Experiences with 2D resistivity measurements (ERT) at the surface

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How to map quick clay?

- Map marine deposits and other sediments (Quaternary Geological maps)
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- Map marine deposits and other sediments (Quaternary Geological maps)
- Use geotechnical investigations
  - Sounding
  - Sampling with laboratory tests
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- Map marine deposits and other sediments (Quaternary Geological maps)
- Use geotechnical investigations
  - Sounding
  - Sampling with laboratory tests
- Use geophysical methods
2D resistivity measurements

- Electrodes are connected to a cable and pushed into the ground.
- A specific electrode configuration (array) is used. Electric current is turned on, the voltage is measured and electric resistance is calculated (Ohms law $R = \frac{U}{I}$).
- The resistivity is the electric resistance multiplied by a geometric factor (ohmm).
Method

2D resistivity measurements

- Main electrode arrays are: Wenner, Schlumberger and Dipole-dipole.
- As the electrode array goes through the cables, the resistivity is mapped laterally.
- When the electrode distance is increased, the current goes deeper, and the resistivity in deeper part is mapped.

Electrode distances: 2 m, 5 m, 10 m

Principle for CVES (Dahlin 1993)
2D resistivity measurements

- Raw data give the apparent resistivity of the subsurface. This represents a weighted mean of all the resistivity values that fall within the influenced volume.

- To get specific resistivity data are inverted. A modelled pseudosection is produced that matches the measured data.

(etter Loke et al. 2003)
Classification of sediments from resistivity values

- Based on previous studies and experience values in Norway, Sweden and Canada
- Comparison of resistivity values and geotechnical data
- Gradual transitions between the classes
- Influence from local variations (pore-water chemistry, saturation, grain sizes and mineral composition)
### First-order classification of sediments in quick-clay areas from resistivity values:

<table>
<thead>
<tr>
<th>Resistivity (Ωm)</th>
<th>Main characterisation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>Unleached marine clay deposits</td>
<td>Saline pore-water, stable clay structure. Good conductivity. Electronic conductive minerals like graphite, sulphides and some oxides, may also give low resistivity values.</td>
</tr>
<tr>
<td>10-100</td>
<td>Leached clay deposits</td>
<td>Low total electrolyte content. Still good conductivity, but poorer than for the unleached marine clay. Silt, fine-grained till, and leached, non-quick clay may fall into the same interval.</td>
</tr>
<tr>
<td>&gt; 100</td>
<td>Dry crust clay deposits, coarse sediments, (bedrock)</td>
<td>Dry clay crust, remoulded, dry clay from quick-clay landslides, and coarser materials (sand, gravel) will have higher resistivity values than marine clay. Most bedrock types will have values of several thousand Ωm.</td>
</tr>
</tbody>
</table>
Examples from projects in quick-clay areas (Mid-Norway)
Melhus

Photos: IL Solberg, Map from NGU
Melhus

• Drilling in 2002

Data from Scandiaconsult report 620298-01

Interpreted quick-clay layer

• Interpretation: one coherent quick-clay layer
Melhus

- 2D resistivity measurements in the same slope, in 2010

- Two layers of leached clay intersected by an unleached clay layer
Melhus

- Compared geotechnical data and resistivity data

Interpreted quick-clay layer from the 2002 drillings
• Additional geotechnical data (SVV/Multiconsult), 2011

• Geotechnical data support the “resistivity-layering”, but if the geotechnical data is used alone, the most likely interpretation is one coherent quick-clay layer in the slope.

Sandven & Solberg 2013
This demonstrates how well geophysical and geotechnical information can be combined to obtain a good understanding of the ground conditions, giving important input for the stability assessments.
Rissa Profil 6

Nord

Kvikk/utvasket leire

Ikke utvasket leire

Utvasket leire

moh.

Sør

Unleached marine clay
Potential sensitive clay
Dry crust clay
Coarse material
Bedrock

Resistivity in Ωm

1.00
2.40
5.77
13.9
33.3
80.0
192
462

Solberg et al. 2010

Gradient elektrodekonfigurasjon
Elektrodeavstand 5 m
Vert./Hor. filter: 0,5
• Intersecting profiles is very useful and give information on 3D geology

• Rissa: 17 profiles compose a network (~ 1 km²) of 2D resistivity data in an area with known stability challenges

Solberg et al. 2012
• When data density is high, maps of depth to bedrock and leached clay thicknesses may be drawn

(Solberg et al. 2013)
• When data density is high, maps of depth to bedrock and leached clay thicknesses may be drawn → compared to an existing hazard zone → the limits could be changed

(Solberg et al. 2013)
Conclusions
Conclusions

2D resistivity measurements are useful for geological and geotechnical purposes:
- Map potential quick clay (extent, position, geometry)
- Give a continuous picture of the ground conditions
- Give information on sediment layering, barriers against landsliding, and drainage pattern
- Important for determining useful drilling locations
- Cost-effective and relatively fast feasible, non-destructive

→ Supplement to geotechnical investigations, not a replacement
NGU projects:
2D resistivity measurements for quick-clay mapping

<table>
<thead>
<tr>
<th>Locality</th>
<th>Year (fieldwork, reporting)</th>
<th>Report no.</th>
<th>Reference</th>
</tr>
</thead>
</table>

- All reports are available from www.ngu.no/no/hm/Publikasjoner/Rapporter/
- A lot of data are also published in papers
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