Australian Government

Geoscience Australia

Constrained 3D inversion of potential field data from the Olympic Cu-Au province, South Australia

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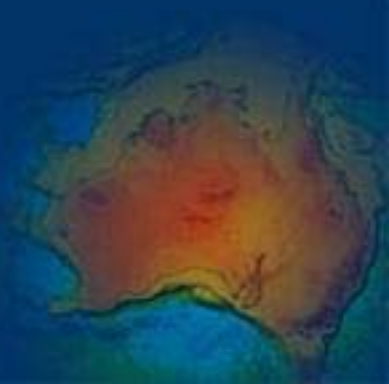
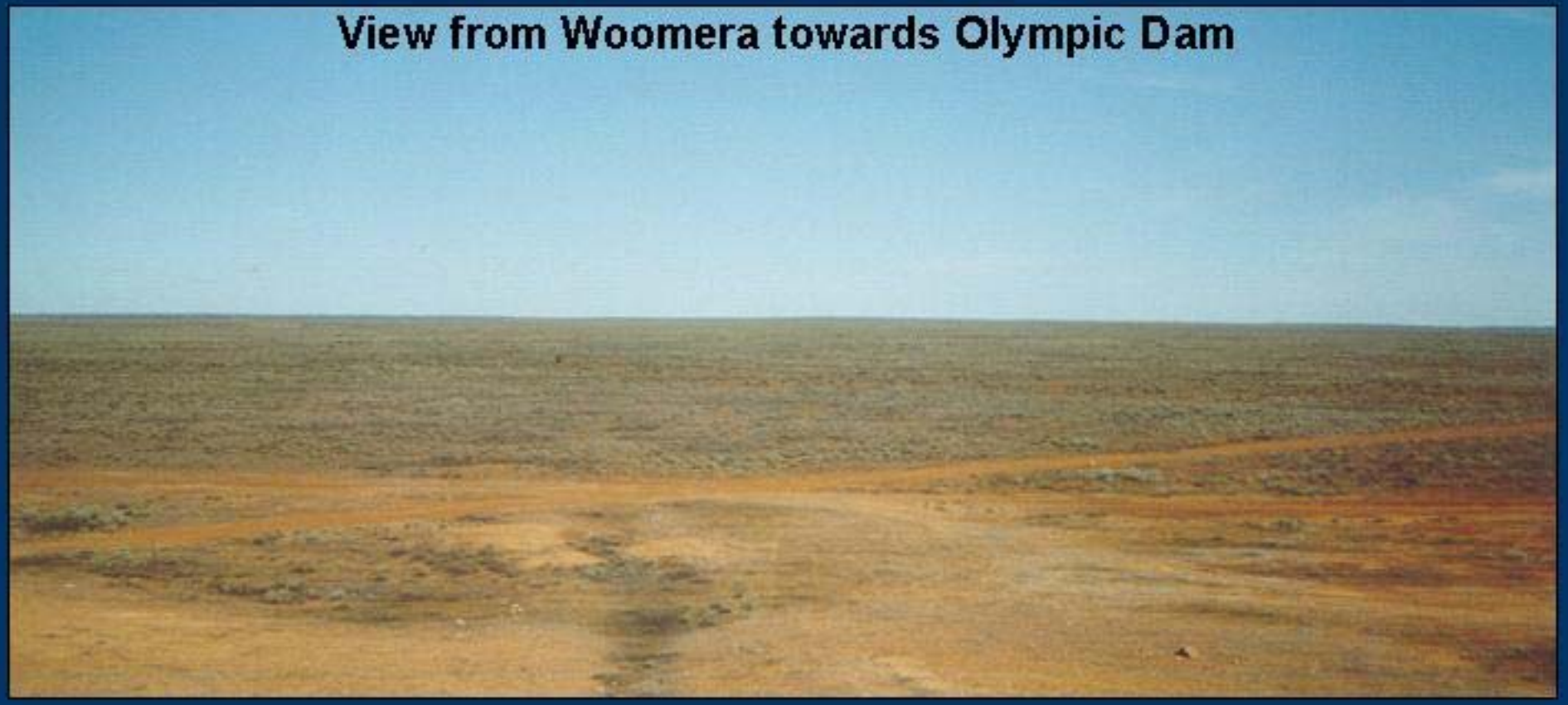
Richard Lane Matti Peljo

17th Australian Geological Convention
Hobart, February 2004

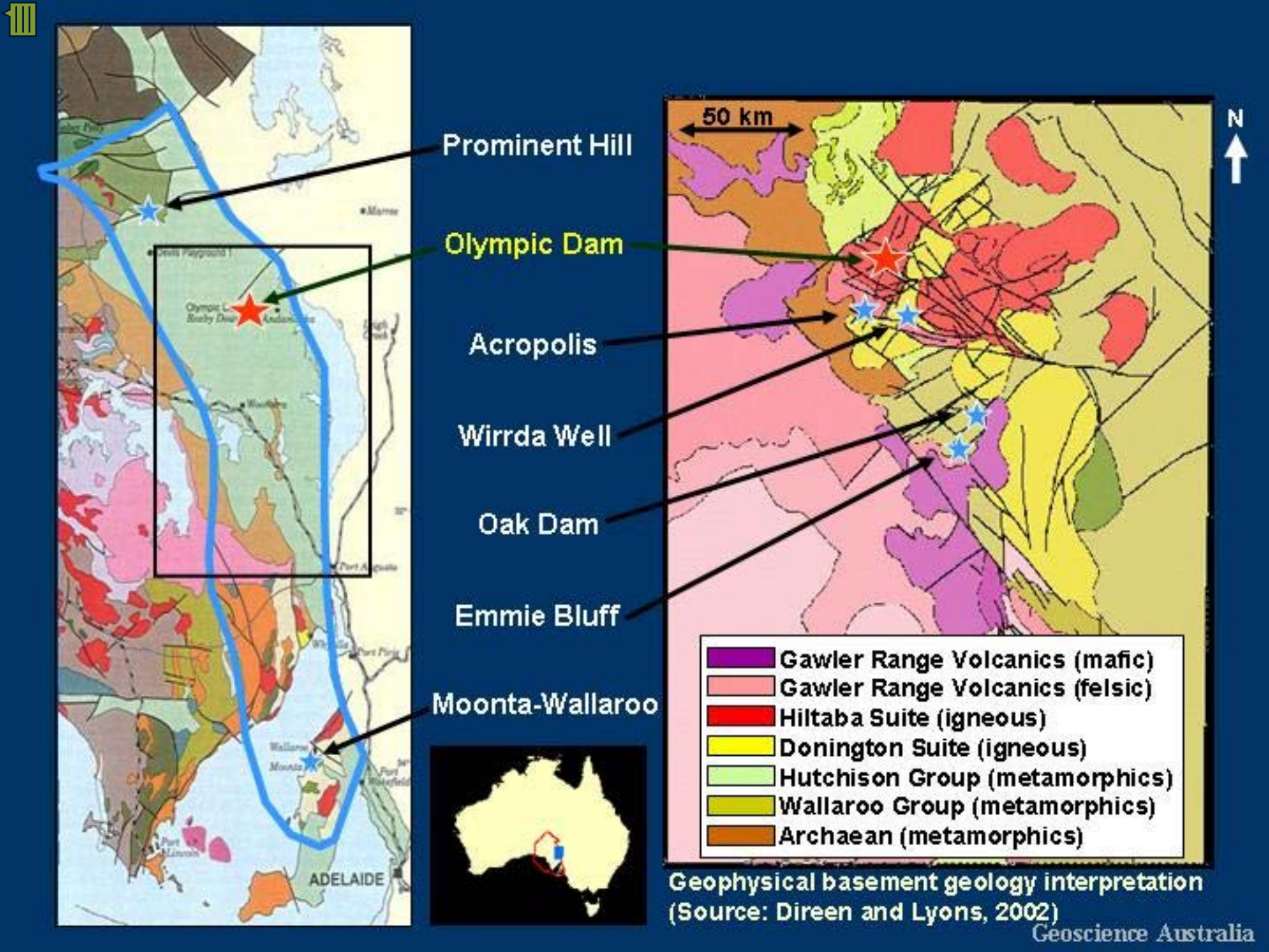


Basement Outcrop? What Outcrop?



Gravity and magnetic data see through cover

but we need new tools to understand the geology



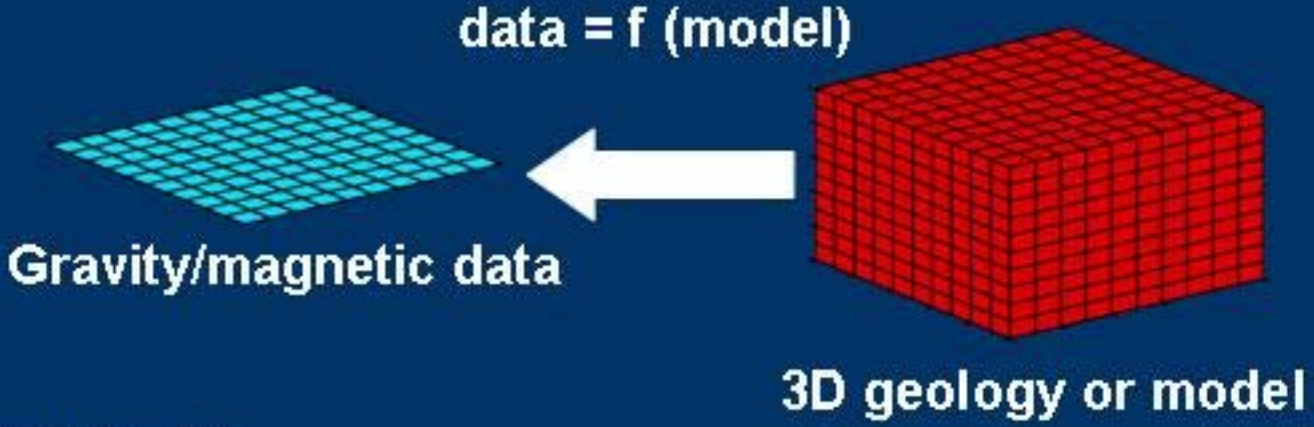
Geophysical basement geology interpretation
(Source: Direen and Lyons, 2002)

Olympic Province Crystalline Basement

- Archaean metamorphic rocks
- Proterozoic metamorphic rocks
  - Hutchison Group metasediments and BIFs
  - Wallaroo Group metasediments & metavolcanics
- 2 major magmatic events
  - 1.85 Ga Donington Suite granitoids
  - 1.59-1.58 Ga Hiltaba Suite granites, gabbros, and Gawler Range Volcanics
- Extensive Mesoproterozoic to Cambrian cover: up to 3 km thick, but generally <1 km

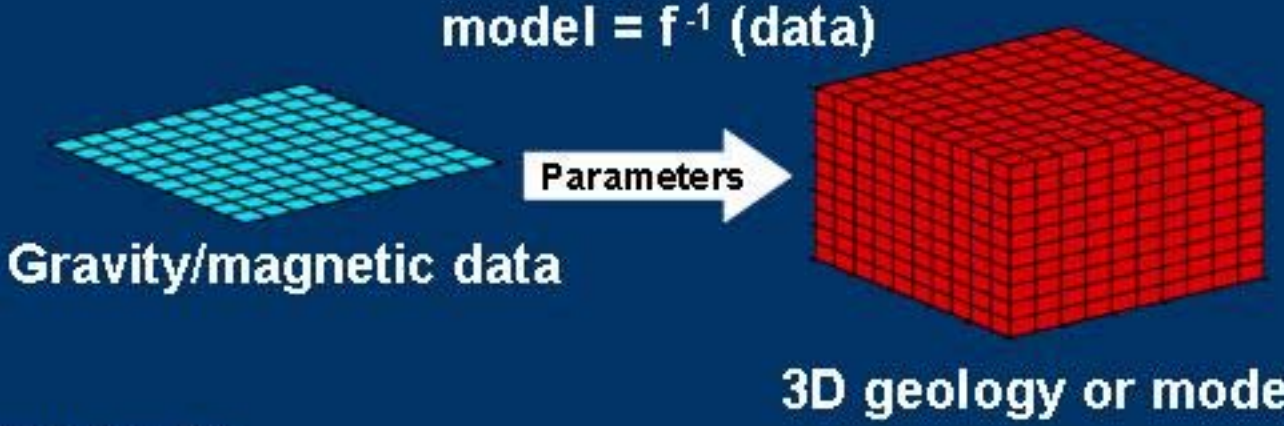
Potential Field Interpretation

- Traditional potential field interpretation relies on interpreter's *skill*, *knowledge*, *objectivity*, and *consistency*
- Profile forward modelling provides basic architecture but only in thin strips



Potential Field Interpretation

- Traditional potential field interpretation relies on interpreter's *skill*, *knowledge*, *objectivity*, and *consistency*
- Profile forward modelling provides basic architecture but only in thin strips
- *Smooth model inversion* calculates a smooth 3D property distribution from 2D data subject to a range of parameters



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

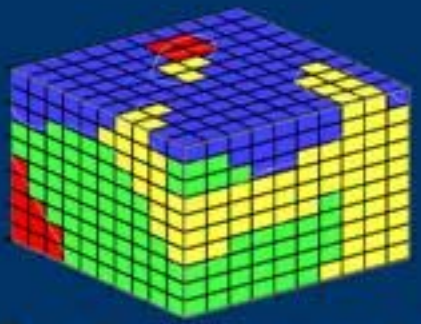
Constrained Inversion Process

Solid geology, seismic structure, cross-sections, drilling, etc

Build model

3D geological model: structures and lithologies

Create reference



3D reference model: physical properties and inversion parameters

(Source: Lane, 2002)

Constrained Inversion Process

Solid geology, seismic structure, cross-sections, drilling, etc

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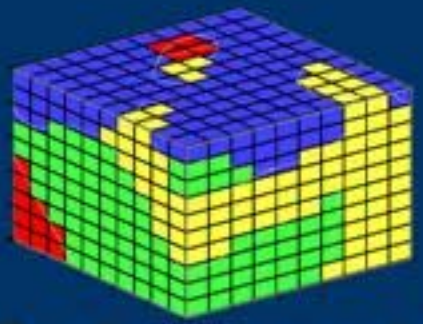
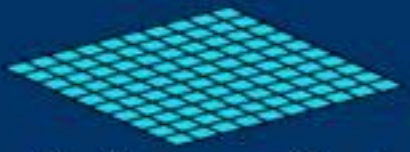


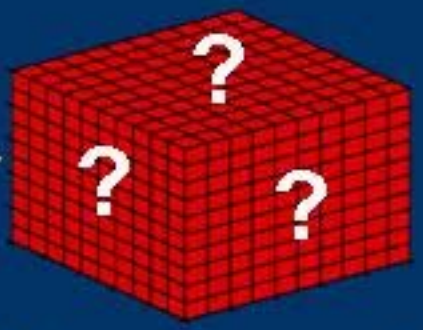
3D reference model: physical properties and inversion parameters

Constraint



Gravity/magnetic data

Inversion



3D inversion model

Compare and update

(Source: Lane, 2002)

Inversion Concepts

- Successful inversion *will always fit the data* (within a defined data error) within an acceptable misfit
  - Remanent magnetisation causes problems
- Constrained inversion *will* fit the data while matching the reference model as closely as possible
  - 'smallness': how closely to match the reference model (higher smallness values = closer match)
- If it is *not* possible to match both the *reference model* and the *data*, the inversion moves away from the reference until it *can fit the data*
  - Can't be deceived by bad models

Area Definition

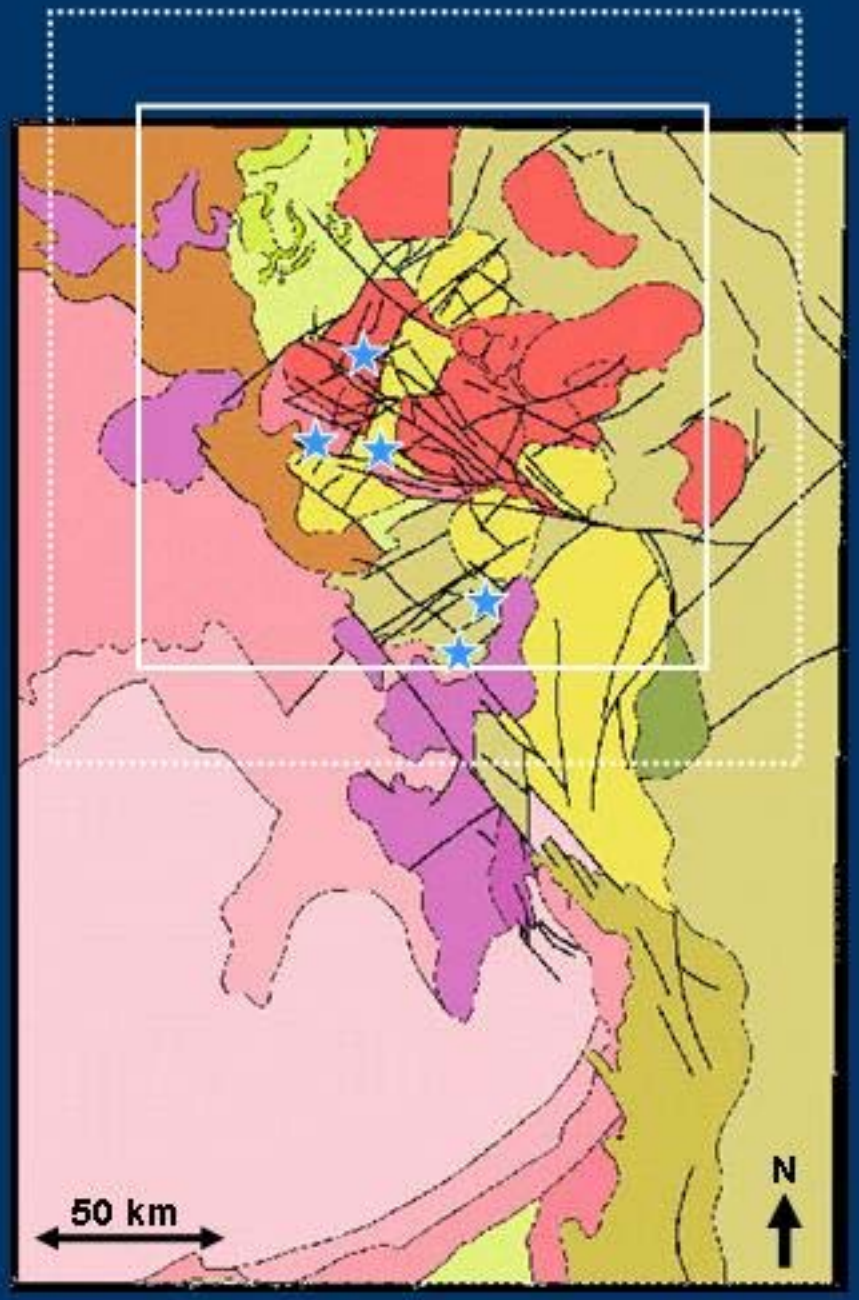
Volume of interest:

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

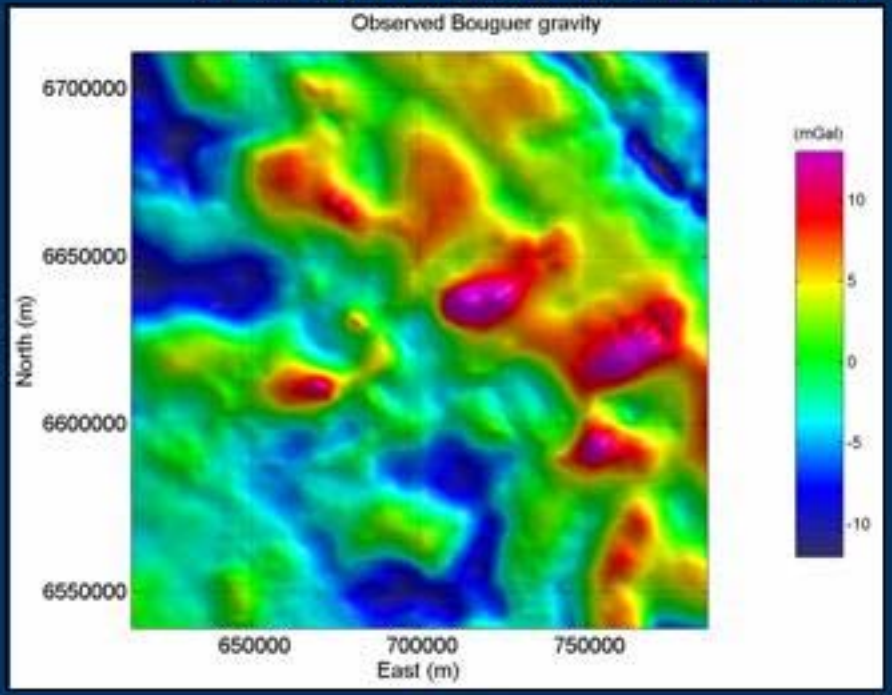
Padded extent:

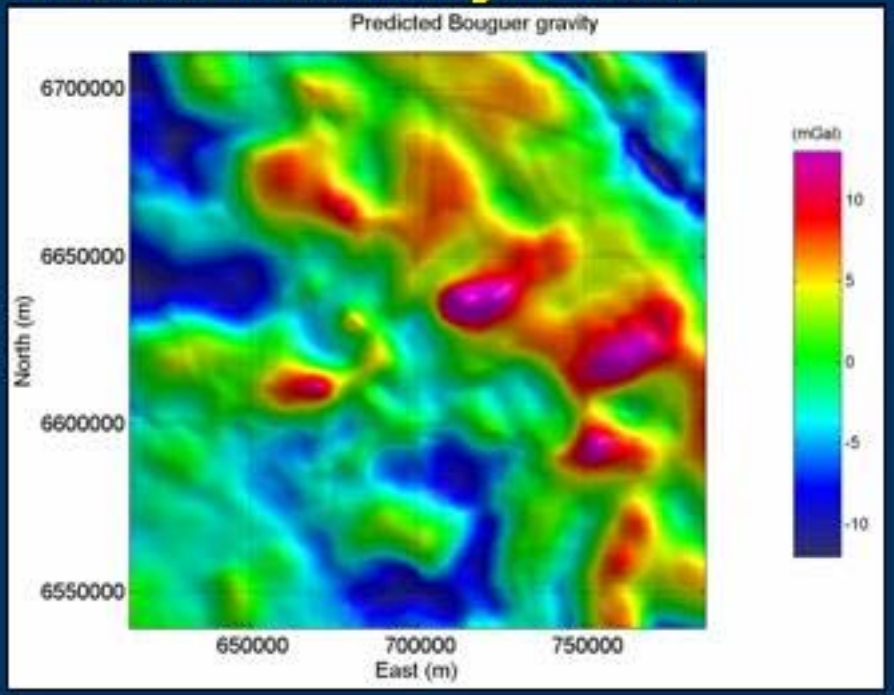
198 km × 198 km × 18 km
= 705,672 km^3

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



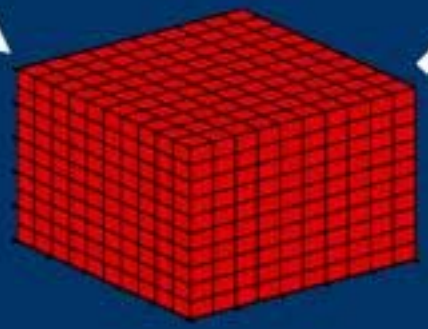
Observed and Predicted Gravity Data



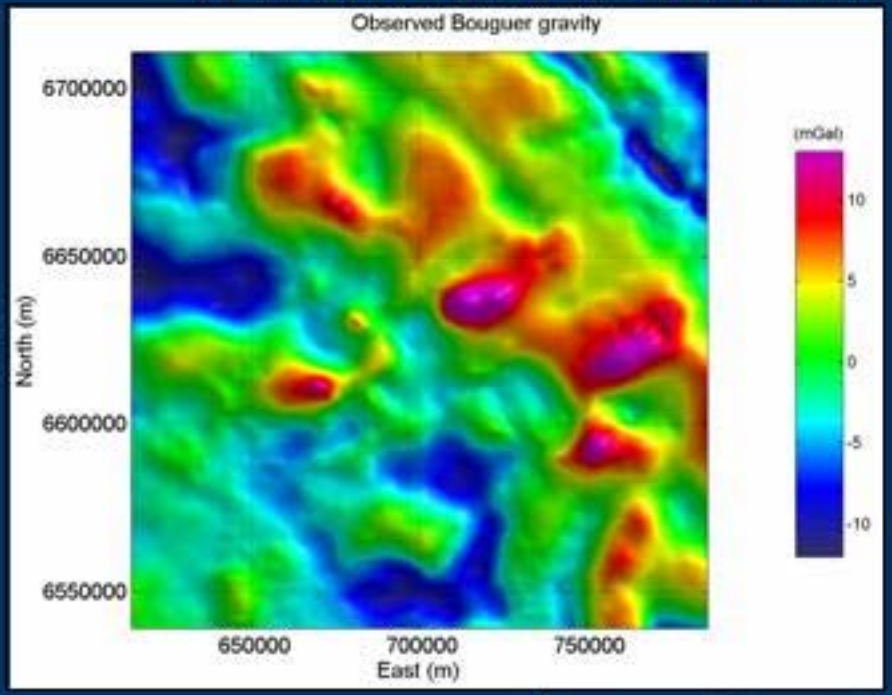


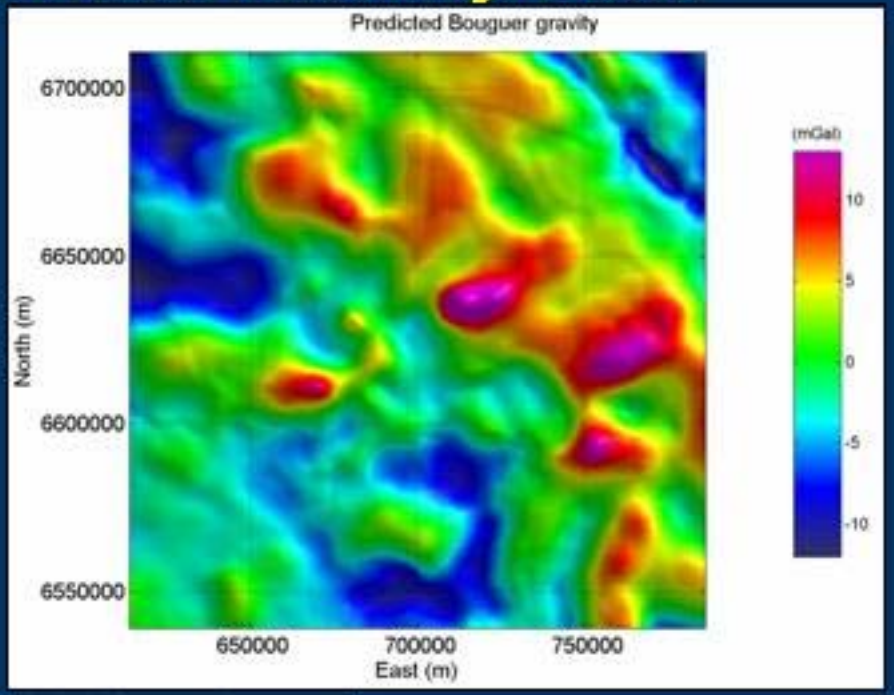
Invert

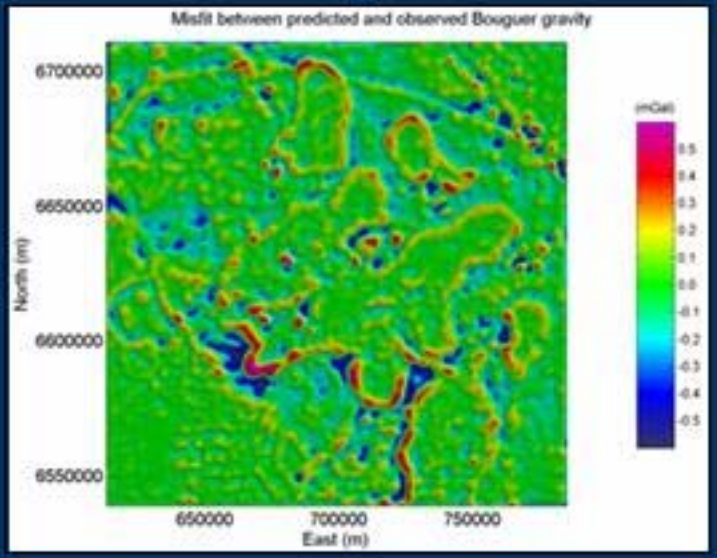
Forward model



Observed and Predicted Gravity Data

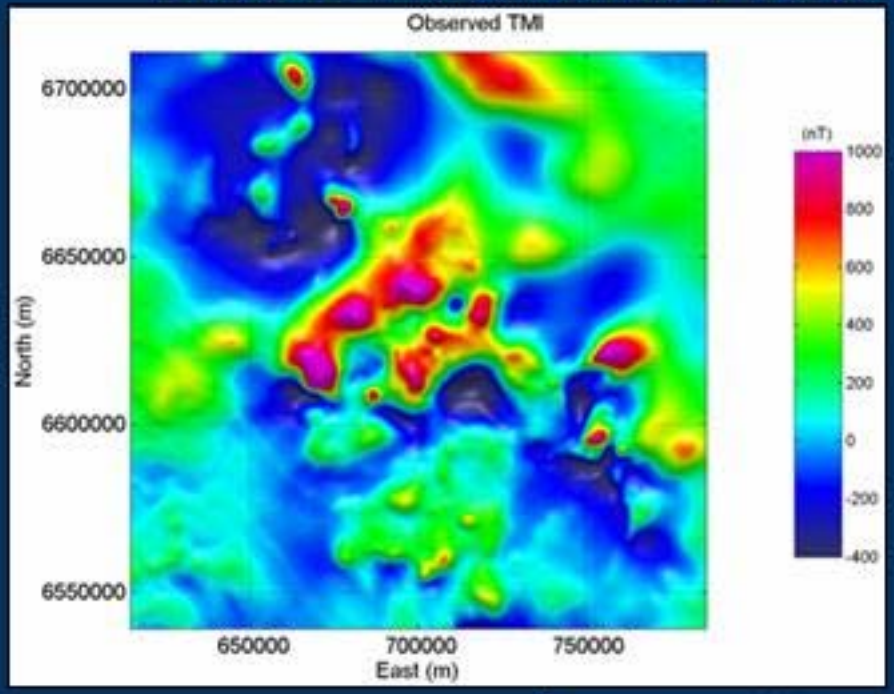


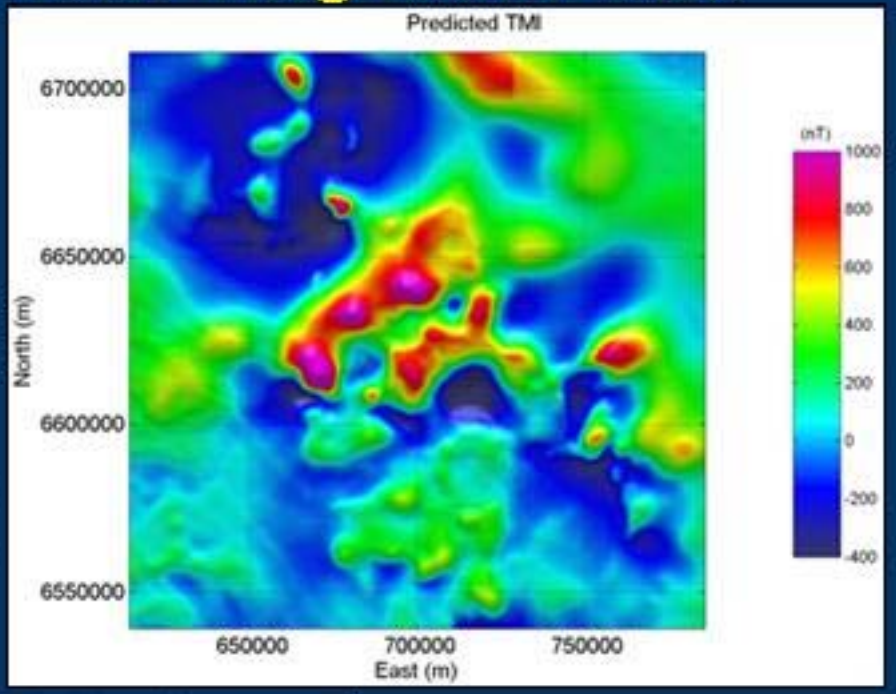


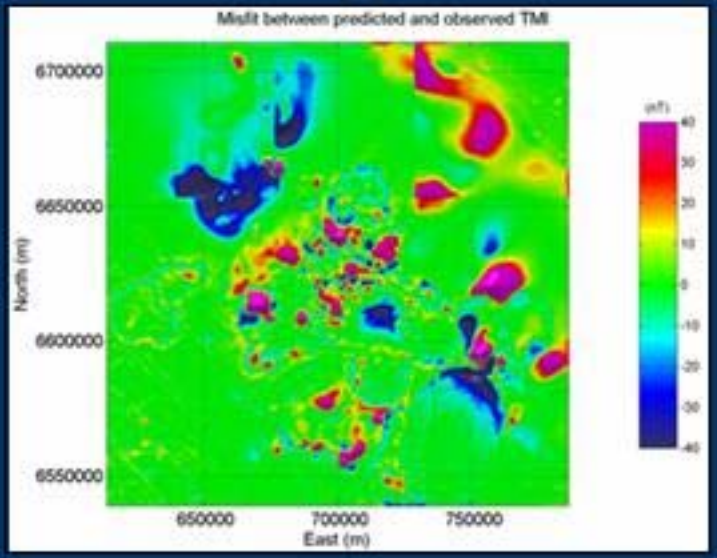


Misfit range ~5% of data range

Observed and Predicted Magnetic Data



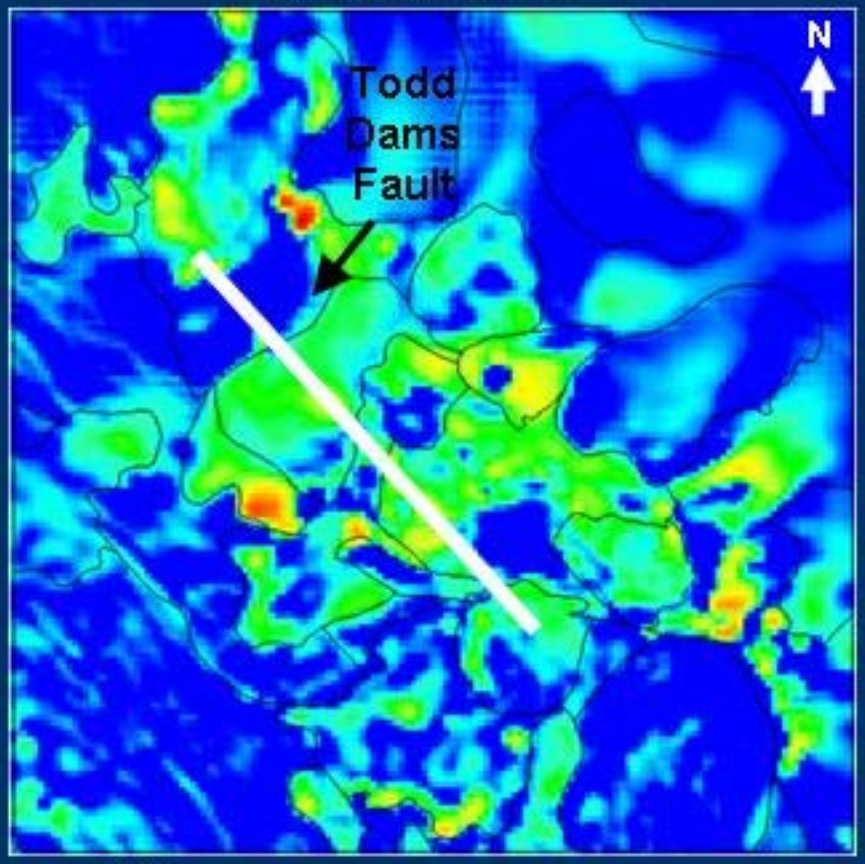


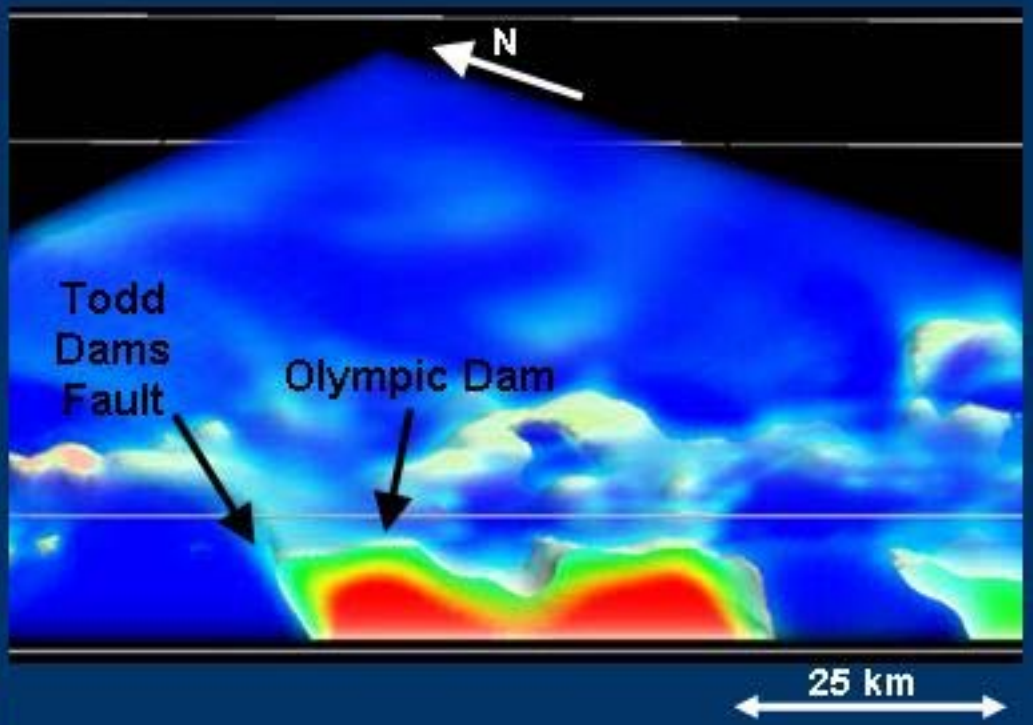


Misfit range ~6% of data range

Unconstrained Magnetic Inversion

-1000 m slice

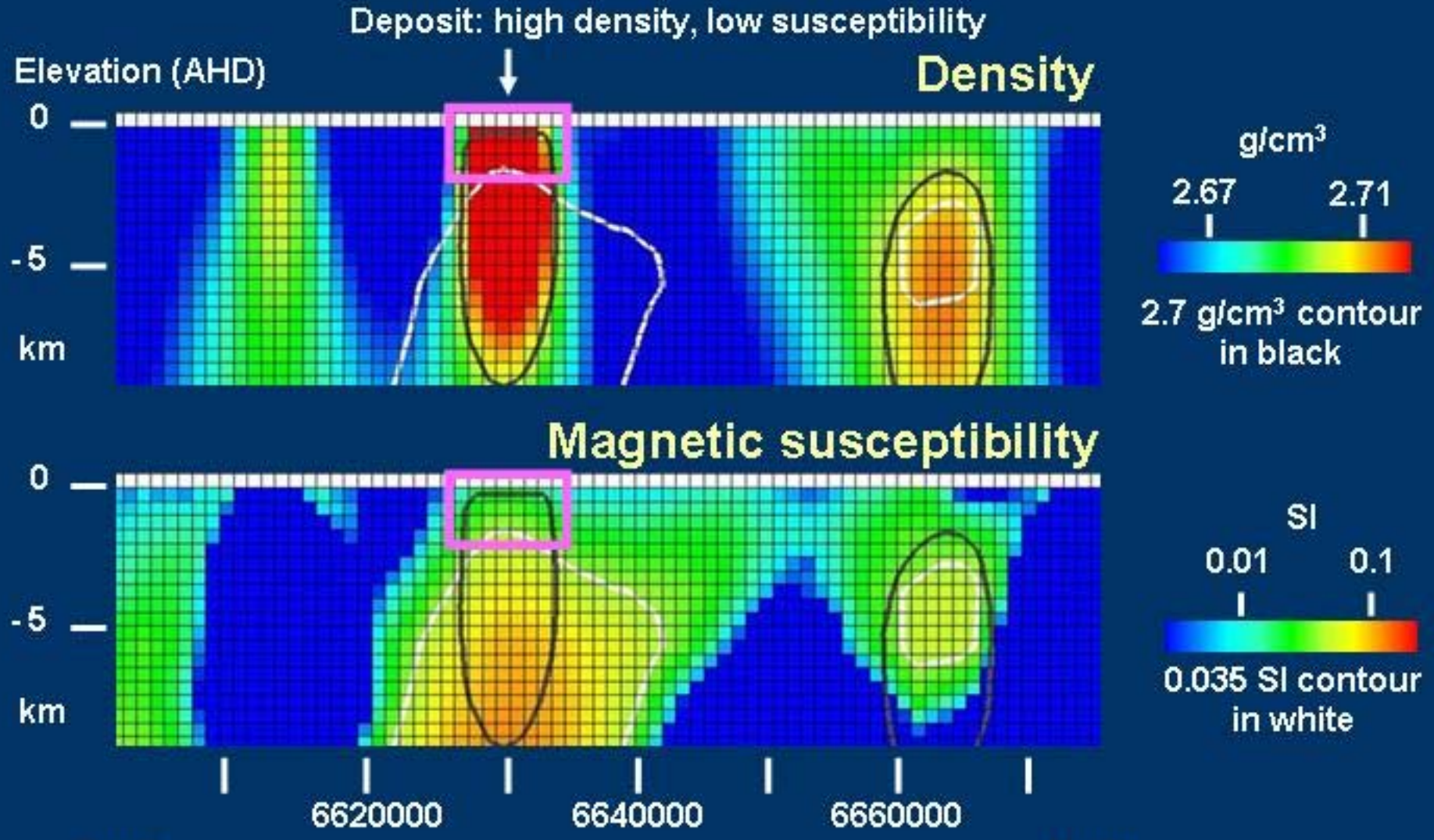




Susceptibility (SI)

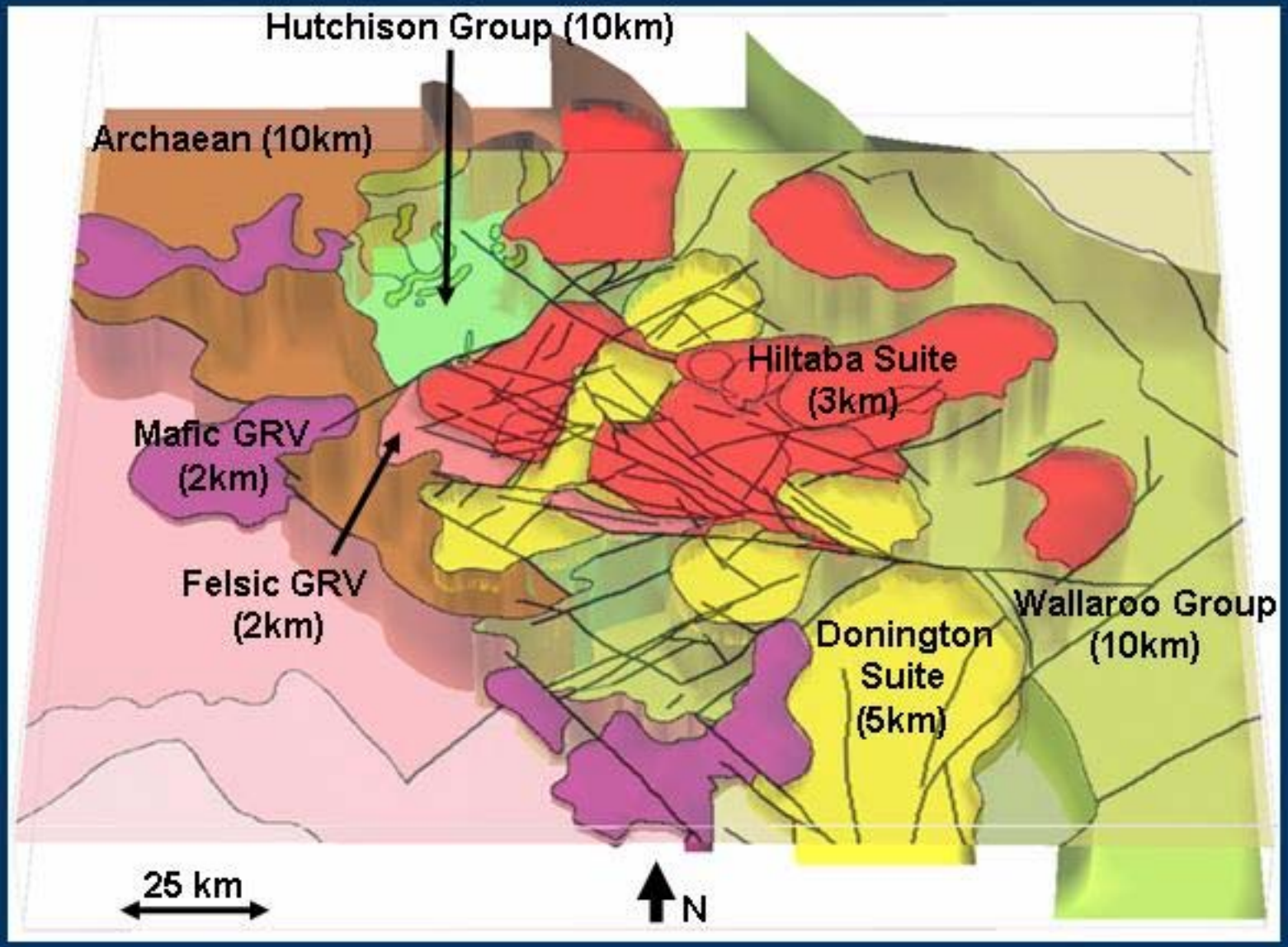
0.002 0.01 0.05

Unconstrained Inversion Section: Olympic Dam (681500mE)



(Source: Lane, 2003)

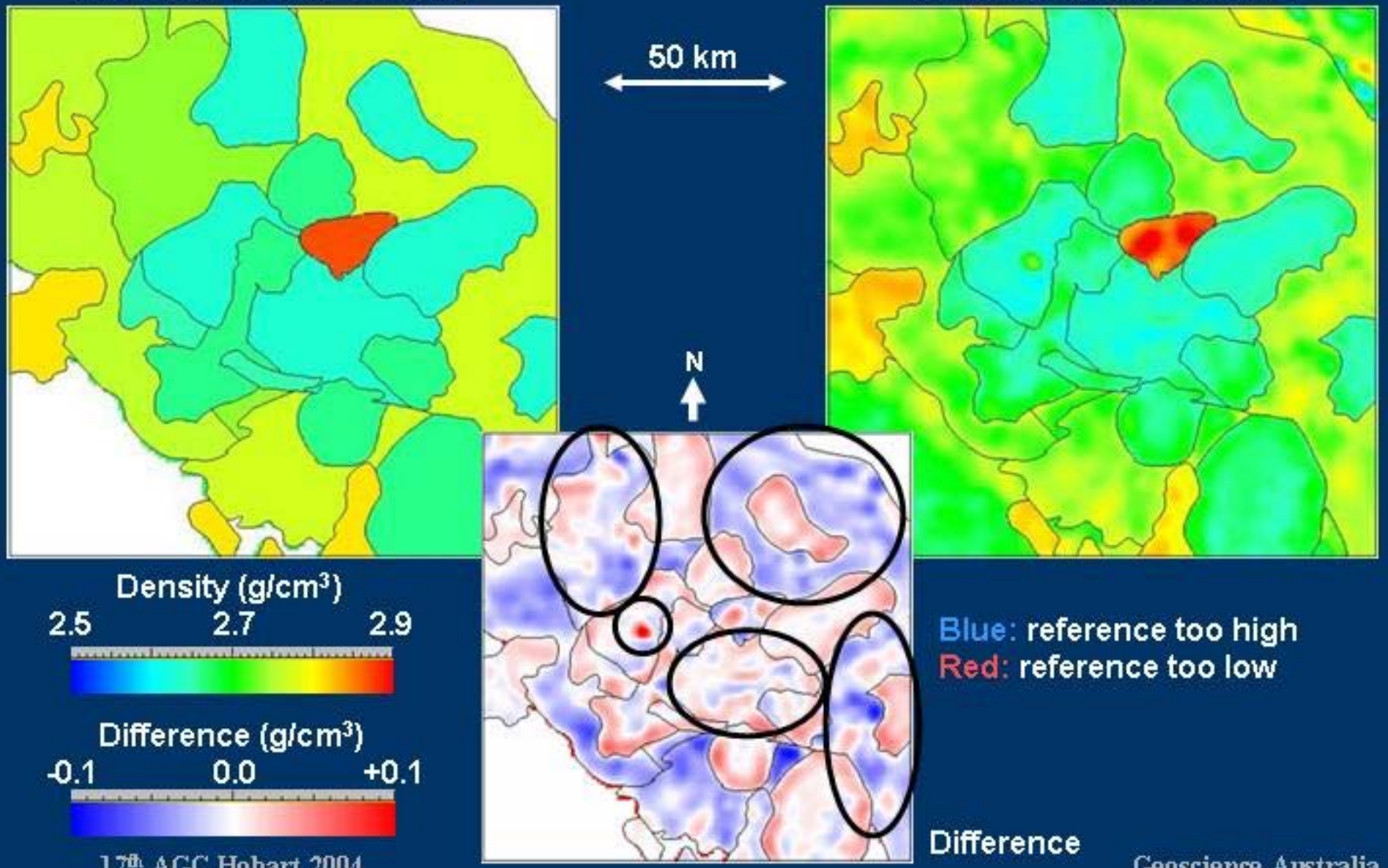
Simple Geological Reference Model



Constrained Gravity Inversion (-1000 m slice)

Reference Model – Density

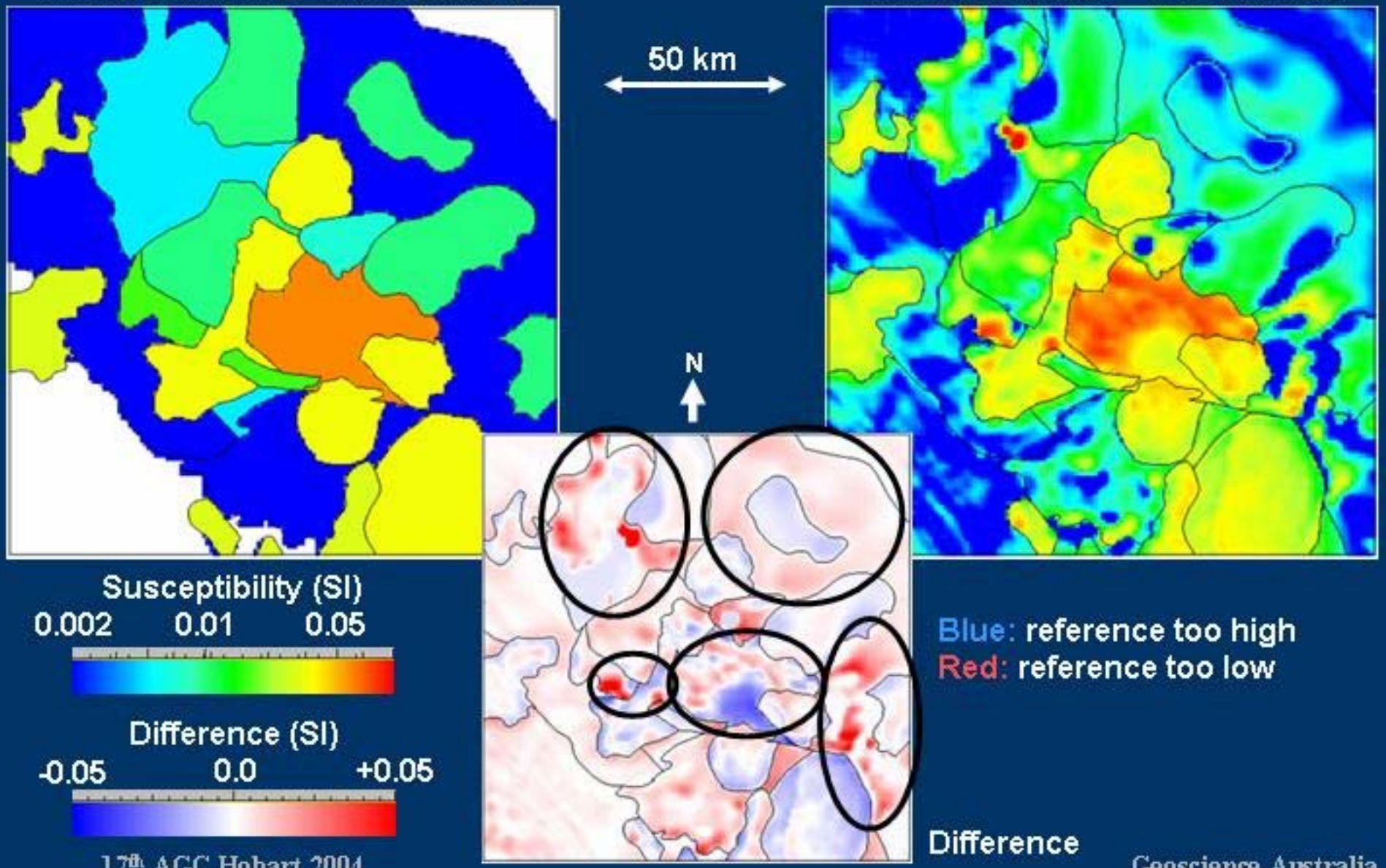
Inversion Model – Density



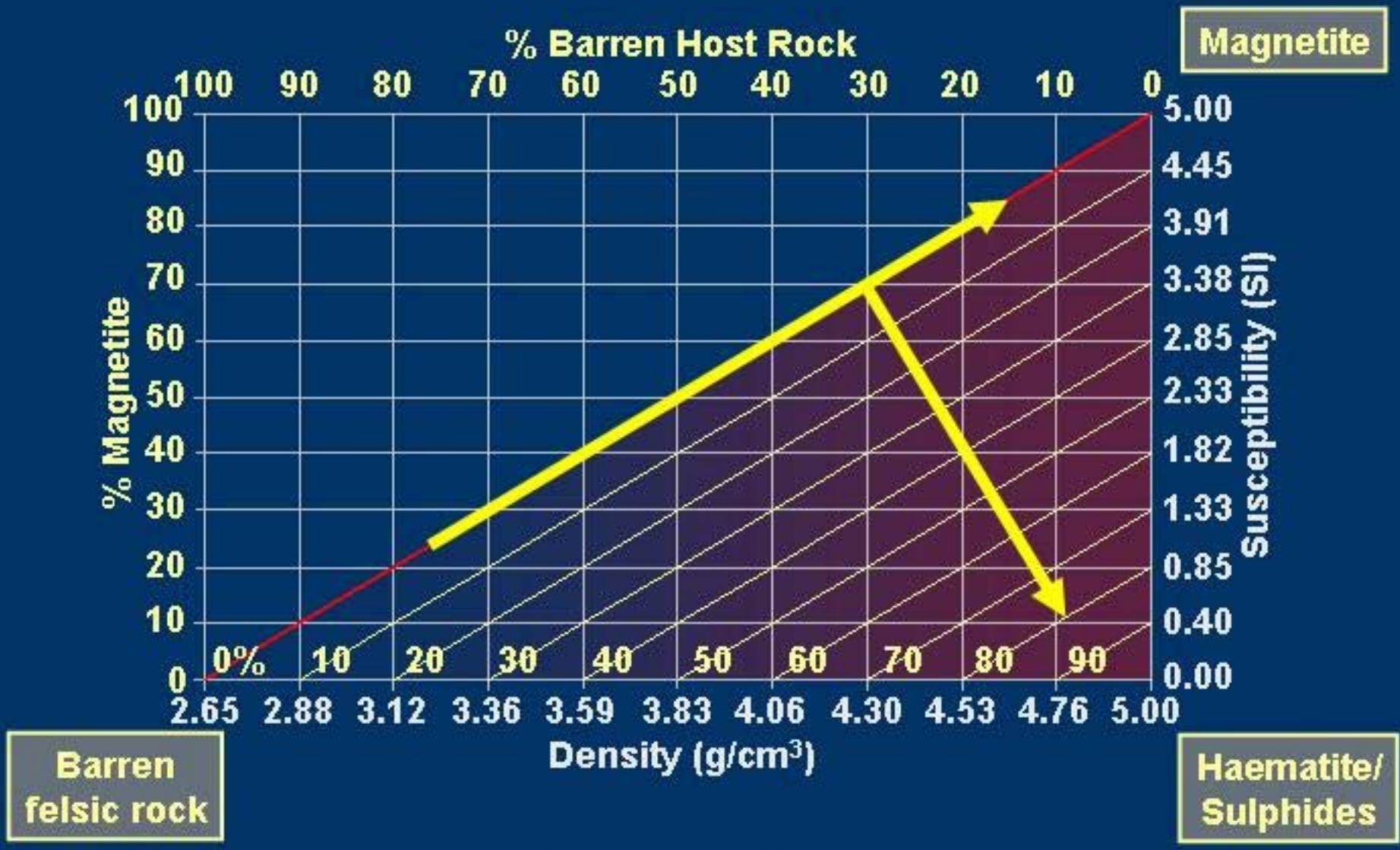
Constrained Magnetic Inversion (-1000 m slice)

Reference Model – Susceptibility

Inversion Model – Susceptibility

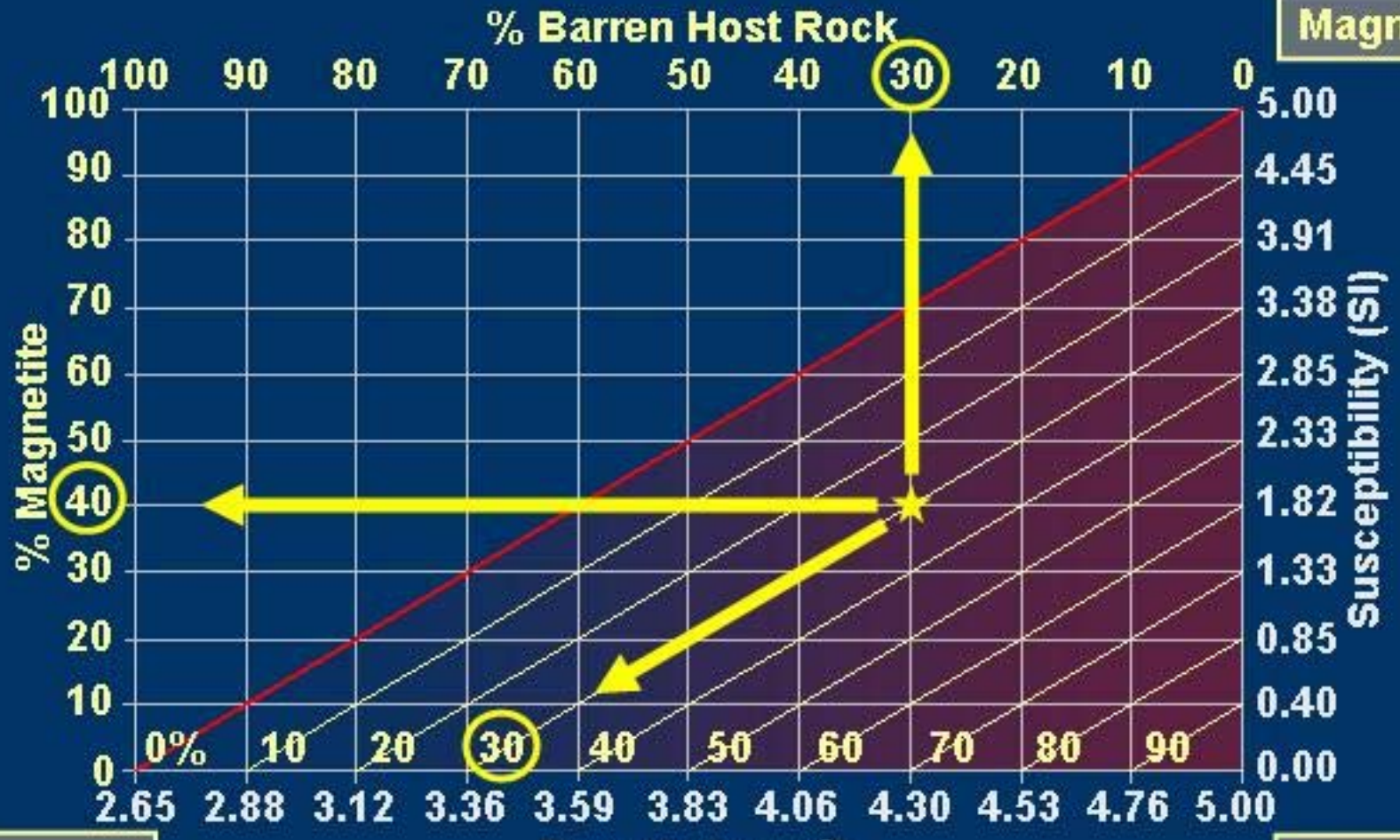


Susceptibility + Density = Geology?



(Source: Hanneson, 2003)

Susceptibility + Density = Geology?

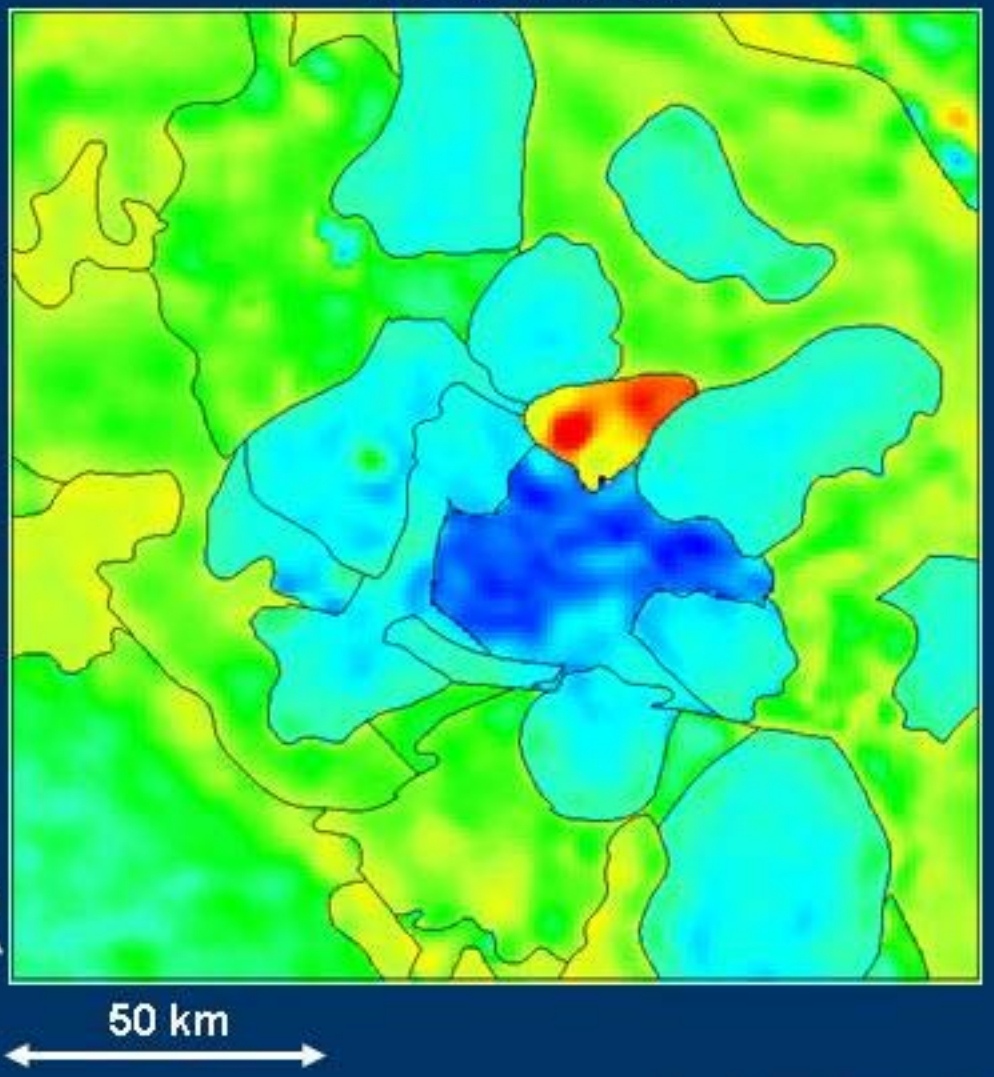


(Source: Hanneson, 2003)

Density of Barren Host Rock

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

-1000 m slice

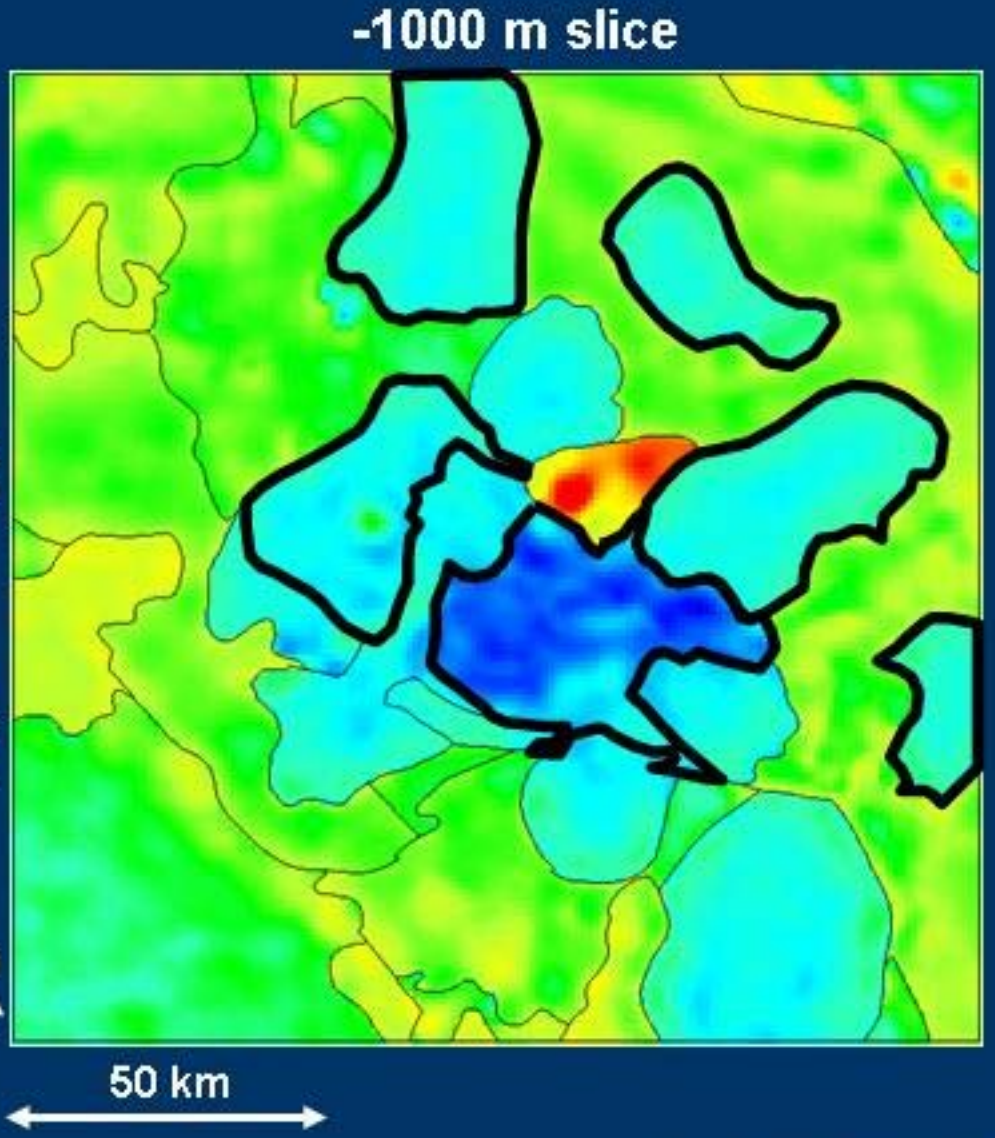


Density of Barren Host Rock

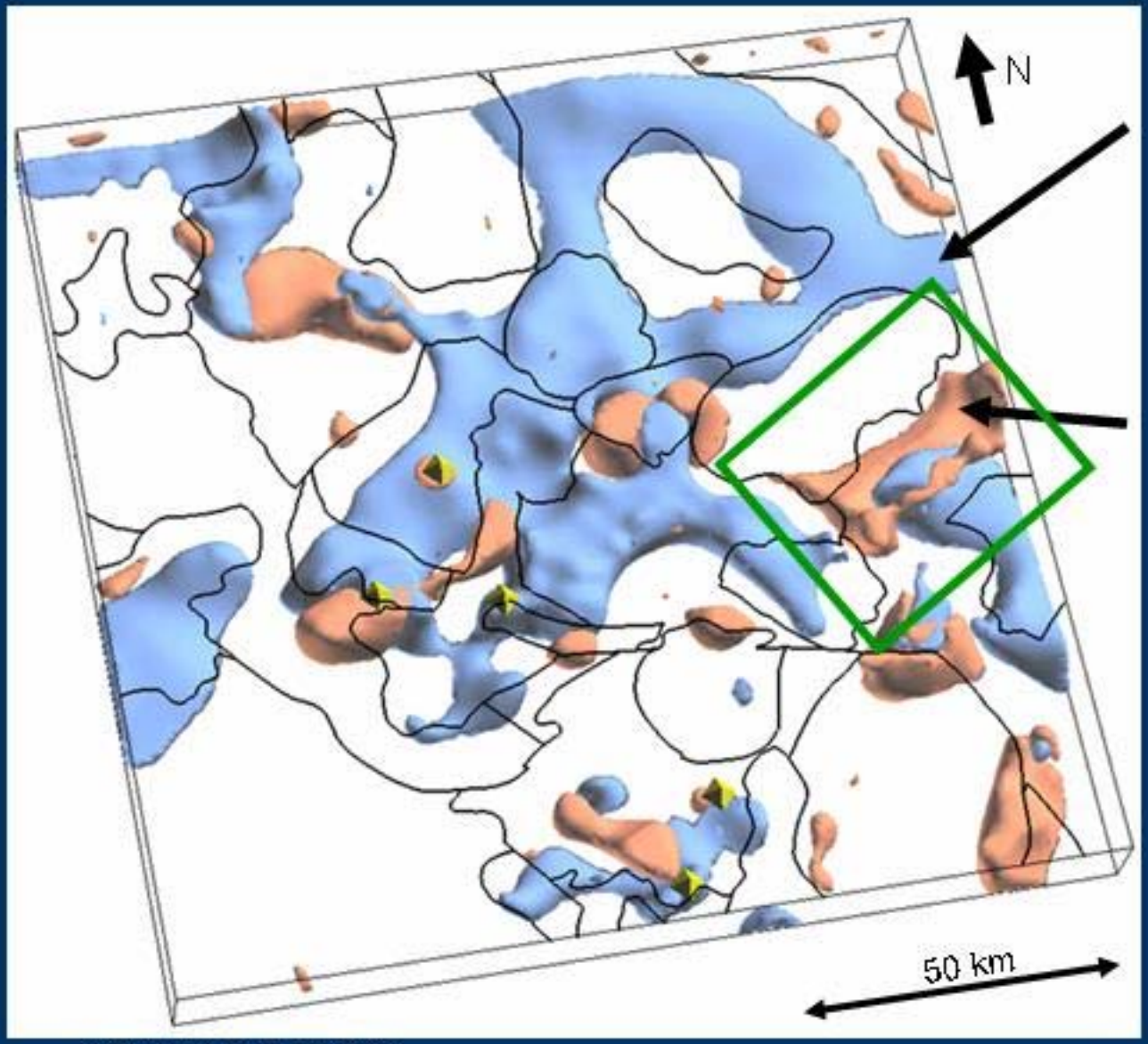
- Can subtract magnetite from the model to determine the density of the host rock

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

$$= \frac{\rho_{cell} - (\rho_{mgt} \times \%_{mgt})}{1 - \%_{mgt}}$$



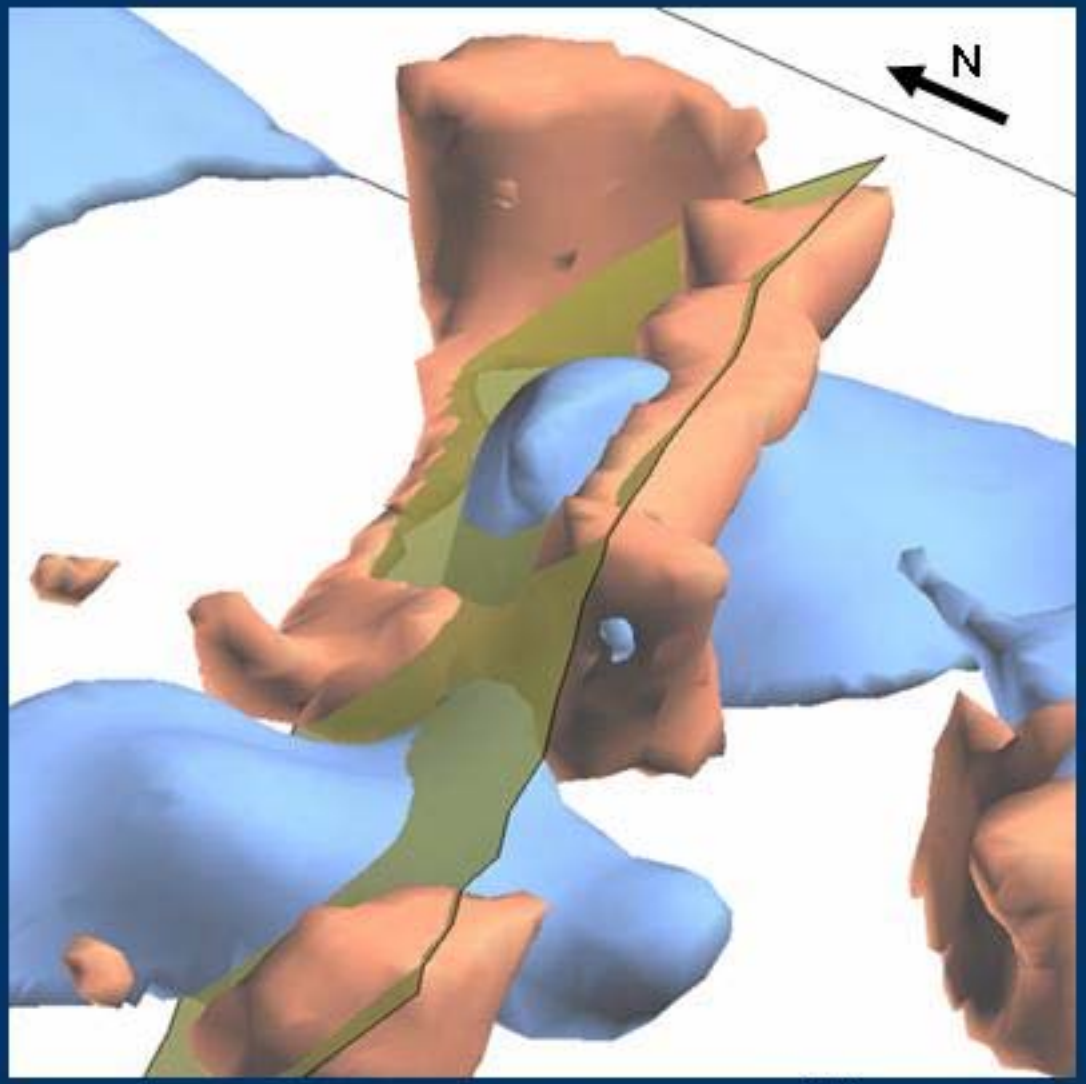
Possible Magnetite and Haematite Map



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

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

Possible Magnetite and Haematite Map



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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

Create 3D Maps Through Cover!

- Potential field inversions can make 3D maps of
  - Alteration
  - Lithology
  - Structure
  - 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 Peter Milligan Tim Moore