Passive seismic for drill-hole optimisation; from Cretaceous cover to tundra thickness

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Passive Seismic

- Tromino Unit
- 3 component geophone
- Combined Data Logger
- Other versions have GPS and radio telemetry
- Battery operated

\[ f = \frac{V_s}{4h} \]

- \( f \) = resonant frequency
- \( V_s \) = Shear wave velocity
- \( H \) = layer thickness
Outline

Case Study #1
● Tillite thickness in Athabasca Basin, Canada

Case Study #2
● Cretaceous cover thickness Arnhem Land, Australia
Unconformity Uranium model (Athabasca)
Issues arising from till

- Major “troughs” in overburden pose logistical difficulties, increased costs, and higher risks when attempting to drill
  - production rates reducing to approximately 20 metres per day, and drilling costs reaching $250 to $300 per metre of overburden.
- Varies form 0 to 200m
- Amplitude and wavelength of gravity signature due to alteration in sandstones are comparable with that of variable thickness of glacial sediments.
- Mapping the overburden thickness can help constrain overburden stripping in geophysical inversion
Flexibility in collar location

- For an 800 m hole
- $5^\circ$ variation in dip
- ~70m radius collar footprint

Adelaide Oval
Till formation

- **Glacial till** is unsorted sediment deposited directly by **glacial ice**. **Glacial till** is a soft rock identified by large angular rock fragments on the surface and within the soil.

- **Multiple glaciations extensive drift cover**
  - complex glacial history

- **Present day landscape primarily result of last primarily result of last glaciation** – Late Wisconsinan

- **Preservation of older sediments in thick drift and buried valleys**

Images from http://members.shaw.ca/len92/geology.htm
Regional Setting

Last Glacial Maximum, 20-23 $C^{14}$ ka BP

Glacial Maximum (From Campbell, 2007)
Drumlins (Athabasca)
Quaternary overlying Cretaceous units

From Andriashek and Fenton, 1989
Passive seismic for drill-hole optimisation
Borehole vs Passive Seismic results

\[ y = 281.2x^{-2.006} \]
\[ R^2 = 0.9015 \]
Case Study #1
- Tillite thickness in Athabasca Basin, Canada

Case Study #2
- Cretaceous cover thickness Arnhem Land, Australia
RC Drilling vs Diamond Drilling

● Positives
  – Cheaper and faster alternative to diamond drilling
  – Requires less water
  – Could be used for geochemical exploration

● Negative
  – Less geological information from sample
  – Depth limitations (250-300m from an efficiency perspective)
  – Difficult to implement in Cretaceous materials >30 m thick
Cretaceous Sediments

Twidale, 1997, 2003
Shear Wave Velocity

Table 1. Modified NEHRP site classes, associated $V_s^{30}$ values and general groupings of geologic units associated with each class, based on 556 measured profiles from California (Wills et al., 2000).

<table>
<thead>
<tr>
<th>Site Class</th>
<th>$V_s^{30}$ (m/s)</th>
<th>Geological Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>&gt; 760</td>
<td>Plutonic/metasomatic rocks incl. most volcanics; pre-Tertiary sedimentary units</td>
</tr>
<tr>
<td>BC</td>
<td>555 - 1000</td>
<td>Cretaceous fine-grained sediments; oolite; sheared/weathered crystalline rocks</td>
</tr>
<tr>
<td>C</td>
<td>360 - 760</td>
<td>Oligocene – Cretaceous sedimentary rocks; coarse-grained younger material</td>
</tr>
<tr>
<td>CD</td>
<td>270 - 555</td>
<td>Miocene fine-grained sediments; Pleistocene alluvium; coarse younger alluvium</td>
</tr>
<tr>
<td>D</td>
<td>180 - 360</td>
<td>Holocene alluvium</td>
</tr>
<tr>
<td>DE</td>
<td>90 - 270</td>
<td>Fine-grained alluvial/estuarine deposits</td>
</tr>
<tr>
<td>E</td>
<td>&lt; 180</td>
<td>Intertidal mud</td>
</tr>
</tbody>
</table>
Shear Wave variability

From Parkseismic.com
Unconformity Uranium model (Australian Setting)

- Sandstone
- Calc-silicate
- Granitic Gneiss
- Amphibolitic gneiss
- Pelitic Gneiss
- Basal Shear
- Shears
- Unconformity

Mineralisation in breccia zones developed in shear corridors

Cretaceous

-50m
-100m
-150m
-0m
Estimating Velocity

Average 702 m/s
Std.Dev 60 m/s
Testing near operating drill rigs

- Increase amplitude of signals but doesn’t provide any benefit in measurement
Profiles

- 15 Minutes record
- Station spacing:
  - 3 Transects @ 100m
  - 1 Regional transect @ 300 and 600m
Profiles

Passive seismic for drill-hole optimisation
Conclusions

- Passive seismic is successful in mapping overburden
  - Glacial till sediments
  - Cretaceous Sediments

- Assumptions are the geological materials have consistent velocities. Any errors are directly proportional to the estimation of thickness.

- Existing drilling can be used to calculate layer velocities.

- Using active sources did not lead to significant improvement in measurement (may be limited bandwidth).

- Useful for determining appropriate drilling techniques for pre-season planning

- Provides additional constraints for geophysical modelling

- Methodology is cheap to deploy and requires minimal training for field acquisition
Questions

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