HVSR passive seismic surveying for estimating depth of weathering and cover thickness over Tanzanian graphite, Albany-Fraser Orogen REE and Paterson Orogen base metal deposits

John Sinnott – Resource Potentials
Passive seismic HVSR data acquired at 3 different projects:

• Graphex’s Shimba flake graphite deposit in SE Tanzania

• Salazar Gold’s REE oxide project in the Albany - Fraser Orogen, WA

• Encounter Resources’ BM2 – Millennium Zn project in the Paterson Province, WA
Located in SE Tanzania

PFS of the Shimba graphite deposit completed, with encouraging results for development

Total indicated and inferred resource of 9.2Mt at 10.7% TGC (graphexmining.com.au)
High grade deposit outline over a late time VTEM helicopter EM anomaly image with 1vd filter

VTEM survey limited to a ~12msec EM decay recording time
All graphitic units dip to the S

FLEM data acquired over Shimba deposit and along strike

Long recording time of 750msec used, (62.5 times longer than VTEM)

Shimba and additional anomalous responses identified in late time FLEM data
Conductor plate modelling of FLEM data carried out

Resistive weathered graphite zone located up dip of conductive responses

Conductor plates projected to surface for focusing field mapping, shallow drilling and trenching
Tromino HVSR data surveying was trialled over up dip projections of modelled FLEM conductors to identify zones of deeper weathering associated with oxidised graphite deposits, relative to adjacent felsic gneiss, where oxidised graphite has potential for open cut mining.
Tromino Line 471000 HVSR Section

Tromino Line 472120 HVSR Section

Tromino HVSR passive seismic trials successful in identifying zones of deeper weathering

Good correlation with FLEM survey data and plate modelling

Can be used to identify zones with shallow weathering and cover to assist with mine infrastructure planning
Located in the Albany-Fraser region, Western Australia

Significant exploration carried out in the region following the recent discoveries of Tropicana (Au) and Nova-Bollinger (Ni)

GSWA 1:250,000 scale mapping predominately Quaternary cover of Pleistocene eolian sand and clay deposits, and lacustrine deposits

Small outcrops of Proterozoic granite and gneiss and interpreted to be bedrock in the project area

This case study reviews geophysical cover thickness investigations using

- Magnetics – Qualitative approach and Euler deconvolution
- Electromagnetics – CDI and LEI processing
- Passive seismic – HVSR depth to bedrock

Geophysical interpretation of project area
Geology snapshot

- **Shear velocity** (complex and simplified)
- **Unconsolidated sands (low)**
- **Hardpan (high)**
- **Mixed Gradient**
- **BOA**
- **BOCO**
- **TOSR**
- **TOFR**
- **Simplified resistivity profile**
- **Simplified magnetic profile**
- **Main HSVR peak frequency**
- **Simplified resistivity profile**
- **Main HSVR peak frequency**

**Layers:**
- **Regolith:**
  - **Soil**
  - **Transported Overburden**
  - **Upper Saprolite**
  - **Lower Saprolite**
  - **Saprock**
  - **Fresh Bedrock**

**Earth materials:**
- **Sand**
- **Dune**
- **Loose soil to hardpan**
- **Soil**
- **Transported Overburden**
- **Upper Saprolite**
- **Lower Saprolite**
- **Saprock**
- **Fresh Bedrock**

**Profiles:**
- **BOA**
- **BOCO**
- **TOSR**
- **TOFR**

**Simplified resistivity profile**

**Simplified magnetic profile**

**Shear velocity (complex and simplified)**

**Unconsolidated sands (low)**

**Hardpan (high)**

**Mixed BOA**

**Gradient**

**Mixed TOFR**

**Main HSVR peak frequency**
Magnetic investigations (2013)

- Thickness of non-magnetic regolith cover (transported and saprolite) investigated by evaluating the magnetic responses of underlying magnetic granite-gneiss
- Qualitative and quantitative (Euler) techniques

High and low frequency magnetic responses provide an indication of burial depth
Magnetic investigations (2013)

- Euler deconvolution carried out using high resolution survey data (100m line spacing) to investigate the depth to magnetic bedrock
- Everything above magnetic bedrock considered regolith
- A remarkable correlation exists between the Euler deconvolution solutions and GSWA mapped outcrop (1:250,000)

Gridded Euler depth solutions (red-deep, blue shallow) showing excellent correlation with outcropping geology
• Airborne EM surveying carried out in the project area to investigate thickness of conductive cover sediments, and to detect anomalous EM responses that could be associated with massive sulphide mineralisation at depth

• VTEM system, 200m line spacing (NW-SE orientation)

• CDI (AMIRA / EMFLOW) and LEI (Airbeo CSIRO algorithm) processing

Comparison of LEI and CDI processing carried out on VTEM data
• Extracting conductivity information from LEI results to image the thickness of selected conductivity units

• LEI conductivity thresholds compared well with drilled depth to fresh rock

• However, not able to discriminate between regolith units

Base of conductive layer units derived from automated picking of selected apparent resistivity values A=2 Ωm, B=3 Ωm, C=5 Ωm, and D=10 Ωm.
Passive seismic surveying (2015)

- 2x Tromino 3G seismometers
- HVSR technique used to estimate depth to fresh rock
- Surveying carried out along historical tracks → 500m line spacing, 100m stations
- Field tests determined that 12min recording time was optimal
- Stations next to drillholes for survey calibration
- Peak daily production: 41 stations

12 and 20 minute recording comparison

Stations acquired next to drillhole collars where possible

Buckets used to protect instrument from wind
Passive seismic surveying (2015)

- Data are typically of excellent quality
- Very low noise, great signal – 12 minute readings!!
- Strong H/V peak observed at the vast majority of stations

Example of a H/V spectral ratio, component spectra and time history – station 87
Passive seismic surveying (2015)

- 1D modelling carried out on readings near drillhole collars
- Slow method if applied to all readings

1D modelling of HVSR response using Grilla software
Passive seismic 1D modelling results at drillholes provided a reliable depth estimate to the top of fresh rock.

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>LITH DESCRIPTION</th>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Creamy brown calcrete and soil</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>Brown clay, puggy forming balls</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>Hardpan, ferruginous and silcrete, sand-clayey</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>White sand and clay, kaolinite?, powdery</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Red black clay</td>
</tr>
<tr>
<td>11</td>
<td>20</td>
<td>Black clay, plastic and difficult to drill</td>
</tr>
<tr>
<td>20</td>
<td>23</td>
<td>Grey clay, saprolite, sericite sheen</td>
</tr>
<tr>
<td>23</td>
<td>33</td>
<td>Brown clay, saprolitic, sericite sheen</td>
</tr>
<tr>
<td>33</td>
<td>38</td>
<td>Grey friable fresher saprolite, sericite sheen</td>
</tr>
<tr>
<td>38</td>
<td>39</td>
<td>Quartz feldspar biotite gneiss, sub-vertical, bands of biotite/biotite schist</td>
</tr>
</tbody>
</table>
Comparison of peak H/V frequency compared to the drilled depth to bedrock (21 readings next to drillhole collars)

Comparing the observed resonant peak frequency with the drilled depth of fresh rock

\[ y = 92.494x^{-0.986} \]

\[ R^2 = 0.8993 \]
Passive seismic surveying (2015)

- Peak frequency of the H/V peak is related to the shear wave velocity and thickness of the overlying layer

\[ f = \frac{V_{S_i}}{4} h_i \]

- General increase of velocity with increasing depth (compaction?, degree of weathering?)

Increase shear wave velocity with increasing thickness of regolith cover
Passive seismic surveying (2015)

- Peak frequency information extracted at each station
- Drilled depth to H/V peak frequency trend equation used to estimate depth to hard rock for all seismic stations
- Estimated regolith thickness ranges from 5 to 47 m

\[
y = 92.494x^{-0.986}
\]

\[
R^2 = 0.8993
\]

Estimated cover thickness using the trend equation
Passive seismic surveying (2015)

- Good correlation with the estimated thickness of conductive cover calculated using VTEM data

500m spaced Tromino lines

200m spaced VTEM lines

Passive seismic estimated regolith thickness (left) and conductive cover thickness estimate (right)
Passive seismic surveying (2015)

- Merging the drilled depth to fresh rock from other drilling
- Passive seismic / drilling shows a good correlation with the VTEM LEI estimate

Passive seismic estimated regolith thickness (left), merged with drilling information (middle), and VTEM conductive cover thickness estimate (right)
Passive seismic surveying (2015)

- Normalised HVSR section, with drilling information and depth of conductive cover profiles (black) overlain
- Dashed white line shows depth to fresh rock using drilling trend equation
- Frequency converted to depth using a constant velocity (400 m/s)
Passive seismic surveying (2015)

• Passive seismic has an excellent correlation with drilling
• In areas of thicker cover LEI approach appears to overestimate cover thickness
• Subtle shallow HVSR responses (pink) appear to be associated with the base of transported cover, observed over all survey lines
Passive seismic surveying (2015)

- Very subtle HVSR response appears to be associated with the base of transported cover
- 12 minute recording perhaps not long enough to enhance this response
- To highlight upper peak associated with base of transported cover, future surveying should utilise a longer recording time (25-30 mins)
- Passive seismic may be able to accurately discriminate weathered profile thickness to assist REE drillhole targeting
Energy sources?

- Waves
- Wind (vegetation)
- Tectonic activity – no earthquakes at the time of the survey

Search of GA databases for earthquakes within the last 30 days (16/08/2016)

Thick vegetation in the project area → tree root movement with wind
Zn sedex deposit located in the prospective Paterson Province, surrounded by Nifty Cu, Telfer Au and Kintyre U deposits.
Thick transported and regolith cover

Zn mineralisation hosted in black shale and intercalated dolomites and shales

Adjacent to dense massive dolomite unit
Thick transported and regolith cover – Permian Paterson Fm and Cainozoic to recent transported sediment

Tromino surveying completed to map cover thickness

14 Tromino lines surveyed (yellow lines)

Cover model used in gravity data processing and modelling
Massive dolomite and fault zone can be identified from gravity data

Gravity data affected by thick transported and regolith cover
Good correlation between HVSR sections and drilling data in NW of survey area
Weaker correlation between HVSR sections and drilling data in SE of survey area, thought to be related to Peterson Formation glacial material not providing sharp density contrast
BM2 – Millennium: HVSR Sections

14 Tromino HVSR passive seismic lines surveyed
14 Tromino HVSR passive seismic lines surveyed

Compared with drilling and Tempest and VTEM AEM data
BM2 – Millennium: Depth of Cover Model

14 Tromino HVSR passive seismic lines surveyed

Compared with drilling and Tempest and VTEM AEM data

3D model of cover generated and used to remove low-density effects in gravity data
Gravity response of modelled cover
BM2 – Millennium: BA Gravity Residual Image

Original BA residual gravity image
BA residual gravity image of bedrock after the modelled transported cover was removed
Passive seismic HVSR surveying has many applications:

- Ambient signal still available far from tectonically active areas, therefore it is not limited to coastal or developed areas
- Comparison of passive seismic results to other geophysical methods is complimentary, and on its own provide useful information that is very easy to acquire
- Identifying zones of preferential weathering related to faults or stratigraphy
- Identifying zones of thin cover for mine infrastructure planning
- Paleochannel mapping for exploration of REEs, potash, U, Au, Li and others
- Cover mapping to assist with removing cover effects and constraining gravity modelling
Special Thanks

Resource Potentials

encounter
RESOURCES LIMITED

Salazar Gold Pty Ltd

Graphex
MINING LIMITED