5. The Straight Eight Fault is intersected at 451500E. Just to the east, a rapid decrease in excess mass suggests association to the fault; modelled here as east-dipping normally faulted basement.
6. Further to the east Doherty Formation (DF) is underlain and interlaced by Squirrel Hills Granite. A small Bouguer rise across the middle of the regional low at 462200E suggests a deepening of DF across the middle.
7. Continuing east, different phases of the Williams Batholith outcrop within the DF. Sharp steeply dipping contacts have been modelled between and within the granites to match the magnetic data. Whether this is symptomatic of the granites, granitic phases and underlying geological structuring remains to be seen.
8. No definitive geophysical signature can be attached to the Cloncurry Fault along this cross-section however.
9. Correlating with outcrop of Soldiers Cap Group (SCG), the volume of granite appears to taper off further to the east. Whilst poorly constrained it has been modelled as fault controlled with a dip gently to the east.
10. Wedged against rising basement (based on regional modelling), the SCG disappears under cover near 485000E. At the very east of the section, Toole Creek Volcanics are inferred from the change of relatively quite magnetics to a noisy signature.

KURIDALA 61 ([Figure 5](#))

1. Again, Bouguer Gravity suggests that at the sub-10km scale, basement rises gradually to the east
2. Based on measured density contrasts and similar testing as Kuridala 37 (see [Appendix IV](#)), Wimberu granite thickens to the west along a gently dipping contact with denser rocks.
3. The eastern edge of the granite is marked by a sharp local Bouguer high. Although not mapped in outcrop, it is expected that the high gravity gradient/magnetic low marks a steep contact with Argylla Formation.
4. The peak of the gravity high with a very high magnetic response, maps Marraba Volcanics in outcrop. Modelling supports surface mapping with steep easterly dips.
5. As somewhat of an enigma, is the discrepancy between outcropping Malbon Group with relatively steep dips and the much

broader Bouguer high. It is assumed that the wavelength disparity is due to:

- a. Shallow basement rocks being the major contribution to the Bouguer high rather than the Malbon Group itself.
 - b. In contrast to observed (albeit sporadic surface) petrophysical measurements, the density of the Malbon, Staveley and Kuridala groups are more or less equivalent. In fact to force a data fit, the density of the Malbon Group had to be dramatically reduced in this instance.
6. The eastern edge of the Malbon group (Mitakoodi Quartzite) is marked by a steeply dipping contact with Answer Slate, as indicated by the magnetic contrast. Curiously, and as part of the issue addressed in 5), this contact is not marked by any gravity anomaly and would not appear to be simply an issue of poor sampling.
 7. Very little evidence exists for the Martin Creek Fault in the PF data, other than a steeply dipping slither of Wimberu granite at approximately 44700E.
 8. To the east of the Martin Creek Fault, Doherty Formation pervades. Squirrel Hill Granite intrudes through at 45000E and the coincident magnetic anomaly suggests a gentle dip to the east. As such, a greater mass of SHG is inferred with increasing depth to match the gravity gradient off the local high to the west.
 9. Outcrop of Mt Angelay granite marks the apex of the regional gravity low but the density contrast requires thickening volume at depth. As such, this constraint forces an easterly listric-like dip on the Cloncurry Fault –assuming that this structure is coincident with the edge of the granite although it is by no means clear. The ‘topography’ on the Angelay Granite is applied to account for variable magnetic character.
 10. Further to the east, a subtle perturbation on the regional gravity field appears to be associated with a thickening section of Saxby Granite within Soldiers Cap Group. Areas with increased magnetisation are similarly associated with near-outcropping granite. However, the multi-layered model does increase the likelihood of field annihilators and more degrees of freedom in body thickness and volume.
 11. At the eastern end of line K61, sections of steeply-dipping Toole Creek Volcanics are inferred to account for the magnetic anomalies with sources at subsurface.

SELWYN 12 ([Figure 6](#))

1. From the Kuridala sections (above) to the more southern lines, sub-10km basement perturbations are no longer required. Without any geological, stratigraphic or seismic control, no attempt at identifying the underlying cause will be entertained - suffice to say that a fundamental change appears to exist.
2. Steep easterly-dipping Malbon Group elements outcrop on the western side of the section. The Marraba volcanics are clearly visible in the magnetics and support the surface-dip information.

3. East, Mary Kathleen and Staveley Formations are conformable. They are heavily intruded by dolerite; masking their non-magnetic character and shifting the centre of the gravity high away from normally denser Malbon Group Formations.
4. Again the inclusion of the basement block is required under the western groups, to account for the broad gravity high. Had deeper surface to depth bodies been utilised, variations in density between units would have caused even greater perturbations on the modelled field response.
5. From 440000 to 484000E, a series of granites intrude the Kuridala Fm. Denser basement rocks wedge off and a thicker pile of granite is required up to 470000E. The eastern edge of this basement block is difficult to constrain but has been placed at the edge of the Kuridala Fm on a steep magnetic gradient and near the inflexion of the gravity high. The multilayered geology with density contrasts between granites, sediments and basement provides for a multitude of possibilities and dips and depth extents are extremely speculative.
6. Further east toward the Cloncurry fault, granite appears to thin rapidly. Assuming the Cloncurry Fault is concordant with the edge of the granite, then it dips at about 45° to the east near surface (based on the magnetics)
7. To the east of the granite is a magnetically quiet zone, which in turn is bounded by Toole Creek Volcanics dipping conformably at depth. At this point basement rocks are shallowest.

SELWYN 93 ([Figure 7](#))

1. The southern most line crosses just to the edge of the southern limit of outcropping Malbon Group. Based on magnetic signature, Marraba Volcanics appear to be present at depth. Dips ARE consistent with previous interpretations.
2. May Kathleen Formation is modelled with shallower basement so as to compensate for the lower mass. However, given the propensity for dolerite within these rocks, it is also possible that the combined density and depth extent is similar to Malbon.
3. Modelling of the Gin Creek Granites is extremely ambiguous. The single measurement on Gin Creek Granites suggests that the material is non magnetic and yet there is a reasonable correlation to its western boundary and a significant magnetic source. As a solution a significant mass of dolerite has been added to the granite and the adjoining Kuridala, but the inclusion means edge interpretations are no longer valid.
4. The Kuridala has been modelled taking into account the easterly but variable surface dip. On this cross-section it is at its widest; translated into being at its greatest depth extent and volume.
5. Squirrel Hills and Cowie Granites thicken towards the centre of the Bouguer low. Its eastern boundary, concomitant with the Cloncurry fault, dips steeply west if not vertical. This represents a dramatic departure from northern lines, both in terms of the dip of sediments

across the fault and the basement gradient. However, given the density contrast from granite to 'basement', the gravity gradient and the offset of the granite from the fault, there is no other option other than to apply a steep westerly-dipping contrast here.

6. Overlaying shallower basement on the eastern side of the fault are Doherty Formation and undifferentiated sediments of the Soldiers Cap Group (including Toole Creek Volcanics). The contact appears to be sharp and near vertical.

RESULTS – GENERAL INTERPRETATION

Some of the elements of the model are fundamental to all x-sections and deserve additional comment. These are:

SUB 10KM FEATURES ([Figure 8](#))

The basement high along the western edge of the study area is relatively uniform between all cross-sections and is fault controlled at least on its eastern edge. Logically, it would appear to represent a thick section of Marraba Volcanics/Malbon Group to depth, but the broader wavelength of the gravity feature when compared to outcrop information suggests a more generic feature.

Basement along the eastern side of the cross-sections is more complex. In the south, the Cloncurry fault is evident with basement shallowing rapidly to the east. On the northern lines, basement appears to gently dip to the west without any major displacement across the Cloncurry Fault. Basement in this sense probably represents amphibolites, gneisses and BIF rocks of the Soldiers Cap Group.

BASEMENT PLUS GRANITES ([Figure 9](#))

Granites account for nearly 40% of the model volume and when combined with the basement rocks, make up 70%. This explains much of the difficulty in constraining the model since:

- Volumetrically, they can be relatively amorphous, particularly if a batholith model is applied (rather than the 'pancake' model)
- From petrophysical data are known to be quite variable in terms of magnetisation and density, both within and between particular units of the Williams Batholith
- The tendency for granites to be inter-fingered within the intruded rock. This leads to more of a blended density and magnetisation, more so than a discrete and mappable boundary.

DOLERITE + GRANITES ([Figure 10](#))

This third model demonstrates the pervasiveness of non-sequence magnetic sources within the cross-sections – dolerites and granites. Whilst in the

absence of remanence the fit to the anomalies can be useful in determining dip, the dip of these features may not necessarily conform to the edges of the major geological blocks.

OUTCROPPING MALBON AND BASEMENT ([Figure 11](#))

The fourth and final model slice draws attention to the ambiguity between the outcropping Malbon group (particularly with the Marraba Volcanics) and the definition of the depth and spatial extent of these dense and often magnetic units.

Assuming no overt structural complexity with repeat of sections, steep surface dips suggest that this group should be more or less confined to a north south band 2 – 5km thick. However, this arrangement could only partially explain the western gravity anomaly and potential exists for an even greater thickness and depth extent than modelled.

DISCUSSION AND CONCLUSIONS

Originally, a line by line approach was attempted to build up a three dimensional model of the principal geological blocks and edge orientations. Whilst in it self useful, it was felt that it was still masking a lot of the inherent ambiguity and not really testing the model in three dimensions.

As an alternative, the five sections have now been modelled concurrently with every effort made to keep the geometries as consistent as possible ([Figure 12](#) , [Figure 13](#) & [Figure 14](#)). This approach has extracted some boundary conditions and these have been set out in the individual results sections. Dips and depths to subsurface features should be considered as qualitative (steep west, gently east etc) and more quantitative assessments would be ignoring the underlying non-exclusivity of boundary conditions.

The overall picture is reasonably consistent, especially in consideration of the inherent 3D complexity of the Isa Proterozoic anyway. Key elements are:

1. That a model has been produced based on a tensional regime with normal steep-faulting only.
2. Consistent dip & signature of the Marraba Volcanics and Malbon Group.
3. The distinction between batholith granites and those more amenable to layering.
4. The bowl-like shape of basement (particularly on the western side) may implicate a period of north south compression. The excess space has been filled with greater volume of granitic intrusives & sediments, as indicated in modelling.

Whilst issues of non-uniqueness have been emphasised on a number of occasions, it is exemplified by the following list of inputs to modelling uncertainty:

1. A poorly sampled region for rock properties, especially in regard to non-surface and unweathered material. It could be argued that under such scenarios, it would be better to use text-book averages rather than attempt to apply specific point values to bulk features.
2. Multi-intra-laminated geological blocks with features often below sampling resolution. Particularly with a multilayer block model (imposed by the scale of features in the gravity and magnetics combined), thicknesses are unresolvable.
3. Prolific dykes throughout Proterozoic sequences blur bulk-density contrasts towards denser rocks, whilst horizontally inter-digitised granites have reduced contrasts at the lower density end. In both cases, they have strong magnetic signatures that make them indistinguishable from each other.
4. All of the above uncertainties hinged solely on surface mapping; basically a single pivot point.

In a nut shell, the task of constructing geological relationships at depth is too difficult for the terrain in question, the constraints employed and the datasets available.

FURTHER WORK

I do not believe that 'more of the same' at higher resolution is going to deliver us any closer to the objectives for this terrain. Whilst more detailed gravity may address specific problems (such as the wavelength disparity over the volcanics in the west), the underlying problem is one of depth control; not easily answered with PF data alone.

To this end the methodology needs to be changed such that:

1. A conceptual model be built and the PF data be used in a validation process only. Validation would then be improved by more site-specific petrophysical data and closer gravity stations.
2. If a conceptual model is not possible, then either seismic and/or EM soundings be undertaken for depth imaging of some of the geological components. The EM is essentially untested and would need some background investigations beforehand however.

Despite all the caveats, it is felt that the above exercise still demonstrates the potential of a combination of techniques to evaluate geological structure at depth. The problem here is that critical elements are currently missing, and despite all attempts, they cannot be objectively bypassed.

REFERENCES

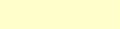
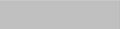
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APPENDIX I
MT ISA PETROPHYSICS DATABASE
[\(EXCEL SPREADSHEET\)](#)

APPENDIX II
COMMENTS BY MIKE RUBENACH ON
GRANITE COMPOSITION WITHIN THE MT ISA BASIN
2003
(PERSONAL COMMUNICATION)

Regardless of age, all the major granite bodies in the Mount Isa Inlier show magma mingling with synchronous mafic rocks (dolerite, gabbro). This was first recognized by Dave Blake, but ignored by others who had been trained in the Chapple and White restite unmixing model. The patterns are quite complex. Granite (or monzogranite) sensu stricto is probably the most common variety, but granodiorite and diorite are locally abundant, the latter being a hybrid between granite and gabbro. As most granites were oxidized and the mafics relatively reduced, mixing commonly produced extra magnetite, so that variably hybridized rocks are often more magnetitic than even the mafic rocks. All of this is documented in JCU PhD theses by Mark, Richardson, and Hoadley, some honours theses, work (including AMIRA) by Pollard, and unpublished work by myself. Chris Butera is doing his PhD with me on mafic rocks in the EFB, their relation to mineralization etc, and is very interested in your modelling and will be in touch. Regards Mike

APPENDIX III
COLOUR LEGEND, DENSITIES AND MAGNETIC SUSCEPTIBILITIES
FOR POTENTIAL FIELD MODELLING
MODELVISION

Name	Type	Code	Colour	Density (g/cc)	Sus (SI)	Comments
Generic	Granite	pg	255/0/167		2.67	0.1 Undifferentiated from sed
Wimberu	Granite	pgm	255/0/255		2.67	0.12 Variable mag components
Squirrel Hills Granite	Granite	pgisp	255/0/0		2.66	0.12
Mt Angeley Granite	Granite	pgia	255/0/167		2.65	0.07
Saxby	Granite	pgtx	255/231/255		2.65	0.05
Mt Dore	Granite	pgid	255/207/183		2.64	0.01
Staveley	Arenite	pks	255/255/0		2.7	0
Agate Downs Silts	SS	pkg	215/199/0		2.65	0
Doherty Fm	Granofels	pkd	167/96/88		2.7	0
Kuridala Fm	Schists	pkd	128/64/0		2.75	0
Mitakoodi Qtz	Quartzites	pnm	255/255/207		2.8	0.013
Marraba Volcanics	Metabasalt	pna	0/255/199		2.85	0.1
Argylla Fm	Felsic Volcanics	pea	255/159/79		2.8	??
Mary Kathleen Fm	Slates	pka	128/128/128		2.72	0
Soldiers Cap Grp	Amphibolite	pol	255/104/0		2.75	0
Soldiers Cap Grp	Metabasalt	pot	0/199/128		3	0.08
Soldiers Cap Grp	Gneiss	po	0/199/255		2.8	0.08

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KURIDALA CROSS-SECTION 37
M.BARLOW, 2003
[\(REPORT\)](#)