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

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Gravity and magnetic data see through cover
but we need new tools to understand the geology
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.

\[
\text{model} = f^{-1} (\text{data})
\]

Gravity/magnetic data \rightarrow Parameters \rightarrow 3D geology or model
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

Create reference

3D geological model: structures and lithologies

3D reference model: physical properties and inversion parameters

(Source: Lane, 2002)
Constrained Inversion Process

1. **Solid geology, seismic structure, cross-sections, drilling, etc**
2. **Build model**
   - 3D geological model: structures and lithologies
3. **Create reference**
   - 3D reference model: physical properties and inversion parameters
4. **Inversion**
   - 3D inversion model
5. **Constraint**
6. **Compare and update**

*Source: Lane, 2002*

*Geoscience Australia*
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 km³

Padded extent:
198 km × 198 km × 18 km
= 705,672 km³

- 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

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Observed and Predicted Magnetic Data

Misfit range ~6% of data range
Unconstrained Inversion Section:
Olympic Dam (681500mE)

Deposit: high density, low susceptibility

Density

Elevation (AHD)

0

-5

km

2.67

2.71

2.7 g/cm³ contour in black

Magnetic susceptibility

0

-5

km

0.01

0.1

0.035 SI contour in white

South

6620000

6640000

6660000

North

(Source: Lane, 2003)

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Constrained Gravity Inversion (-1000 m slice)

Reference Model – Density

Inversion Model – Density

50 km

Density (g/cm³)

2.5 2.7 2.9

Difference (g/cm³)

-0.1 0.0 +0.1

Blue: reference too high
Red: reference too low

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Constrained Magnetic Inversion (-1000 m slice)

Reference Model – Susceptibility

Inversion Model – Susceptibility

50 km

Susceptibility (SI)
0.002 0.01 0.05

Difference (SI)
-0.05 0.0 +0.05

Blue: reference too high
Red: reference too low

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Susceptibility + Density = Geology?

(Source: Hanneson, 2003)
Susceptibility + Density = Geology?

(Source: Haneson, 2003)
Density of Barren Host Rock

- Can subtract magnetite from the model to determine the density of the host rock
Density of Barren Host Rock

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

\[
\rho_{\text{host}} = \frac{\text{Mass}_{\text{cell}} - \text{Mass}_{\text{mgt}}}{\text{Vol}_{\text{cell}} - \text{Vol}_{\text{mgt}}}
\]

\[
\rho_{\text{cell}} - (\rho_{\text{mgt}} \times \%_{\text{mgt}})
\]

\[
\frac{1 - \%_{\text{mgt}}}{1 - \%_{\text{mgt}}}
\]
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
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10 km
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

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