SMI BRC
WH Bryan Mining & Geology Research Centre

DMQ Wrap-up – May 2017

Prospectivity Analysis

Geologically Constrained Gravity Inversion towards a new granite architecture

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16th May, 2017

The University of Queensland
Australia

1. A Primer
    - Geophysical 3D Inversion
    - The Ambiguity problem
    - Constrained Inversion

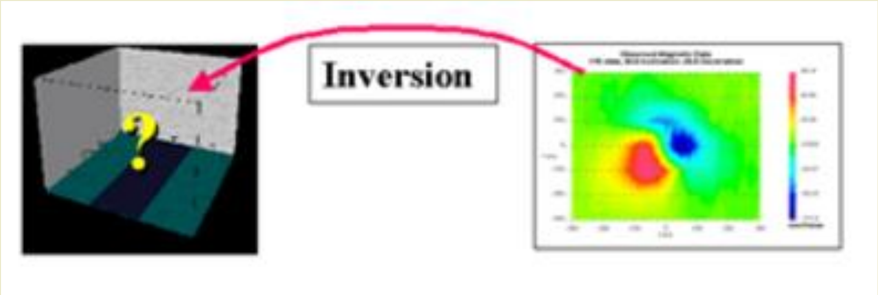
2. The VPmg advantage

3. Regional Scale Apparent Density Model

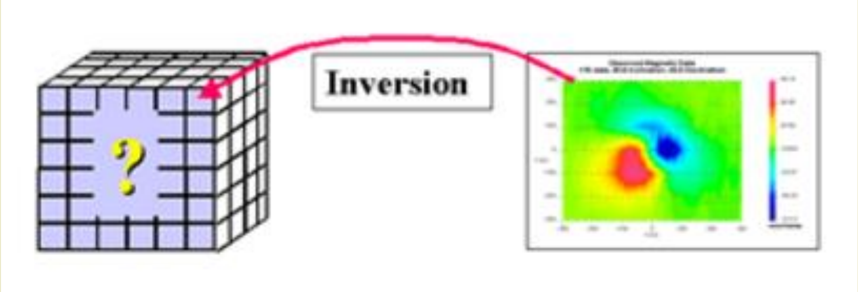
4. Defining Granite Morphology from Regional Gravity Data
    - applying geological constraints simply
    - density values
    - (convoluted) path to a new granite model

5. Summary

3D Geophys Inversion – A primer

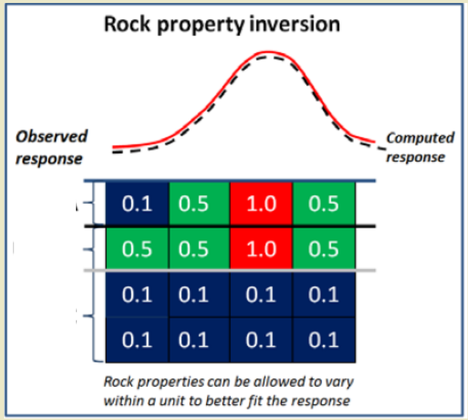


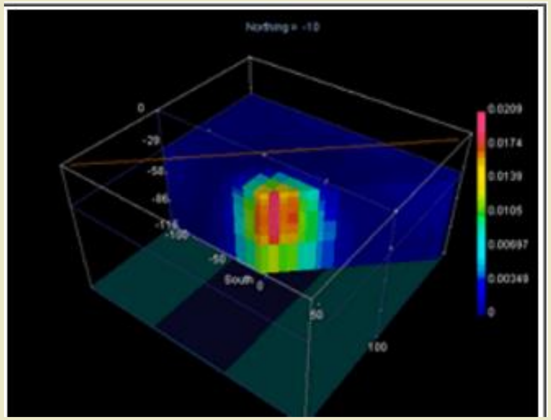
Some grav/mag data



3D Discretization

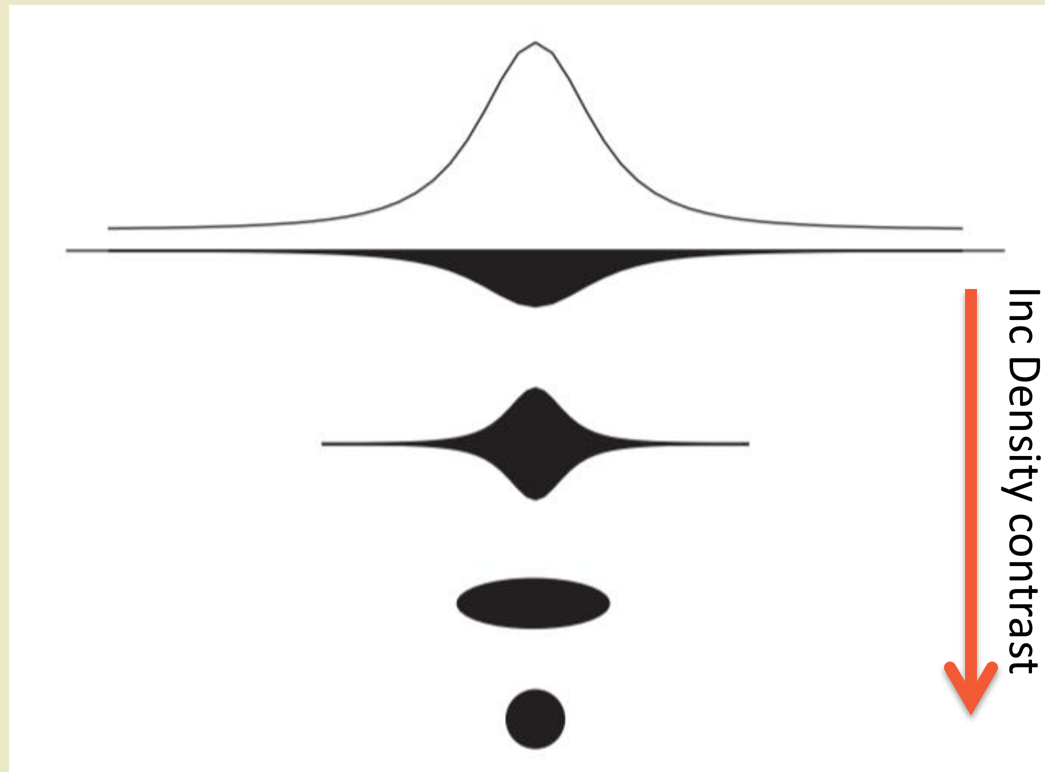
Iteratively calc a model that matches the obs data





The Ambiguity Problem – A primer

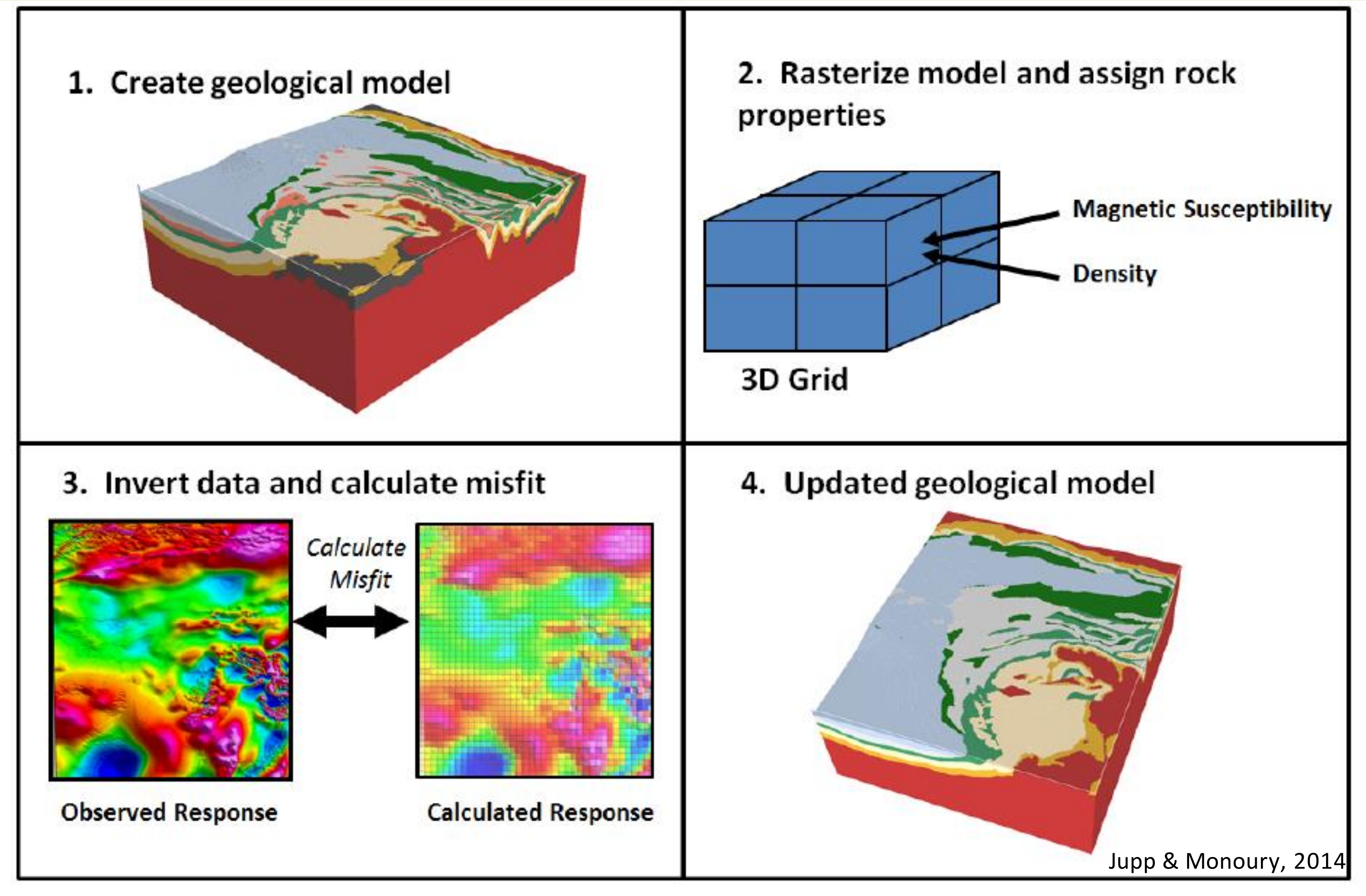
How sensitive the data is to the shape of a contact/boundary depends on the density contrast



Higher the contrast, -> the less volume of mass required

Constrained Inversion – A primer

Reducing the ambiguity problem – **constrained** inversion

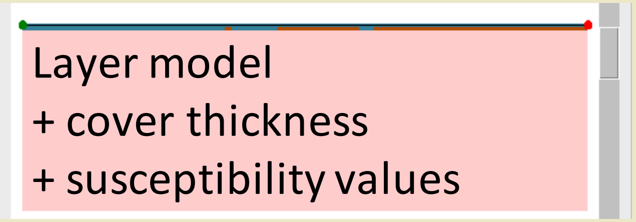


Jupp & Monoury, 2014

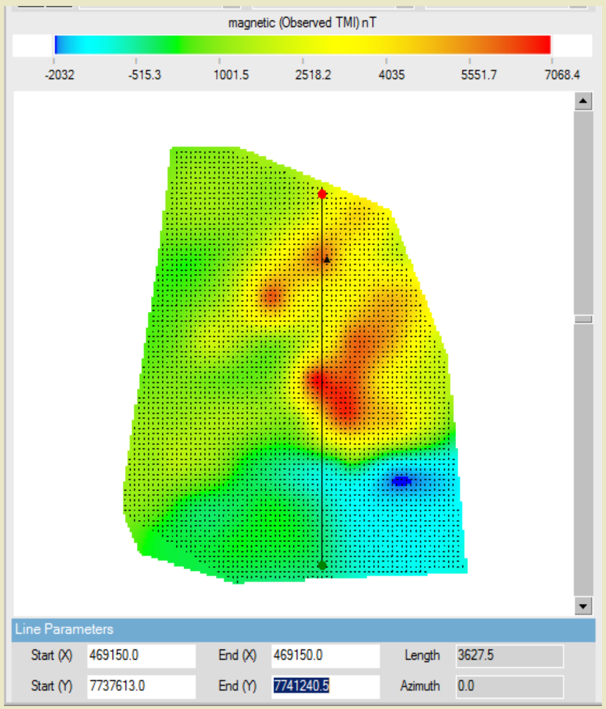
Constrained Inversion – A primer

A magnetic example.....

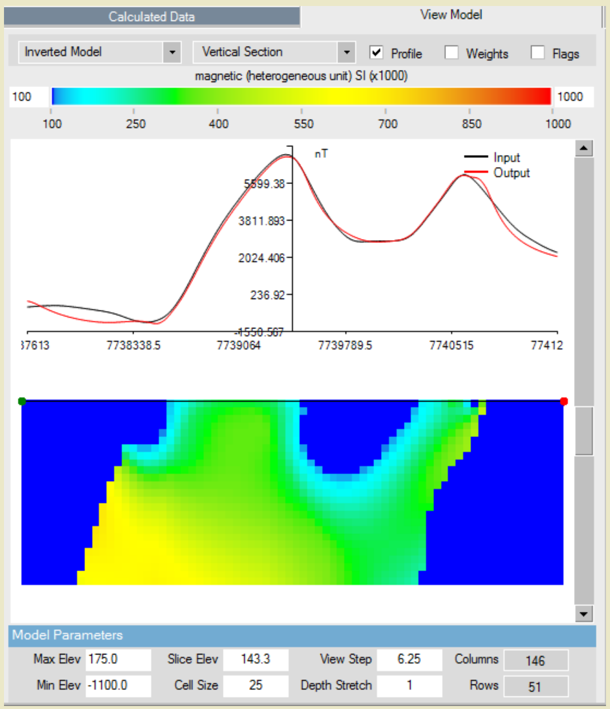
+ Constraints



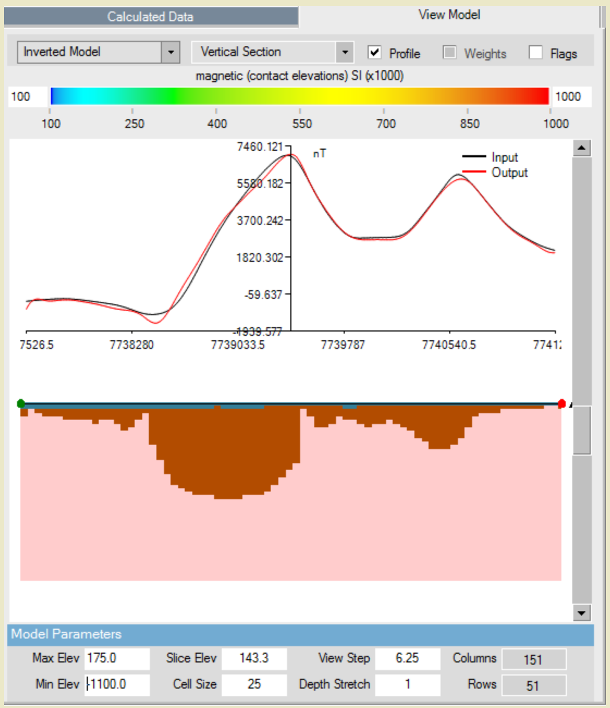
Aeromag data



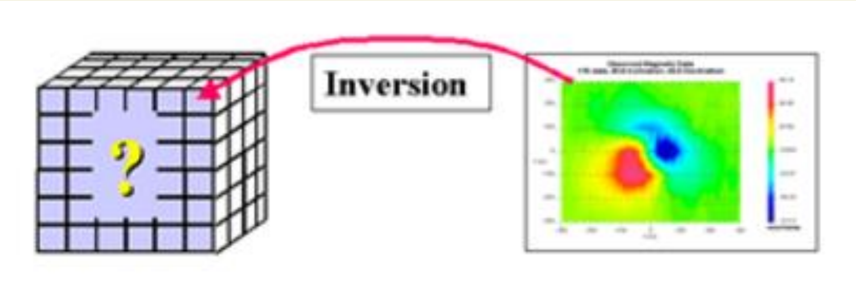
Unconstrained

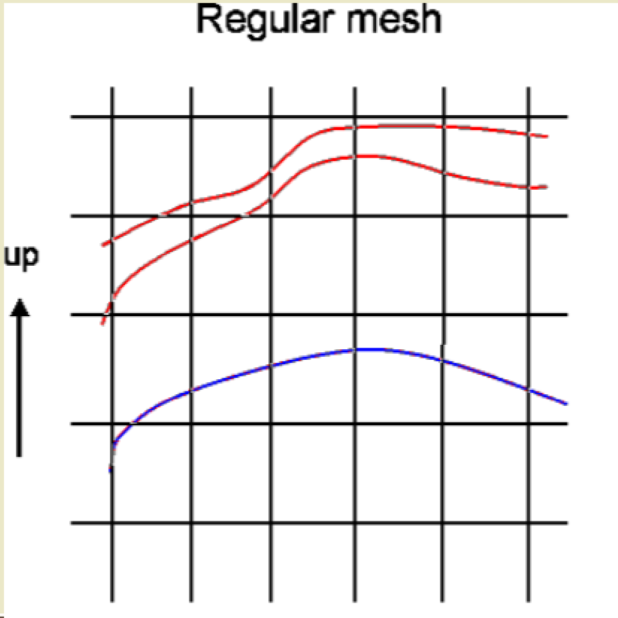


Constrained Model

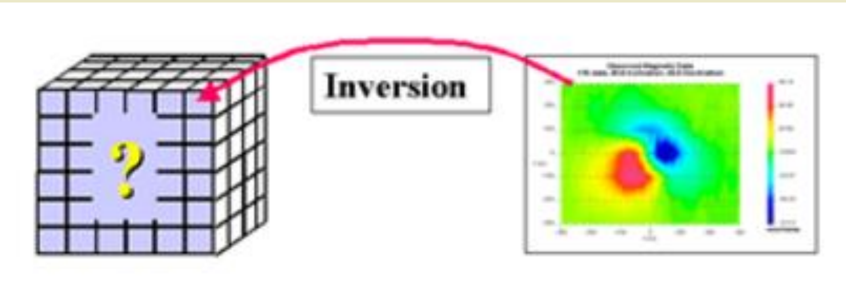


The VPmg Advantage



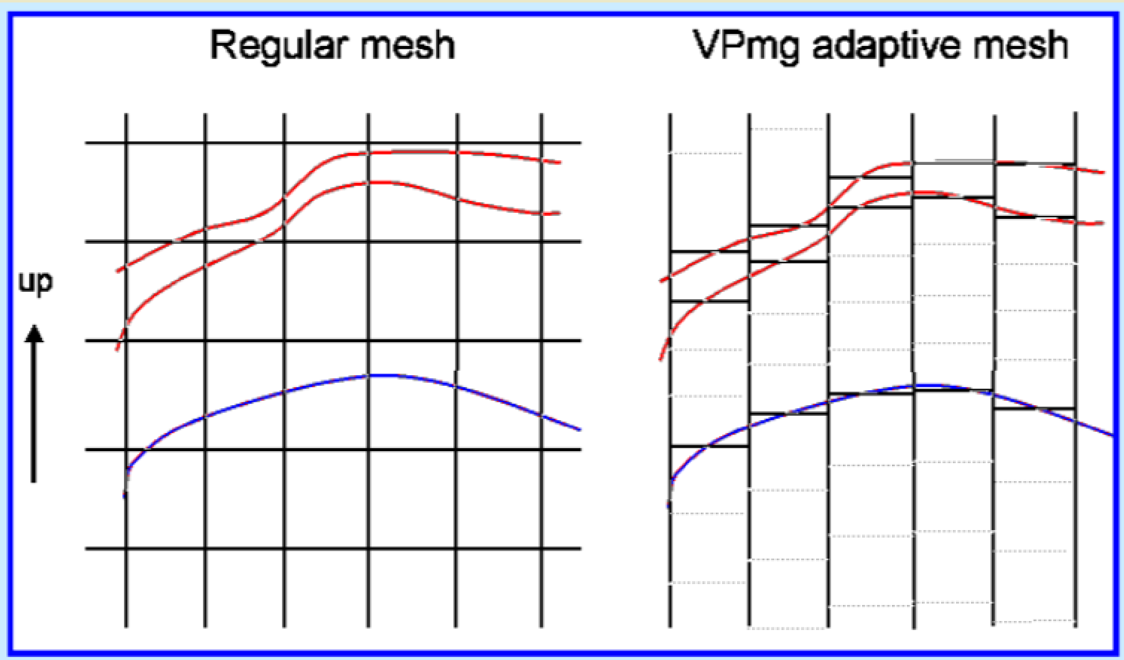


The VPmg (Vertical Prism mag grav) Advantage



Deforming (adaptive) mesh

- Vertical rectangular prisms
- Internal horizontal contacts -> divide prism into cells
- Cells boundaries can move up/down, prism boundaries are fixed



Advantages:

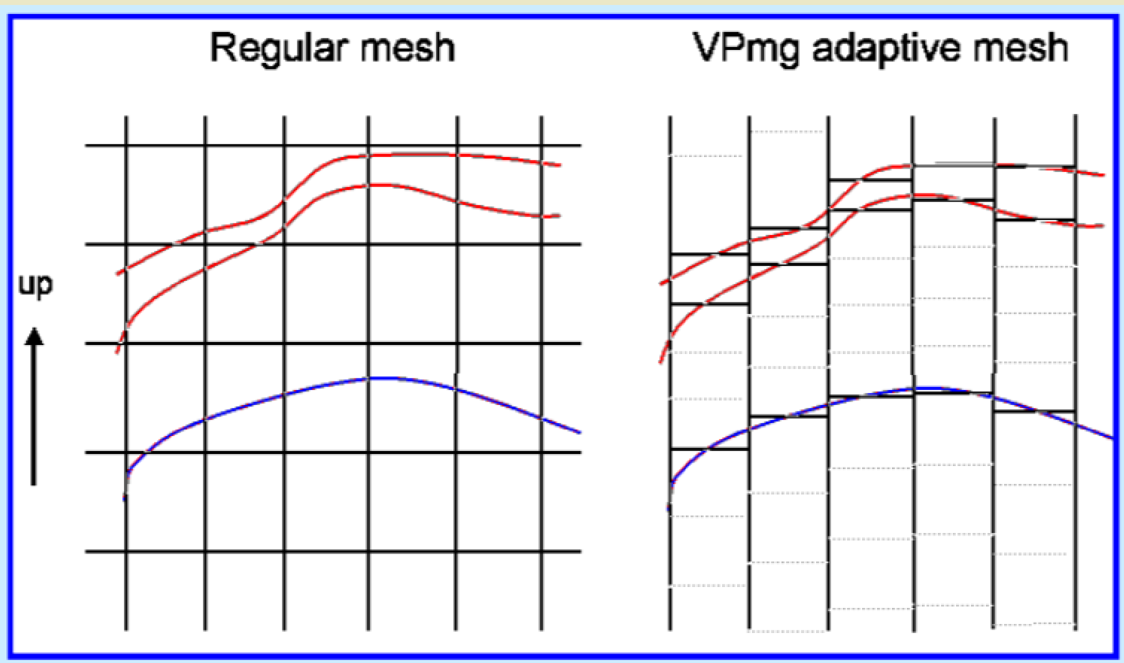
- Detail in geological model retained, especially thin units
- Surfaces, (topo), represented more accurately
- Fewer cells -> faster run times

The VPmg Advantage

Geol Unit Property Table

Property Table (Regional model

	Unit	Density	Min	Max	Hetero	Weights	Cell Size	Colour
1	Unit 1	2.2	0.00	0.00	☐	-	-	
2	Unit 2	2.7	0.00	0.00	☐	-	-	
3	Unit 3	3.0	0.00	0.00	☐	-	-	
4	Unit 4	2.6	0.00	0.00	☐	-	-	
5	Unit 5	2.55	0.00	0.00	☐	-	-	
6	VPmg basement	2.67	0.00	0.00	☐	-	-	



Advantages:

- Upper & lower bounds imposed phys properties
- Control which units actively change during inversion
- Geol contacts can be fixed, bounded or free
- **Inversion operates directly on geological model**

The VPmg Advantage

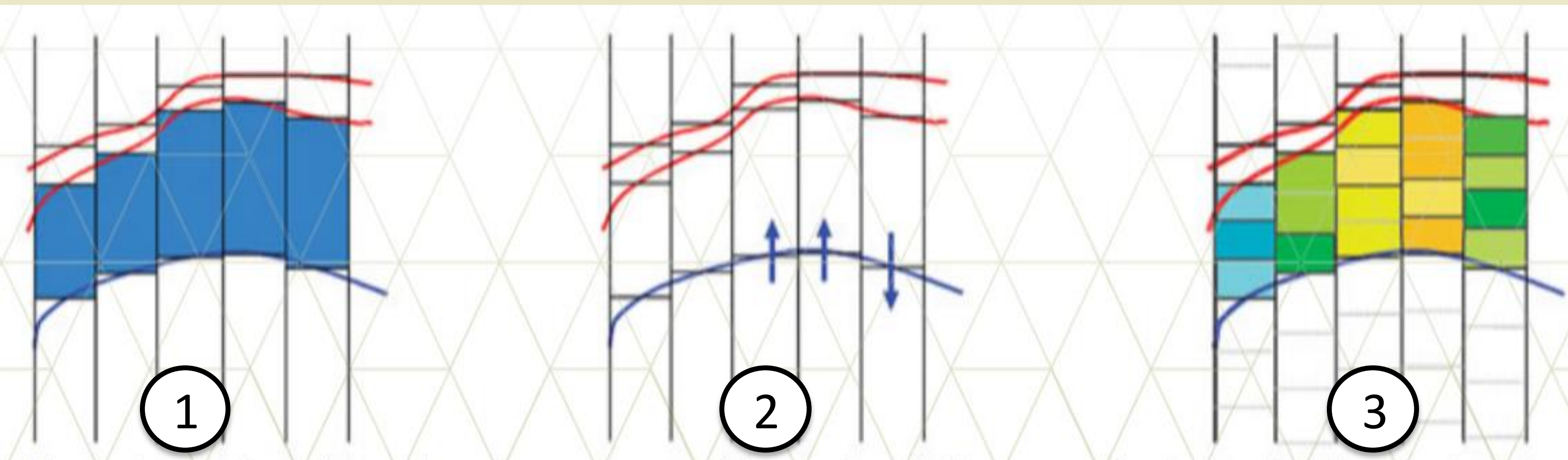
Three VPmg inversion styles:

1) Homogeneous property – Physical property (dens, sus) of geological unit changes

2) **Contact geometry - Shape of geological unit changes**

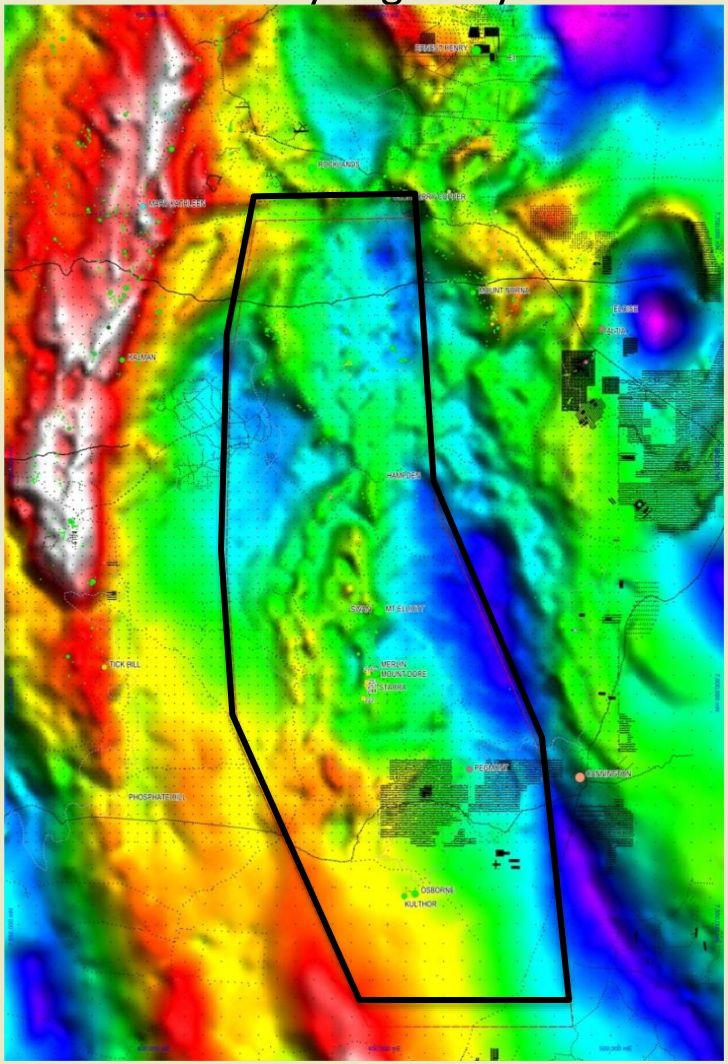
3) Heterogeneous property – physical property within geological unit changes

.......while maintaining sharp geological contacts

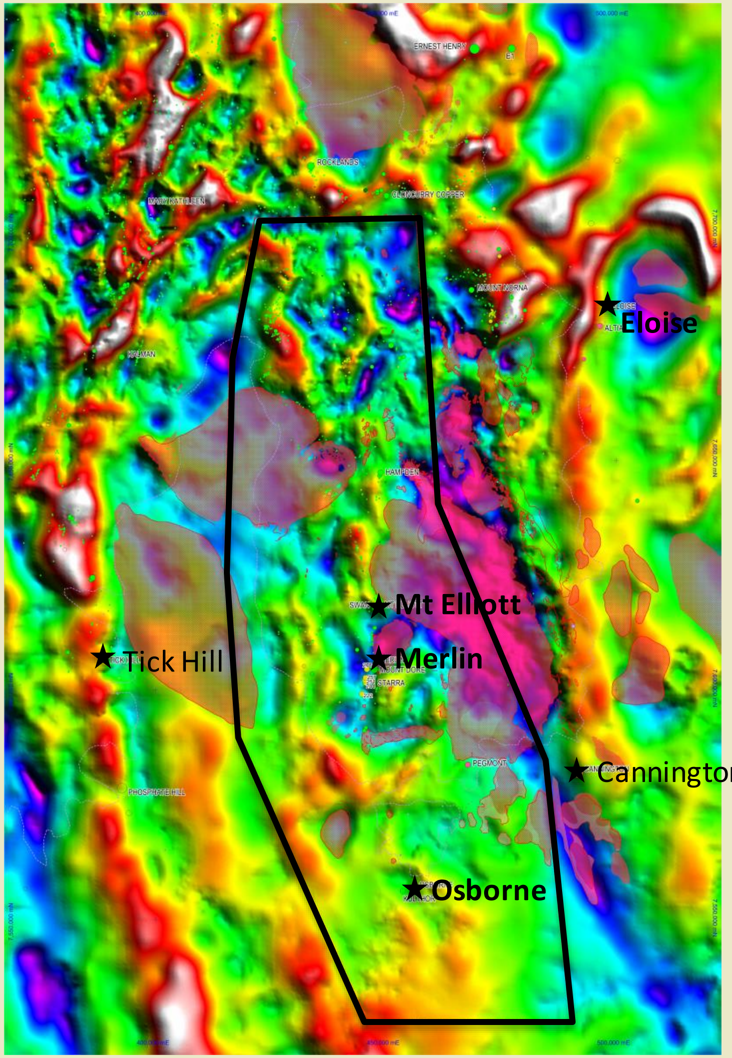


Development of the Apparent Density Model

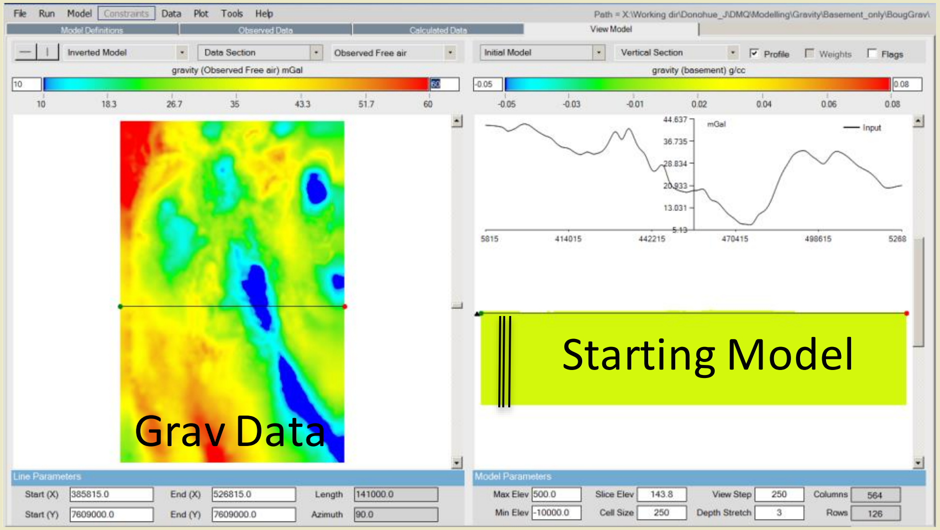
GA Gravity & gravity stns



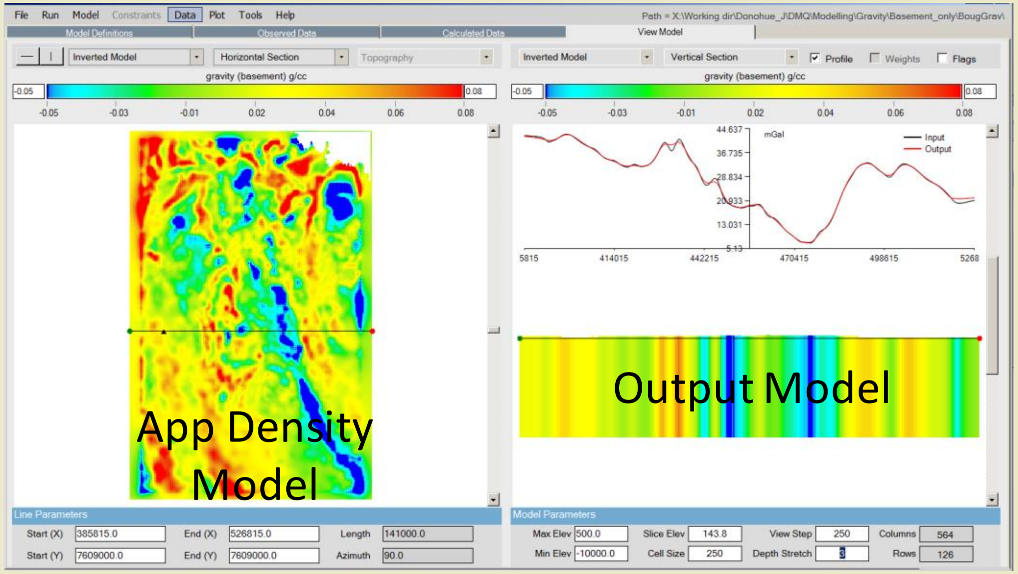
App Density & granite O/C



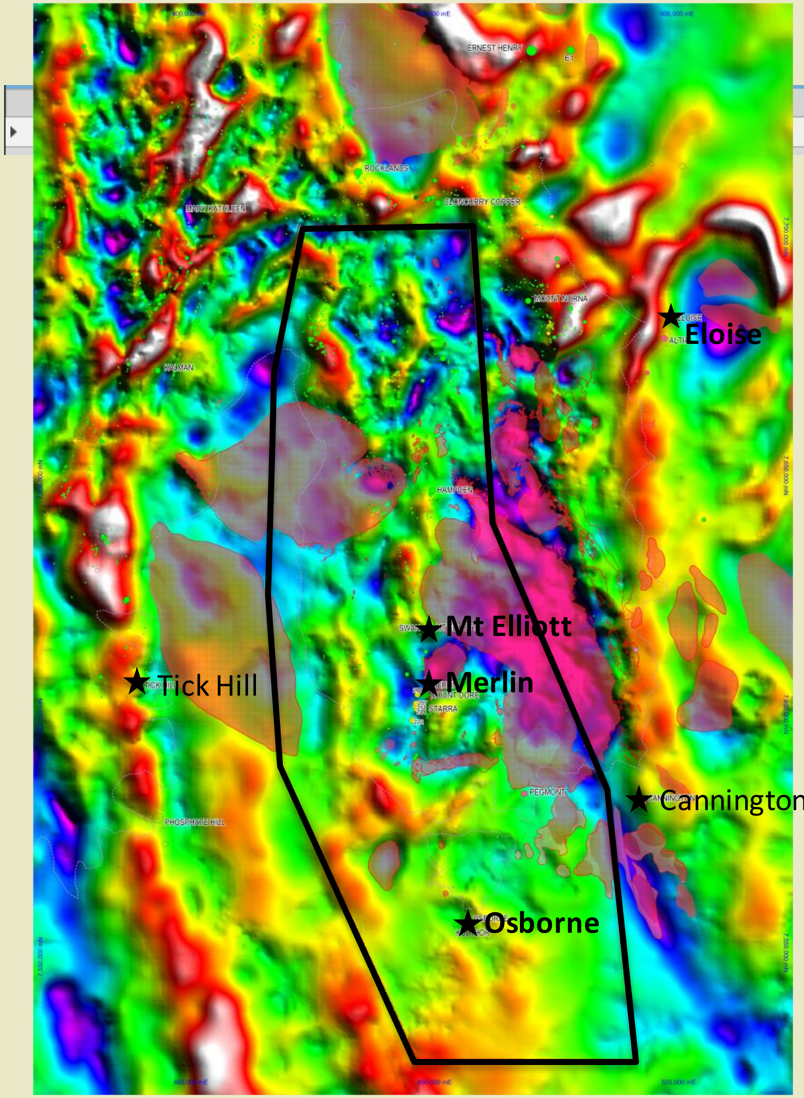
Development of the Apparent Density Model



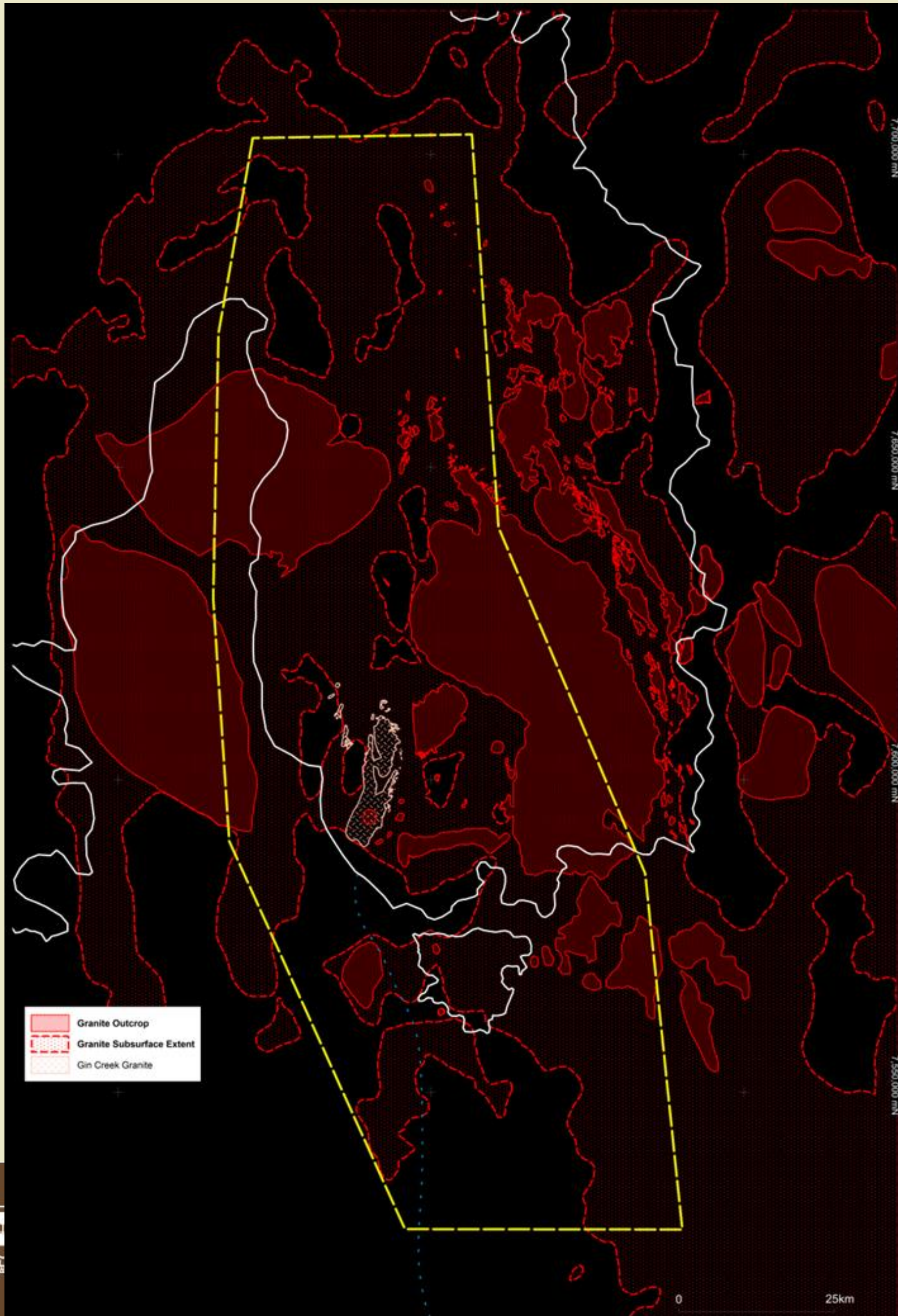
+



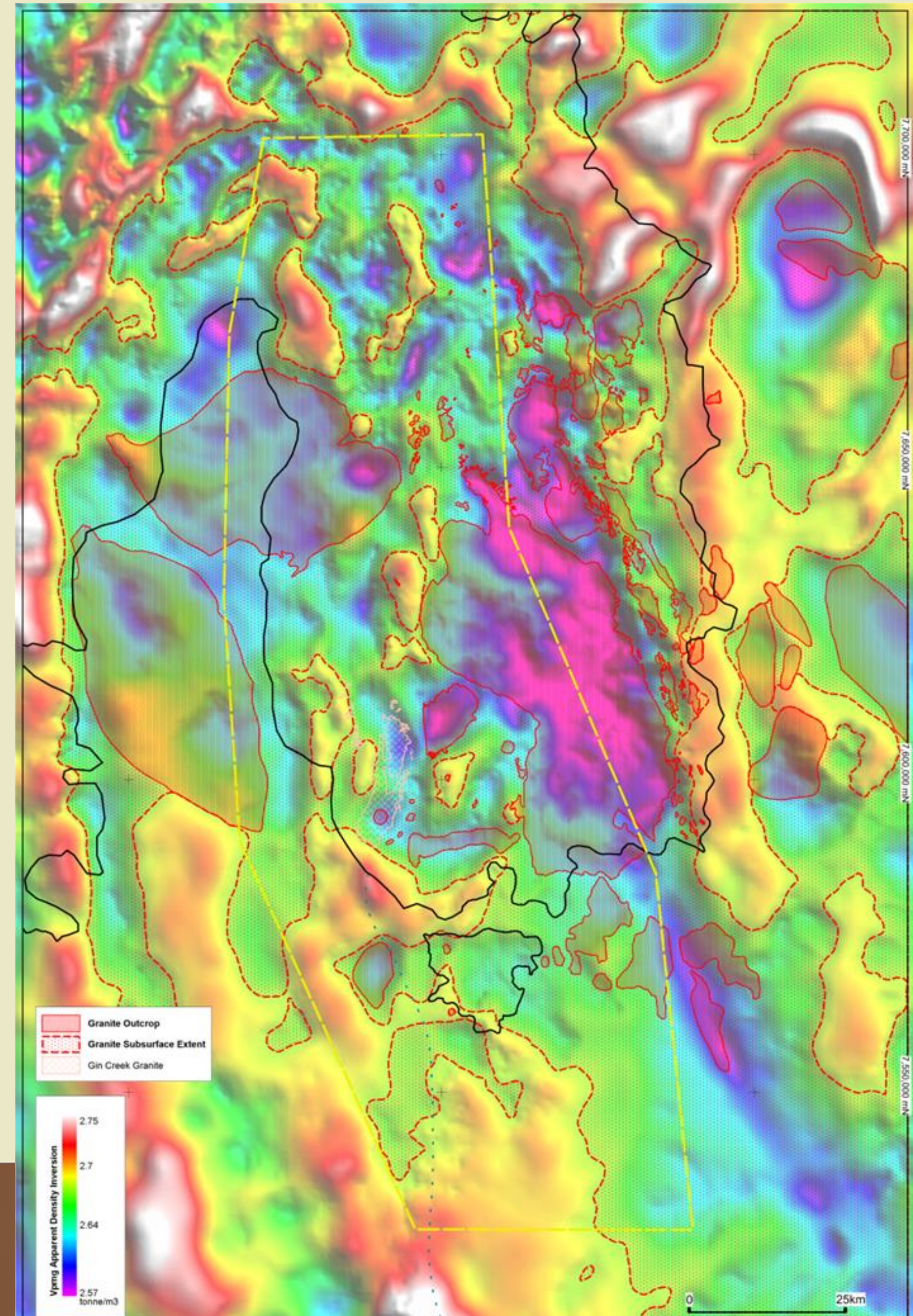
App Density & granite O/C



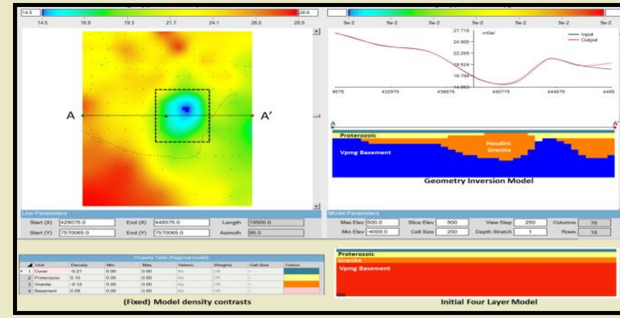
‘Extent’ of Granite



App Density & granite O/C

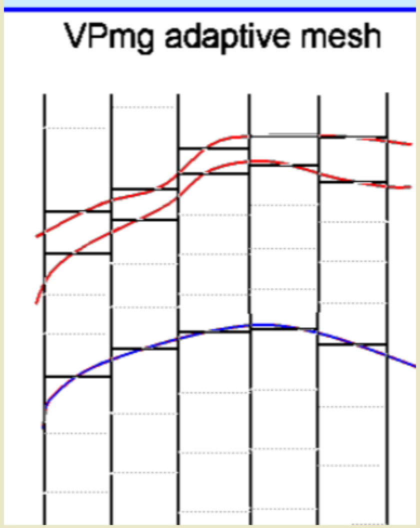


Granite Geometry?



Geol constraints had to be easy to deal with!

“layered” constraining input models promising.......



↔

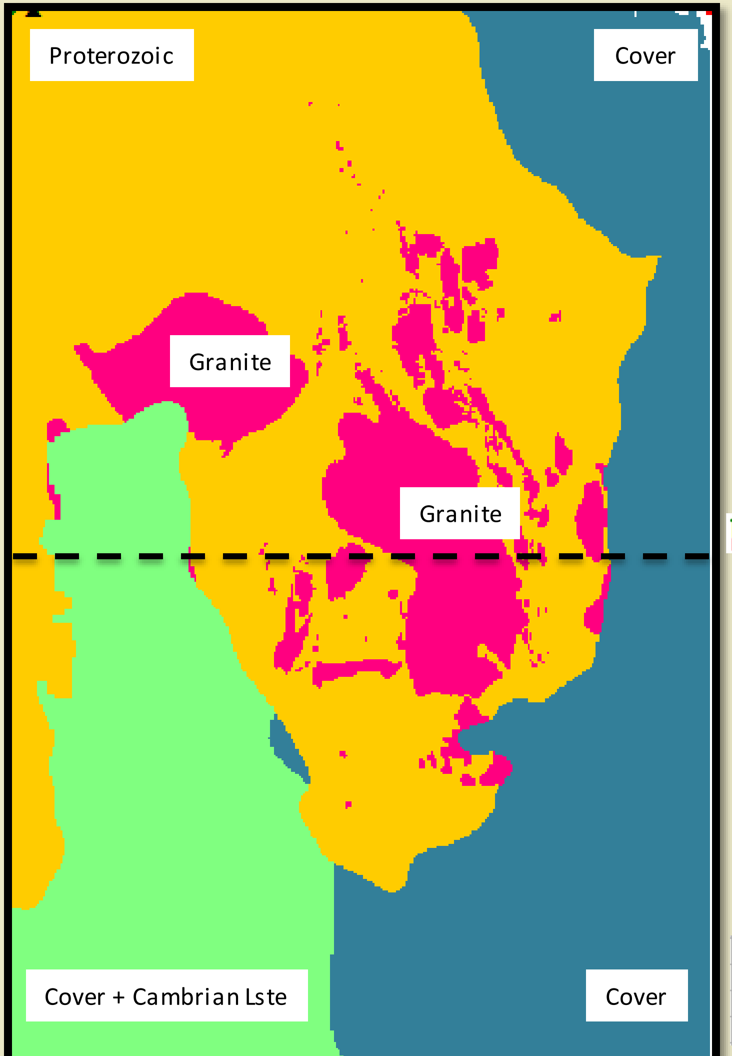
VPmg Input Model file

```
#MOD_3D#
New MH model 14 Nov v6 Prot 2.5km thick over granite, contact free, Granite base fixed
  383085.000  524585.000 7511985.000 7722985.000
    500.00      500.00
6
-0.22  0  0  Cover
-0.11  0  0  Granite
 0.12  0 0   Prot
-0.13  0  0  LsteCover
-0.17  0  0  Qtzite
 0.12  0  0  Basement
271.7  0.01  0
0  0  0  0  0
383335  7512235 222.62  4      -75.62  2.04    -2575.62       0.03    -3075.62        0.05
383835  7512235 224.15  4      -72.84  2.04    -2572.84       0.03    -3072.84        0.05
384335  7512235 218.99  4      -70.92  2.04    -2570.92       0.03    -3070.92        0.05
384835  7512235 227.8   4      -69.43  2.04    -2569.43       0.03    -3069.43        0.05
385335  7512235 226.64  4      -68.3   2.04    -2568.3        0.03    -3068.3         0.05
385835  7512235 218.85  4      -68.12  2.04    -2568.12       0.03    -3068.12        0.05
386335  7512235 218.08  4      -67.95  2.04    -2567.95       0.03    -3067.95        0.05
386835  7512235 212.97  4      -68.72  2.04    -2568.72       0.03    -3068.72        0.05
387335  7512235 213.65  4      -69.64  2.04    -2569.64       0.03    -3069.64        0.05
387835  7512235 215.61  4      -70.94  2.04    -2570.94       0.03    -3070.94        0.05
388335  7512235 217.01  4      -72.65  2.04    -2572.65       0.03    -3072.65        0.05
388835  7512235 216.78  4      -74.38  2.04    -2574.38       0.03    -3074.38        0.05
389335  7512235 215.91  4      -76.38  2.04    -2576.38       0.03    -3076.38        0.05
389835  7512235 215.35  4      -78.38  2.04    -2578.38       0.03    -3078.38        0.05
390335  7512235 214.9   4      -80.05  2.04    -2580.05       0.03    -3080.05        0.05
390835  7512235 212.71  4      -81.55  2.04    -2581.55       0.03    -3081.55        0.05
391335  7512235 206.93  4      -82.84  2.04    -2582.84       0.03    -3082.84        0.05
391835  7512235 202.28  4      -83.57  2.04    -2583.57       0.03    -3083.57        0.05
392335  7512235 199.17  4      -84.3   2.04    -2584.3        0.03    -3084.3         0.05
392835  7512235 197.86  4      -85.26  2.04    -2585.26       0.03    -3085.26        0.05
393335  7512235 196.28  4      -86.26  2.04    -2586.26       0.03    -3086.26        0.05
393835  7512235 195.64  4      -88.19  2.04    -2588.19       0.03    -3088.19        0.05
```

1) GIS - Interrogate solid geology at VPmg prisms as ‘Cover’, ‘Prot’ or ‘Granite’

2) Manipulate GIS output in Excel to generate VPmg input model

VPmg DENSITY MODEL

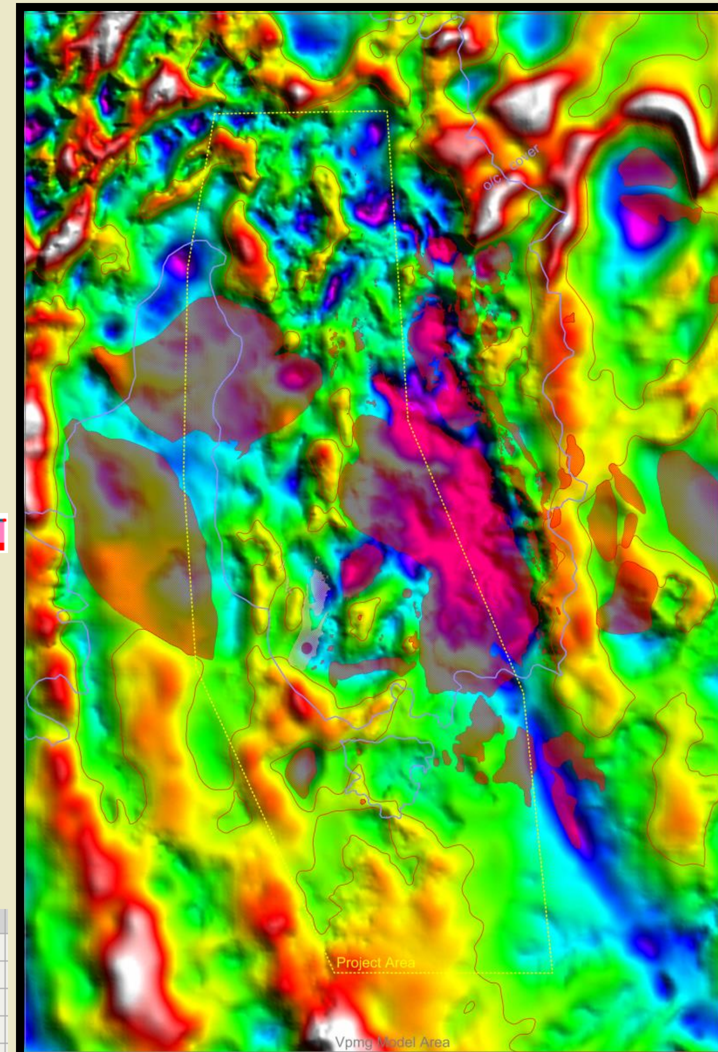


VPmg Input Model @ 120m RL

Input Model Xsection

Layer model densities

Unit	Density
Cover	-0.22
Granite	-0.11
Prot	0.12
LsteCover	-0.13
Basement	0.12



Spatial limits of VPmg model

Assigning Density Contrasts to the Vpmg Model

How sensitive the data is to the shape of a contact/boundary depends on the density contrast.

Final ('high') density contrast used.......

	LOW		MEDIUM		HIGH	
b/g	2.67	contrast	2.67	contrast	2.67	contrast
'Cover'	2.45	-0.22	2.45	-0.22	**2.45**	-0.22
'Cover LST'					**2.54**	-0.13
'Granite'	2.61	-0.06	2.61	-0.06	**2.59**	-0.08
'Proterozoic'	2.73	+0.06	2.79	+0.12	**2.78**	+0.11

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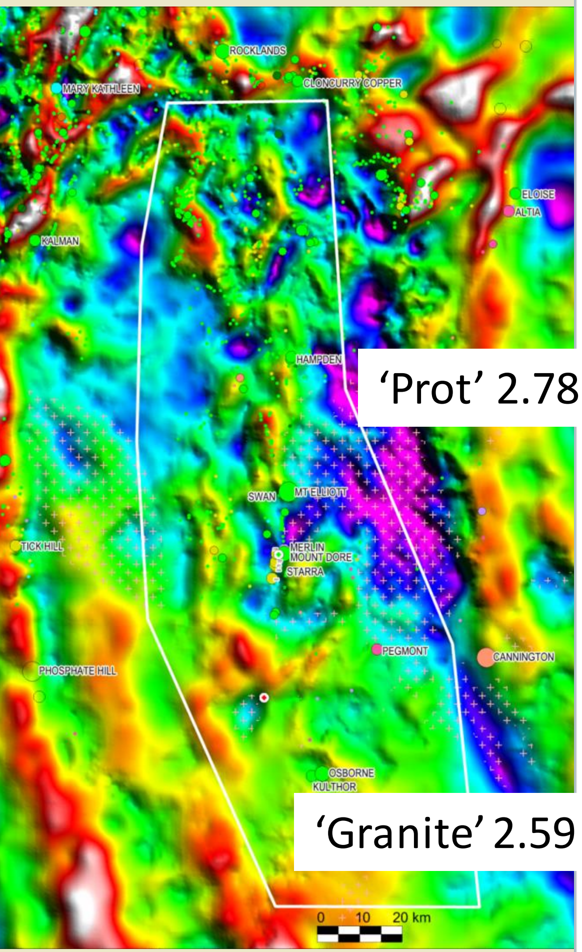
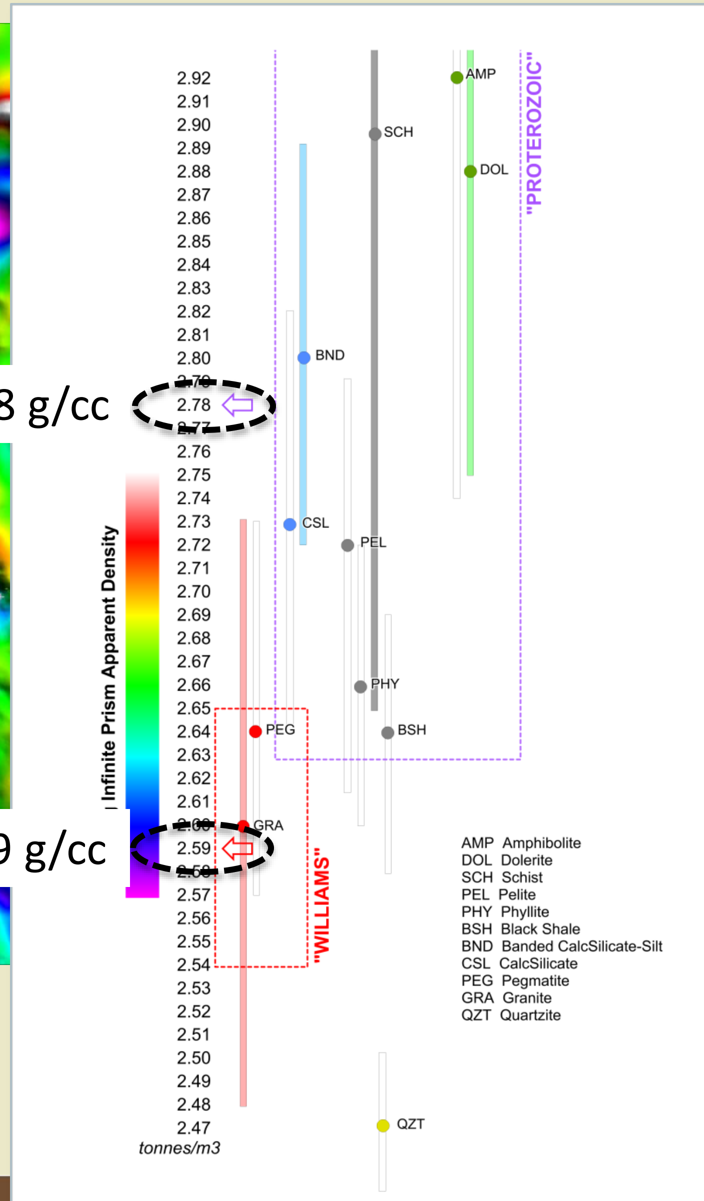
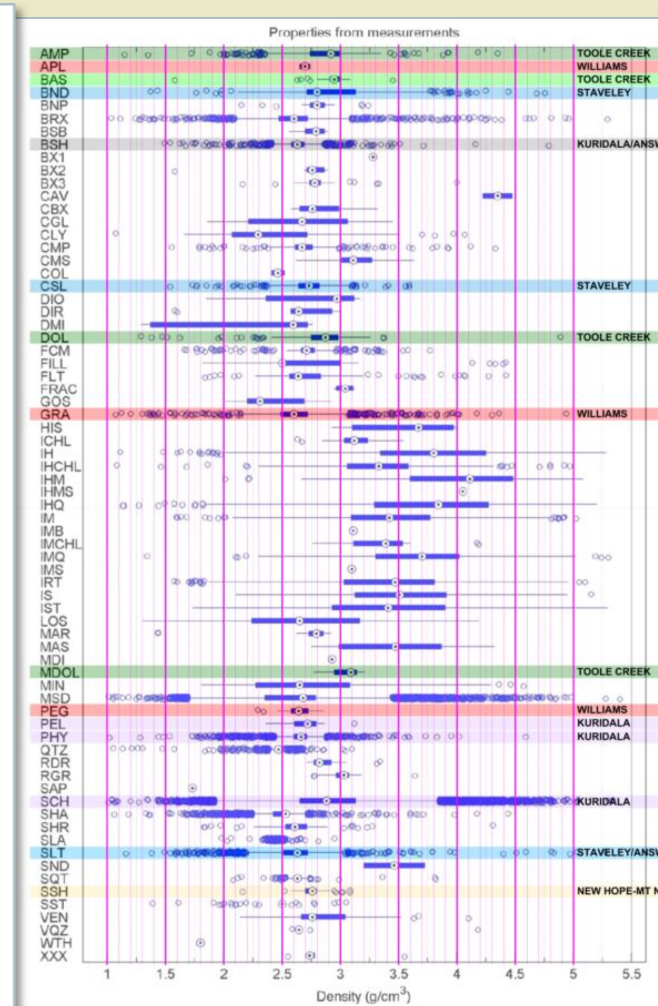
Assigning Density Contrasts to the Vpmg Model



‘Prot’ 2.78 g/cc

‘Granite’ 2.59 g/cc





App. Density Model

Chinova DDH Density data

Assigning Density Contrasts to the Vpmg Model

Mira Mt Dore Study: $Prot_{avg}$ - Granite Density Contrast = **+0.17**

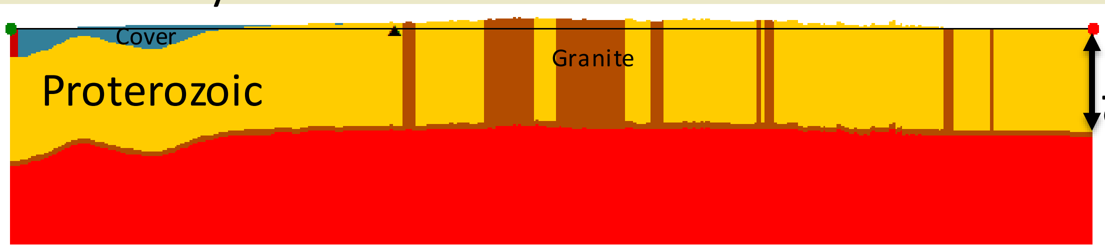
DMQ: $Prot_{avg}$ - Granite Density Contrast = **+0.19** (higher contrast -> less mass)

Final ('high') density <u>contrast</u> used.......

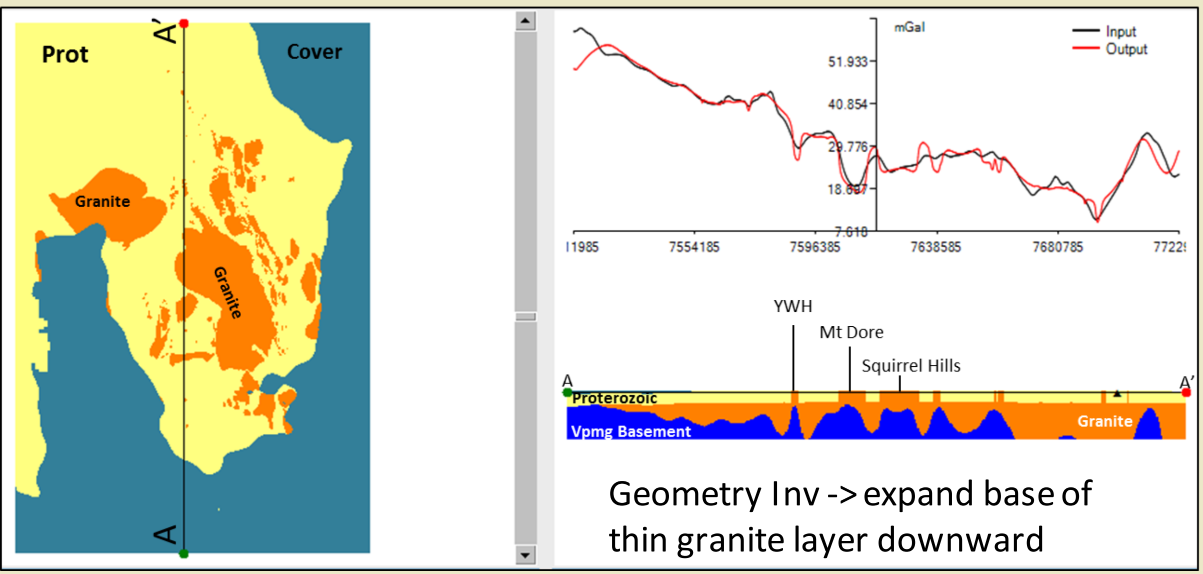
	LOW		MEDIUM		HIGH	
b/g	2.67	contrast	2.67	contrast	2.67	contrast
'Cover'	2.45	-0.22	2.45	-0.22	**2.45**	-0.22
'Cover LST'					**2.54**	-0.13
'Granite'	2.61	-0.06	2.61	-0.06	**2.59**	-0.08
'Proterozoic'	2.73	+0.06	2.79	+0.12	**2.78**	+0.11

Investigating granite thickness (via G Inv)

Model Style 'A'

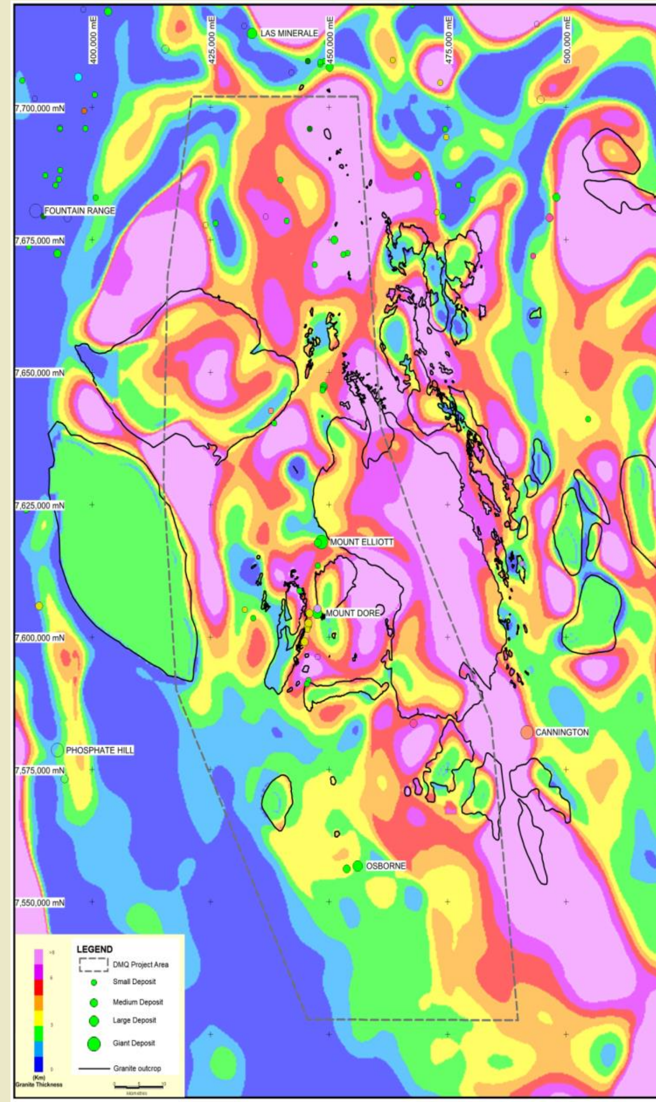


Input Model: 2km thick Prot over thin granite layer
(Base of thin granite free to expand)



Geometry Inv -> expand base of thin granite layer downward

Thickness of granite (km)



Investigating granite thickness (via G Inv)

Model Style A
(Granite base free)

Starting model

Output model

Model Style B
(no granite o/c,
Granite top & bottom free)

Starting model

Output model

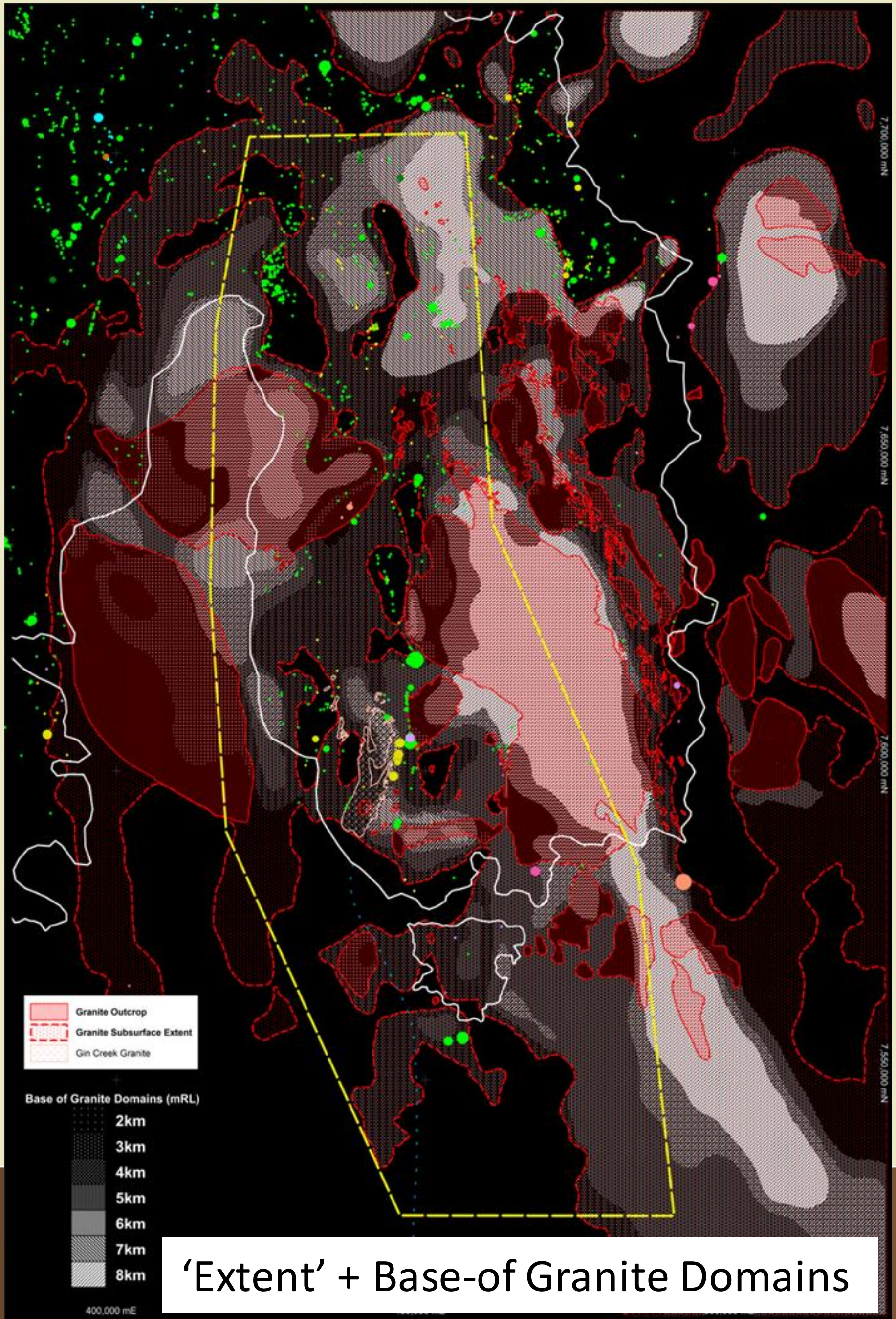
Model Style C
(Granite top free)

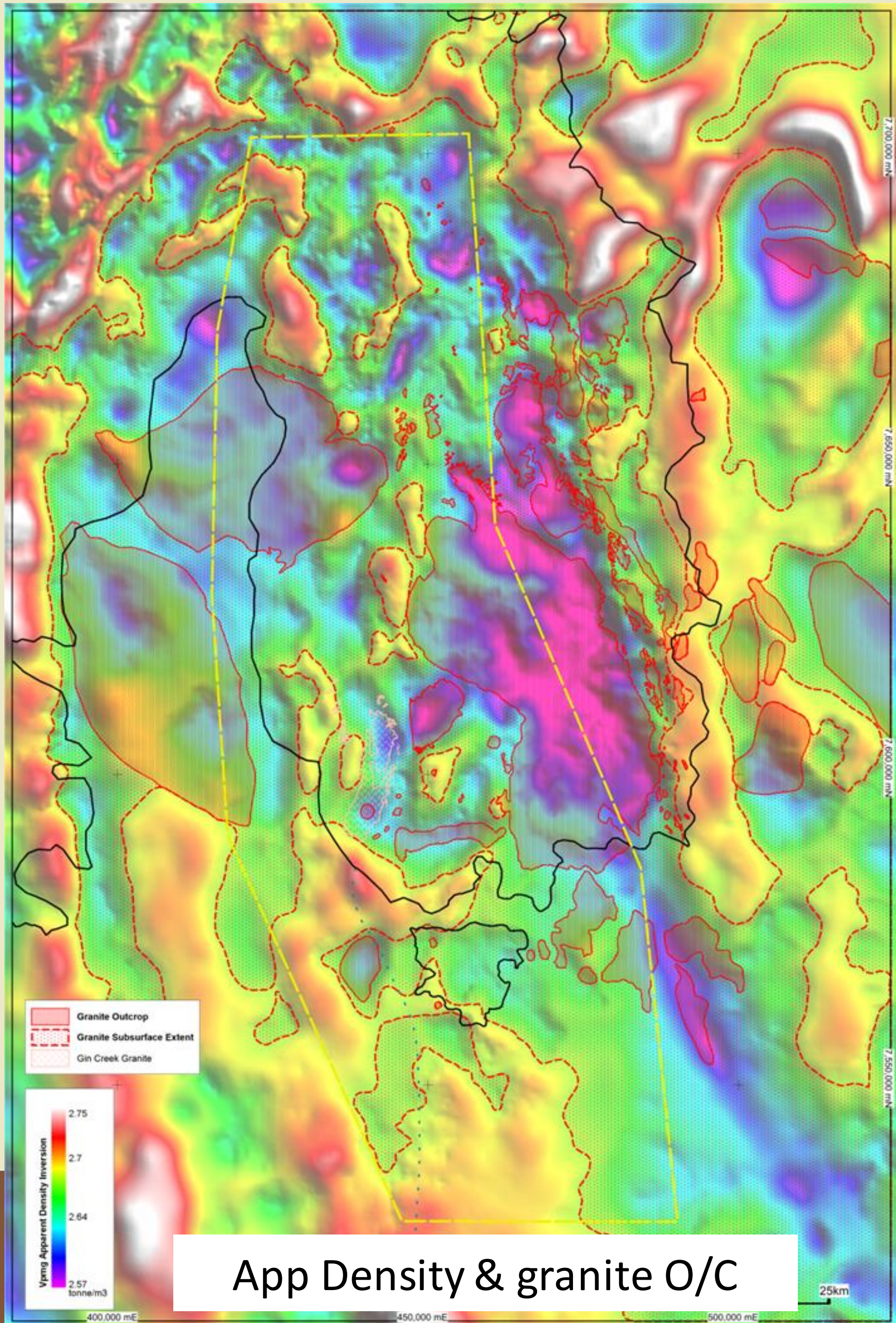
Starting model

Output model

Not that useful for defining granite morphology.......

Generating 'Base-of-granite' Domains from granite thickness



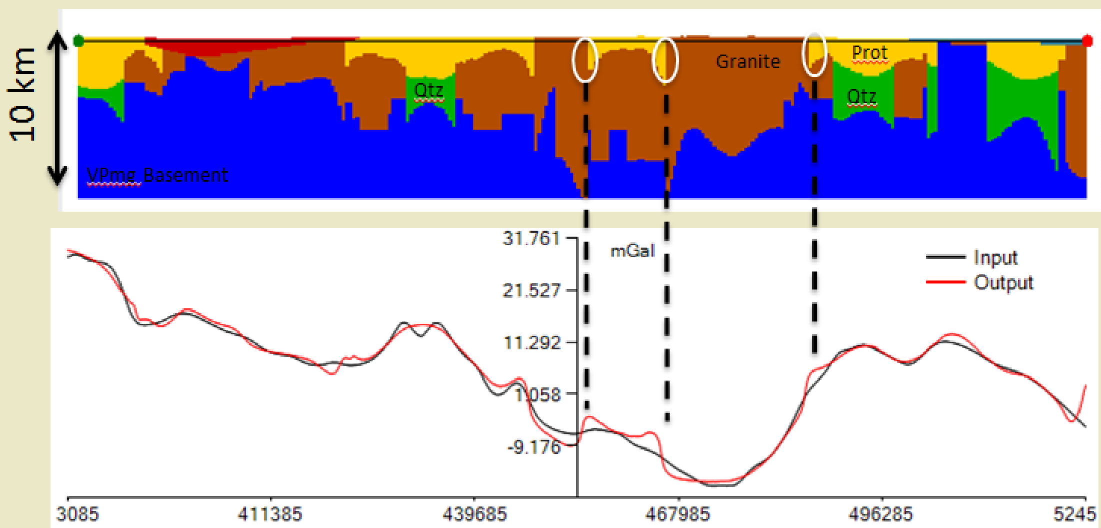


‘Base-of-granite’ Domain Geometry Inversions

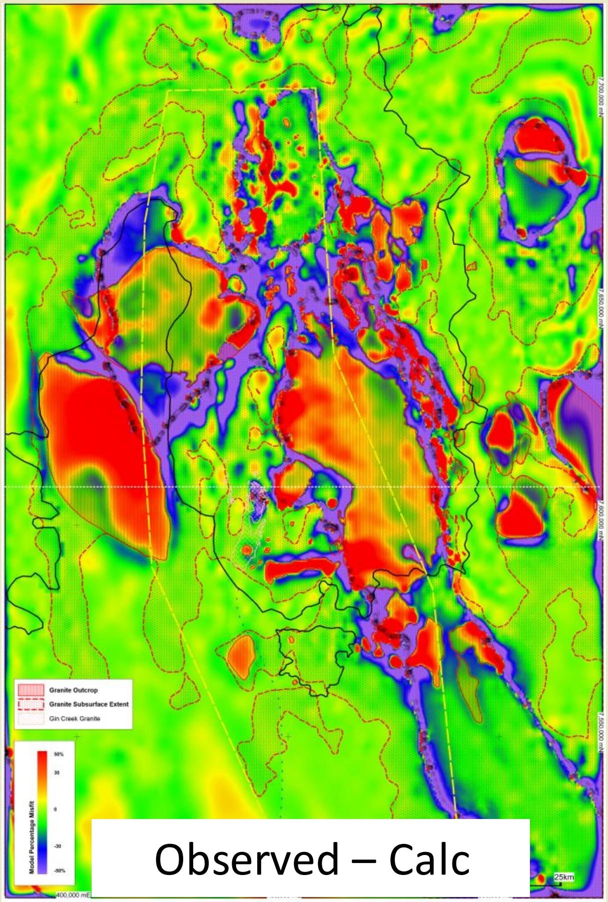
Starting model

1) Added Quartzite unit (low density zones that are not granite)
2) Top of granite set @ 0.5 x depth of granite base
3) Top-of-Ganite – Base-of-Prot interface allowed to change
4) Allowed fixed base-of-granite below outcrop areas to change also

Output model

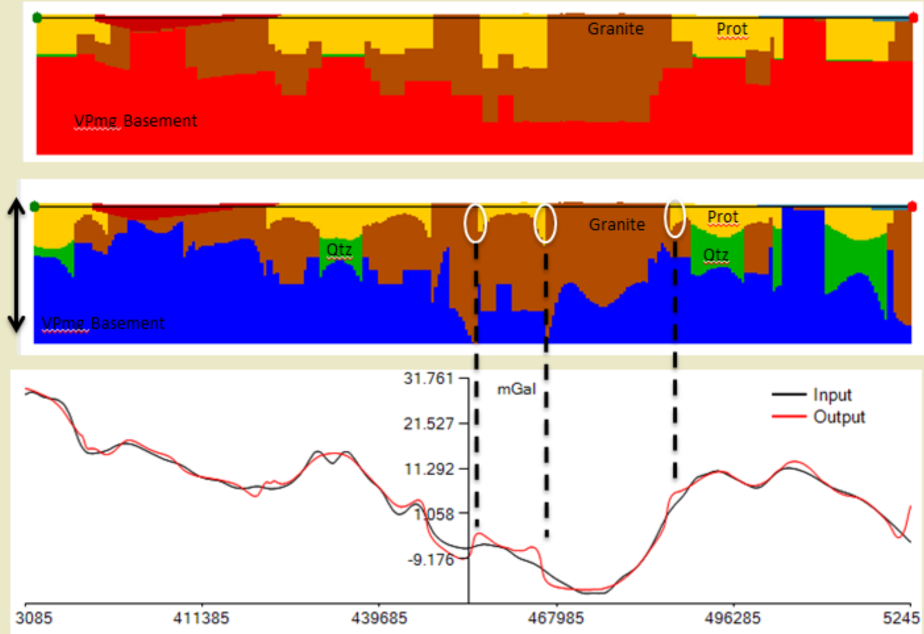


Problem with O/C in ‘Base of granite’ domain models.....



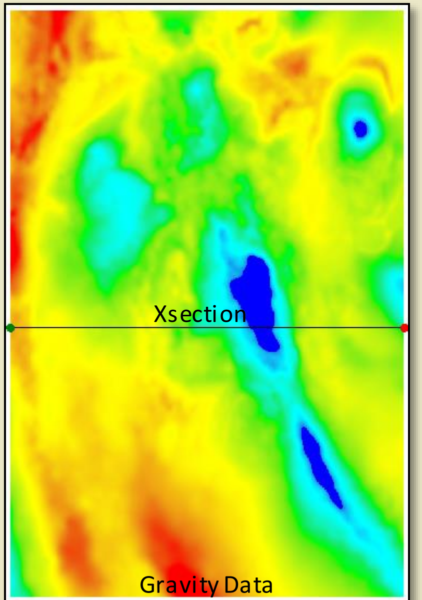
Starting model

Output model



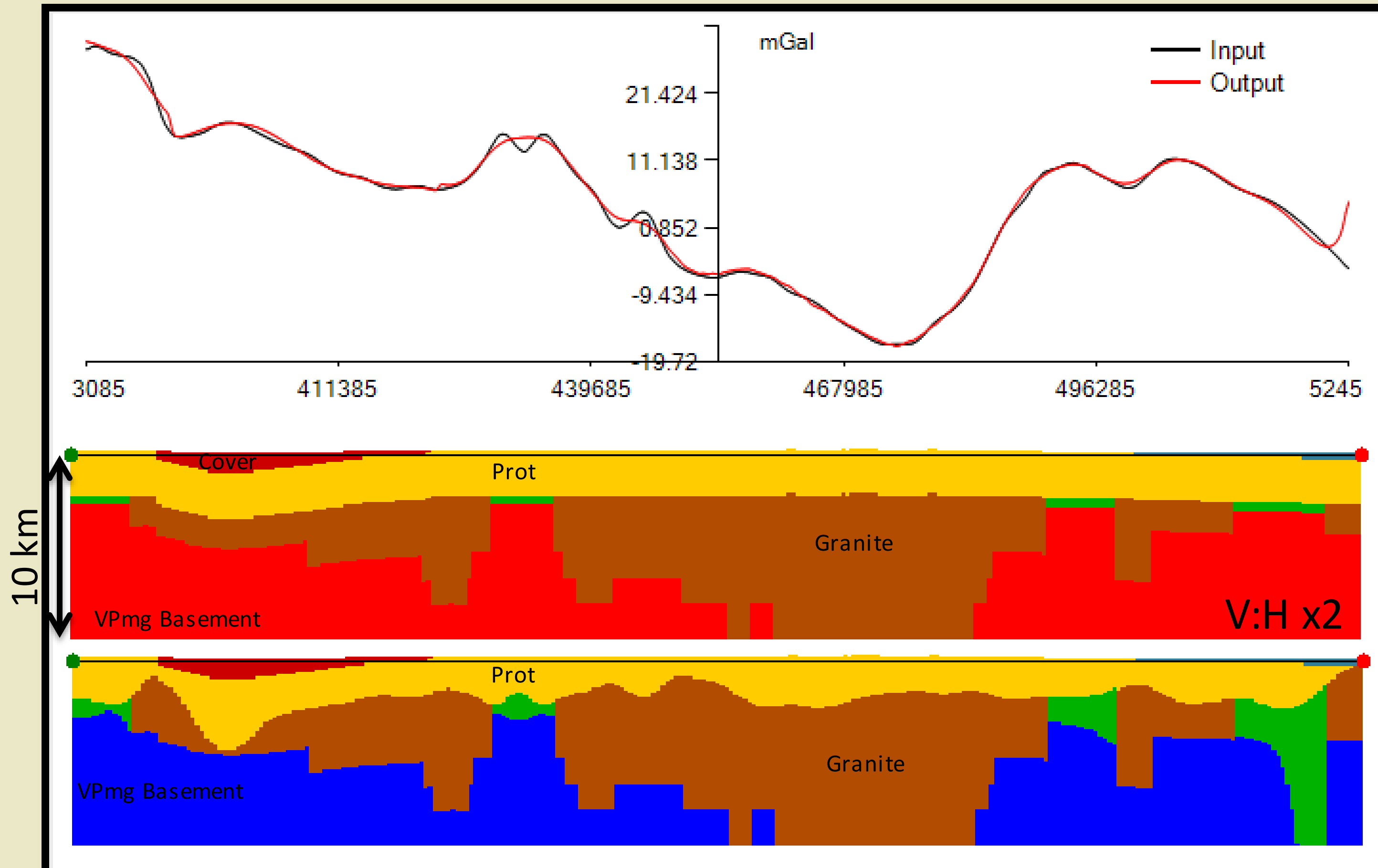
Geometry Inv can’t adjust/smooth the vertical density contrast at surface

Develop the ‘Grow’ granite upwards option



Input model

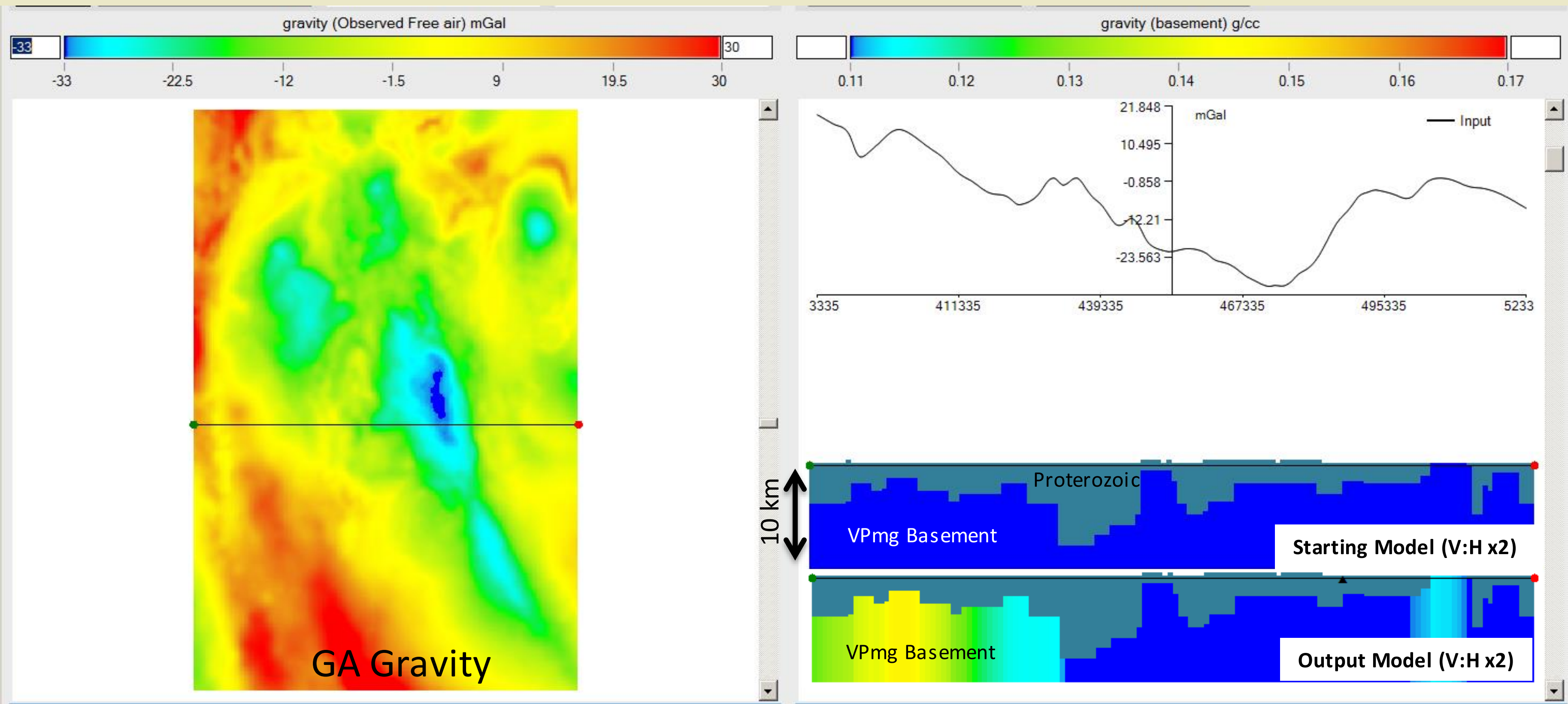
Output model



Step change in getting useable models.....

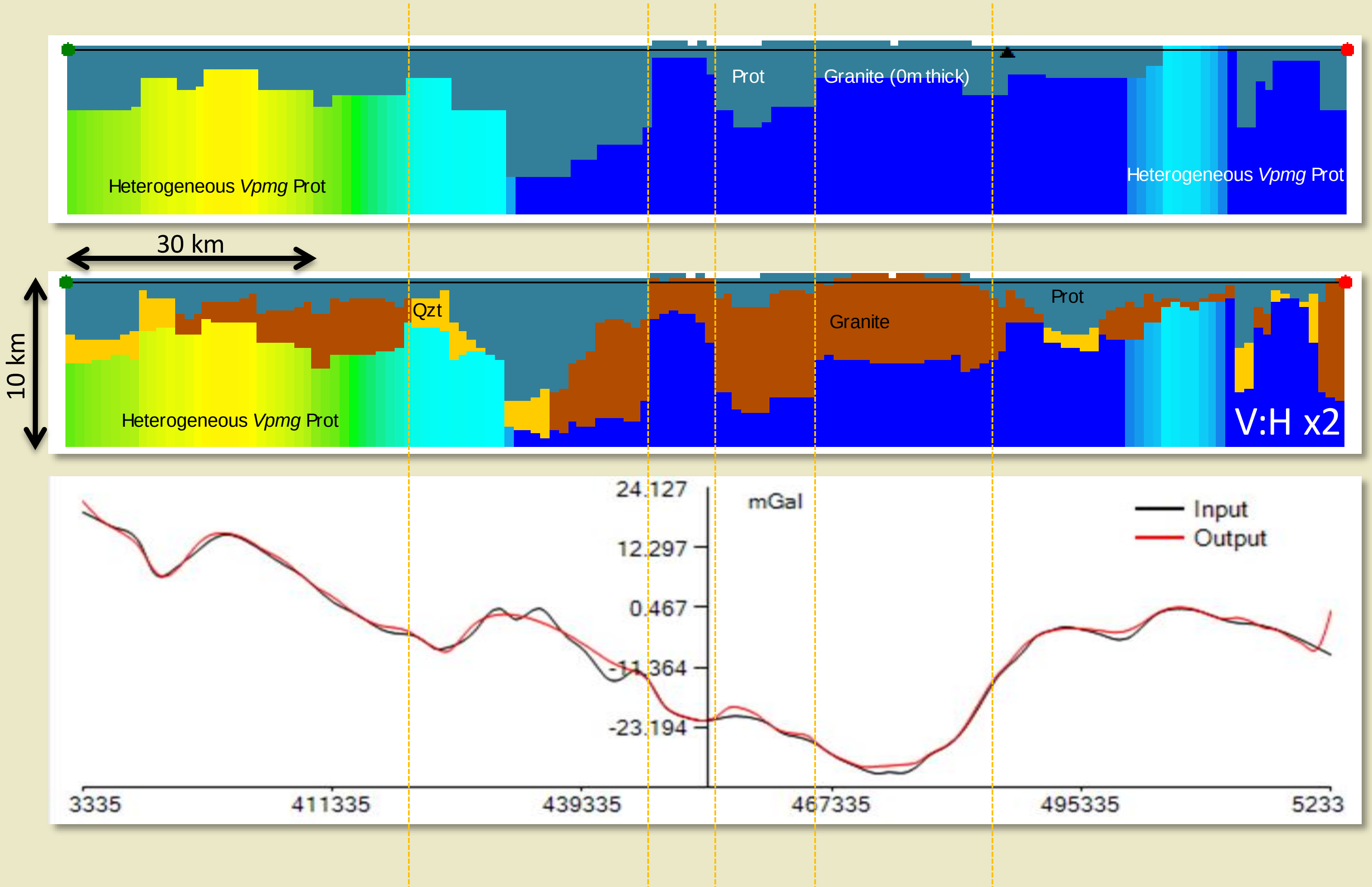
- Domained input model to granite ‘<u>mid-depths</u>’,
- Granite layer (& low density Qtz) set to 0m thick
- Two step procedure

1) Address poor misfits beyond AOI via Heterogeneous Inversion of Vpmg Basement

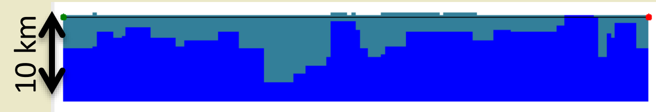


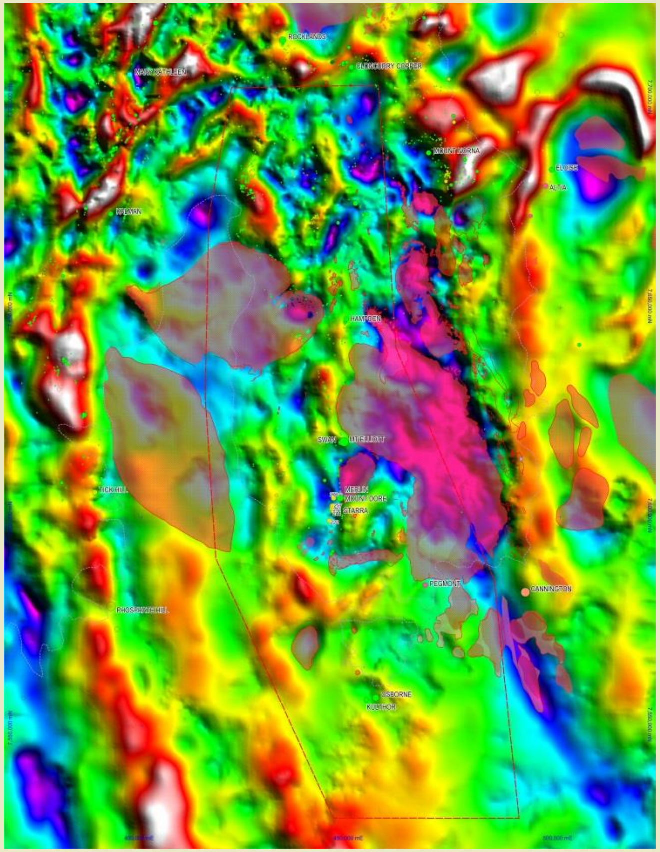
Step change in getting useable models.....

2) Invoke growing of granite volumes from granite unit 0m thick via Geometry Inversion (+ magnify adjustments made to shallow interfaces)

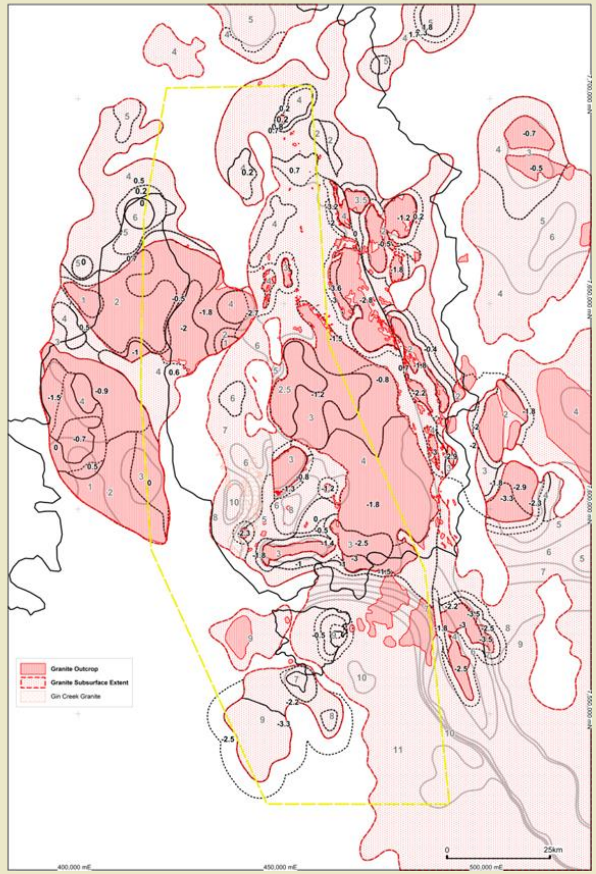


After many refinements.....

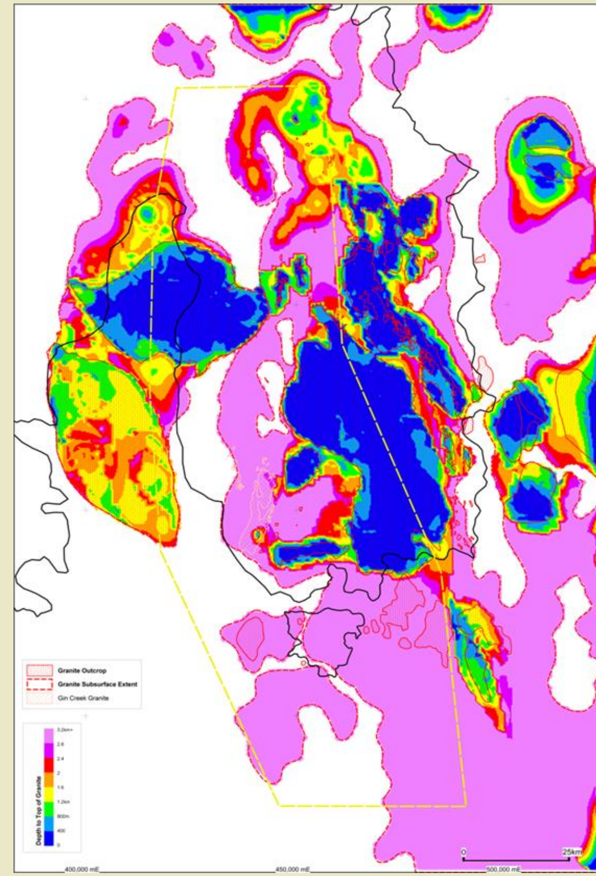




App Density

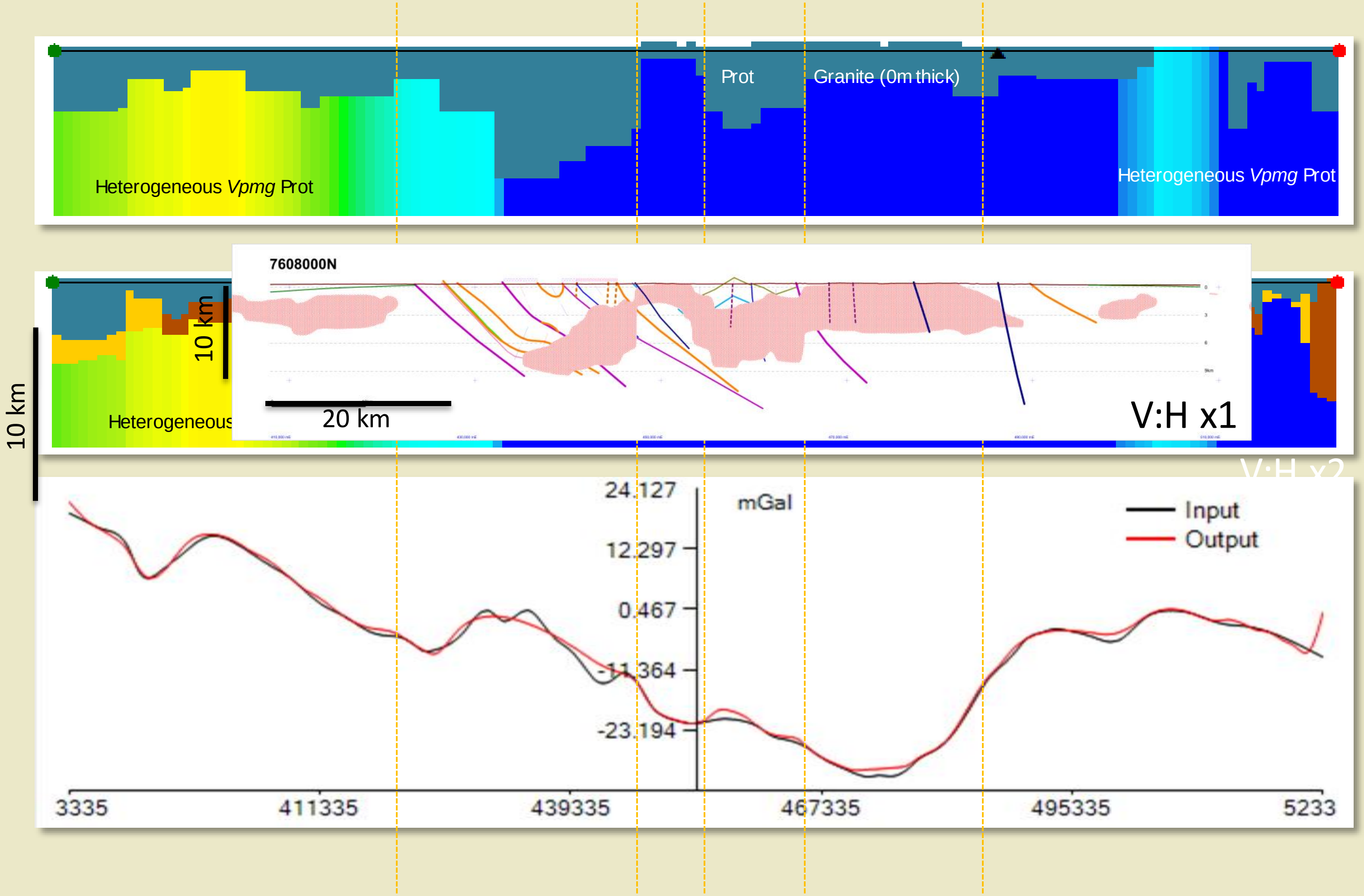


Revised ‘Mid-Depth’ Domains

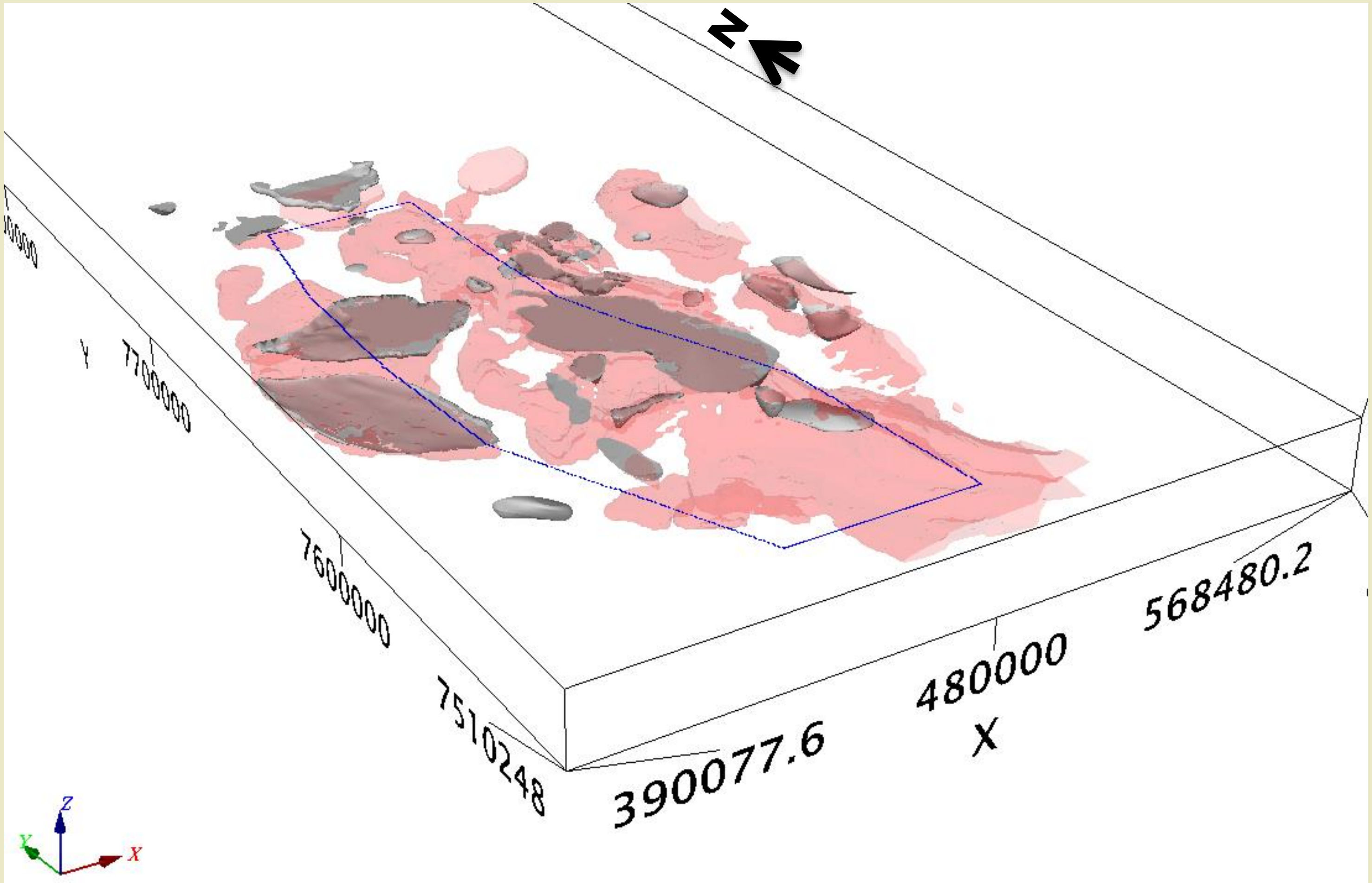


Depth to top of Granite
(0 - 3.2 km)

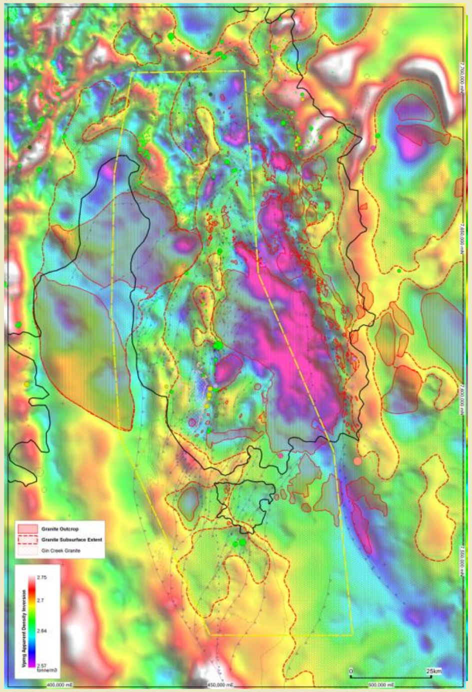
After many refinements.....



The final granite geometry.....



Summary



VPmg regional scale App. density model suggests more sub-surface granite than previously acknowledged

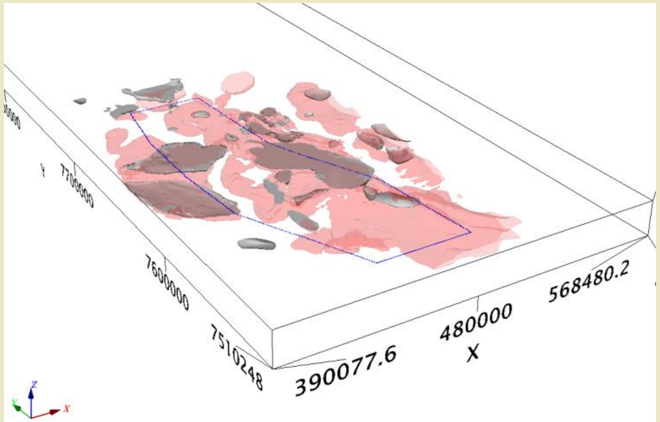
Close spatial relationship between min occ. and margins/shoulders of granites in the App. Density model

Geological constraints simplified to a three unit density model; Granite – Prot – Quartzite, +/- Cover

Determine potential granite thicknesses via Geometry Inversion of gravity data

Domain the 3D volume according to an <u>interpreted</u> depth of 'mid-granite level'

Perturb a 0m thick granite layer via geometry inversion to match the gravity data (while honouring outcrop)



Geophysics

Some text