Identification of quick clay using electrical resistivity methods

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**Based on paper by Long, Pfaffhuber, Bazin, Kåsin, Gylland and Montaflia, QJEGH (2017)*

Multiconsult NGI UCD DUBLIN

Rolf Sandven
1957 - 2016

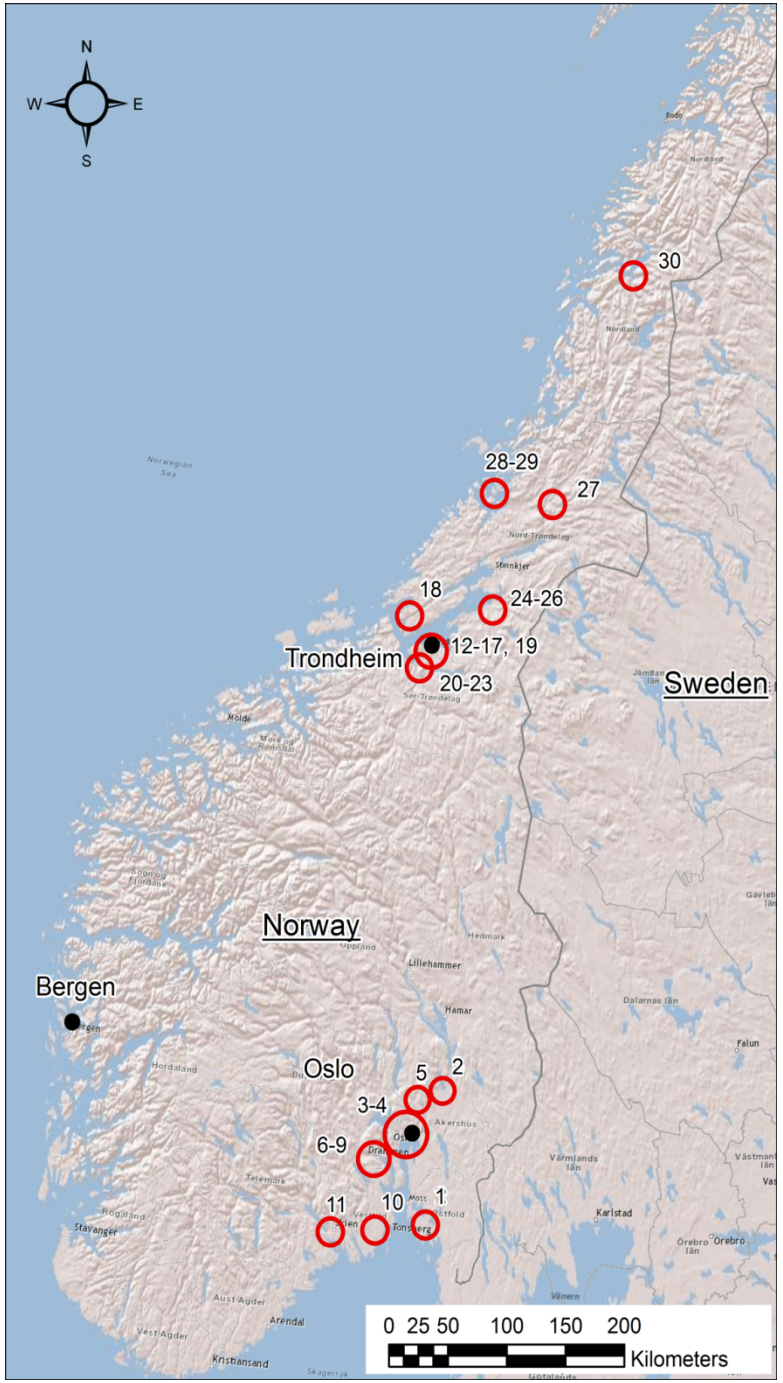


Outline of talk

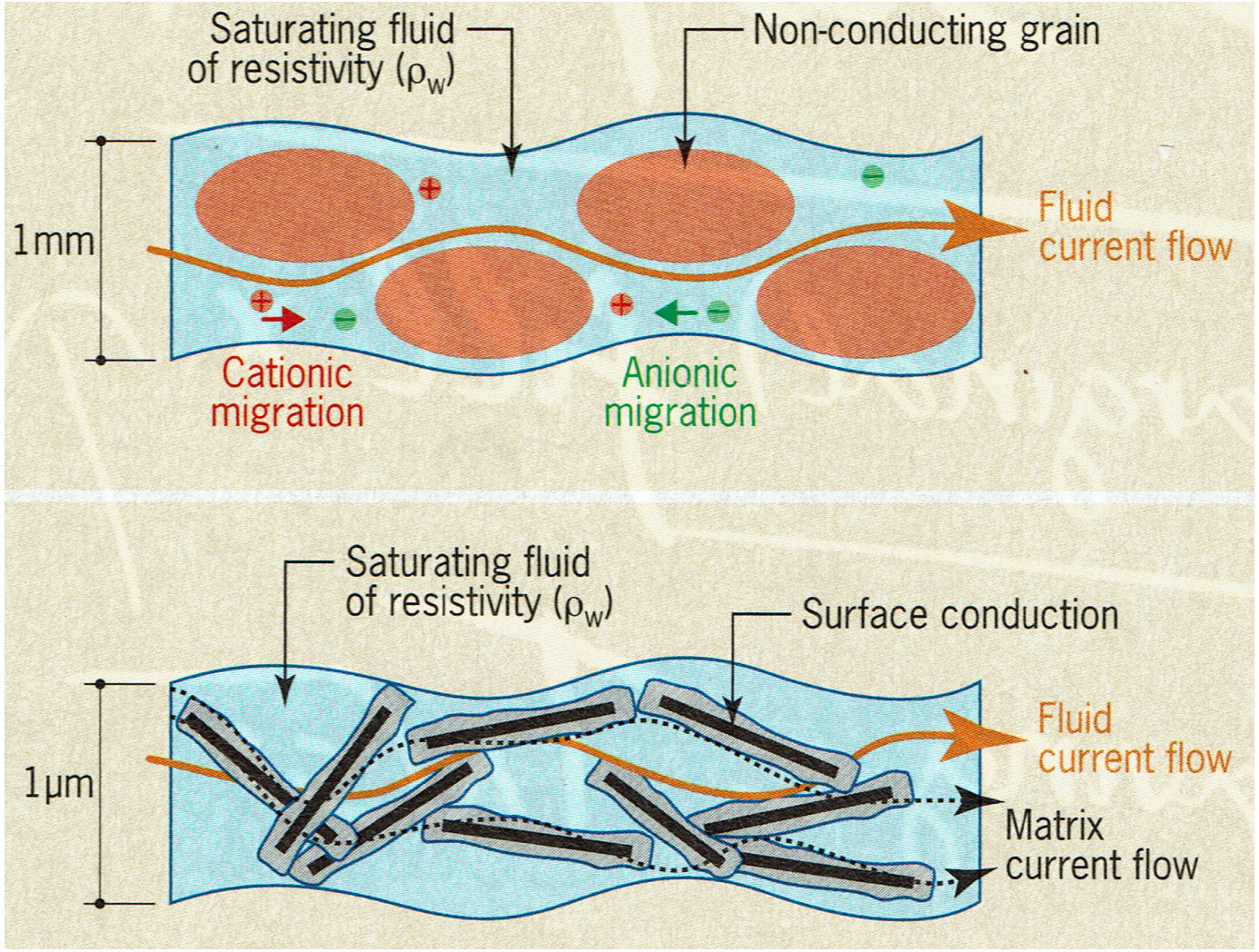
- Study sites
- Measurement methods and controls
- Some examples from Norwegian sites
- Link with geotechnical parameters
- Can resistivity be used to detect quick clay?
- Recent examples
- Conclusions

Study sites

Sites in Norway where there is resistivity measurements and good geotechnical characterisation



Resistivity controls



Ground Engineering, September, 2010

<u>Granular soil / rock</u>

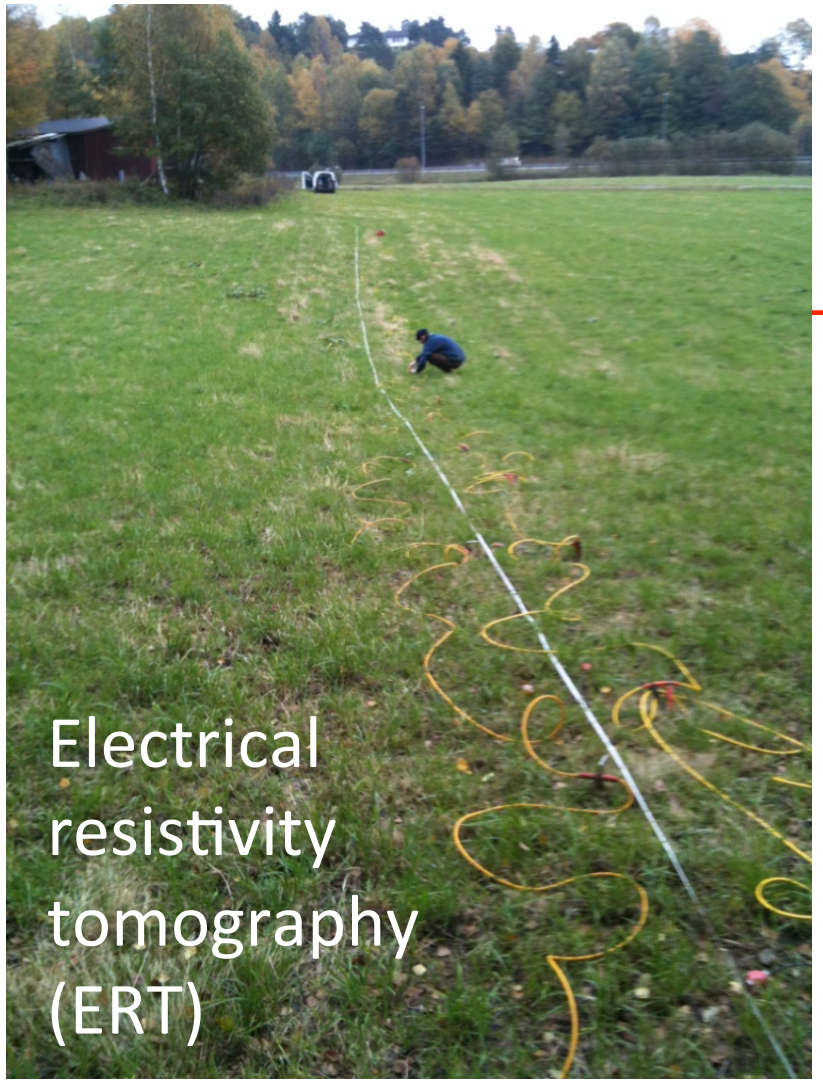
Main controls are porosity (n) and resistivity of the pore fluid (ρ_w) (Archie's Law)

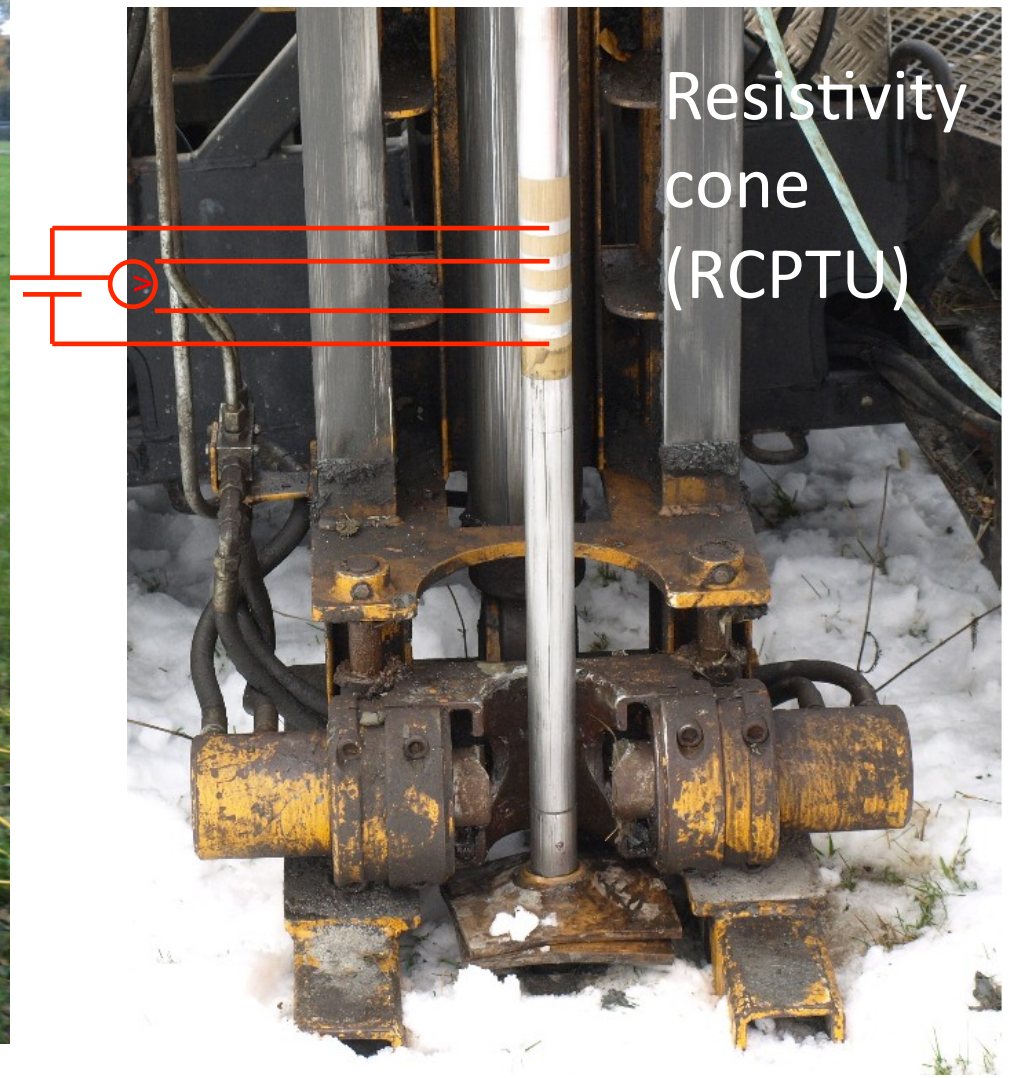
<u>Clay soil</u>

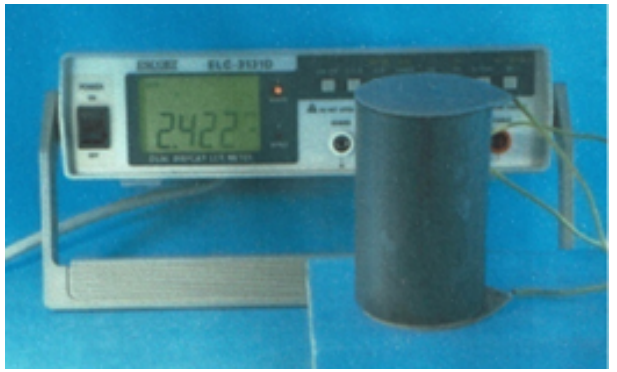
Key properties are n and ρ_w but could clay content play a role?

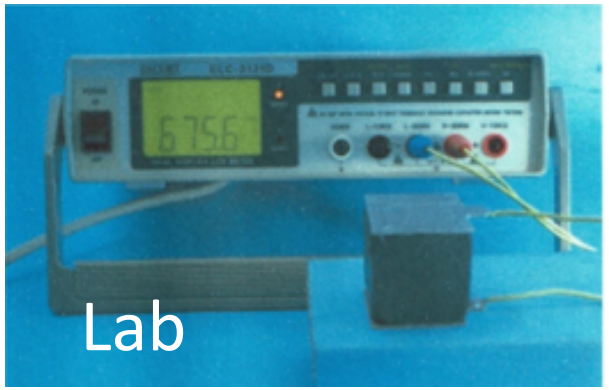
- clay content
- plasticity

Measurement methods





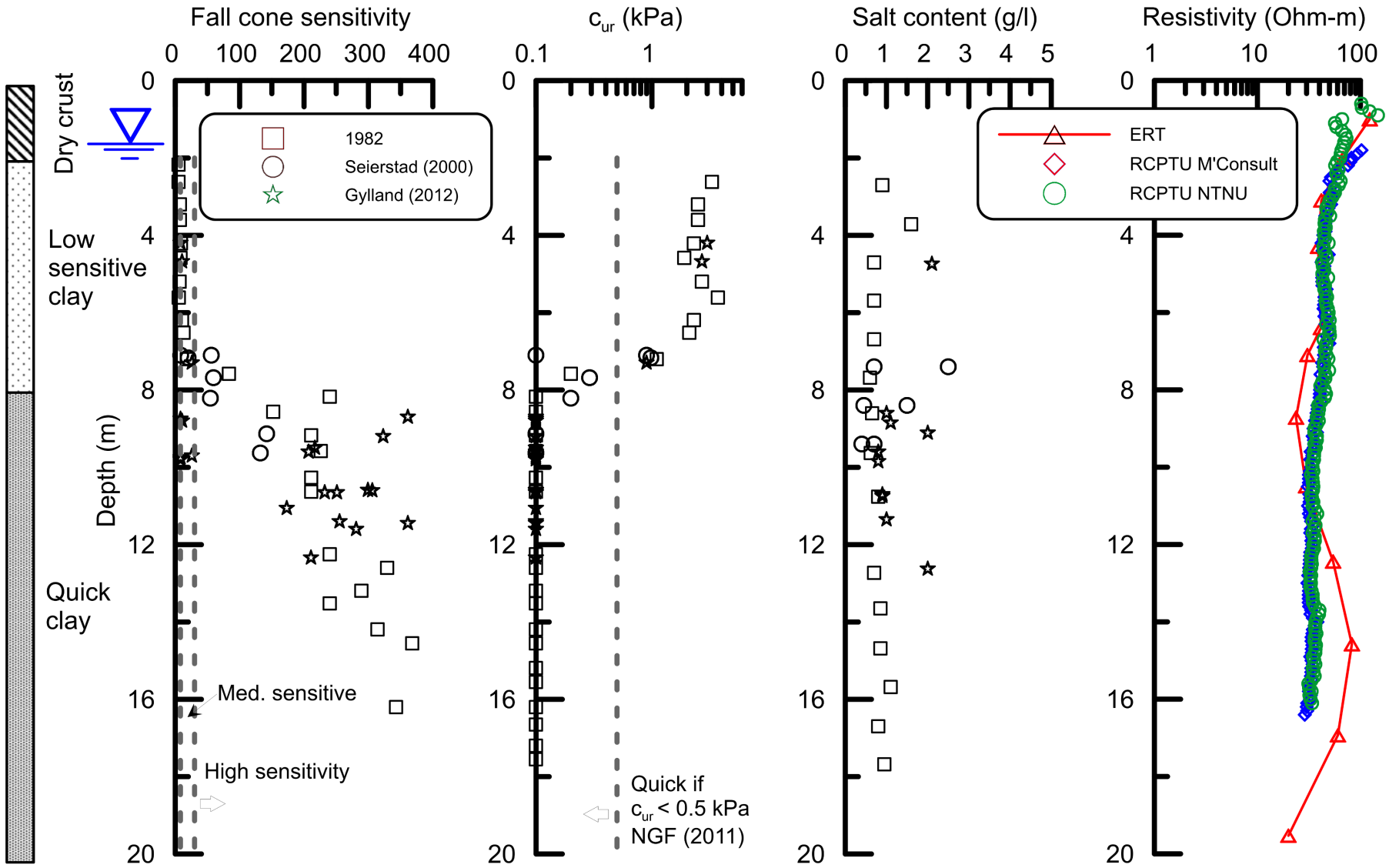




+AEM, Andi Pfaffhuber

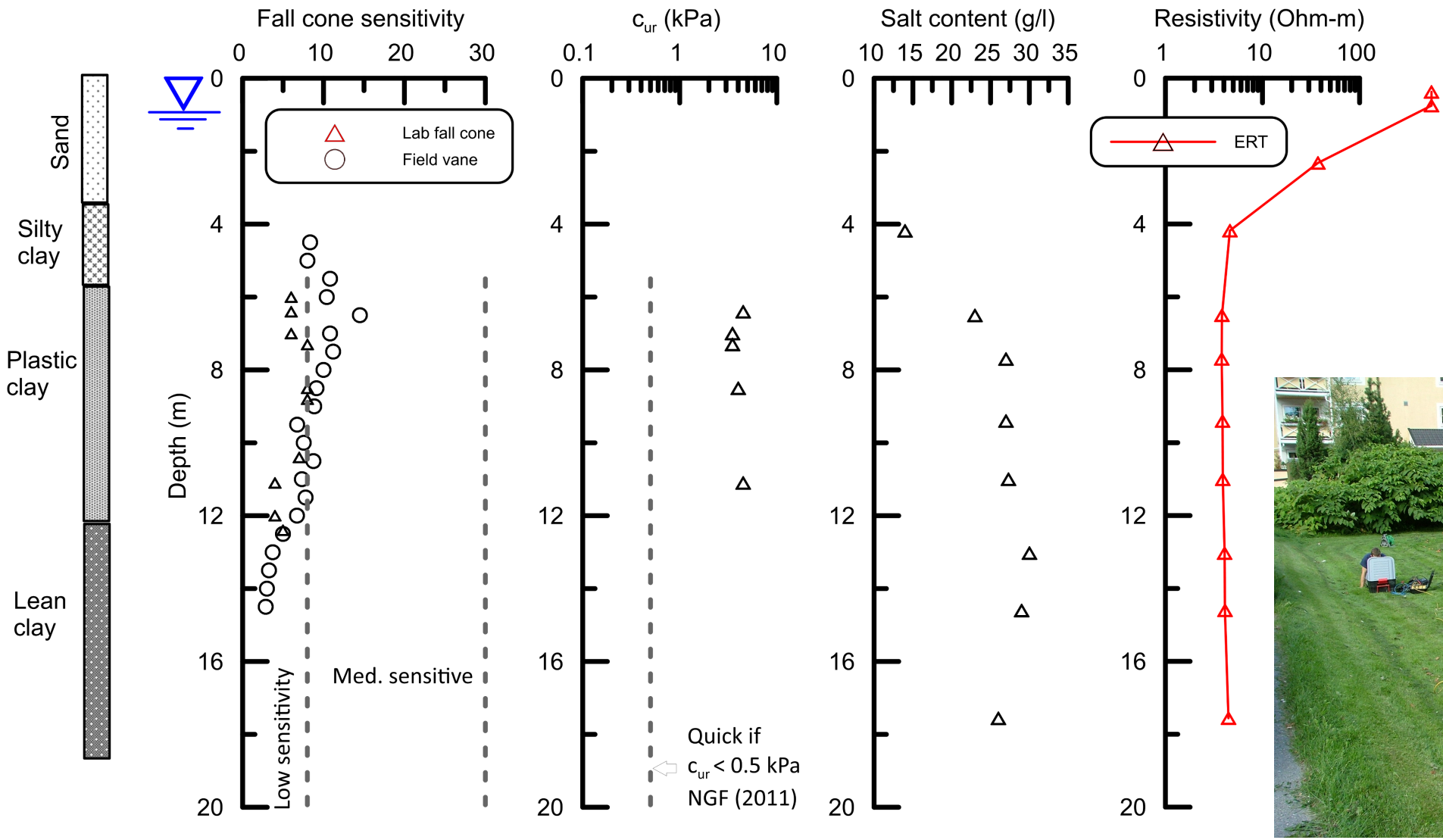
Some examples from Norwegian sites

Tiller - Trondheim



- Low sensitive clay over quick clay
- Whole profile has been leached
- (Salt ≈ 1 g/l)
- Resistivity between 10 Ωm and 100 Ωm
- All methods similar

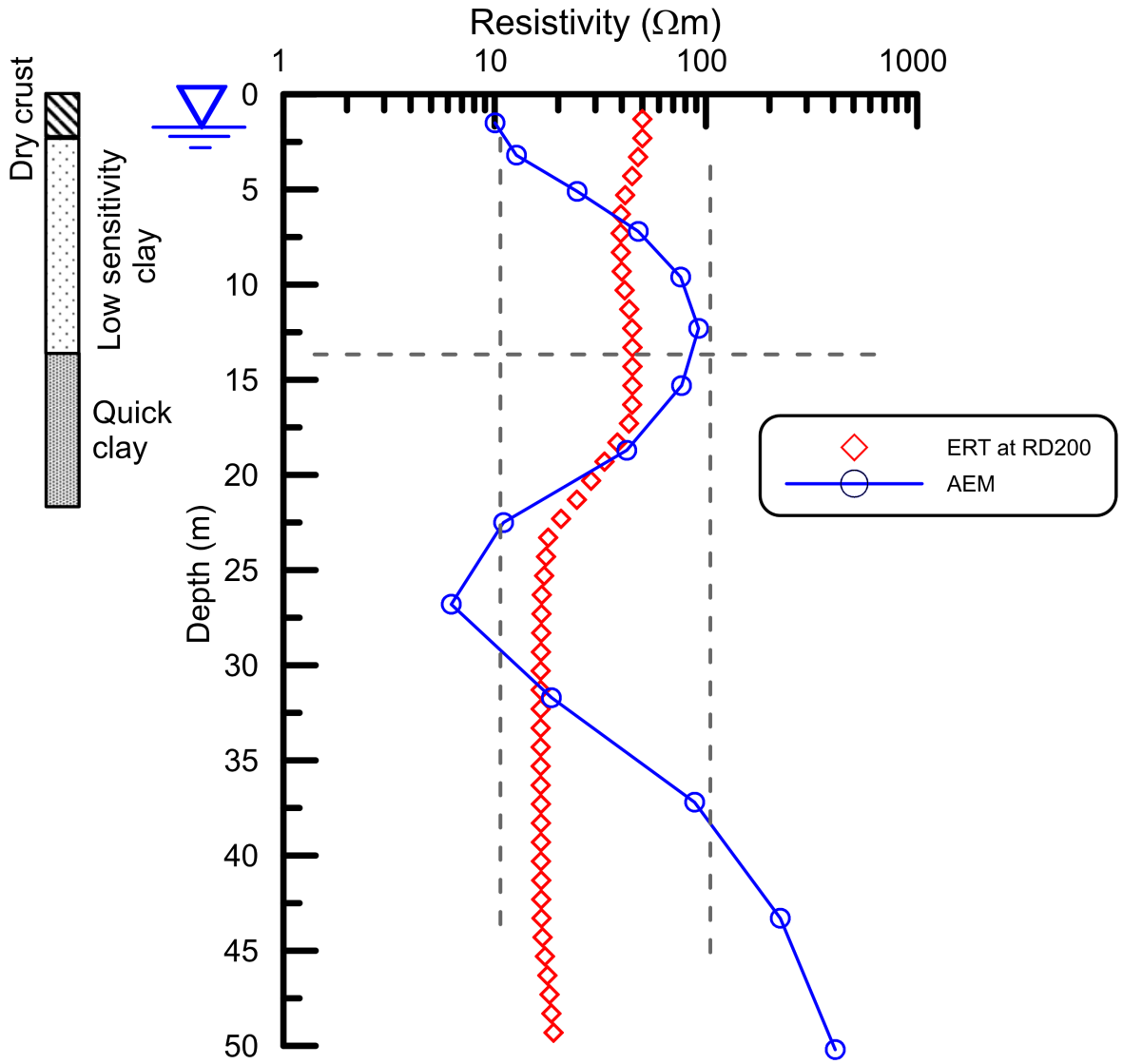
Museumparken - Drammen



- No quick clay
- No leaching
- Salt ≈ 27 g/l
- Resistivity < 10 Ωm



Rv2 – Nybakk to Kløfta

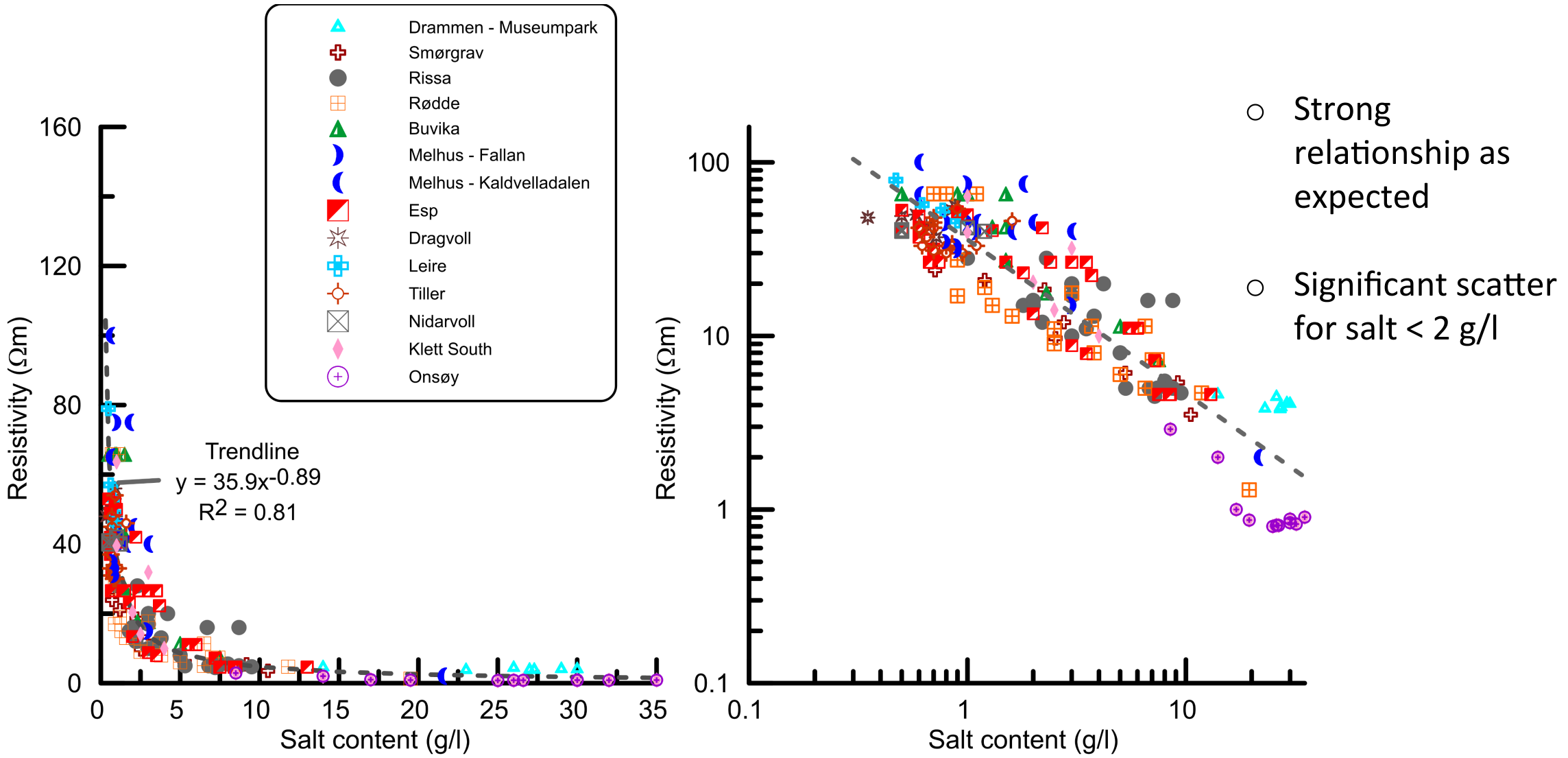


- BH2284
- AEM and ERT similar
- NB: Scale differences between lab (cm), RCPTU (10's cm), ERT (m – 10's m) and AEM (10's m – 100's m)

Link with geotechnical parameters

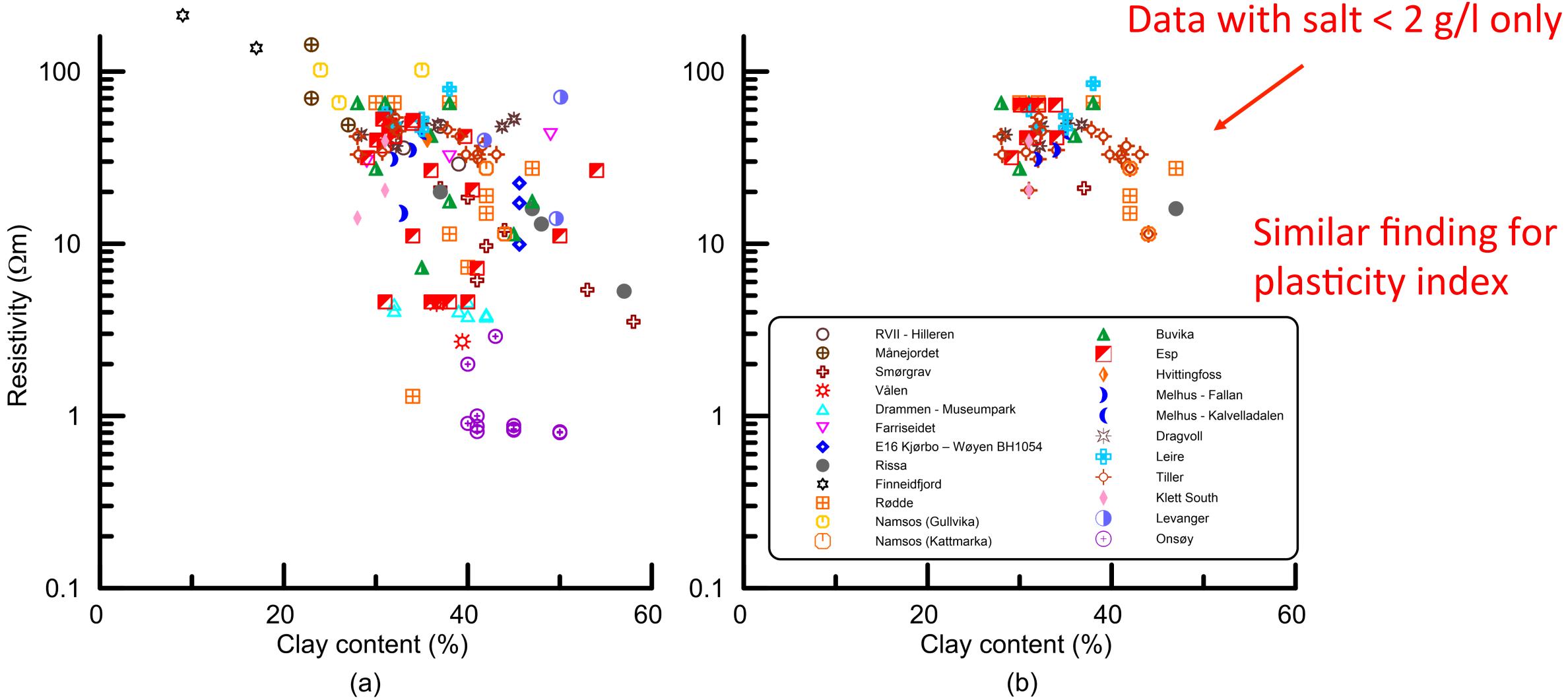
- Salt content of the pore fluid
- Clay content (and plasticity)
- Remoulded shear strength

Resistivity and salt content of pore fluid



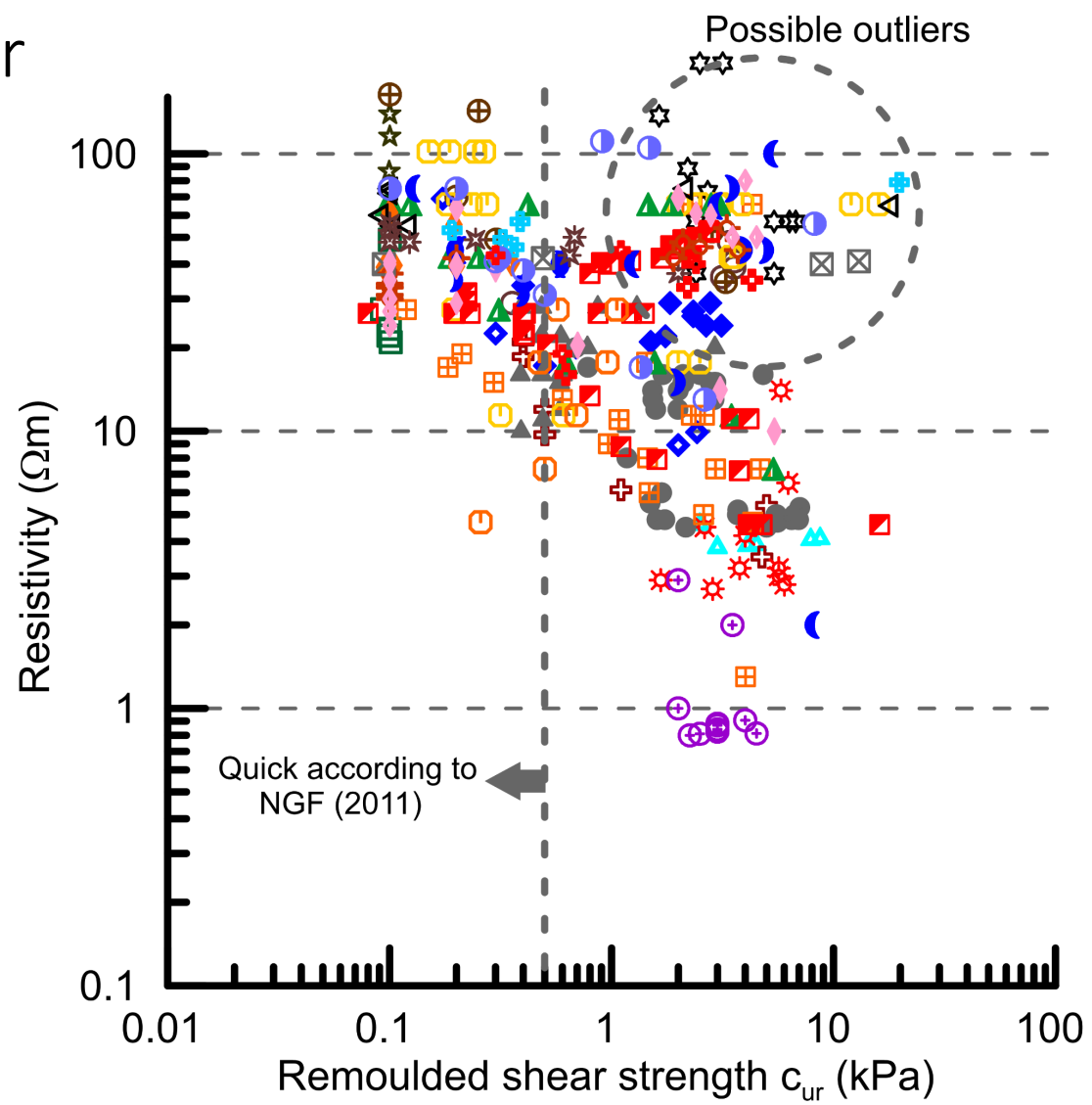
- Strong relationship as expected
- Significant scatter for salt < 2 g/l

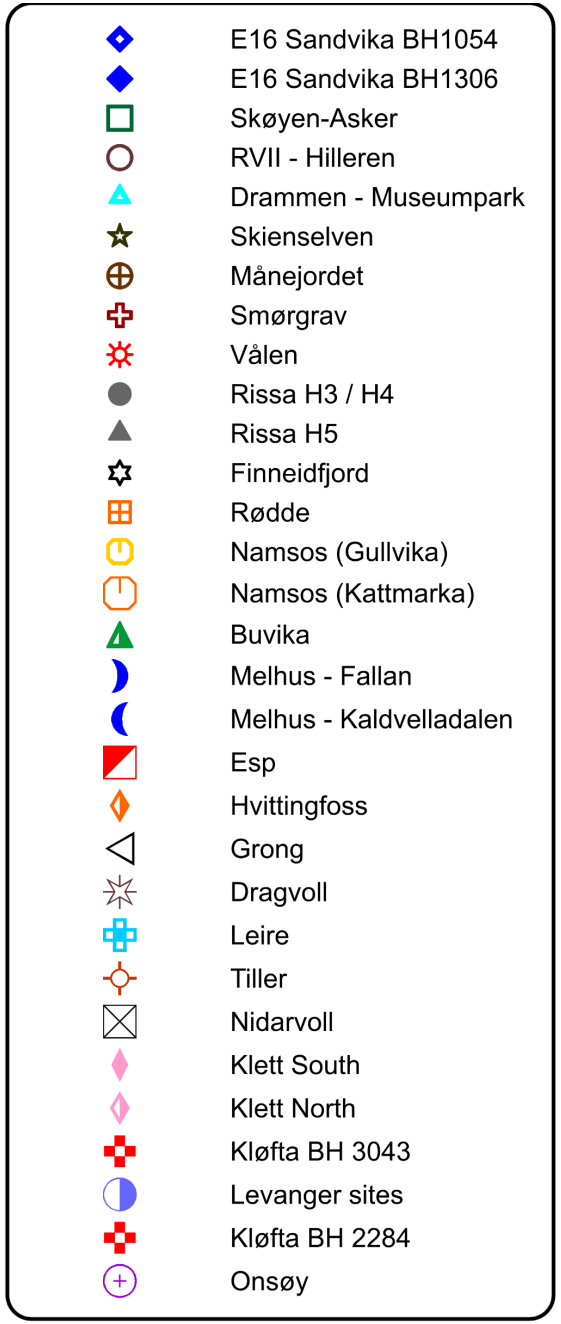
Resistivity and clay content



Resistivity v c_{ur}

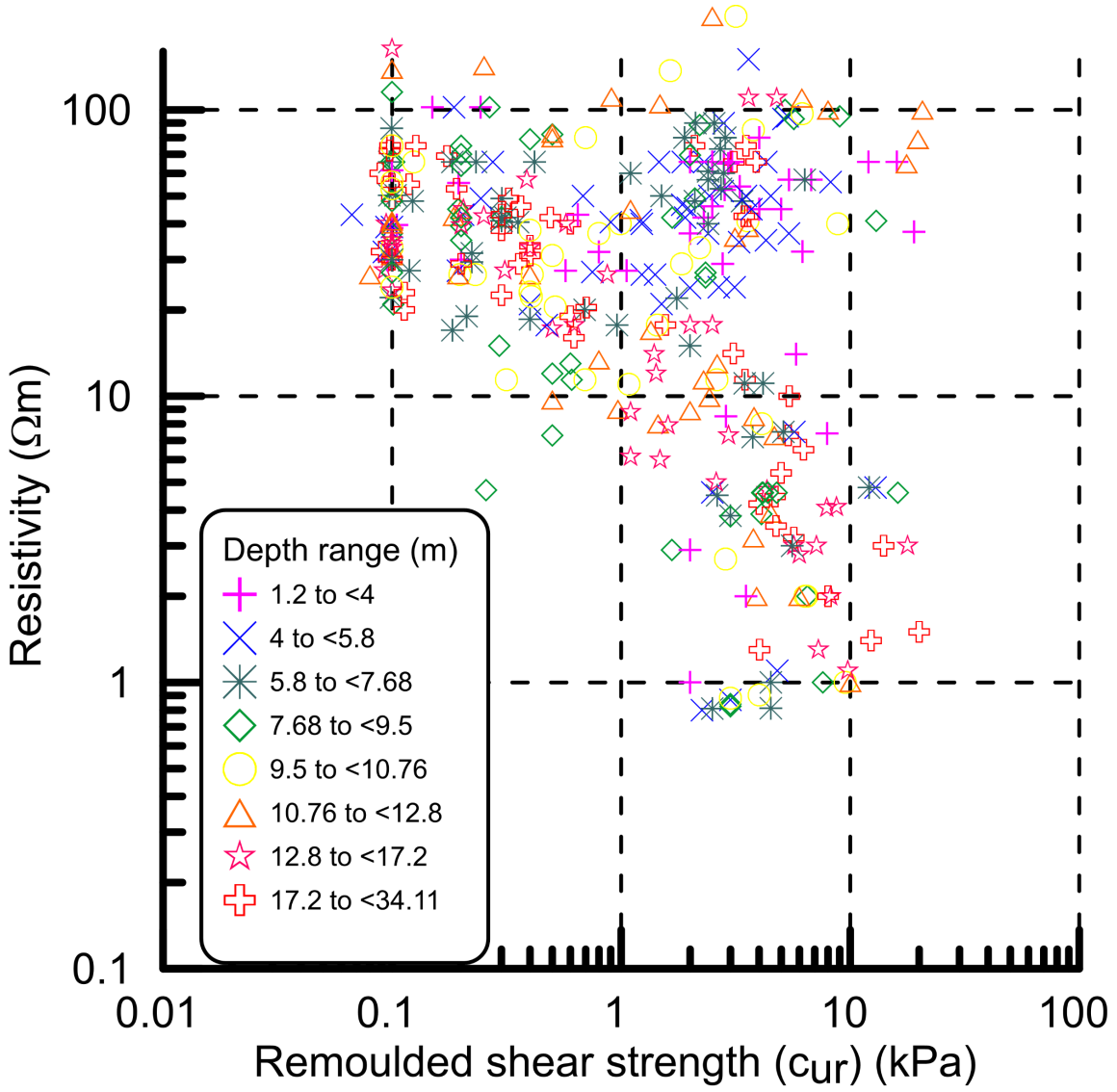
- Potentially very useful
- Quick if c_{ur} < 0.5 kPa
- Trend but significant scatter
- Some high resistivity and high c_{ur}(false positives)
- If resistivity > 10 Ωm soil may be quick (No false negatives)
- i.e. if resistivity < 10 Ωm then soil is conclusively unleached marine clay





Res v c_{ur} – depth zones

- Data in outlier area correspond to depth < 7.68 m (Dry crust or deep weathering)
- Resistivity – c_{ur} correlation limited to data below this zone



Suggested resistivity limits

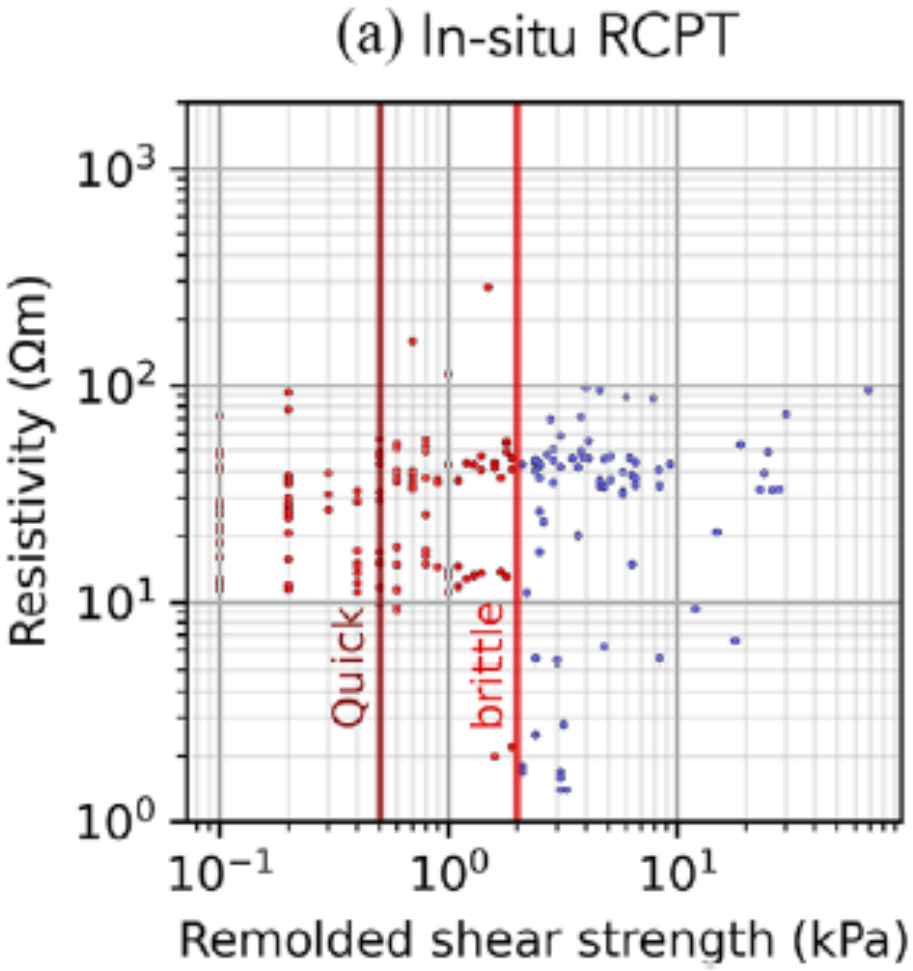
- Solberg et al. 2012

Material	Resisitivty range (Ωm)
Unleached marine clay	1 – 10
Leached possibly quick clay	10 – 80 / 100
Dry crust clay, slide deposits, coarser material	> 100

- With et al. (2022) – quick clay in Sweden
  Quick clay can occur with resistivity as low as 3 Ωm (5 Ωm often used)

- Need to be careful with limits and should not be applied too rigorously

Recent example





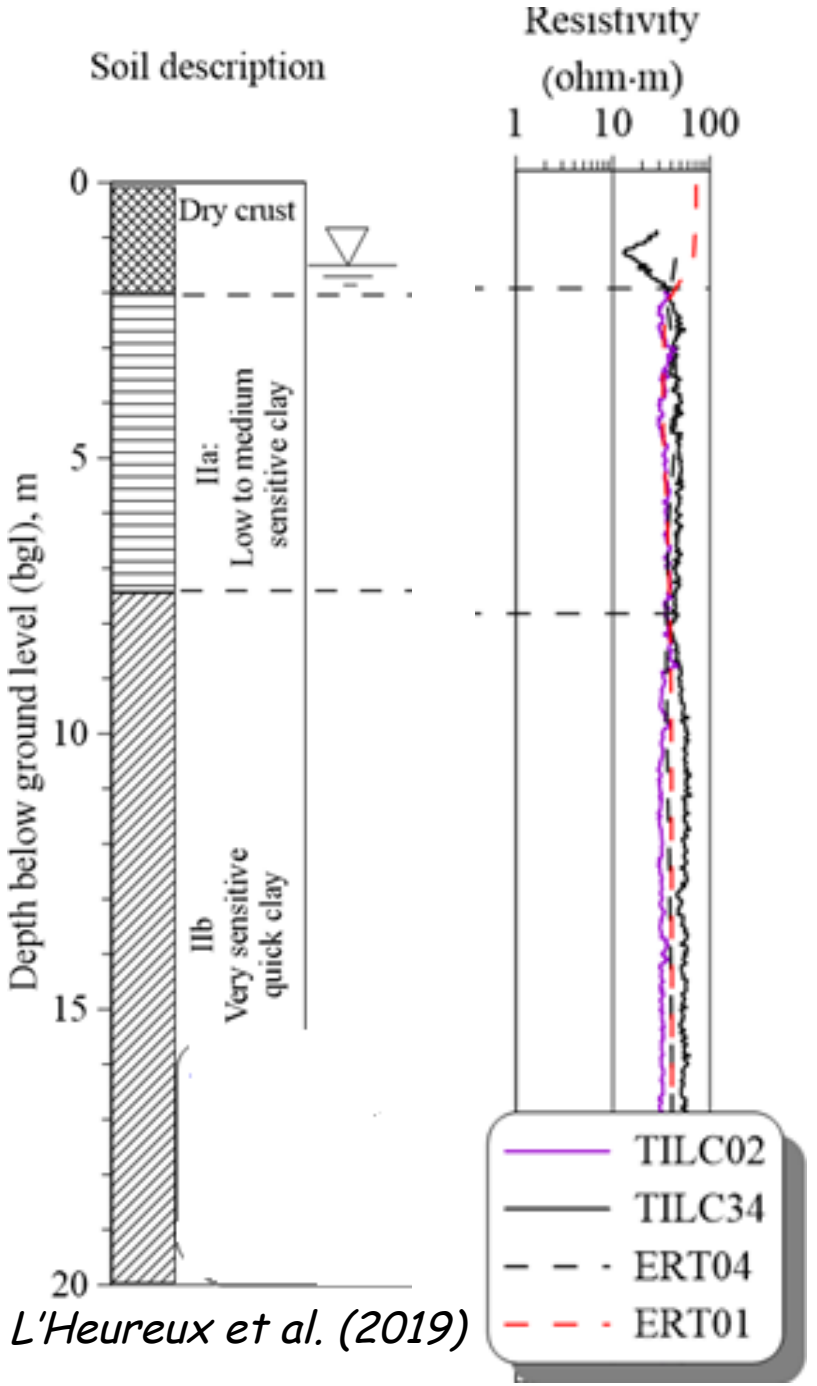
- Christensen et al. (2020 and 2021)
  E6 Stjørdal to Åsen
  Not exclusively marine clays
- Quick clays only occur between resistivity 10 Ωm to 100 Ωm
- Not unique: other sediments have resistivity falling in this range
- Material below 10 Ωm never quick

Tiller-Flotten NGTS site

NTNU
Mini-block
sampling







L'Heureux et al. (2019)

Conclusions

- Resistivity values consistent from boreholes, surface or airborne. NB: Scales.
- Pore water salinity main controlling factor
- Small influence of clay and plasticity – especially when salt < 2 g/l
- Resistivity – c_{ur} correlation applies mostly to depths > 7.5 m
- High resistivity (> 10 Ωm) points to leached possibly quick clay
- Low resistivity (< 10 Ωm) points conclusively to unleached clay
- Early stage potential to make quick clay mapping more efficient

Thanks for listening!

