WP3A: APPLICABILITY OF ERT AND GPR FOR BEDROCK STRUCTURE DELINEATION IN HYDROGEN STORAGE SITE INVESTIGATIONS

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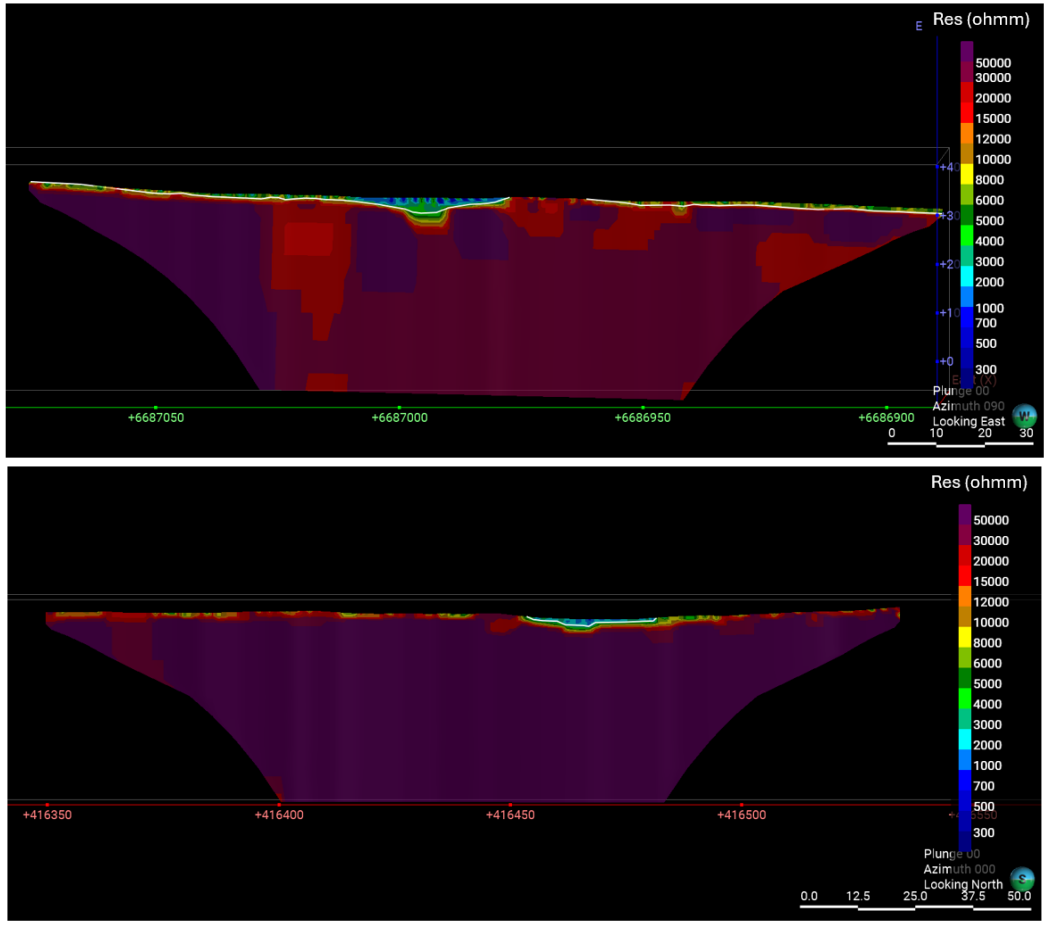
WP3A: Field investigations: geophysical measurement campaign

- Ground based geophysical measurement campaign was conducted in Kilpilahti site during spring and early summer 2025
- The campaign included seismic measurements, electrical resistivity tomography (ERT) and ground penetrating radar (GPR)
- Today, we discuss about applicability of ERT and GPR for hydrogen storage studies and see the results from the Kilpilahti site

Electrical Resistivity Tomography (ERT)

- ERT is a geophysical method used to measure electrical conductivity variations in the ground
- It works by injecting an electrical current into the ground and measures the resulting voltage differences
- Different soil types, rocks, and water content conduct electricity differently, so the measurements help create an image of subsurface structures



ERT measurements in the Kilpilahti site 3.-6.6.2025

Kilpilahti
ERT Survey lines

ERT line

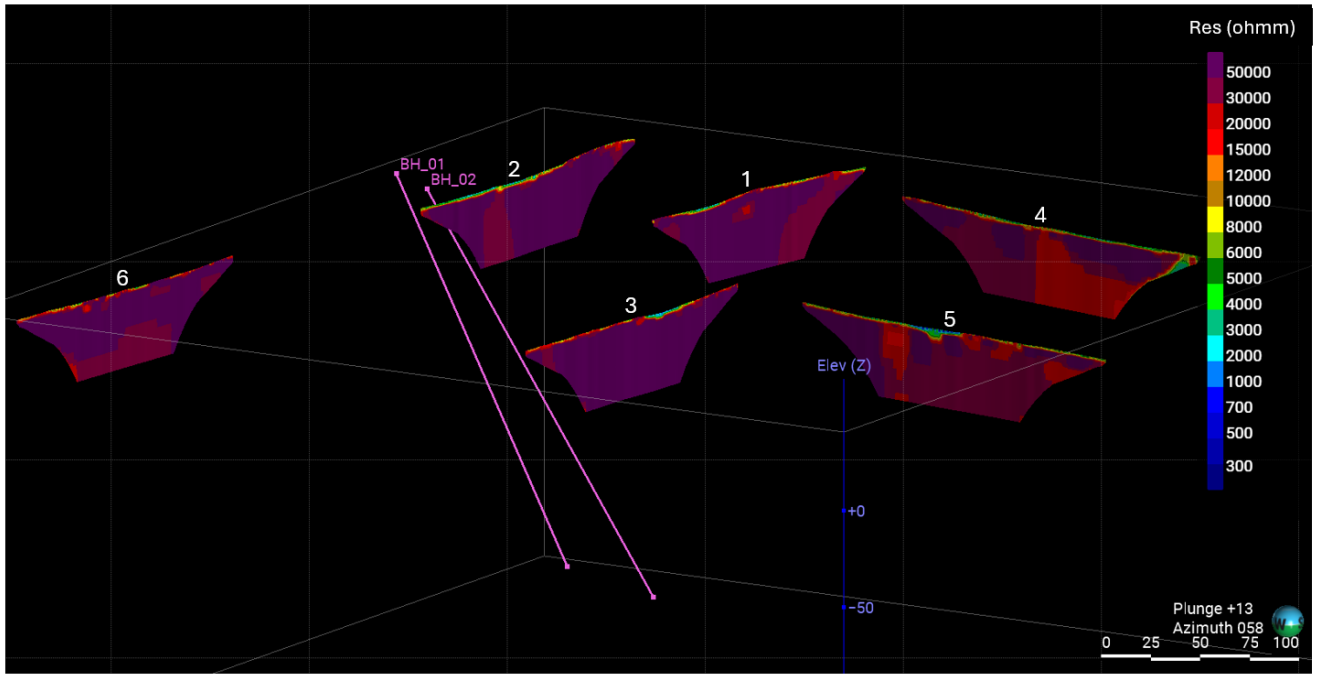
Study site

0 0.07 0.15 0.22 0.3
Kilometers

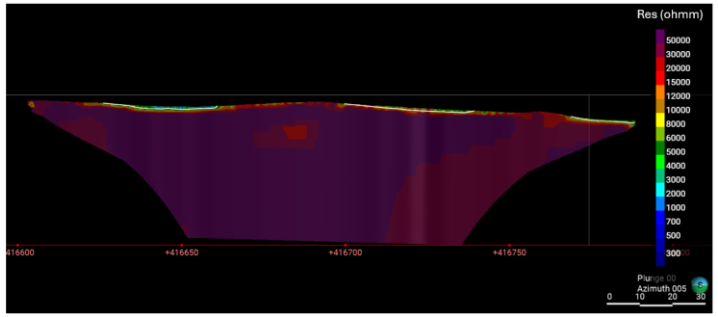
ABEM Terrameter LS2

Results from the Kilpilahti site

- Generally, the resistivity values are high
- Suggests that there are no major electrically conductive structures, such as wide fractures or fault zones
- Bog areas show a bit lower resistivity values due to high water content



Hydrogen UnderGround



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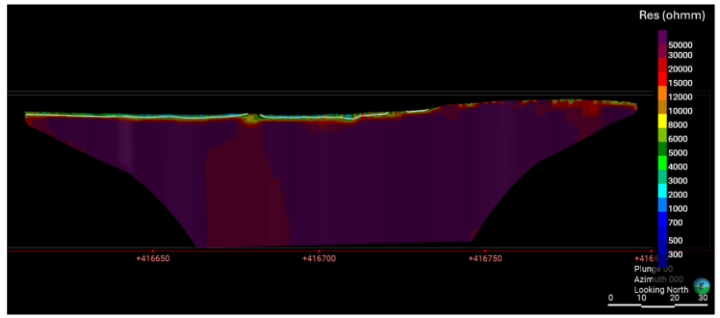

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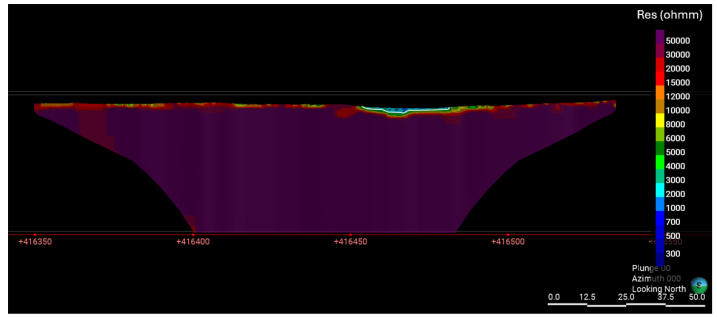

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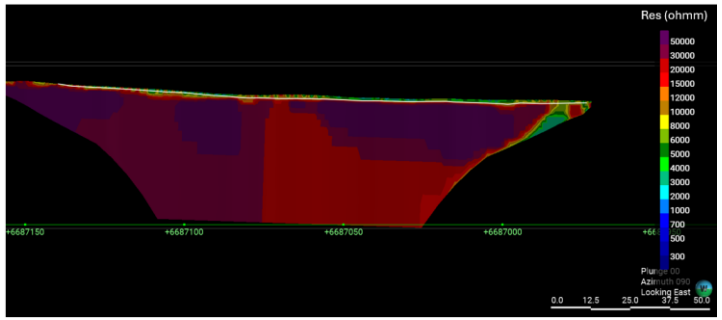

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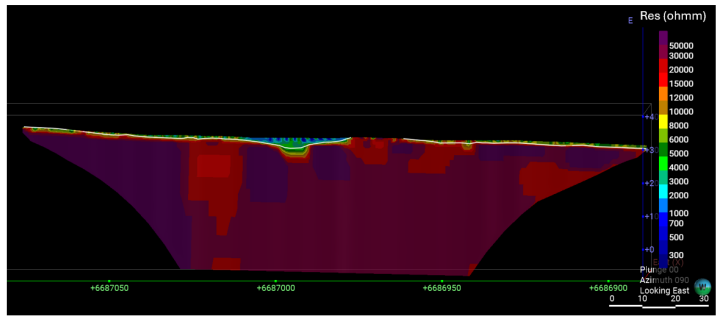

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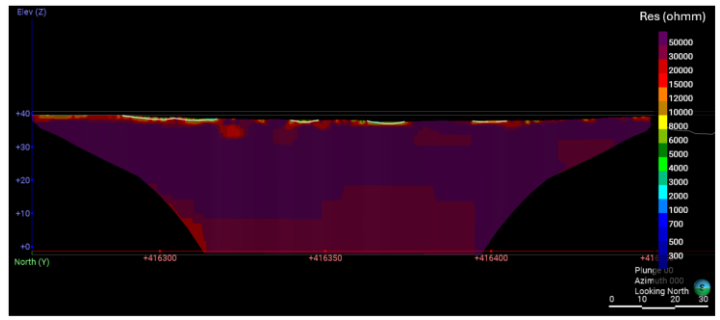

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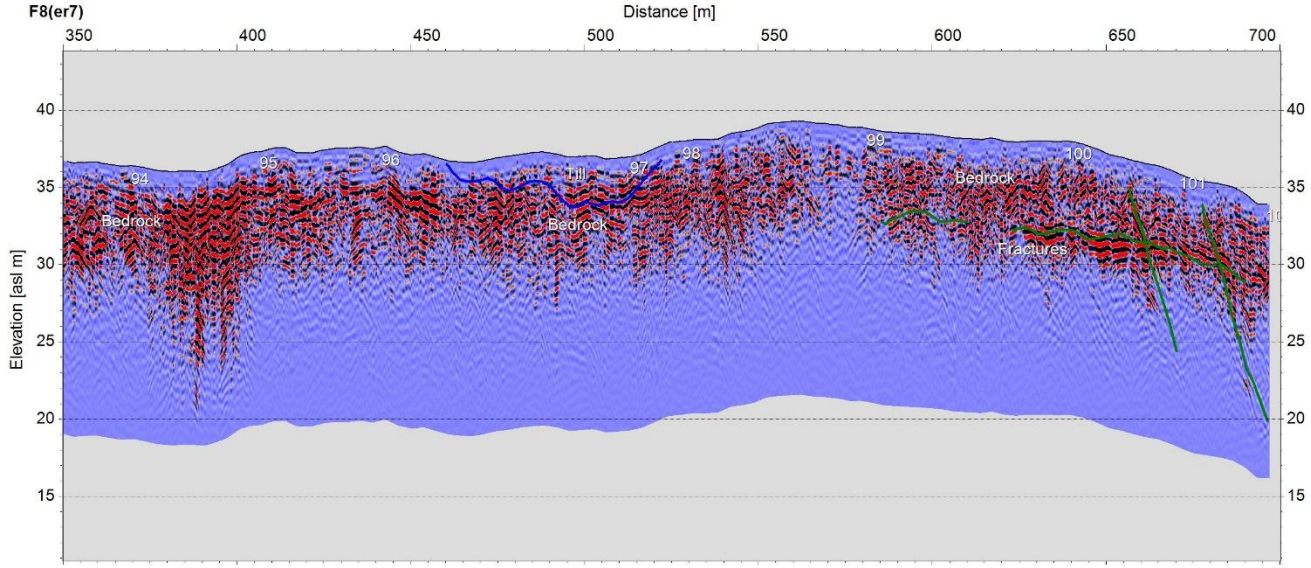
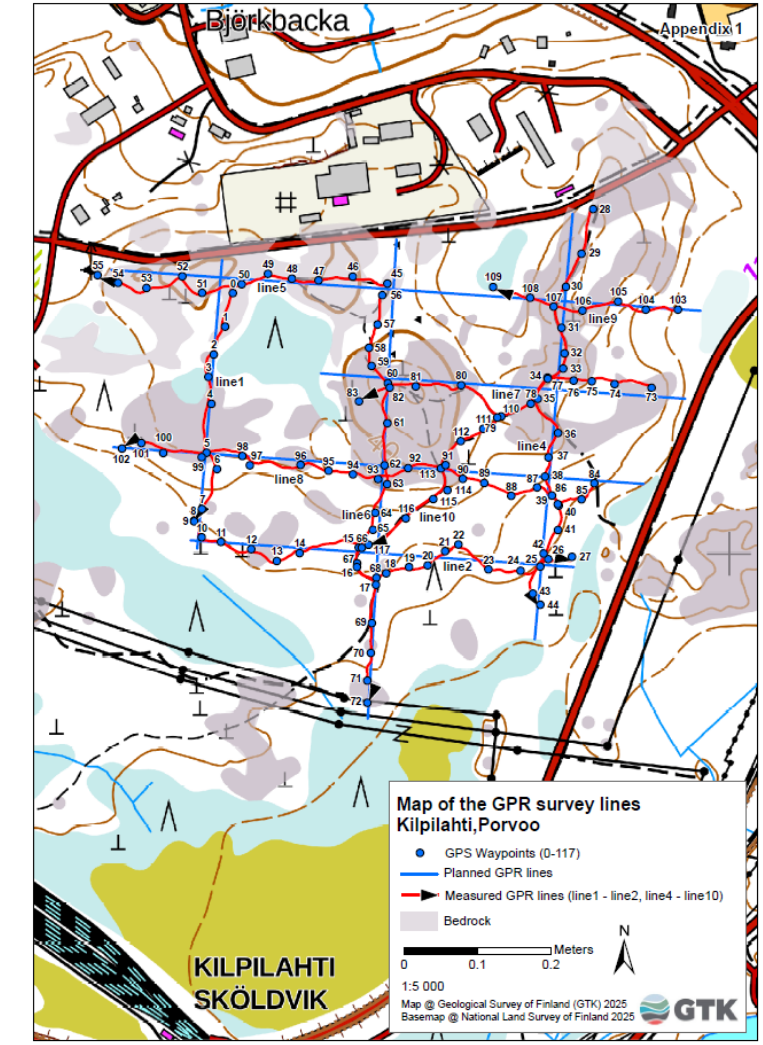
Ground penetrating radar (GPR)

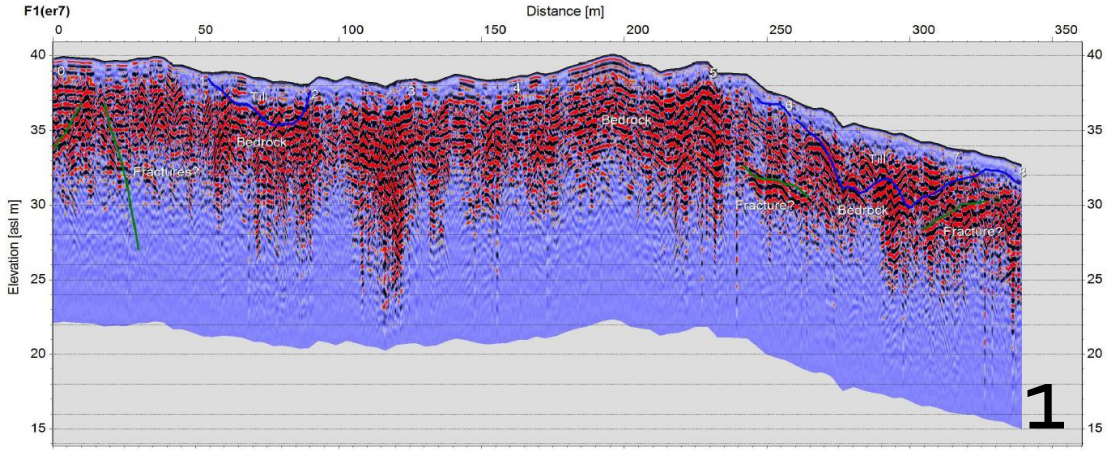
- GPR is a geophysical method that uses radar pulses to image the subsurface
- It works by sending high-frequency electromagnetic waves into the ground and recording the reflections from different layers and objects.
- The strength and timing of these reflections reveal variations in material properties, such as soil, rock, water, or buried objects.

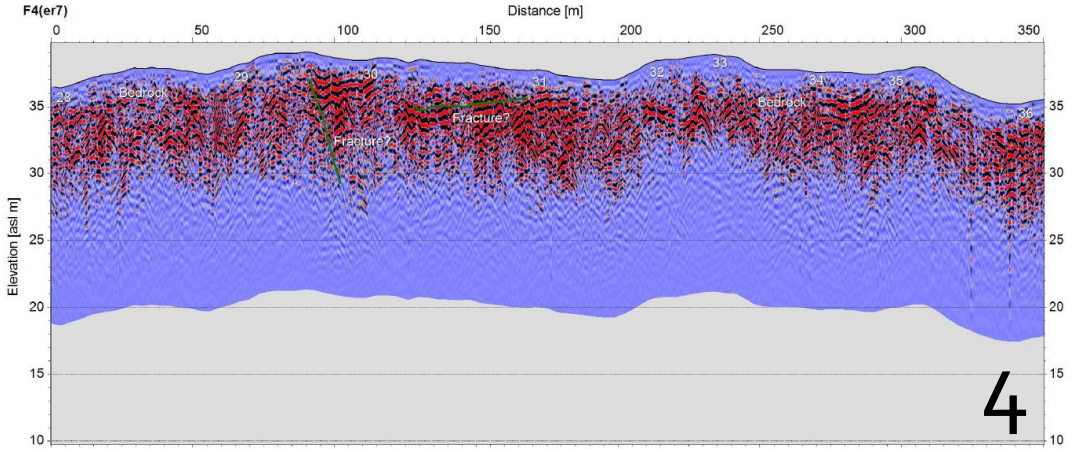


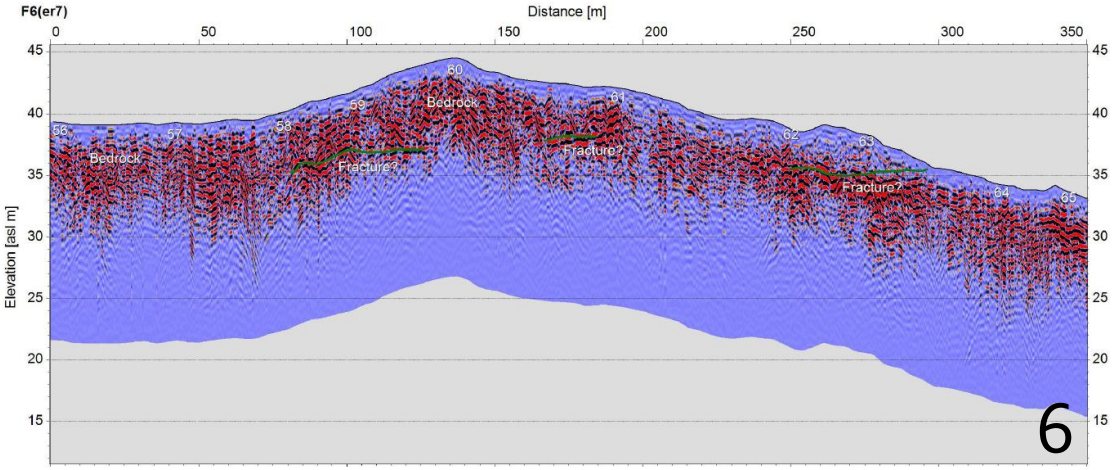
GPR measurements in the Kilpilahti site 3.-4.6.2025

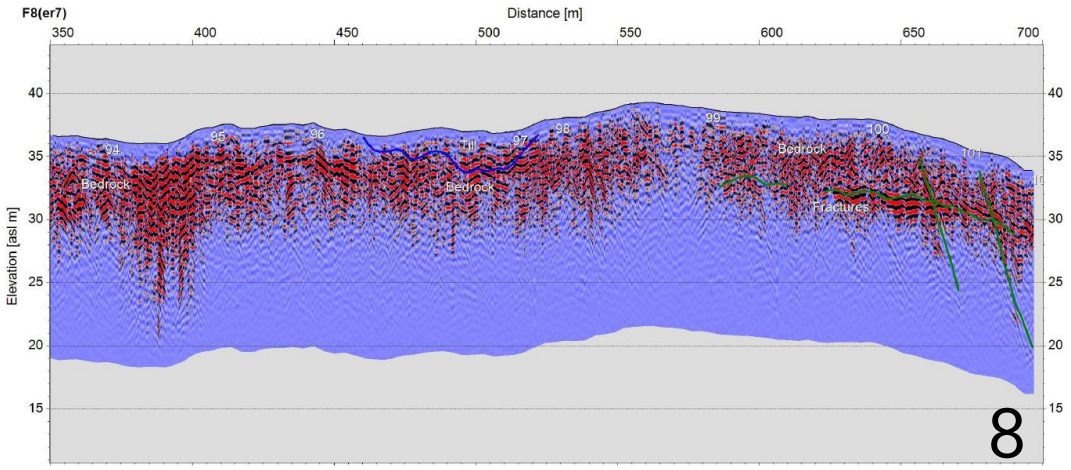
SIR-4000 with 100 MHz antenna




F1(er7)
Distance [m]
Elevation [asl m]
Bedrock
Fracture?
1

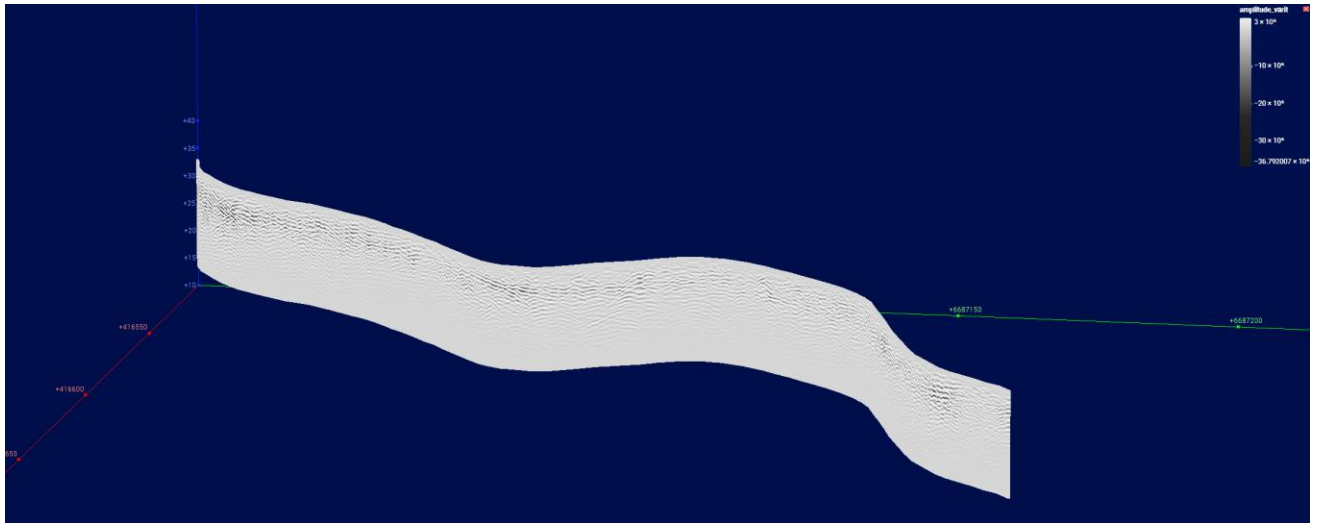

F4(er7)
Distance [m]
Elevation [asl m]
Bedrock
Fracture?
4

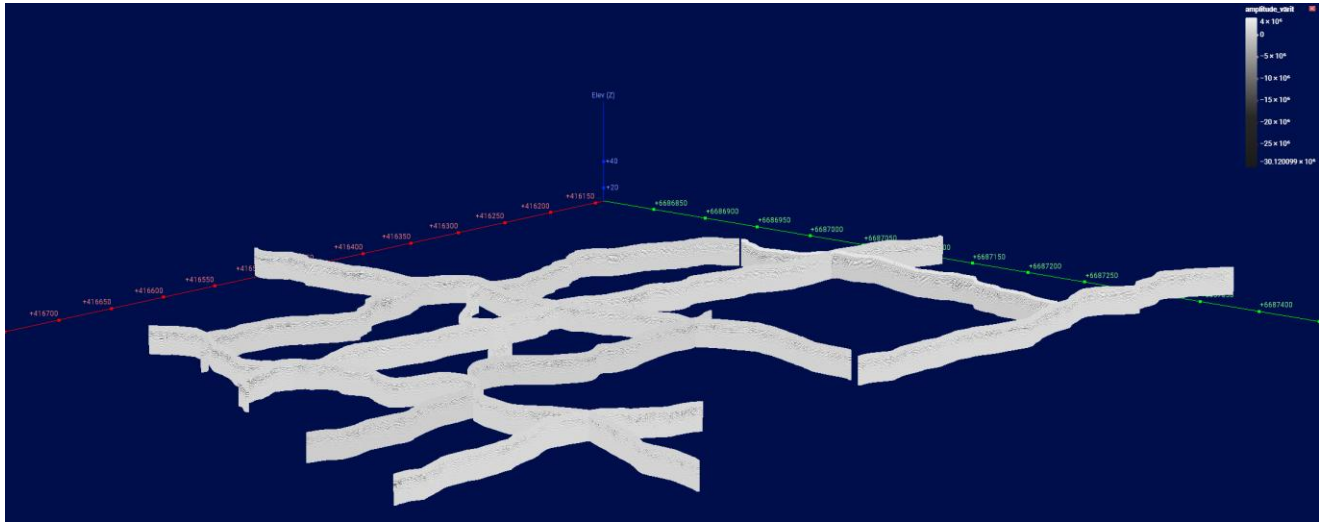

F6(er7)
Distance [m]
Elevation [asl m]
Bedrock
Fracture?
6


F8(er7)
Distance [m]
Elevation [asl m]
Bedrock
Fracture?
8

Results from the Kilpilahti site

- Only few reflections indicating fractures or fault zones in the bedrock – however, the vertical features are challenging to detect
- The most significant possible fault or fracture zones over lines 6 and 8, in the center and western part of the study area
- Overburden depth was determined: often very thin (bedrock exposed) and maximum depth 3 m





Discussion of the results

- Fault/fracture zone recognition:
  - ERT didn't show any major fault/fracture zones → good result for the Kilpilahti site, but note that the resolution is limited
  - GPR shows some fault/fracture zones, but due to lack of other data, the interpretation is unsure and the directions can not be determined
  - In general, ERT is more efficient showing large fault/fracture zones and GPR smaller near surface fault/fracture zones
  - Both methods recognize well horizontal structures, but GPR has a limited resolution with vertical structures

Feature	GPR	ERT
Fracture/fault zone recognition	★★	★★
Determination of overburden thickness	★★	★★
Determination of rock types	★	★
Depth penetration	★	★★
Resolution	★★★	★★
HSE	★★	★★
Cost-efficiency and measurement speed	★★★	★★
Data processing	★★★	★★
Data interpretation	★	★★★

Discussion of the results

- Determination of overburden thickness:
  - Challenging to interpret the overburden and bedrock boundary from the GPR data due to lack of other data and soil type
  - Can be determined from the ERT data, but GPR has better resolution for shallow levels
- Determination of rock type
  - Neither of the methods is suitabe for determing rock types
  - However, boundaries of different rock types may be recognized with further analysis and comparison to different methods

Feature	GPR	ERT
Fracture/fault zone recognition	★★	★★
Determination of overburden thickness	★★	★★
Determination of rock types	★	★
Depth penetration	★	★★
Resolution	★★★	★★
HSE	★★	★★
Cost-efficiency and measurement speed	★★★	★★
Data processing	★★★	★★
Data interpretation	★	★★★

Discussion of the results

- Depth penetration
  - Depends on the measurement configuration
  - In general, ERT has a better depth penetration. In this survey, ERT penetrates up to 40 m, whereas GPR up to 15 m
- Resolution
  - Depends on the measurement configuration
  - GPR has a better resolution (around 30 cm in this measurement), especially at shallow depths
  - ERT has a lower resolution (a couple of meters at topmost layers, tens of meters at deeper levels)
- Data processing and interpretation
  - Processing can be done within a couple of working days for both methods
  - ERT easier to interpret, GPR often needs correlation to other methods

Feature	GPR	ERT
Fracture/fault zone recognition	★★	★★
Determination of overburden thickness	★★	★★
Determination of rock types	★	★
Depth penetration	★	★★
Resolution	★★★	★★
HSE	★★	★★
Cost-efficiency and measurement speed	★★★	★★
Data processing	★★★	★★
Data interpretation	★	★★★

Discussion of the results

- Heatlh, safety and environment
  - Both methods have minor effects on the environment
  - ERT uses electric current which may cause a minor electric shock if touched during measurement
- Cost-efficiency and measurement speed
  - Both methods reasonably fast and cost-efficient, especially compared to drilling
  - GPR is very adjustable and can be conducted by one or two persons, ERT requires usually a team of three persons

Conclusions

- ERT and GPR are suitable and recommended methods for characterizing bedrock for H_2 storage site studies
- They are able to detect major bedrock structures and determine the overburden thickness with reasonable accuracy
- Neither of the methods is not recommended to be used alone, can lead to misinterpretations
- Robust and cost-efficient methods for near surface characterization

THANK YOU!