Seismic and Magnetotelluric surveys in Georgina – Arunta

Seismic Acquisition and Processing team

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- ANSIR/AuScope for MT equipment
Georgina-Arunta Survey Line

- 373 km seismic reflection line (09GA-GA1)
- Seismic and gravity data were acquired in June - July 2009
- Magnetotelluric (MT) data were acquired in May - July 2009
Georgina-Arunta Survey Line

- 57 MT sites were deployed at 39 locations along the deep seismic reflection transect
- 39 broadband MT sites and 18 long period MT sites
Seismic Acquisition and Processing
Seismic Reflection Method

Seismic reflections are used in geophysical exploration to image subsurface structures. The method involves the generation of seismic waves at the surface and the detection of the waves as they reflect off subsurface features. The diagram illustrates the process with the source point generating seismic waves that travel through the ground and reflect off different layers. The first arrival of energy is detected, and reflections from specific beds (like bed A and bed B) are indicated. The corresponding idealized reflection seismogram shows how these reflections are recorded.

Key components of the diagram include:
- **Source point**: The point from which seismic waves are generated.
- **Reflections**: From bed A and bed B, showing how waves reflect off different geological layers.
- **Seismic wave paths**: The paths taken by the seismic waves.
- **Weathered zone**: The uppermost layer of the Earth's crust.
- **Shale beds**: Layers of shale within the subsurface.
- **Sandstone beds**: Bed A and Bed B, representing different geological layers.
- **Reservoir**: The target layer, often containing oil or gas.
Seismic Acquisition Parameters

Symmetrical split spread with maximum 6 km offset
300 channels, receiver groups at 40 m intervals

(not to scale!)
Seismic Acquisition Parameters

**Source Array:** 60 m centred between pegs

**Vibe Point (VP) Interval:** 80 m

**Vibe Config:** 15 m pad/pad 15 m move up

**Sweeps:** 3 x 12 seconds vibes variable frequency sweeps

1) 7-56 Hz
2) 12-96 Hz
3) 8-80 Hz
Front Crew

Laying cable

Stomping geophone
AHV-IV Vibes

Geophone

Peg

Pad
Recording Data

Recorded at 2 ms sampling interval and 20 s recording length
Back Crew

Picking up geophones

Pulling in cable
Seismic Processing

The overall goal is to produce an image of the sub-surface by enhancing and correctly positioning reflections and reducing undesired energy (noise).
Seismic Processing Sequence

1. Setup Geometry
2. Statics Correction
3. Normal MoveOut (NMO) Velocity Analysis
4. Auto-statics Correction
5. Dip MoveOut (DMO)
6. Stack
7. Migration
MT Acquisition and Processing
MT Method

- Magnetotelluric (MT) is a passive electromagnetic (EM) sounding technique
- Measures variations in the Earth’s natural electric (E) and magnetic (B) fields in time series
- Ratio of E / B is used to derive resistivity distribution of Earth’s crust and upper mantle
- Frequency range $10^4$ Hz to $10^{-4}$ Hz ($10^{-4}$ s to $10^4$ s)
- Investigation depths of tens of metres to hundreds of kilometres
MT Source Field

- High frequencies >1 Hz from Spherics
  - Lightning (thunderstorm) activity world-wide
- Low frequencies <1 Hz from
  - Interaction between solar wind and magnetosphere
- Vary with periods of seconds, minutes, hourly, daily, yearly cycles
Depth of Investigation

- **Depend upon frequency and resistivity**
  - High frequencies image the near-surface
  - Low frequencies penetrate to greater depths
  - Higher resistivity means deeper penetration

- **Skin depth** is an approximate estimate depth of EM energy penetration at particular frequency and resistivity
MT Acquisition System

- 9 MT systems from ANSIR/AuScope
- Portable data recorder with 24 bits resolution
- GPS clock synchronization
- Magnetic sensors - induction coils and fluxgate magnetometer
- Electric sensors - copper/copper sulfate electrodes with dipole length 50 m)
Magnetic Sensors

Broadband Induction coils

3 component Fluxgate magnetometer
Electric Sensors

System layout
## MT Acquisition Parameters

<table>
<thead>
<tr>
<th>Type of MT</th>
<th>Broadband</th>
<th>Long period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording channels</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Sampling rate</td>
<td>1000 Hz</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Recording time</td>
<td>30 - 60 hours</td>
<td>5 - 7 days</td>
</tr>
<tr>
<td>Site spacing</td>
<td>8 - 10 km</td>
<td>15 - 20 km</td>
</tr>
<tr>
<td>Deployment</td>
<td>3 or 4 sites at a time</td>
<td>5 or 6 sites at a time</td>
</tr>
<tr>
<td>Data format</td>
<td>MiniSeed</td>
<td>MiniSeed</td>
</tr>
</tbody>
</table>
Example of Time Series Data

Magnetic N
Magnetic E
Electric N
Electric E
Magnetic N
Magnetic E
Magnetic Z
Electric N
Electric E
MT Processing Sequence

Time series data pre-processing

- Transform data into frequency domain
- Derive spectra and impedance tensors
- Calculate apparent resistivity and phase
- Calculate tipper function for long period data
- Store MT response into EDI file
- Data analysis
- Modelling
MT Data Response

- **Apparent resistivity** is a volume average of a heterogeneous half-space.
- **Transverse magnetic (TM) mode**: the electric field is perpendicular to geoelectrical strike.
- **Transverse electric (TE) mode**: the electric field is parallel to geoelectrical strike.
Data Analysis

- Analyse MT response for the data set
- Define the dimensionality and electric strike angle of the data set
- Several techniques have been used, such as, phase tensor decomposition, Mohr circle technique, WALDIM method, vertical induction vector (arrow), etc
- PseudoSection of data set gives a qualitative impression of resistivity variations with depth and distance
# Data Analysis

<table>
<thead>
<tr>
<th>Type of MT response</th>
<th>Broadband data</th>
<th>Long period data</th>
<th>Merged data</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of period</td>
<td>30 periods</td>
<td>26 periods</td>
<td>45 periods</td>
</tr>
<tr>
<td>Range of period</td>
<td>0.003 s to 100 s</td>
<td>10 s up to 14000 s</td>
<td>0.003 s up to 10000 s</td>
</tr>
</tbody>
</table>
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PseudoSection of Apparent Resistivity and Phase

**TM mode:**
- High
- Apparent resistivity
  - XY
- Phase
  - XY

**TE mode:**
- High
- Apparent resistivity
  - XY
- Phase
  - XY

Section length 550 km
Distance 370 km

Frequency
- High
- Low

Frequency
- High
- Low
Inversion and Modelling

- 1D model used different 1D codes

- A preliminary 2D model implemented by using the Non-Linear Conjugate Gradient (NLCG) algorithm of Rodie and Mackie (2001)

- Wide range of regularization parameters were tested for different 2D models

- Test robustness of the model (forward model, compare with other geophysical results)
Preliminary 2D MT model

Distance 370 km

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Limitations of the Model

• MT inversion is non-linear, non-unique and an unstable problem. There are an infinite set of models.

• Impossible to accurately estimate physical properties from a finite set of uncertain data.

• The model may not exactly represent some features due to large station spacing.

• Complicating factors need to be considered, static shift, distortion, 3D effects.

• Prior geological and geophysical information should be applied to constrain the 2D model.
Seismic Image and MT Preliminary 2D Model

Distance 370 km
Conclusions

- Seismic and MT data were acquired along a 373 km transect
- The Seismic and MT data have been processed and analysed
- Seismic image and MT preliminary 2D model show that near-surface sediments are well-resolved. They also provide evidence of geological structures in this region
Thank you!