Constrained inversion of gravity and magnetic data: a real time exploration tool?

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Objectives

• To invert potential field data from the Voisey’s Bay project to produce three-dimensional density and susceptibility models of the region containing the ore bodies located at Voisey’s Bay

• Gravity
  – Role data collection
  – Examine basic parameters commonly used in Grav3D (UBC-GIF)
  – Test methods of constraining gravity inversion

• Magnetics
  – Examine preliminary inversions using UBC inversion codes
Outline

- Physical Property Data
- Density Model Construction
- Gravity Data
- Forward Models
- Unconstrained Gravity Inversion
- Constrained Gravity Inversion
  - Regional models
  - Kriging models
- Magnetic Data and Magnetic Inversions
### Physical Property Data

- **Density data**
  - Derived from the regression of geochemical data (provided by VBNC)
  - Drill separation ~50m and sample spacing ~2m

- **Magnetic susceptibility data**
  - Over 500 core samples collected (14 sample the Ovoid)
  - Susceptibilities were measured using a standard AC bridge susceptibility meter and a DC process to remove the effect of induced magnetic fields

<table>
<thead>
<tr>
<th>Name</th>
<th>Count</th>
<th>Density (g/cc)</th>
<th>Susceptibility (SI) x 10^-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td><strong>Enderbitic gneiss (ENGN)</strong></td>
<td>2340</td>
<td>2.81</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Massive Sulphide (MASU)</strong></td>
<td>5222</td>
<td>4.61</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Troctolite (TR)</strong></td>
<td>4317</td>
<td>3.18</td>
<td>0.026</td>
</tr>
</tbody>
</table>
Density Model Construction

- Regions were generated in Gocad using the surfaces and wireframes provided by VBNC
  - Model 1: Regional Model
    - OB $\rightarrow$ 1.92 g/cc
    - ENGN $\rightarrow$ 2.81 g/cc
  - Model 2: Kriged Model
    - MASU and TR $\rightarrow$ Kriging
  - Model 3: Decimated Model
    - ENGN, MASU and TR $\rightarrow$ Kriging (25%)

- Relative to 2.67 g/cc
- Illustrated using MeshTools3D (UBC-GIF)
Gravity Data

- The gravity data were collected along 105 lines
  - Line spacing ranges from 200m to 1000m
  - Station spacing ranges from 25m to 50m

- Only 3 lines were collected over the Ovoid
  - Station Spacing ~25m
  - Line Spacing ~200m

- Regional field was calculated using standard upward continuation methods
  - The residual field was calculated by vertically projecting (Gocad) the regional field to the observation locations
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Forward Model

- A forward model (FM) was calculated from the kriged density model using gzfor3d (UBC-GIF)

- A visible offset is observed between the maximum amplitude and position of the survey lines
  - Offset is ~70m west
Unconstrained Inversion

- The UBC-GIF codes were used to invert the residual dataset

![Diagram showing Unconstrained Inversion with default parameters and parameterized inversion with Le=100m, Ln=50m]
A two layer regional model was incorporated into the inversion process.

- **Example 1:** Reference Model / Initial Model
- **Example 2:** Weighting Model
Constrained Inversion: Two Layer Regional Model

• A two layer regional model was incorporated into the inversion process
  • Example 1: Reference Model \ Initial Model
  • Example 2: Weighting Model
Constrained Inversion: Two Layer Regional Model

• The UBC-GIF codes were used to invert the FM dataset

• Le and Ln → Smoothing in the horizontal direction

• Lv length scale → Smoothing in the vertical direction

• Beta → Anomaly depth
Constrained Inversion: Two Layer Regional Model

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- The FM data was inverted using
  - Le, Ln, Lv → 20m, 20m, 5m
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  - Weighted model

- Result: The recovered density anomaly has an amplitude and a density distribution which compares favorably with the kriged model
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  – Residual data
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• **Example 2:**
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  – A reference model was created using 25% of the drill logs
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Magnetic Data \ Inversions

- Ground magnetic data was used for inversions

- A Koenigsberger ratio (remanent/induced magnetic intensity) of ~1.5 indicates that remanence cannot be ignored

- The NRM direction is ~30°

- The pyrrhotite present in the Ovoid is hexagonal and non-magnetic so the magnetization is associated with magnetite
Magnetic Inversion - UBC

• Regional field was removed using a method developed by Li and Oldenburg (1998)

• The susceptibility anomalies are comparable to the location of high density regions observed within the Ovoid

• High density regions $\rightarrow$ concentrations of magnetite?
Conclusions

• Gravity
  – Length scales and depth weighting parameters have a major influence on recovered models
  – A reasonable model of the Ovoid can be obtained when overburden is included in the inversion
  – Incorporating drill log information into the inversion guides the inversion towards an acceptable solution

• Magnetics
  – Examples shown are preliminary and further work is needed to constrain magnetic inversions
  – Further integration is necessary to understand the relationship between the gravity, magnetics and geochemistry
Acknowledgements

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