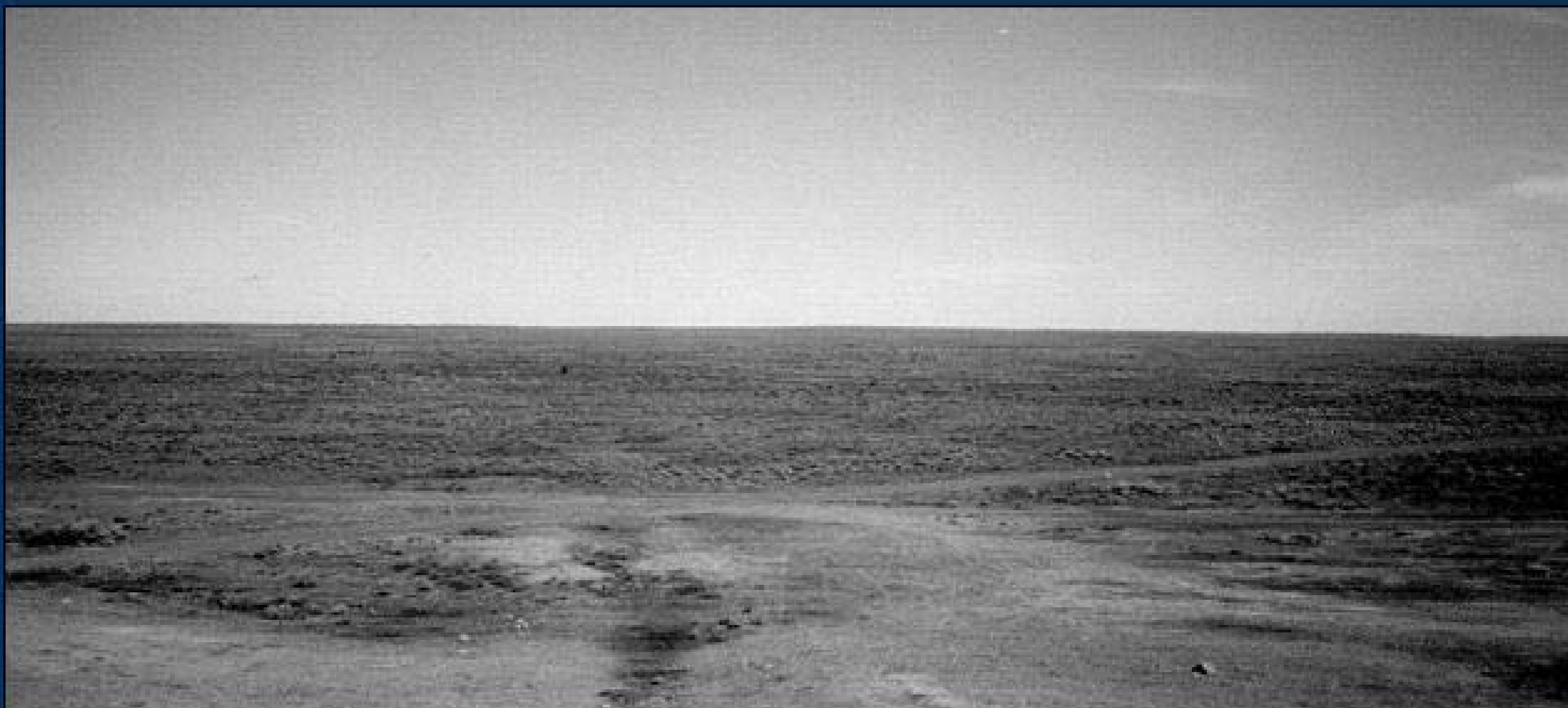
Australian Government

Geoscience Australia

3D INVERSION
of
POTENTIAL FIELD DATA
from the
OLYMPIC Cu-Au PROVINCE

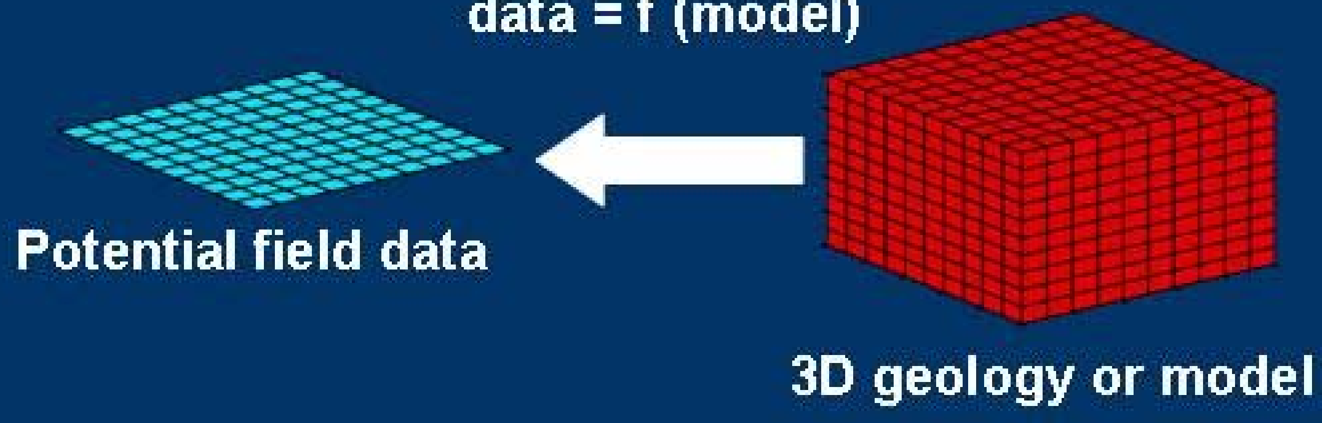
Nick Williams Richard Lane Peter Milligan
Patrick Lyons

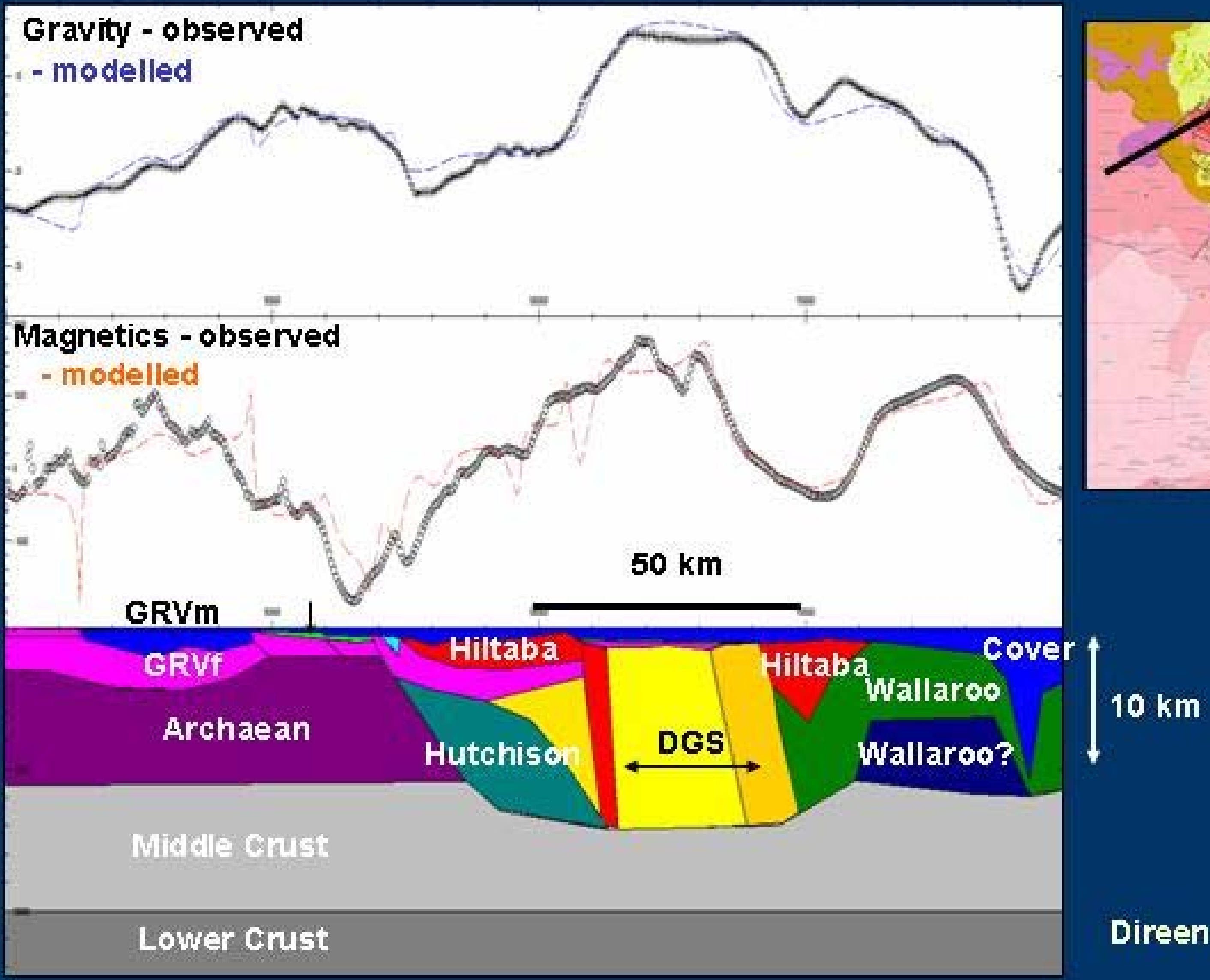


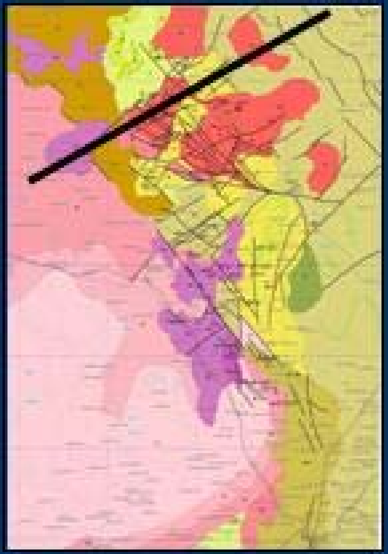
Interpretation of magnetic and gravity data relies on interpreter's *skill*, *knowledge*, *objectivity*, and *consistency*

PROFILE FORWARD MODELLING

- Profile forward modelling calculates the predicted response of a hypothesised geological model of density and susceptibility
- Provides basic architecture, but only in thin strips





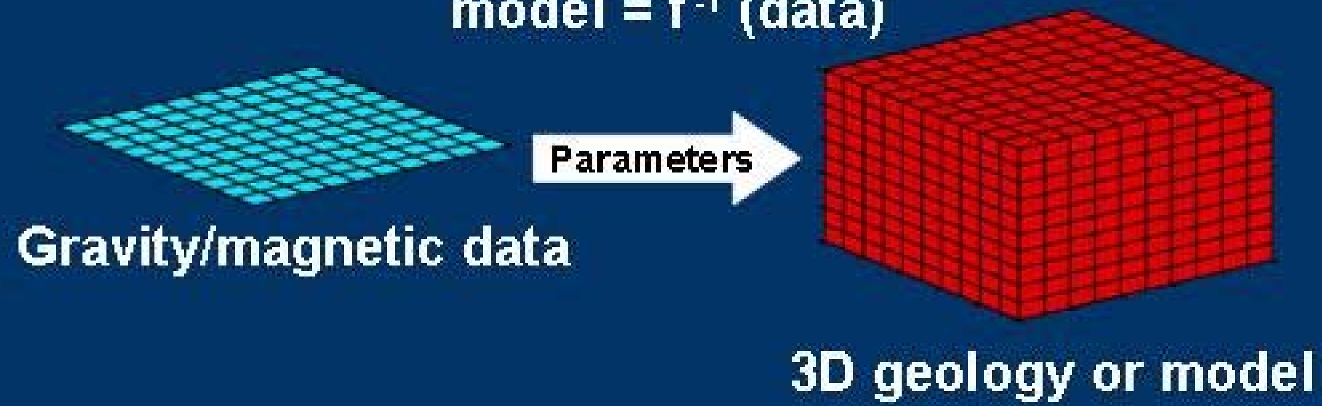


Direen *et al.*, 2002

INVERSION

- Inversion calculates a property distribution (density and susceptibility) from the data subject to a range of parameters
- No depth information in the data, so the result is non-unique. This is GAUSS'S LAW

model = f^{-1} (data)



WHY INVERT?

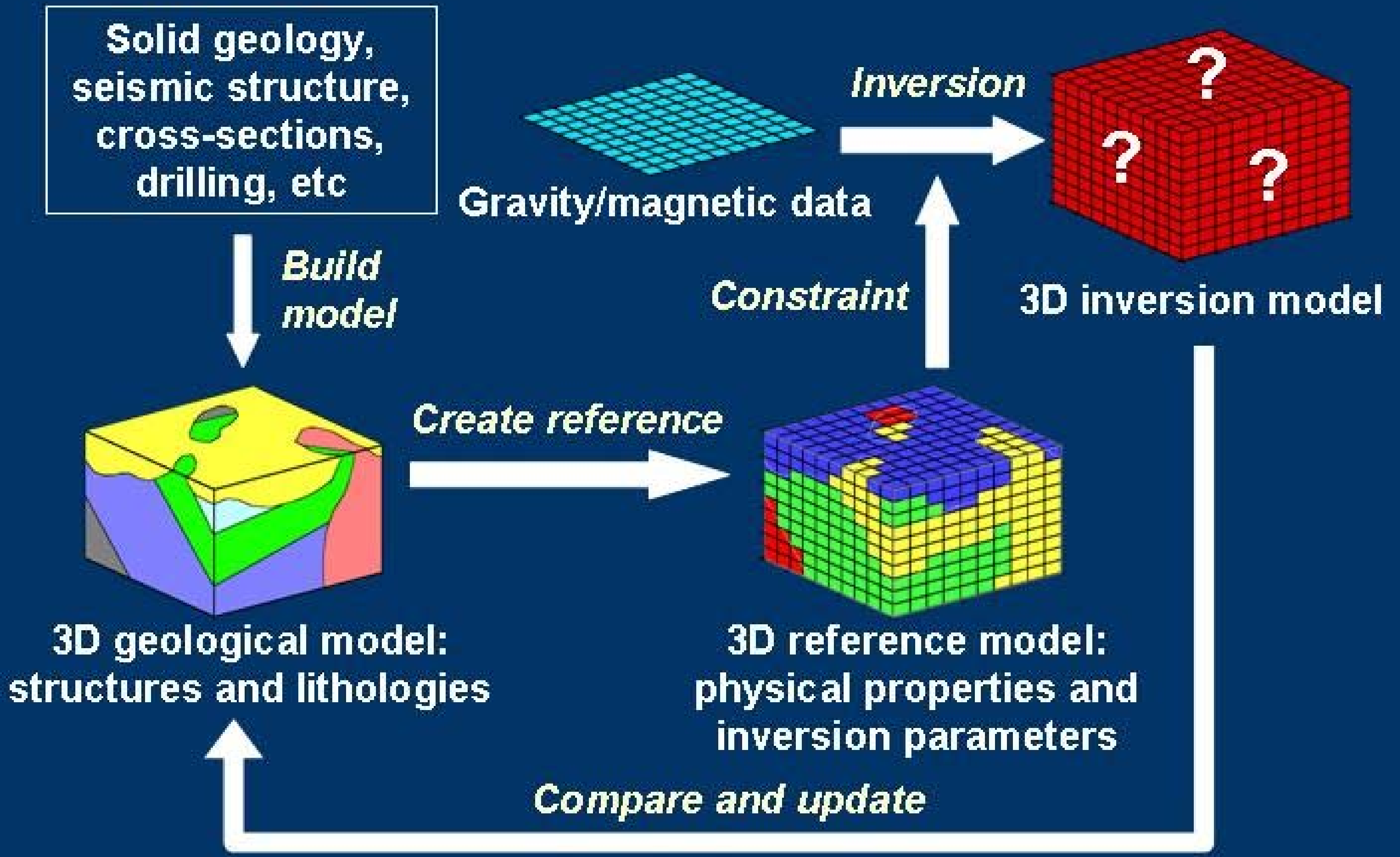
- 3D structure – difficult to connect individual 2D cross-sections
- Can be guided by existing knowledge
- Rigorously and objectively account for all features in the data
- Ensure consistency between models and observations
- Allow for systematic errors in the data
- Show where models are not compatible with data
- The method is independent of scale

Guide 2.

Regional host sequence:

- **Olympic Cu-Au province**: oxidised, feldspathic; minor carbonate, BIF, graphite
- **Central Gawler gold province**: granitoids; graphitic metaseds; Archaean gneiss & greenstones – more reduced?

CONSTRAINED INVERSION



Source: Lane, 2002

UBC-GIF MAG3D & GRAV3D

- Successful inversion *will always fit the data*, within error within and acceptable misfit
  - Cannot deal with remanence
- Constrained inversion *will* fit the data while matching the reference model as closely as possible
  - *Smallness*: The bigger the smallness, the closer the desired match to the reference model
- If it is *not* possible to match both the *reference model* and the *data*, the inversion moves away from the reference model until it *can fit the data*
  - Can't be deceived by erroneous models

REGION INVERTED

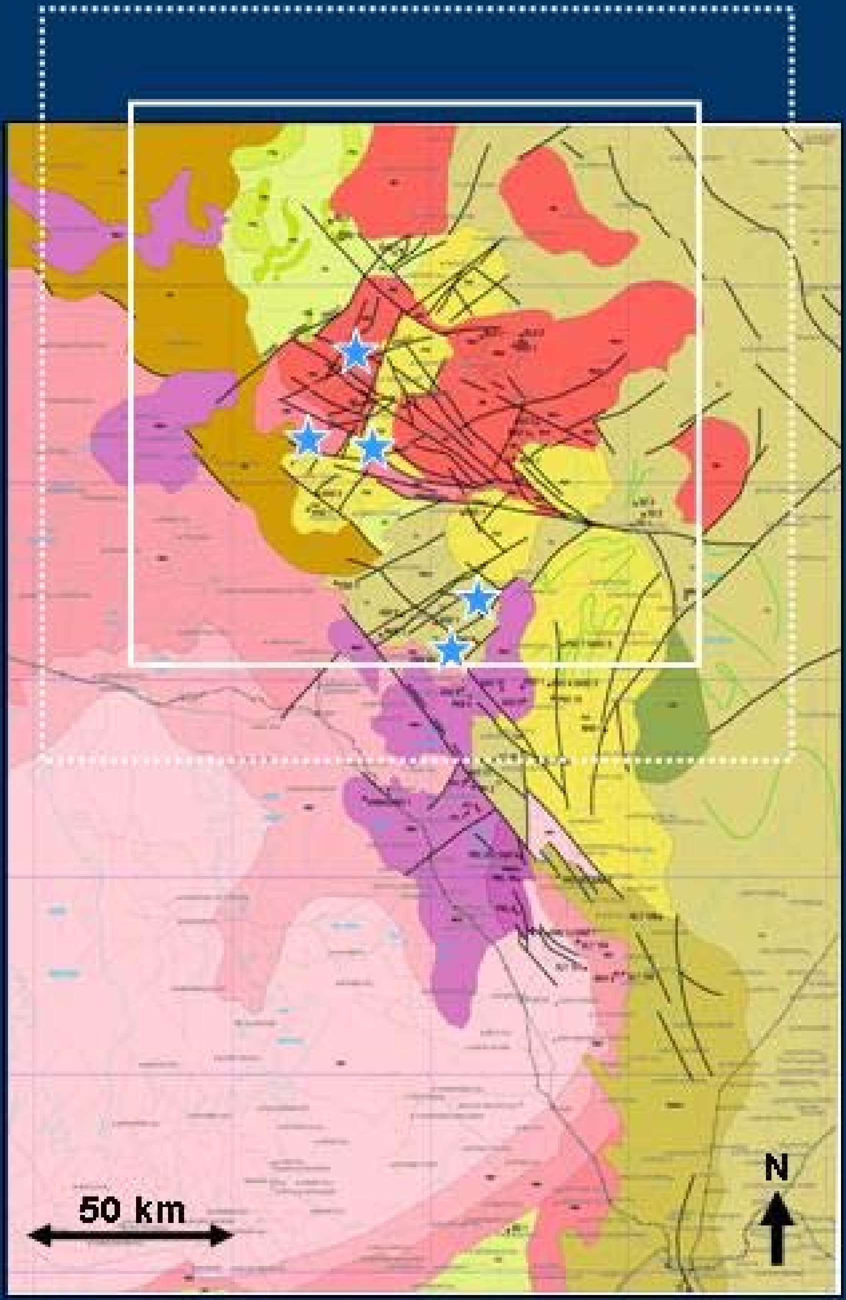
Volume of interest:

150 km × 150 km × 12 km
= 270,000 km^3

Padded extent:

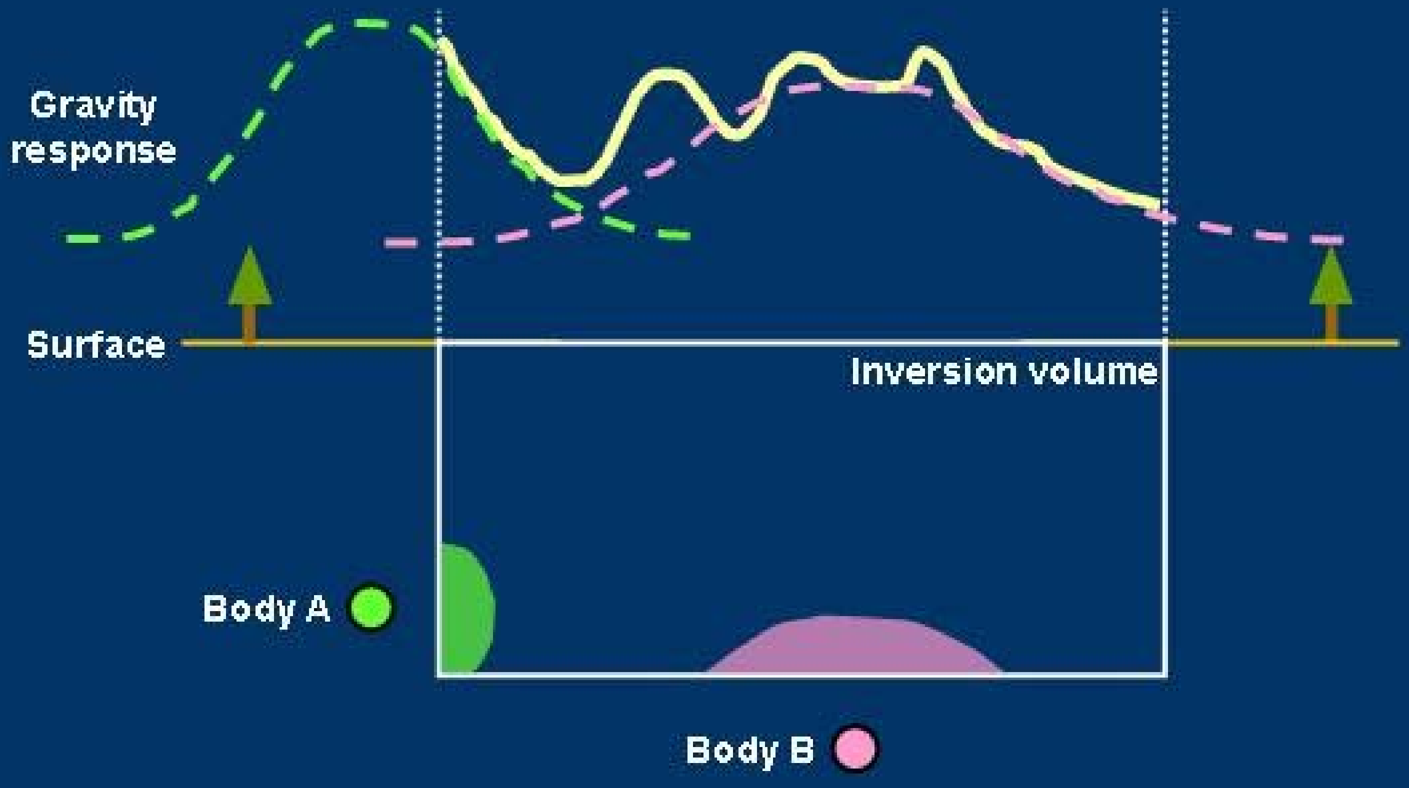
198 km × 198 km × 18 km
= 705,672 km^3

- Use 1 km × 1 km × 0.5 km cells for inversion
  = 1,411,344 cells



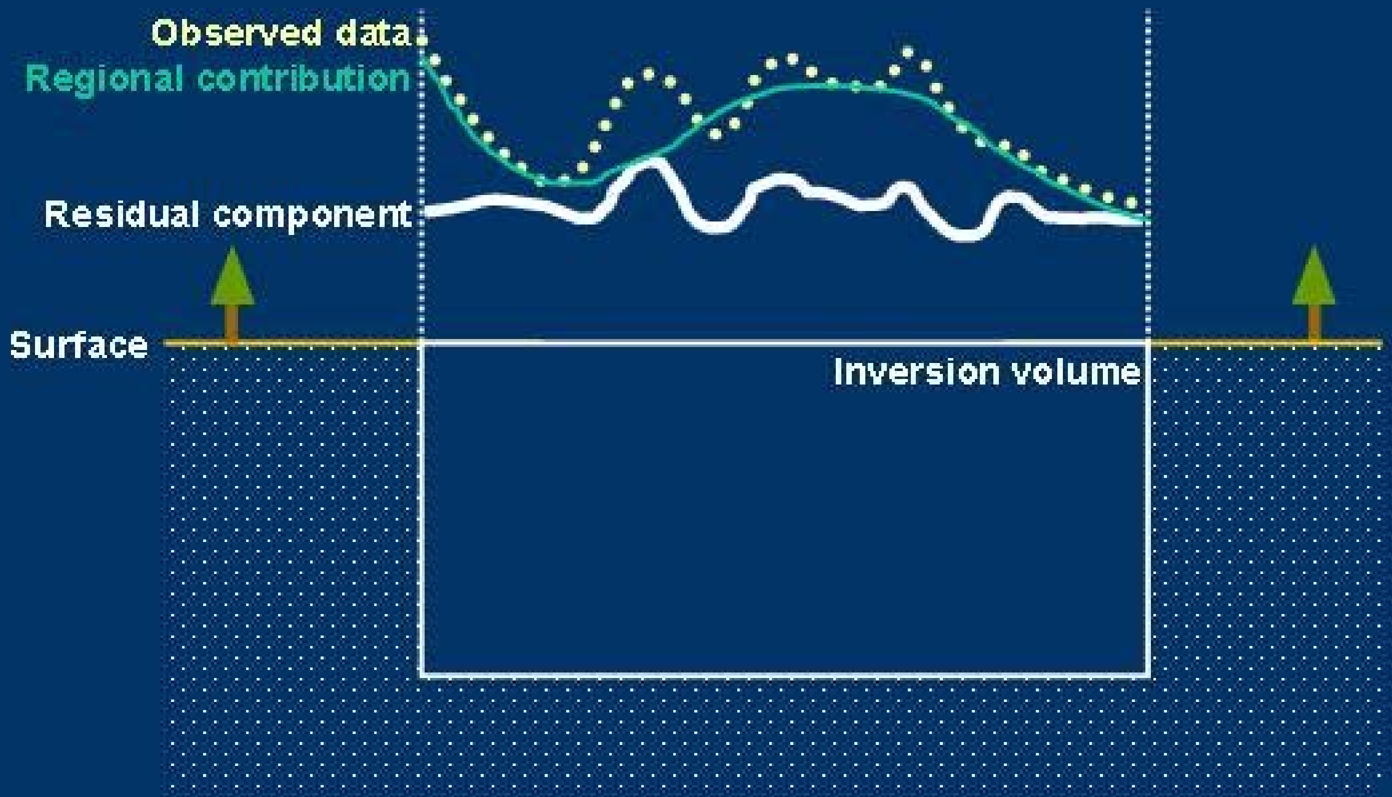
REMOVE REGIONAL & EXTERNAL EFFECTS

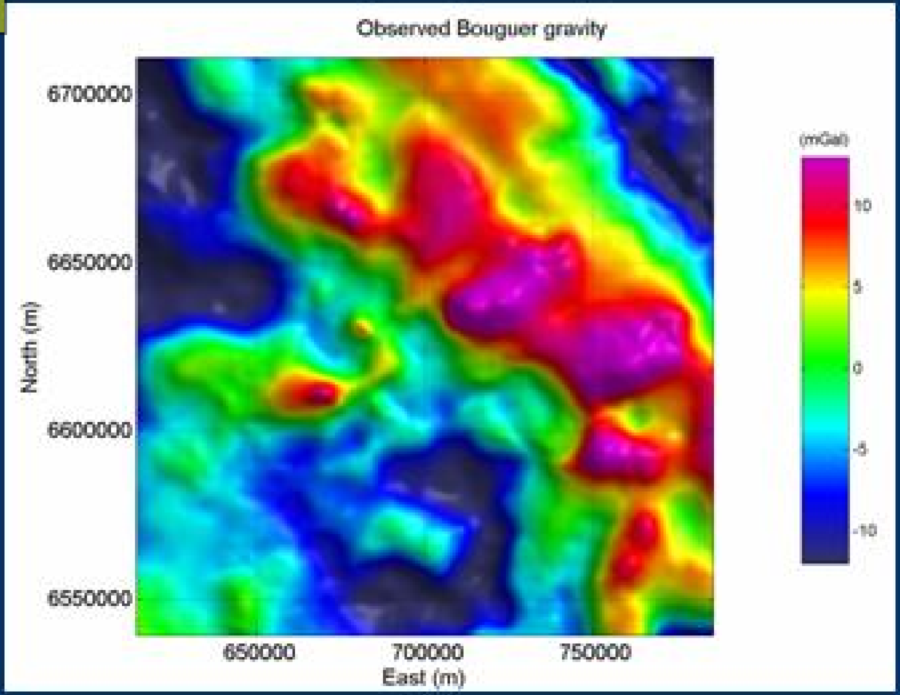
- For the inversions to work, features within the volume of interest must be able to reproduce all of the observed data

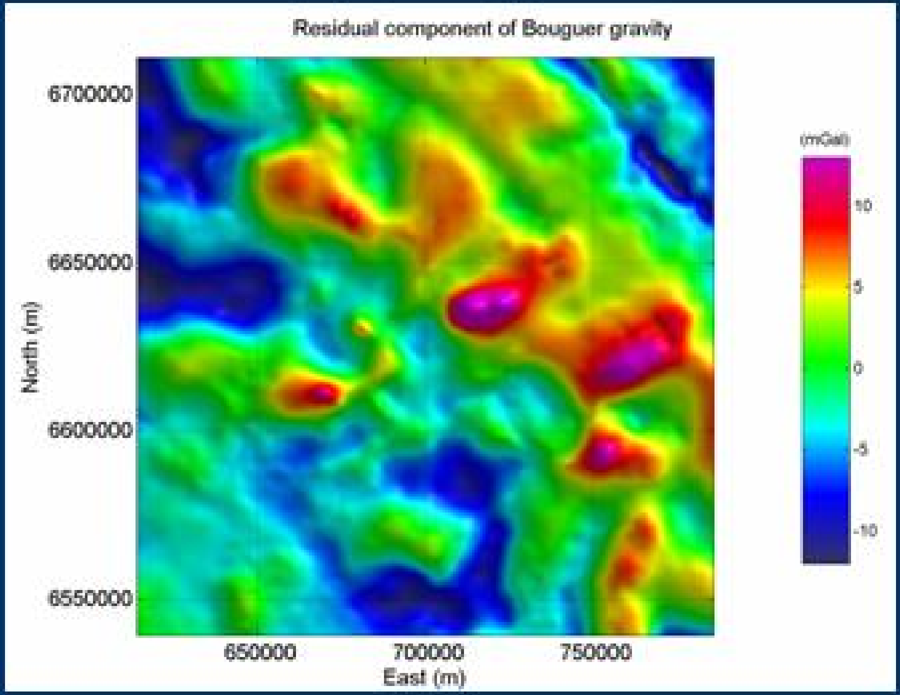


REMOVE REGIONAL & EXTERNAL EFFECTS

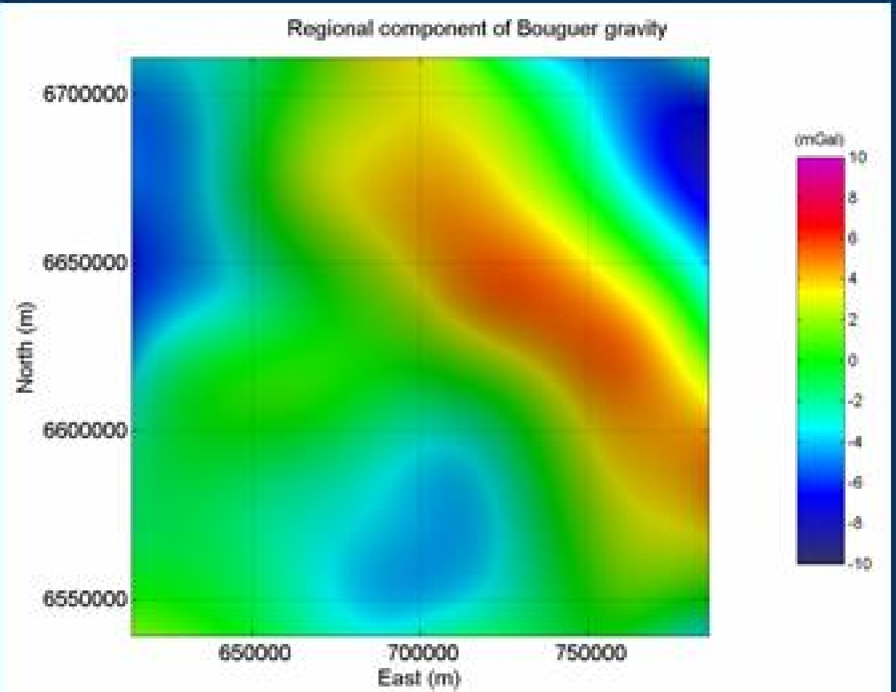
- For the inversions to work, features within the volume of interest must be able to reproduce all of the observed data
- The effects of features outside the volume must be removed from the data

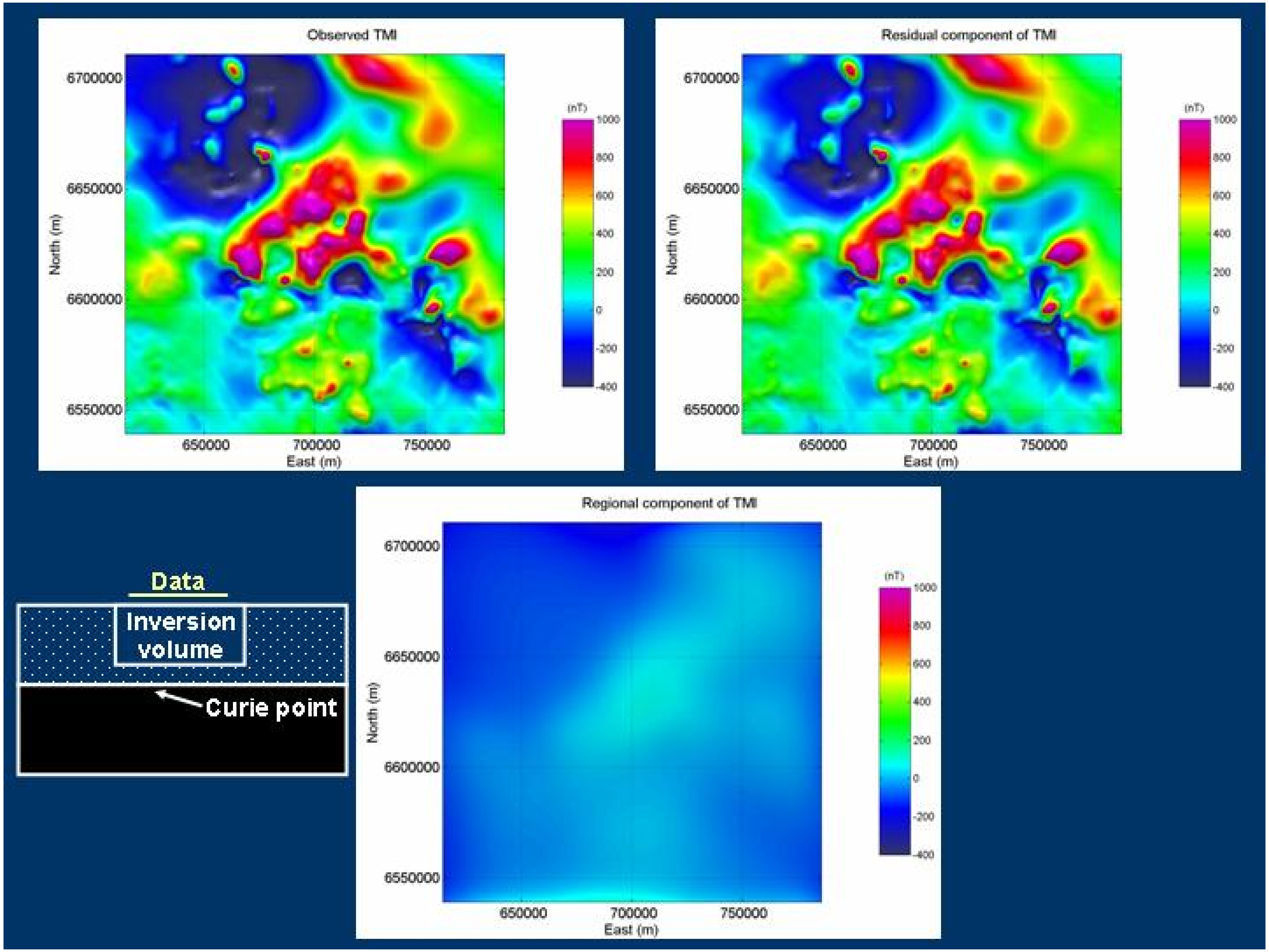



Observed Bouguer gravity
(mGal)
10
5
0
-5
-10
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)

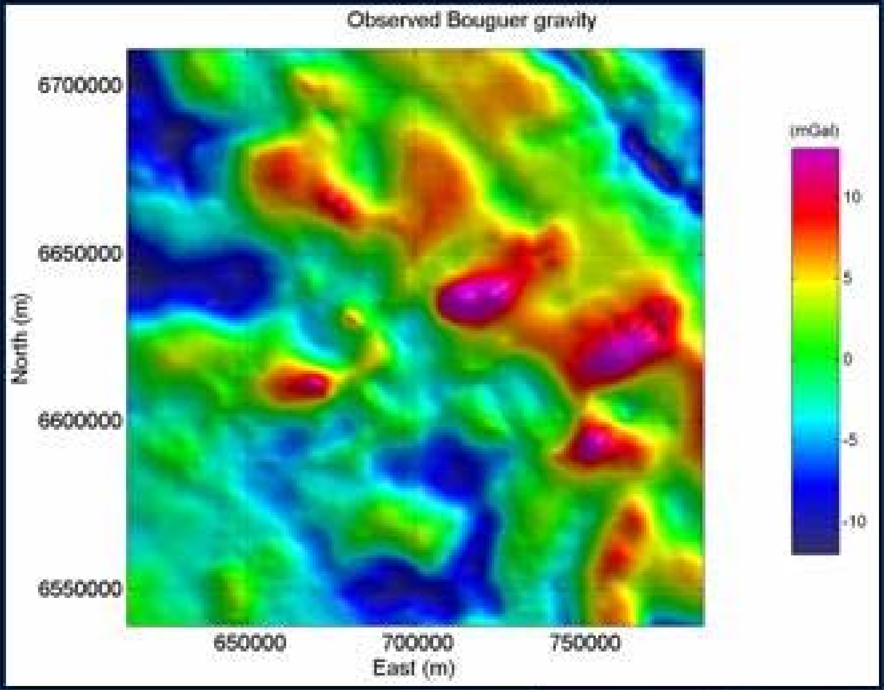

Residual component of Bouguer gravity
(mGal)
10
5
0
-5
-10
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)

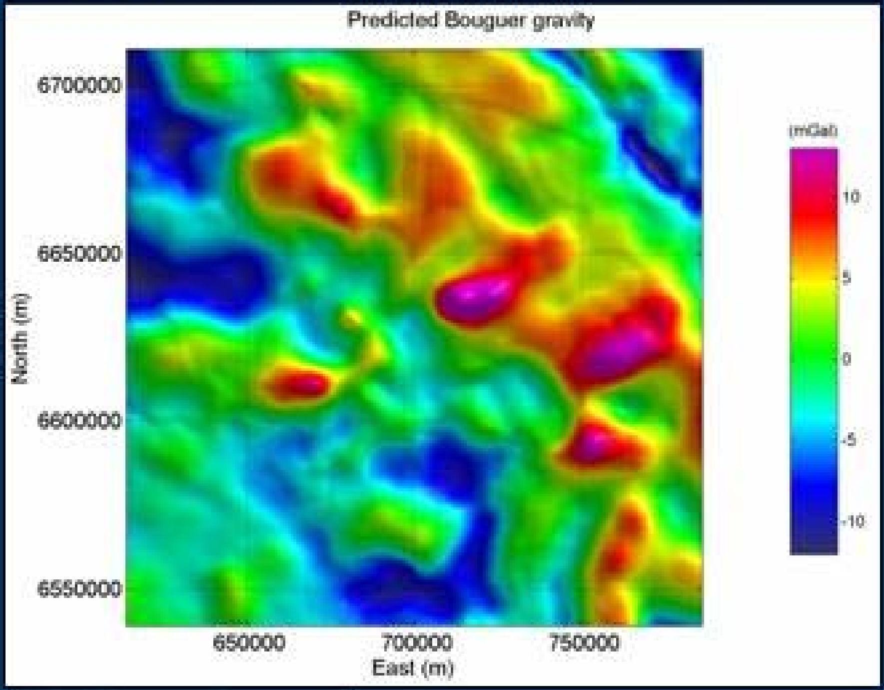

Data
Inversion
volume


Regional component of Bouguer gravity
(mGal)
10
8
6
4
2
0
-2
-4
-6
-8
-10
6700000
6650000
6600000
6550000
North (m)
650000
700000
750000
East (m)


Observed TMI
Residual component of TMI
Regional component of TMI
North (m)
East (m)
6700000
6650000
6600000
6550000
650000
700000
750000
(nT)
1000
800
600
400
200
0
-200
-400
Data
Inversion volume
Curie point

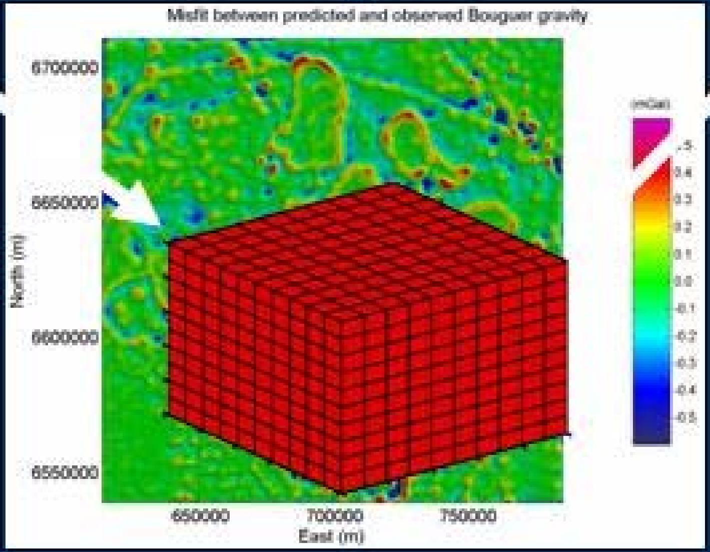
OBSERVED AND PREDICTED GRAVITY DATA





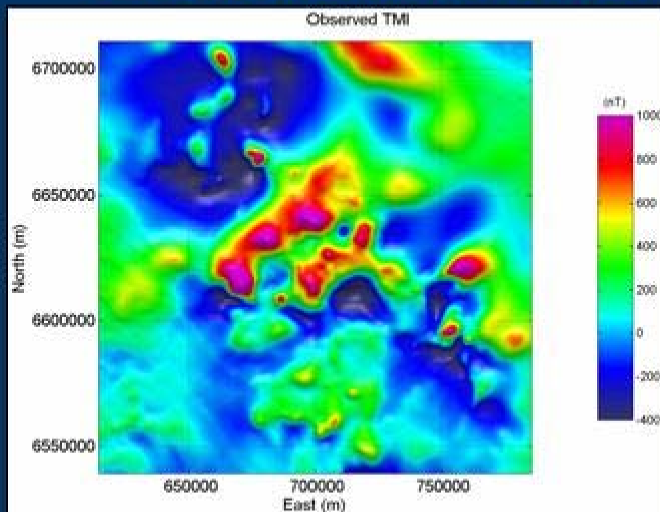
Invert

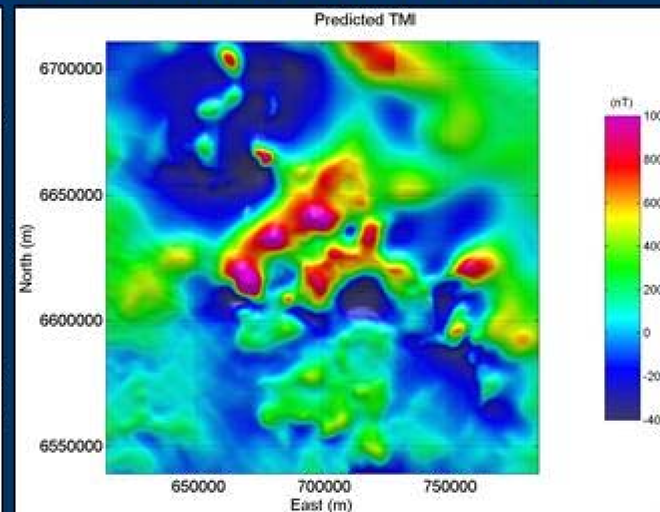
Misfit range ~5% of data range



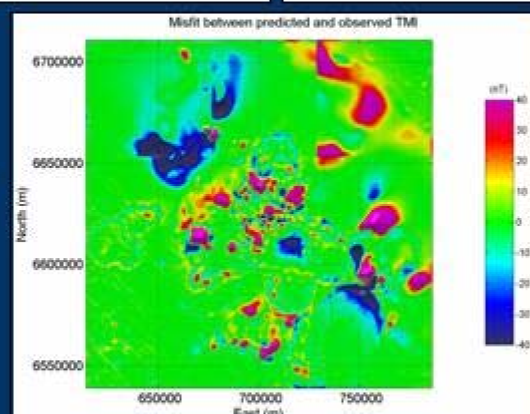
Forward model

OBSERVED AND PREDICTED MAGNETIC DATA



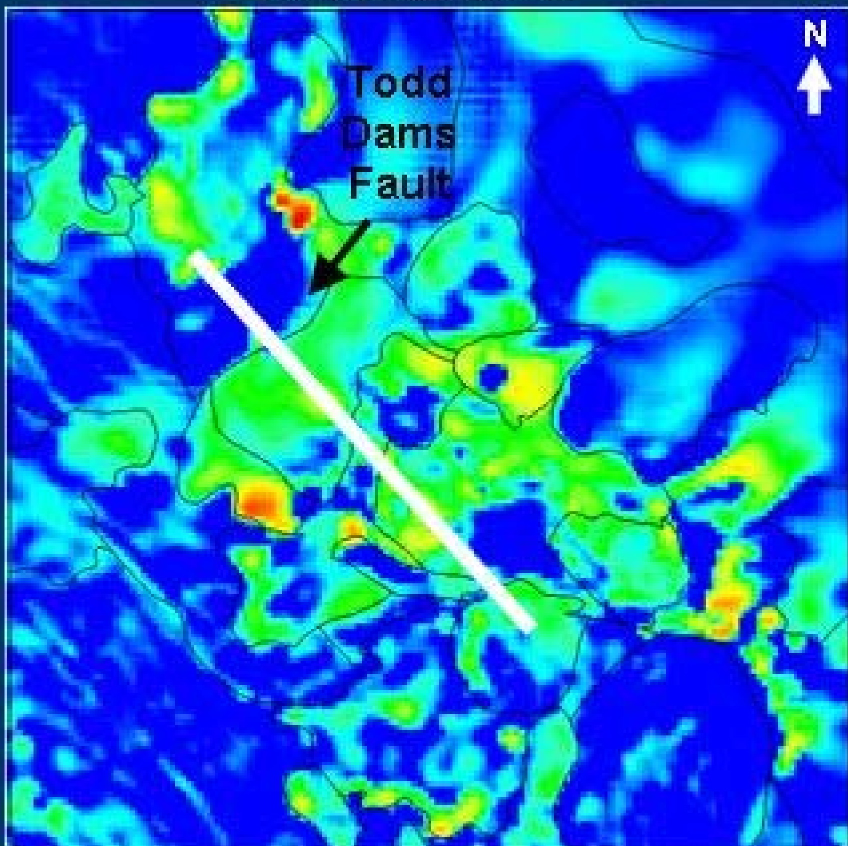


Misfit range ~6% of data range

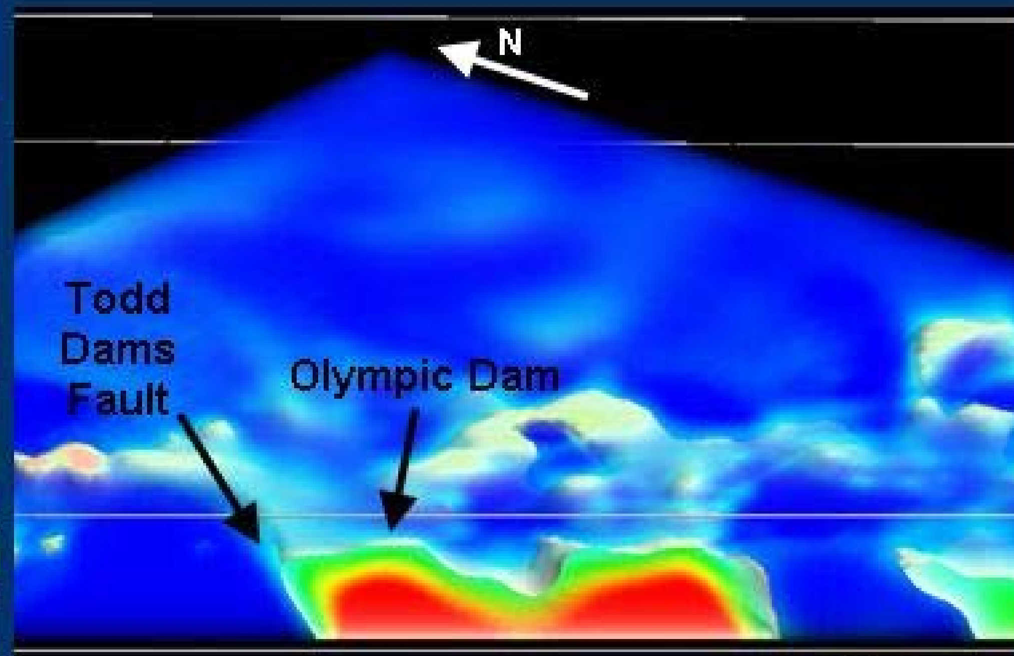


UNCONSTRAINED MAGNETIC INVERSION

-1000 m slice



50 km

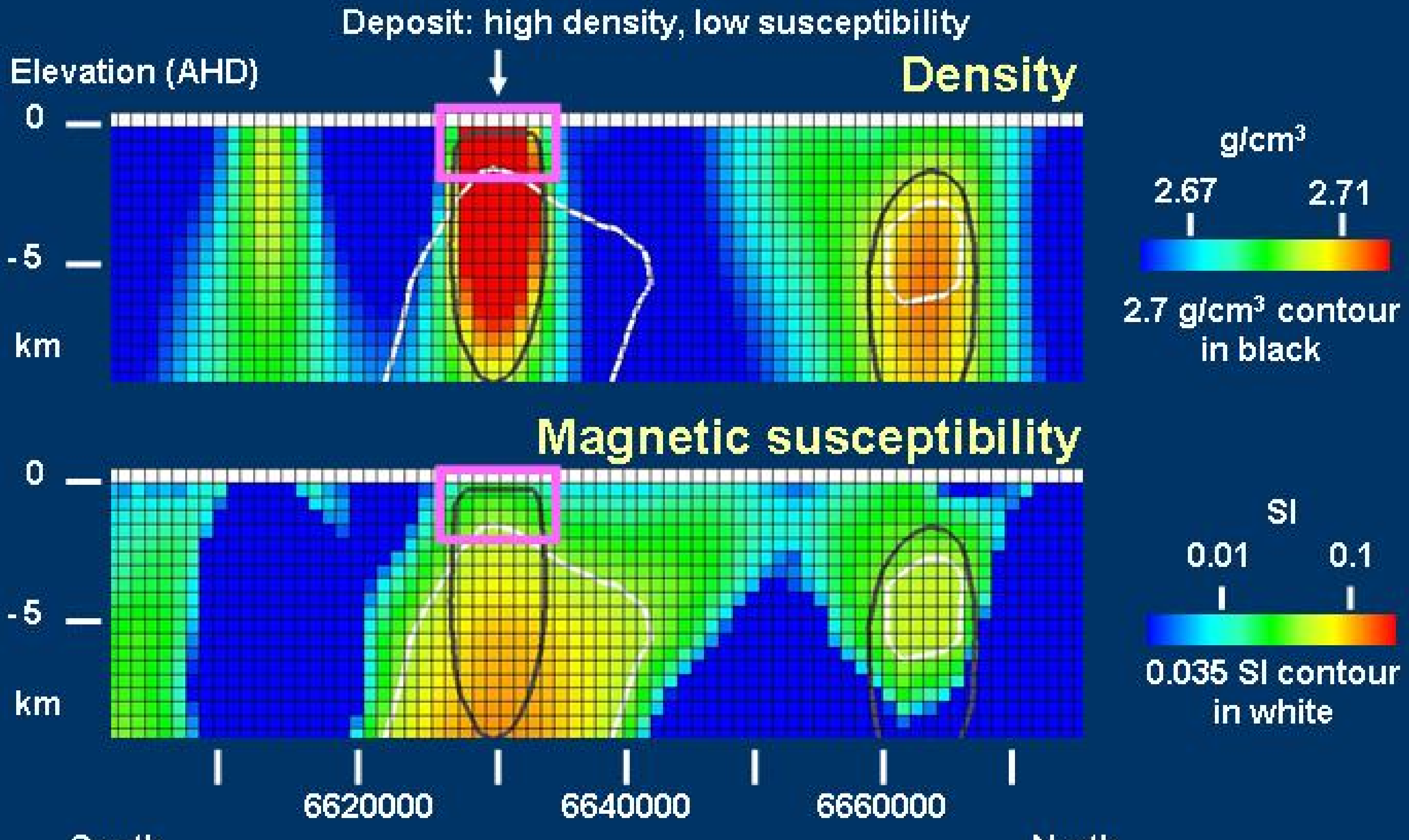


25 km

Susceptibility (SI)

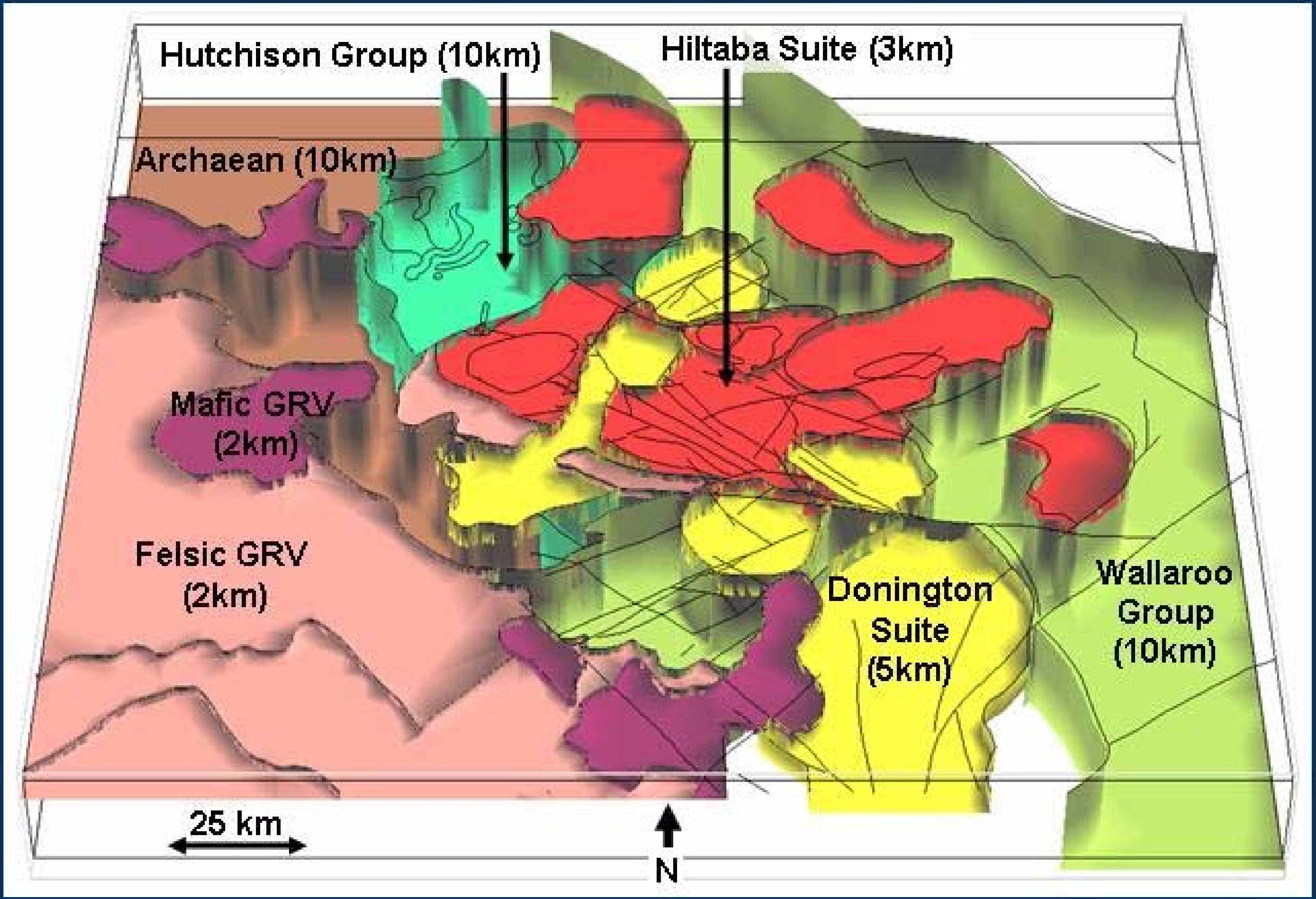
0.002 0.01 0.05

UNCONSTRAINED INVERSION SECTION OLYMPIC DAM 681500 mE

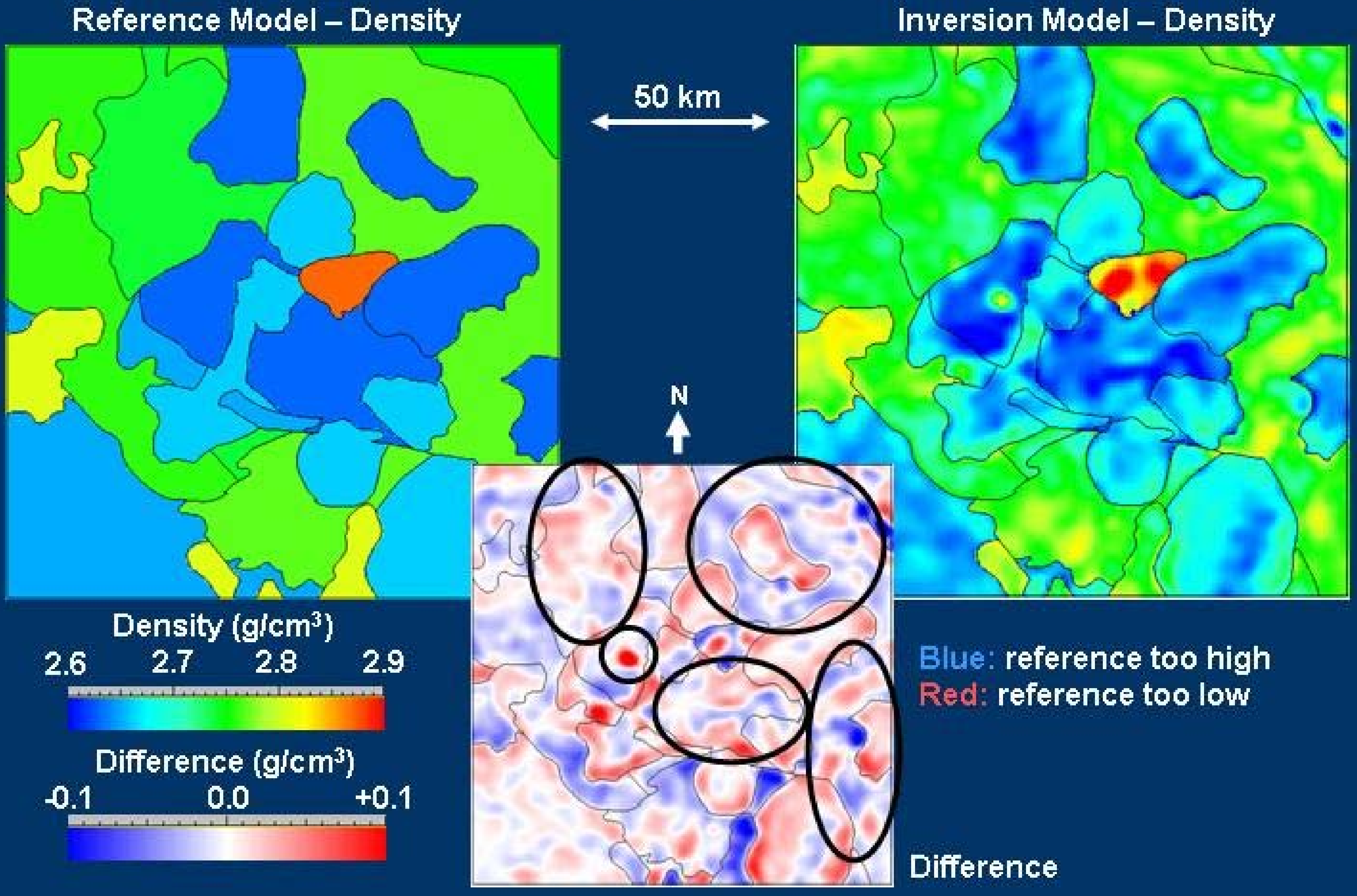


Source: Lane, 2003

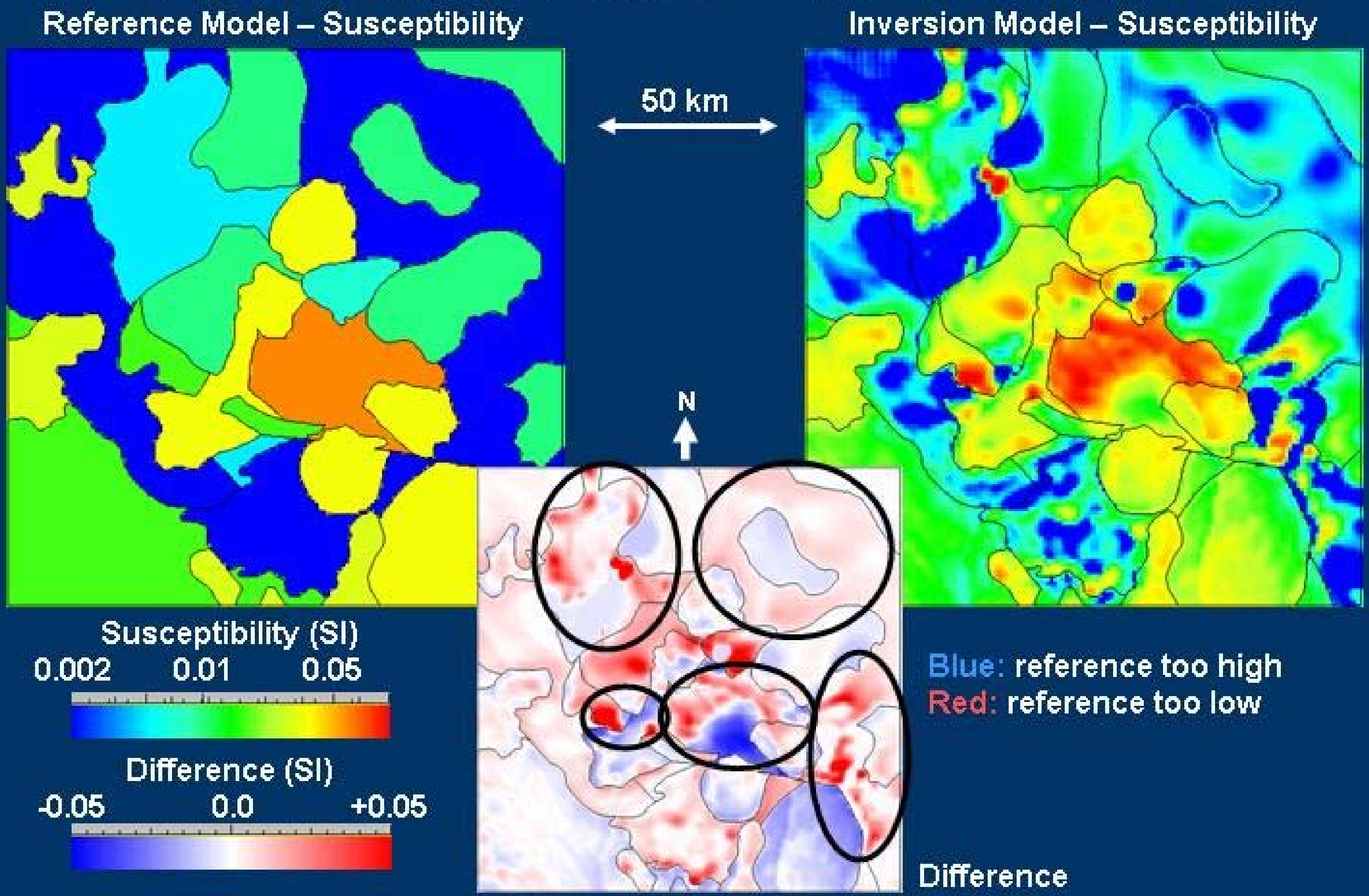
SIMPLE REFERENCE MODEL



CONSTRAINED GRAVITY INVERSION



CONSTRAINED MAGNETIC INVERSION

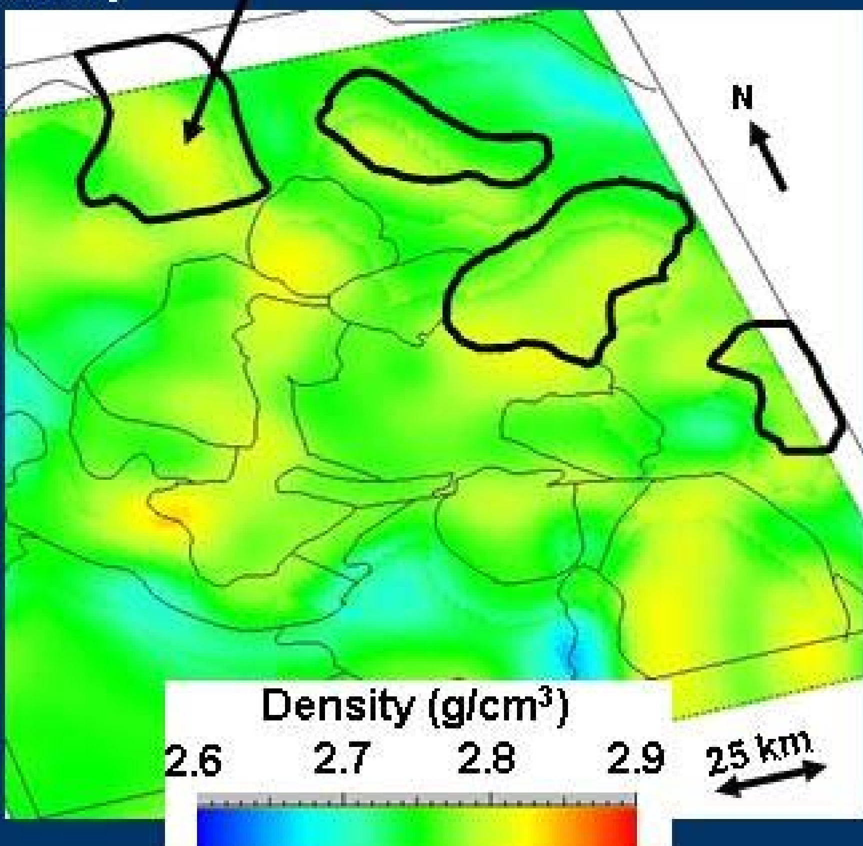


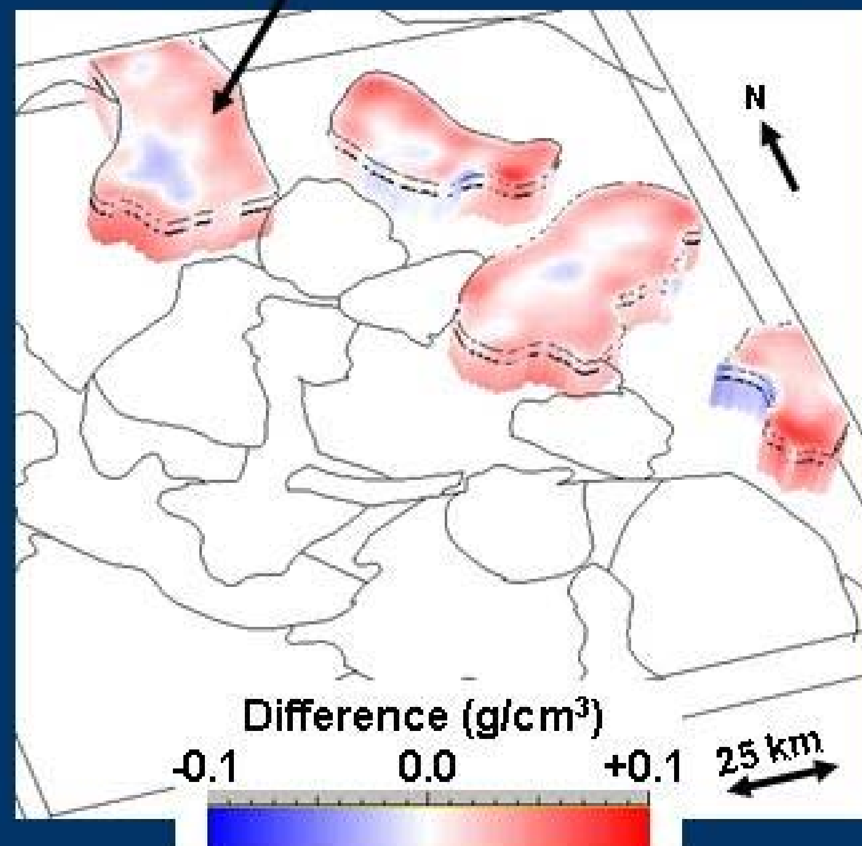
EXCESS MASS

	Reference density (g/cm^3)	Inversion density (g/cm^3)	Difference (g/cm^3)
1 km Cover	2.60	2.61	+0.01
3 km Hiltaba Suite	2.63	2.65	+0.02
6 km Hutchison Gp	2.75	2.78	+0.03

Excess mass ≈ 2.3×10^{14} kg

Inversion density





EXCESS MASS

	Reference density (g/cm^3)	Inversion density (g/cm^3)
1 km Cover	2.60	2.61
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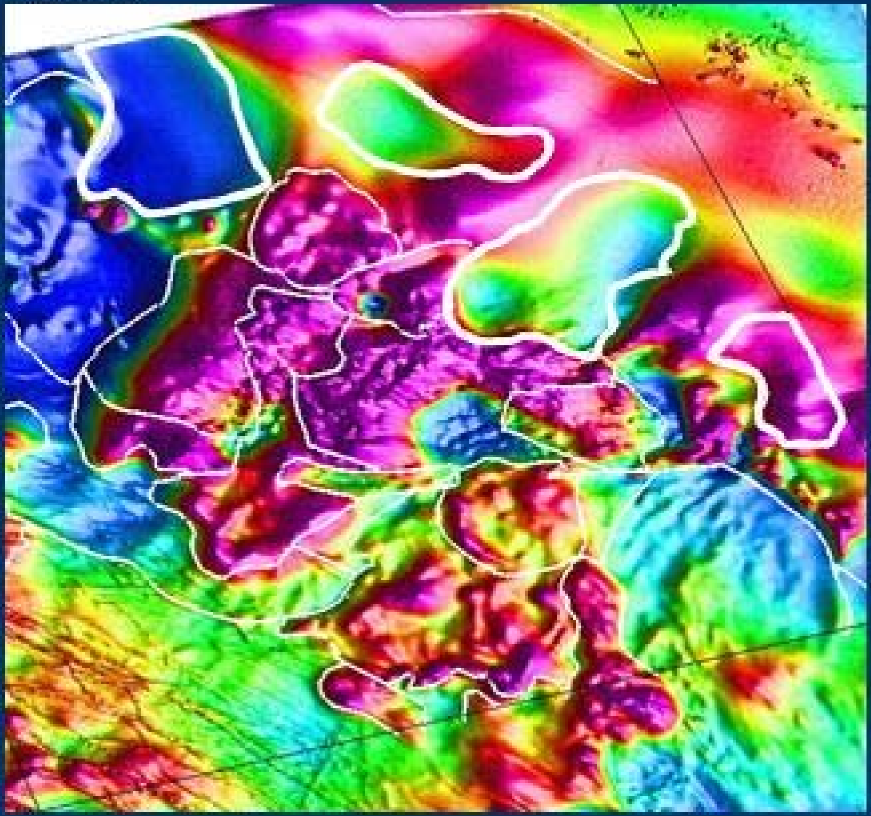
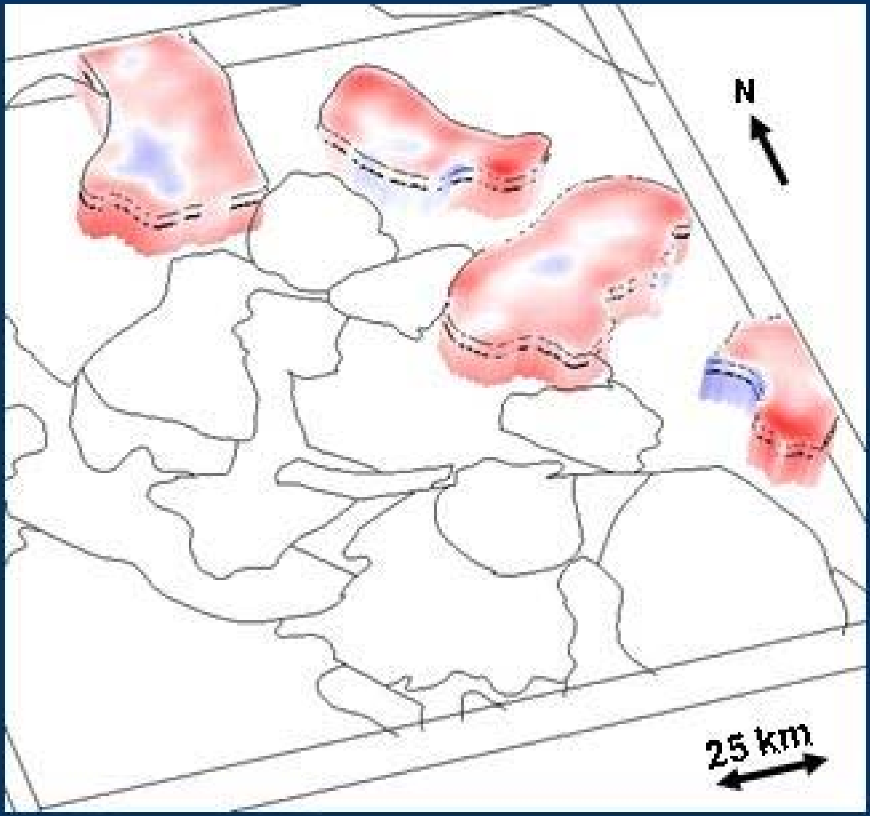
6 km Hutchison Gp	2.75	2.78

Excess mass ≈ 2.3×10^{14} kg

Total Magnetic Intensity





EXCESS MASS

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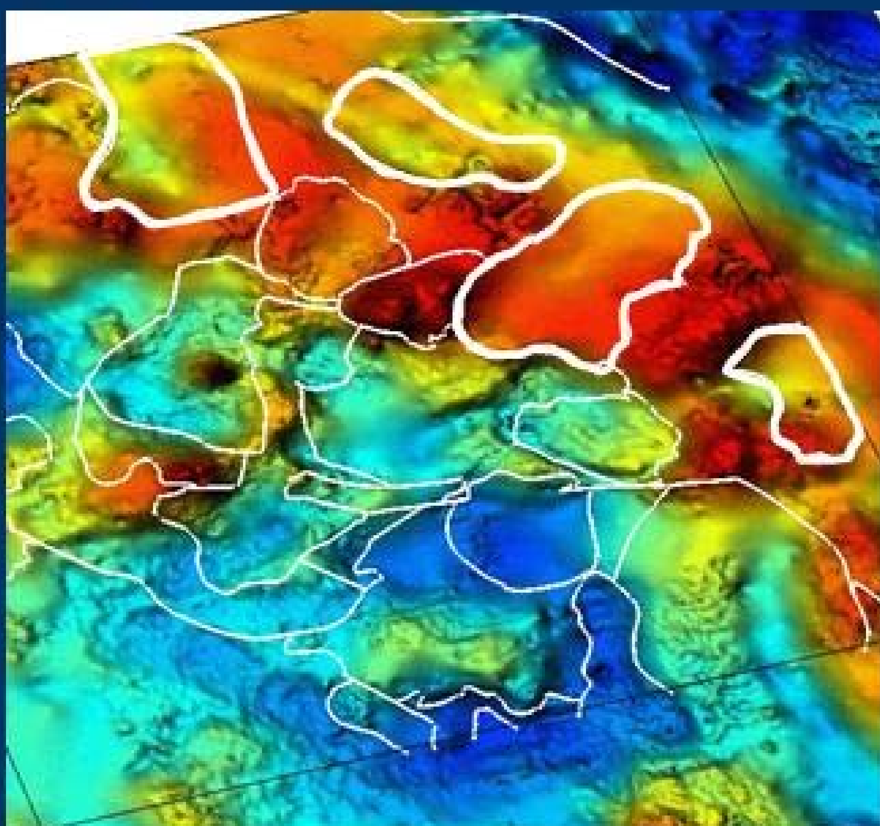
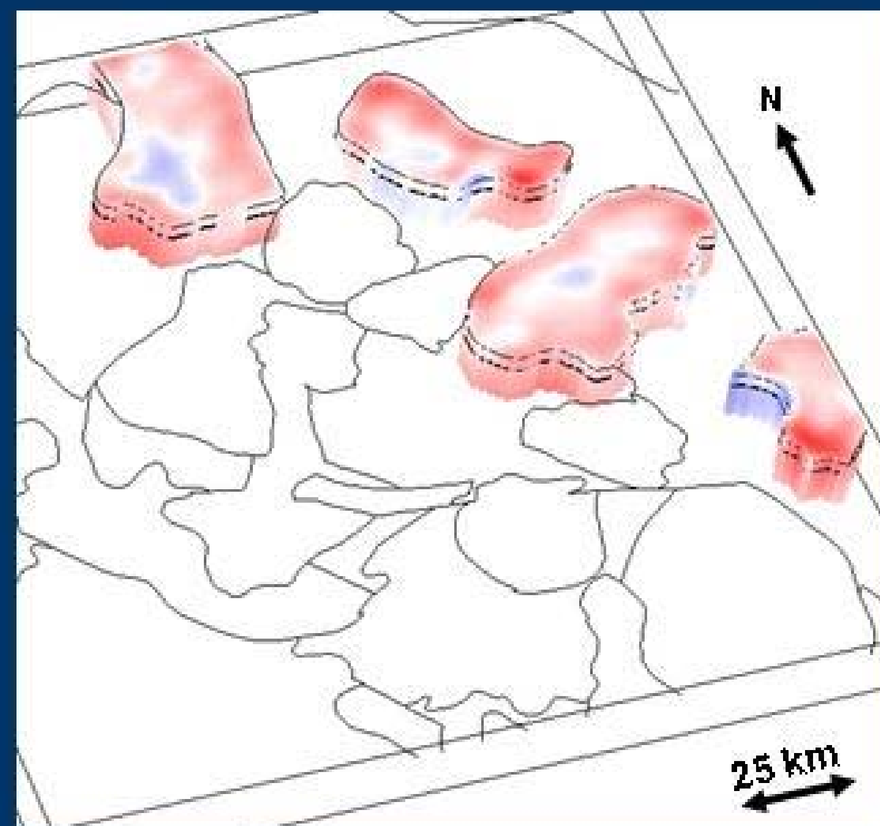
Excess mass ≈ 2.3×10^{14} kg

Bouguer Gravity



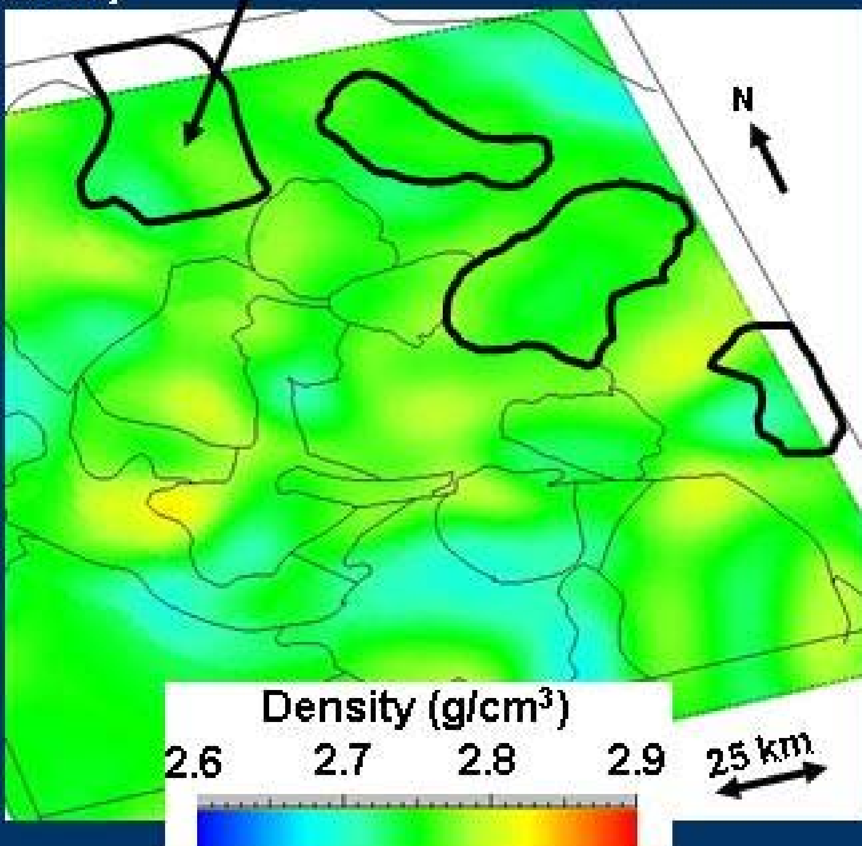


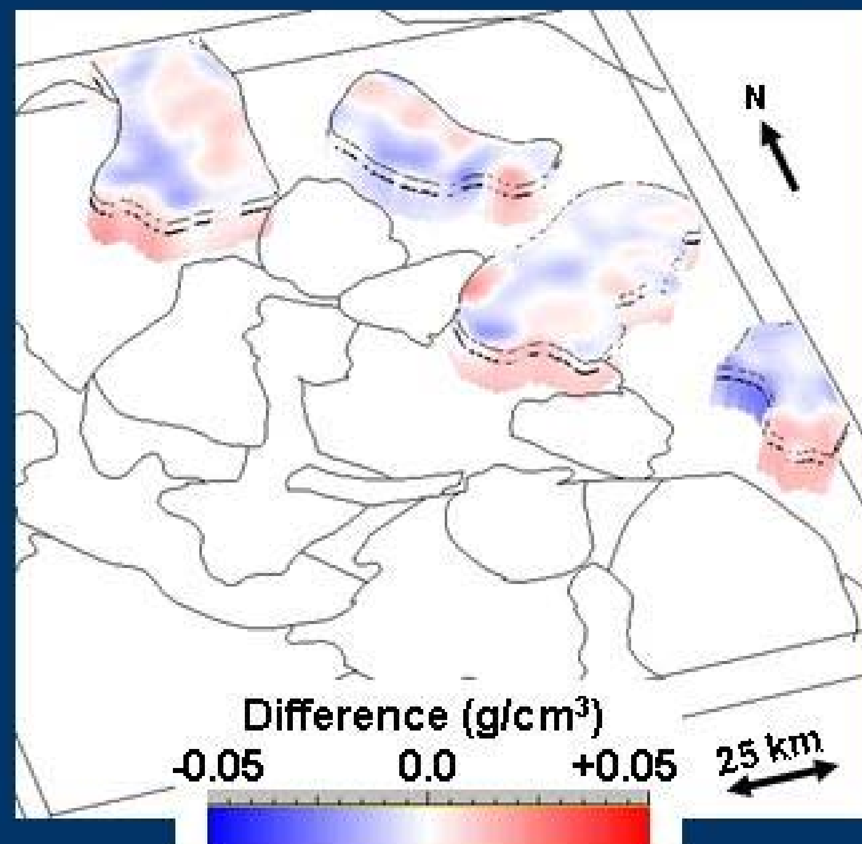
EXCESS MASS COMPENSATION

	Reference density (g/cm³)	Inversion density (g/cm³)	New ref. density (g/cm³)	Difference (g/cm³)
1 km Cover	2.60	2.61	2.60	+0.00
3 km Hutchison Gp	2.63	2.65	2.75	+0.12
6 km Hutchison Gp	2.75	2.78	2.75	+0.00

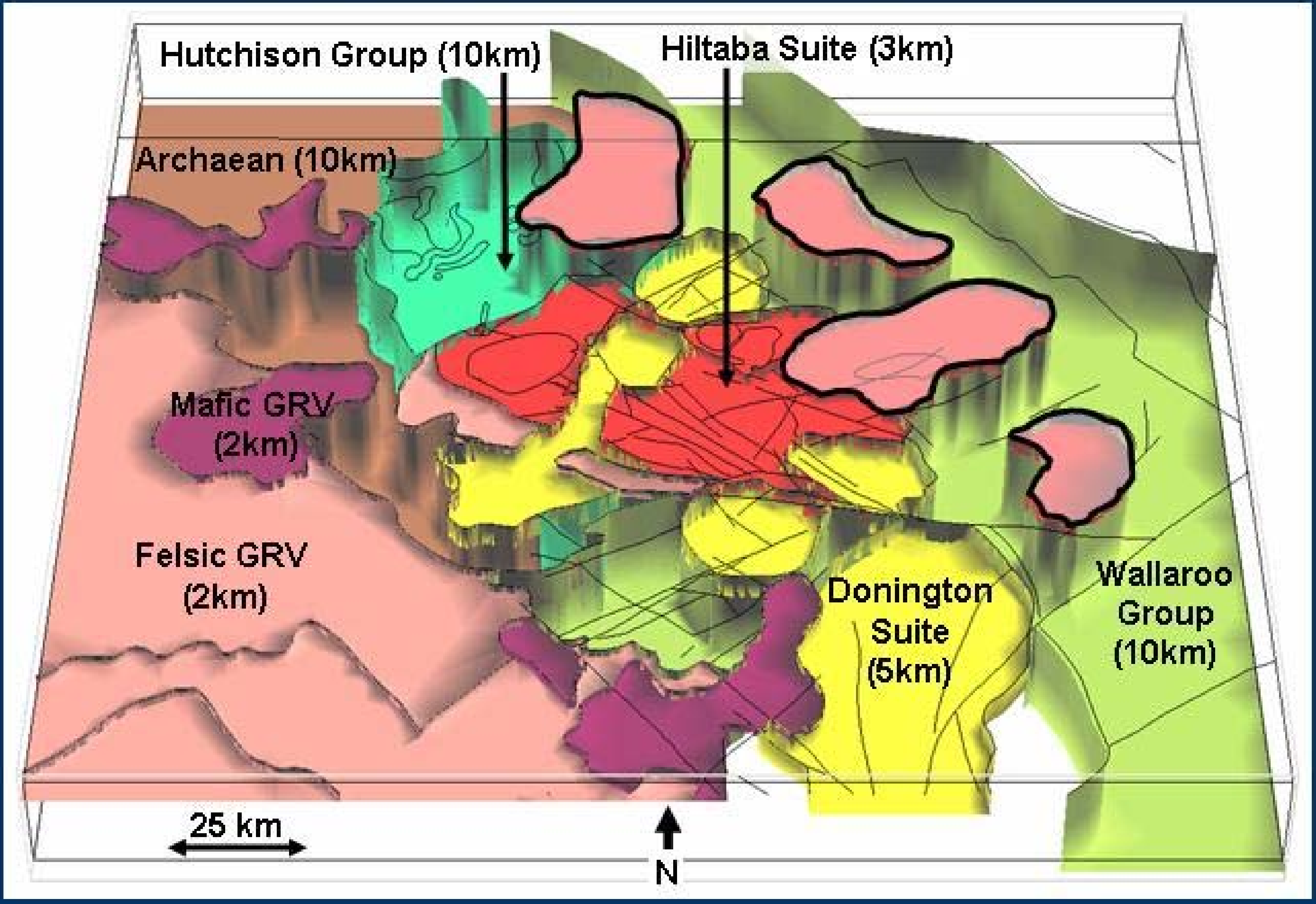
Excess mass ≈ 0.3×10^{14} kg

Inversion density

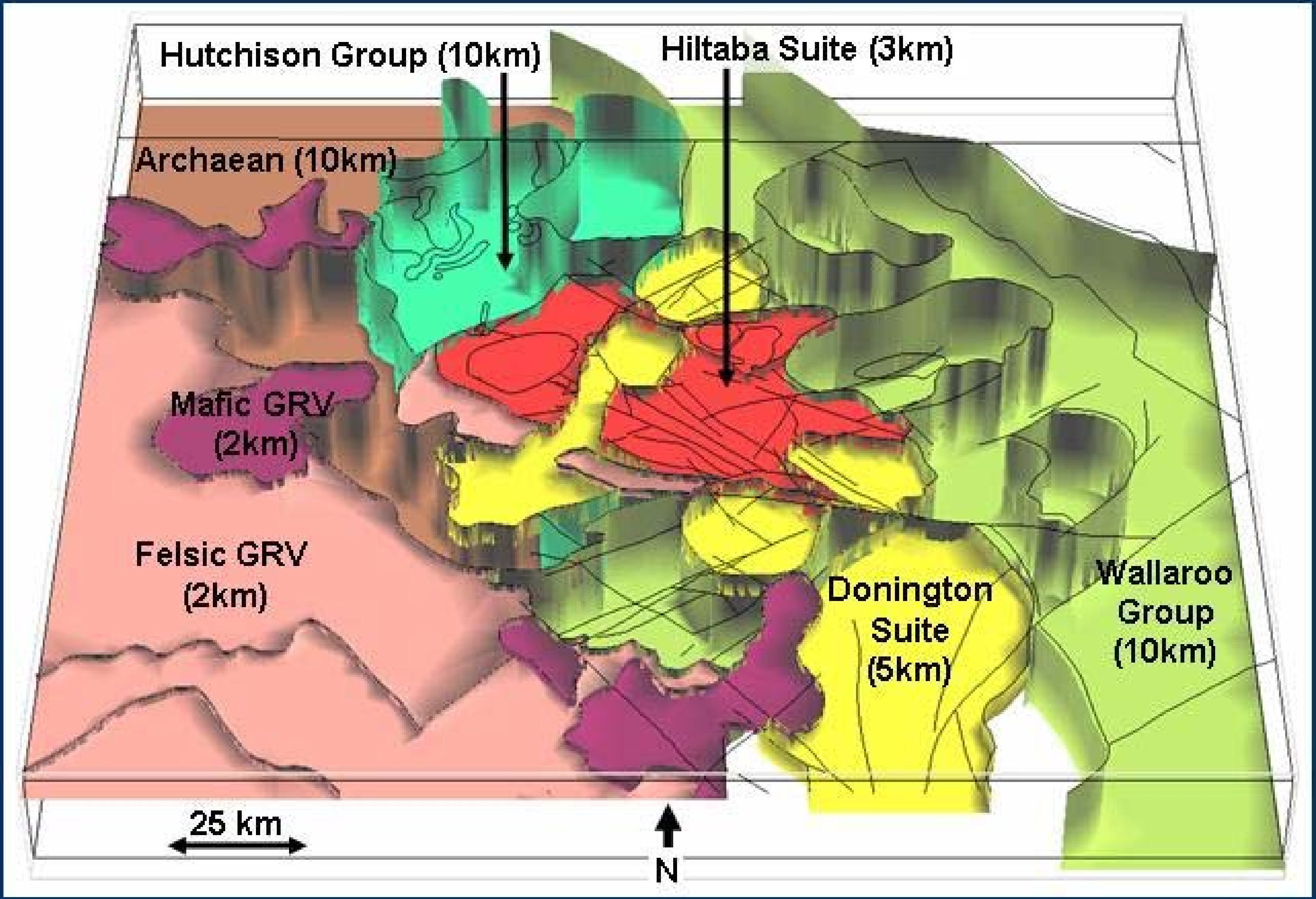




REFERENCE MODEL Mark I



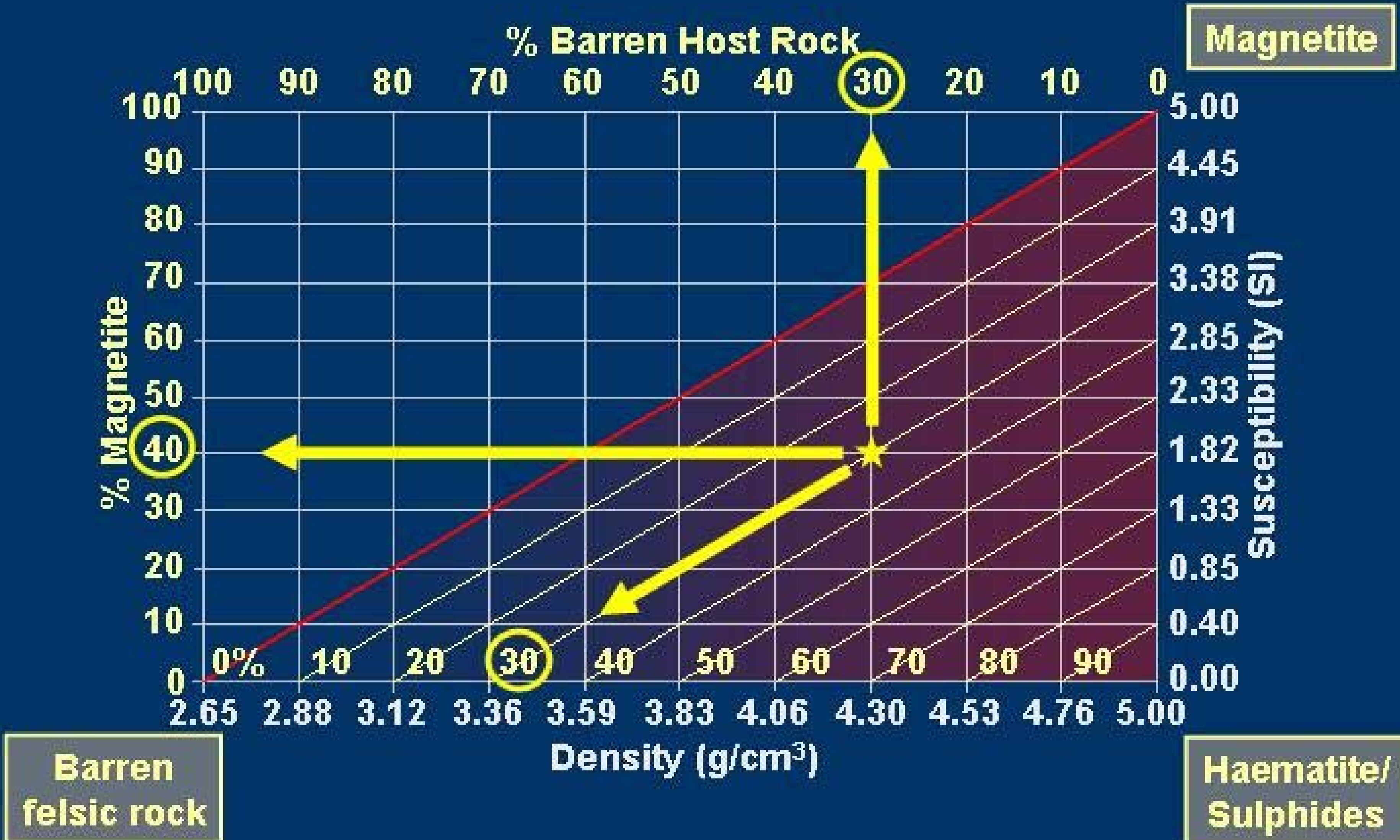
REFERENCE MODEL Mark II



FURTHER IMPROVEMENTS

- Better top-of-basement surface (seismic, company data)
- Better geological constraints (seismic, drill holes, company data)
- More physical property measurements for each unit
  - Characterise each unit type by its density and susceptibility
- Treat known volumes of alteration separately from their host
  - Isolate Olympic Dam, Acropolis, *etc.*
  - Use characteristic alteration density and susceptibility in reference model
- Add major faults

SUSCEPTIBILITY + DENSITY = GEOLOGY?



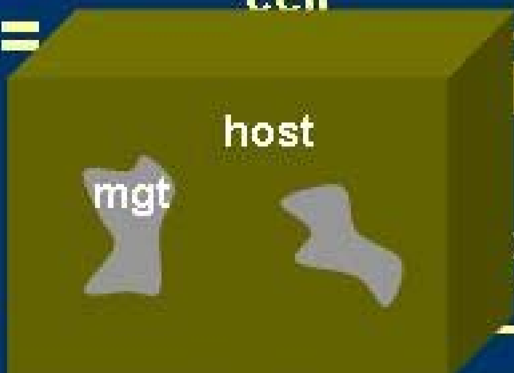
Source: Hanneson, 2003

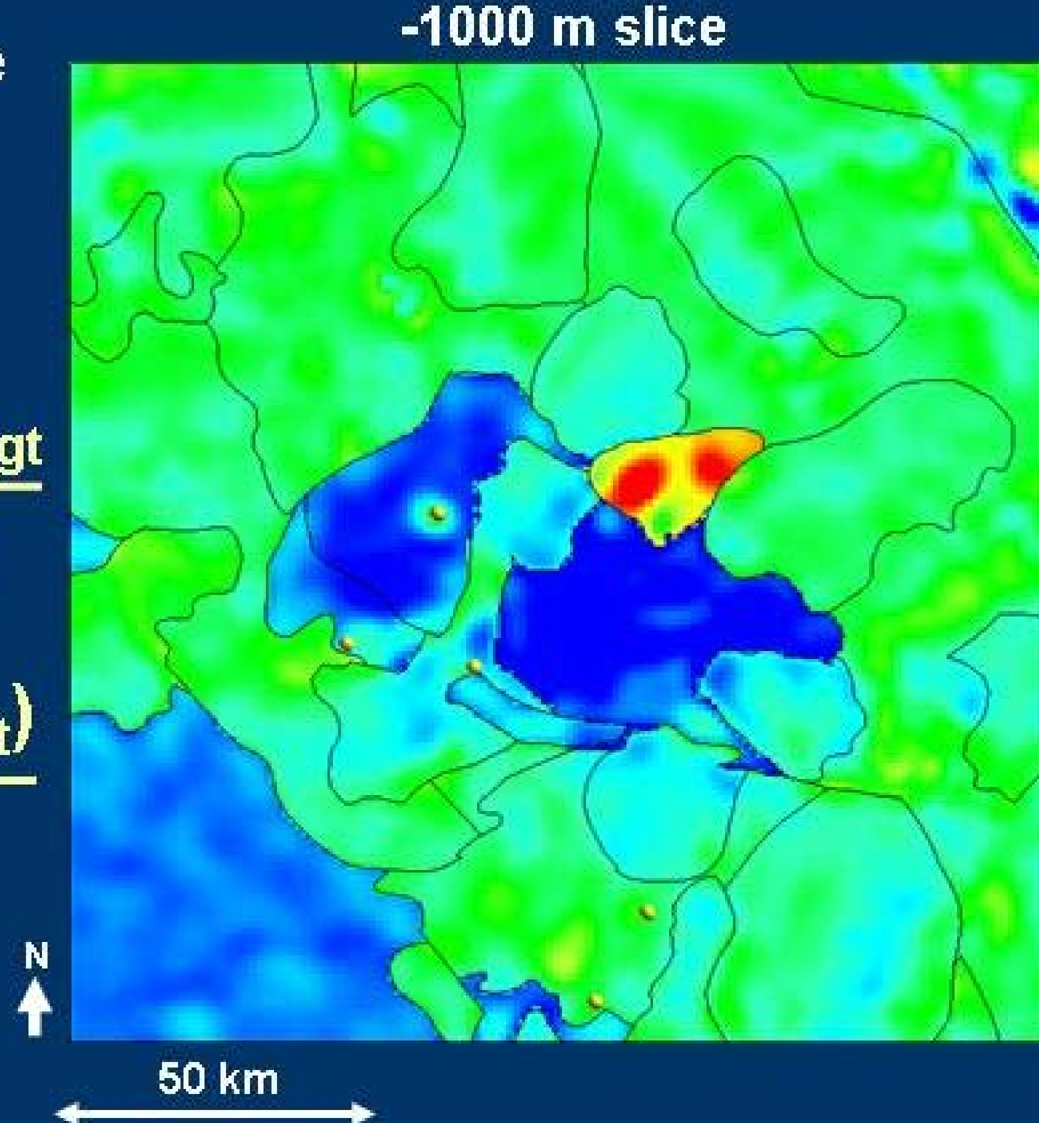
DENSITY OF BARREN HOST ROCK

- Can subtract magnetite from the model to determine the density of the host rock

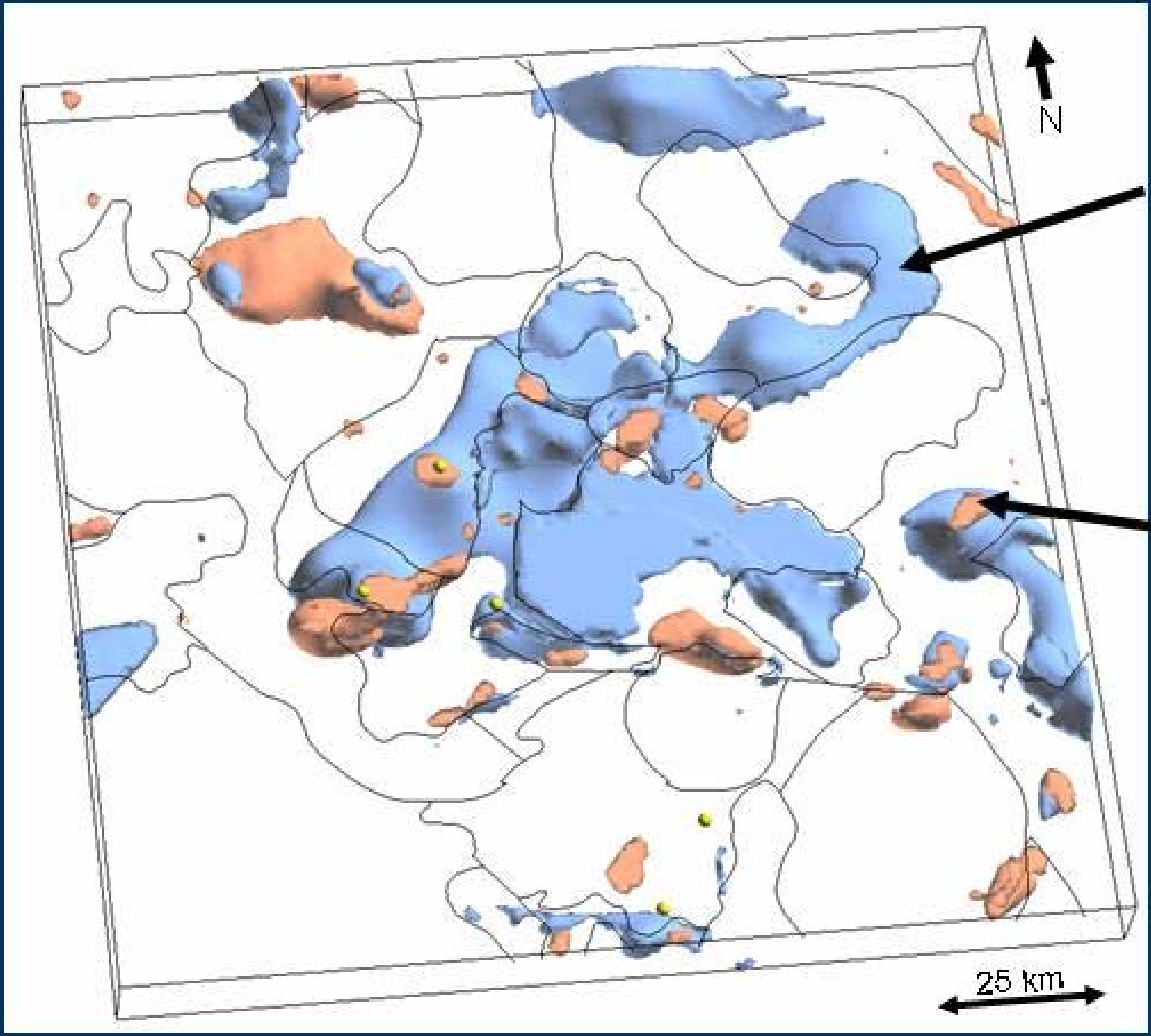
$\rho_{host} = \frac{Mass_{cell} - Mass_{mgt}}{\ldots_{mgt}}$

$= \frac{\ldots \%_{mgt})}{1 - \%_{mgt}}$





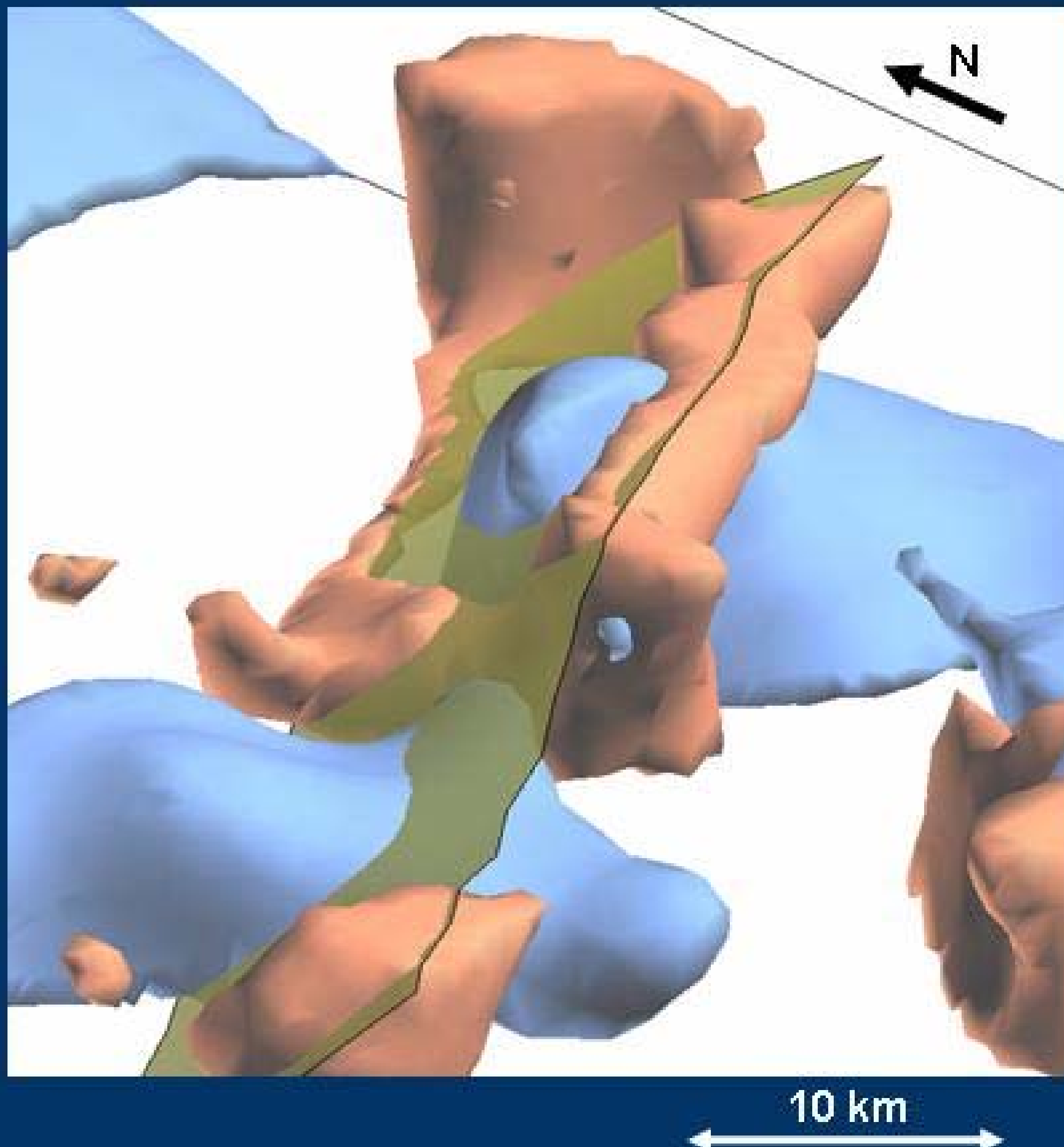
POSSIBLE MAGNETITE & HAEMATITE MAP



1.5% "magnetite"
Includes all susceptible minerals as their magnetite equivalent

0.5% "haematite"
Includes haematite, sulphides, gold, other dense minerals, and remanent magnetisation

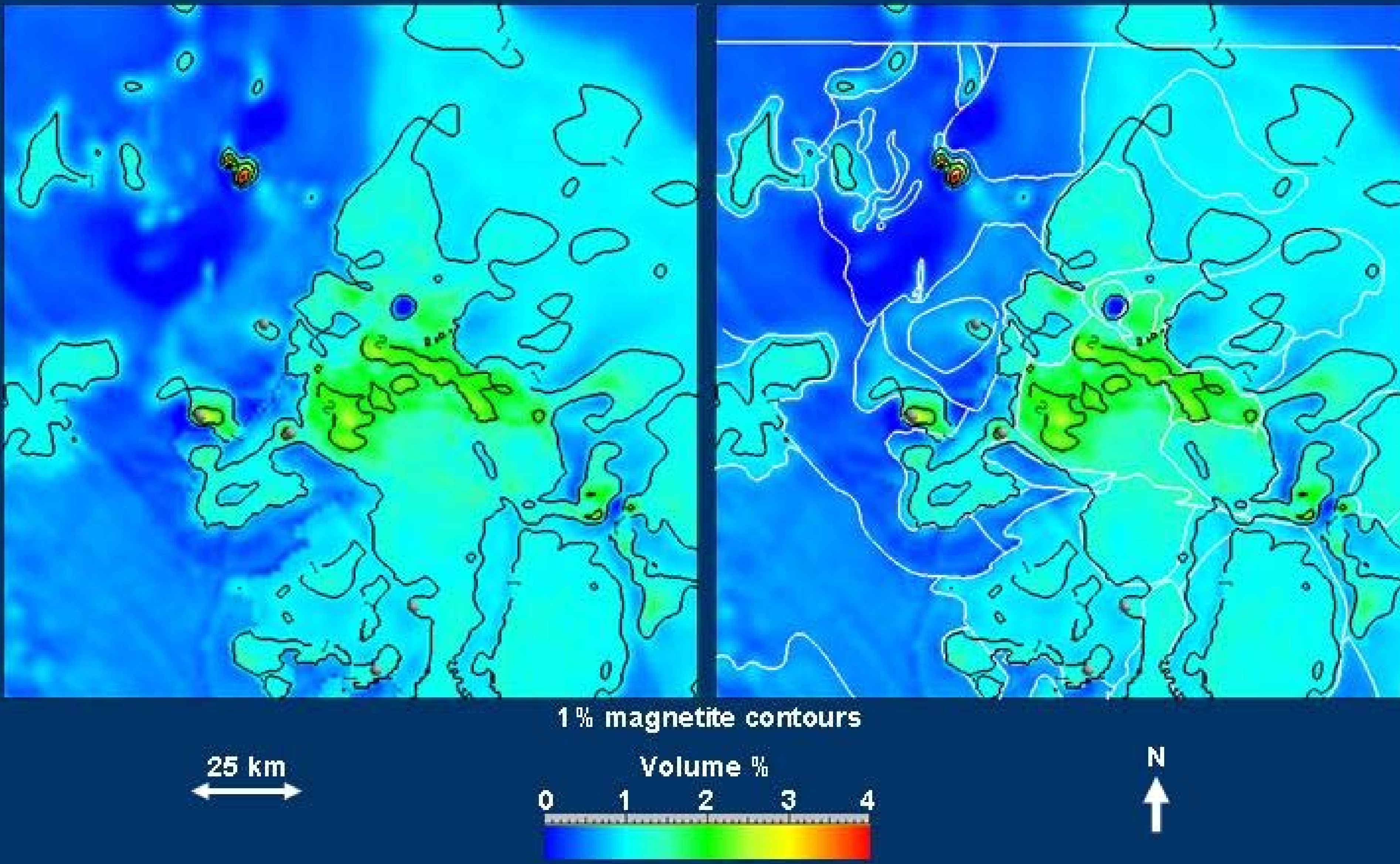
POSSIBLE MAGNETITE & HAEMATITE MAP



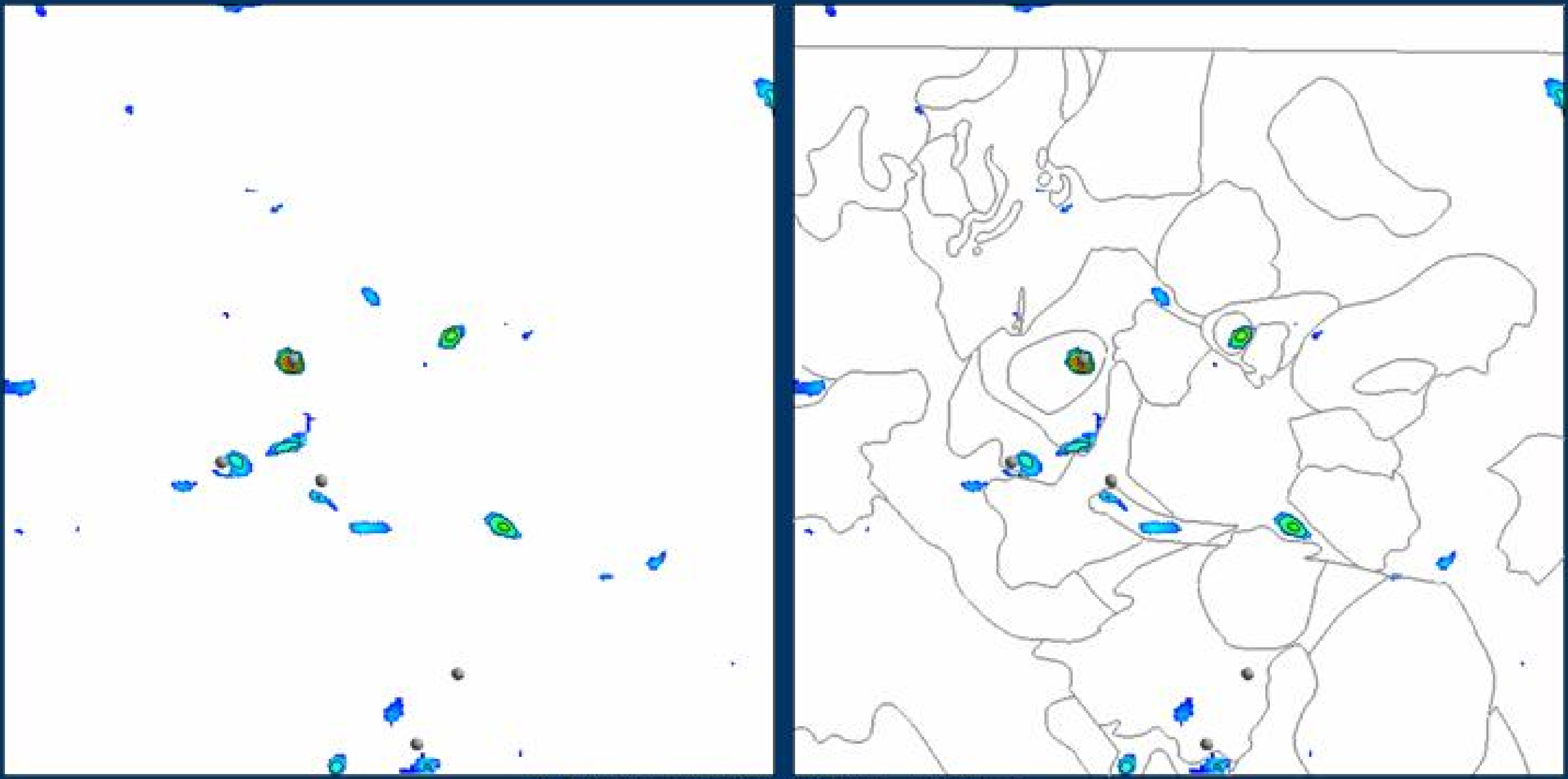
1% "magnetite"
Includes all susceptible minerals as their magnetite equivalent

1% "haematite"
Includes haematite, sulphides, gold, other dense minerals, and remanent magnetisation

BASEMENT MAPS OF PREDICTED MAGNETITE



BASEMENT MAPS OF PREDICTED HAEMATITE/SULPHIDES



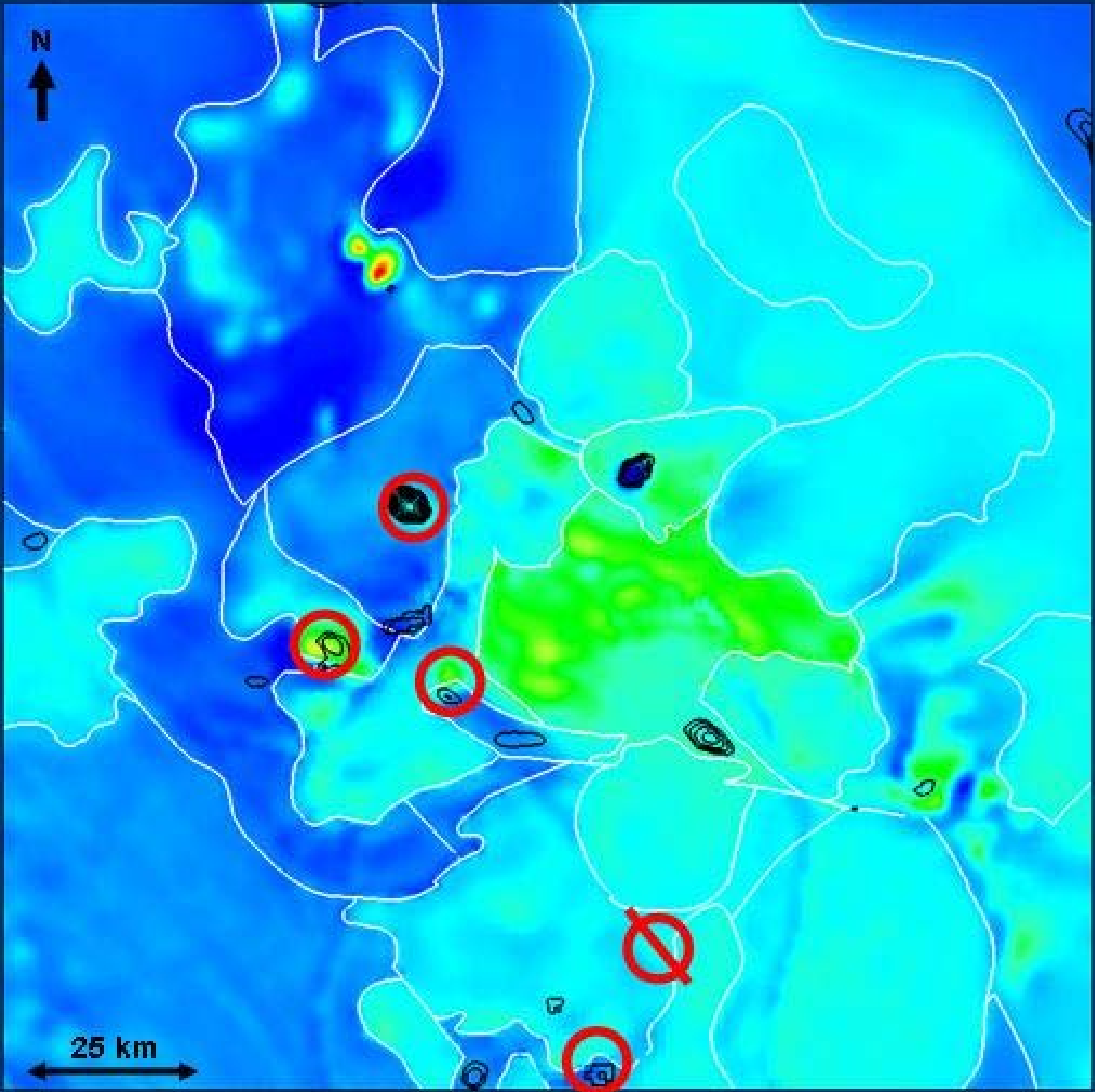
0.5% haematite/sulphide contours

Basement Alteration Map

- Coloured by magnetite
- 0.5% contours of haematite/ sulphides (black)
- Outlines of geology units

Volume %

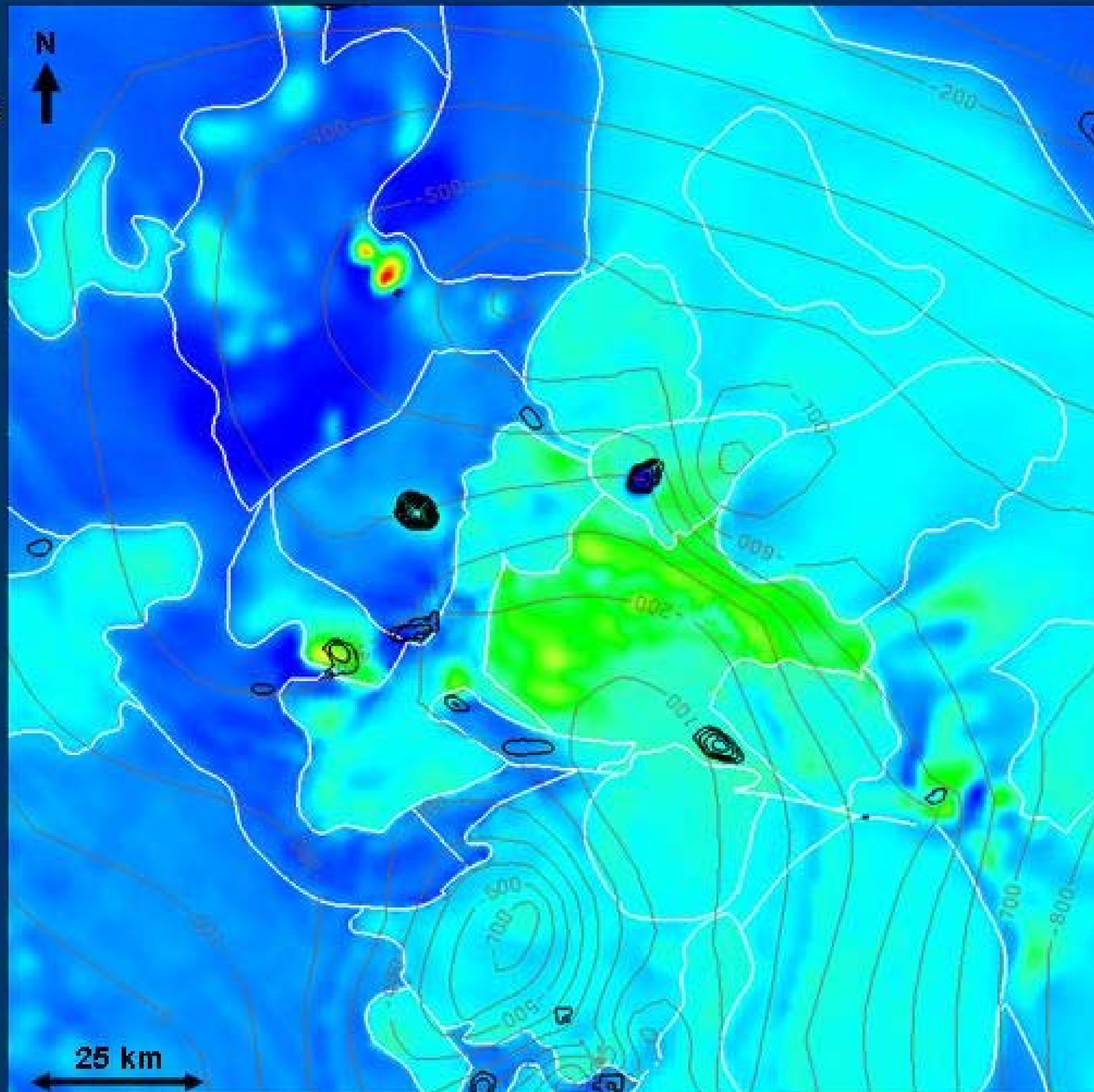
0 1 2 3 4



Basement Alteration Map

- Coloured by magnetite
- 0.5% contours of haematite/ sulphides (black)
- Outlines of geology units
- Contours of basement depth (brown)

Volume %



ASSUMPTIONS

- Good gravity and magnetic data coverage
- Inversion parameters are appropriate
- Constraining model is reasonably accurate
  - Geometries
  - Physical properties
  - Depth to basement
- End-member mineral approximation is legitimate
  - Choice of end-member minerals
  - Physical properties of end-member minerals

THE FUTURE

- Need improved physical property databases and understanding
  - More company/state survey/university/GA measurements
- Improve model detail
  - More units
  - Better geometries
- Recently acquired seismic lines (250km on 2 lines)
  - Test predictive capability of regional inversions
  - Improve geometries
- Test results against drill hole information

CREATE 3D MAPS THROUGH COVER!

- Potential field inversions can make 3D maps of
  - Alteration – magnetite or haematite/sulphides
  - Lithology – Hiltaba Suite v. Hutchison Group
  - Structure – Todd Dams Fault
  - Anomalous entities
- BUT … you NEED
  - Good density and susceptibility measurements
  - Good gravity and magnetic coverage
  - Some geological understanding (drilling, seismic, mapping)
- Basic inversions are useful, but better inputs will give more reliable 3D maps

THANK YOU

Acknowledgements

Nick Direen   Matti Peljo   Roger Skirrow
Gawler Mineral Promotion Project
PIRSA Mineral Resources Group