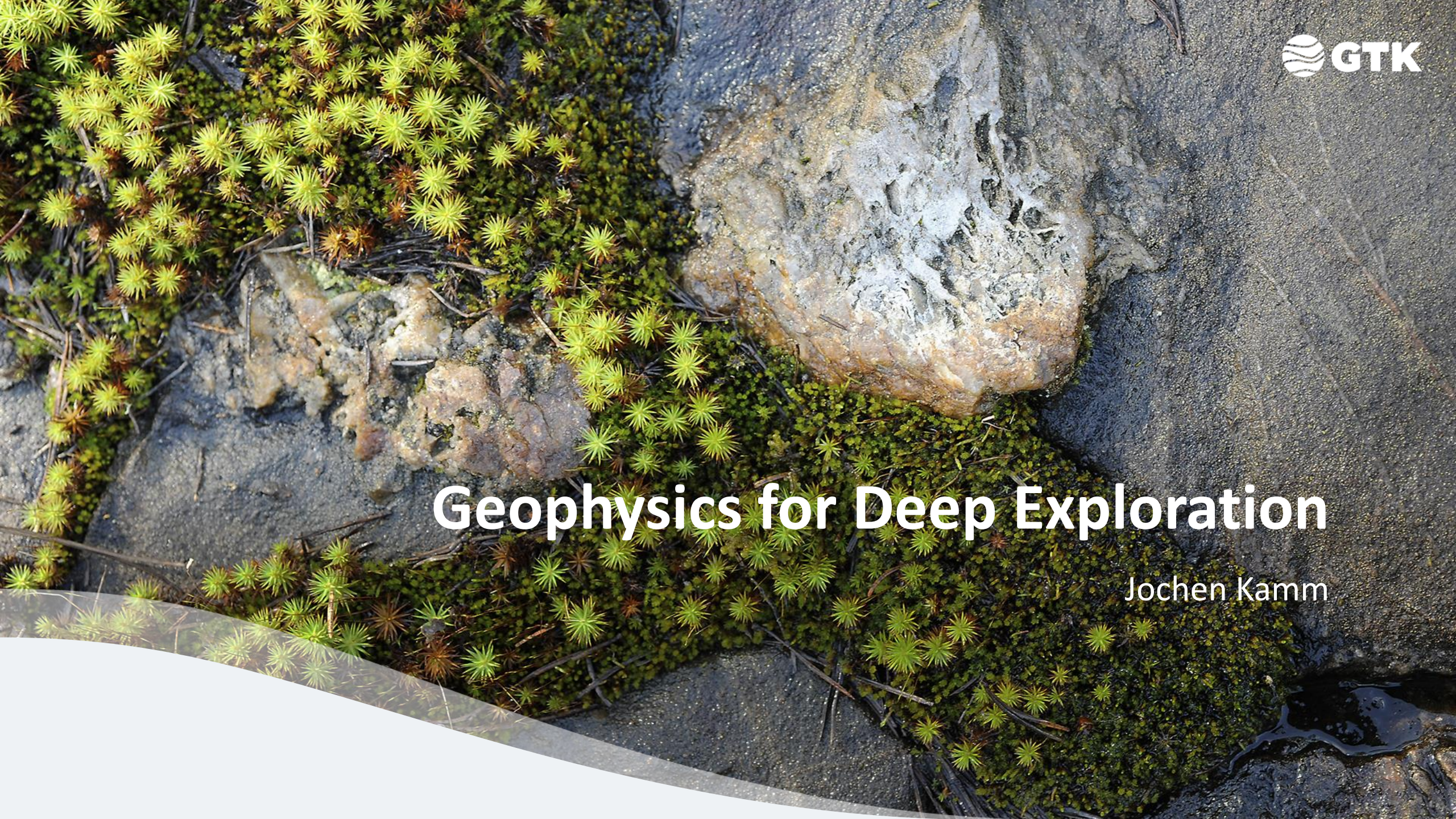
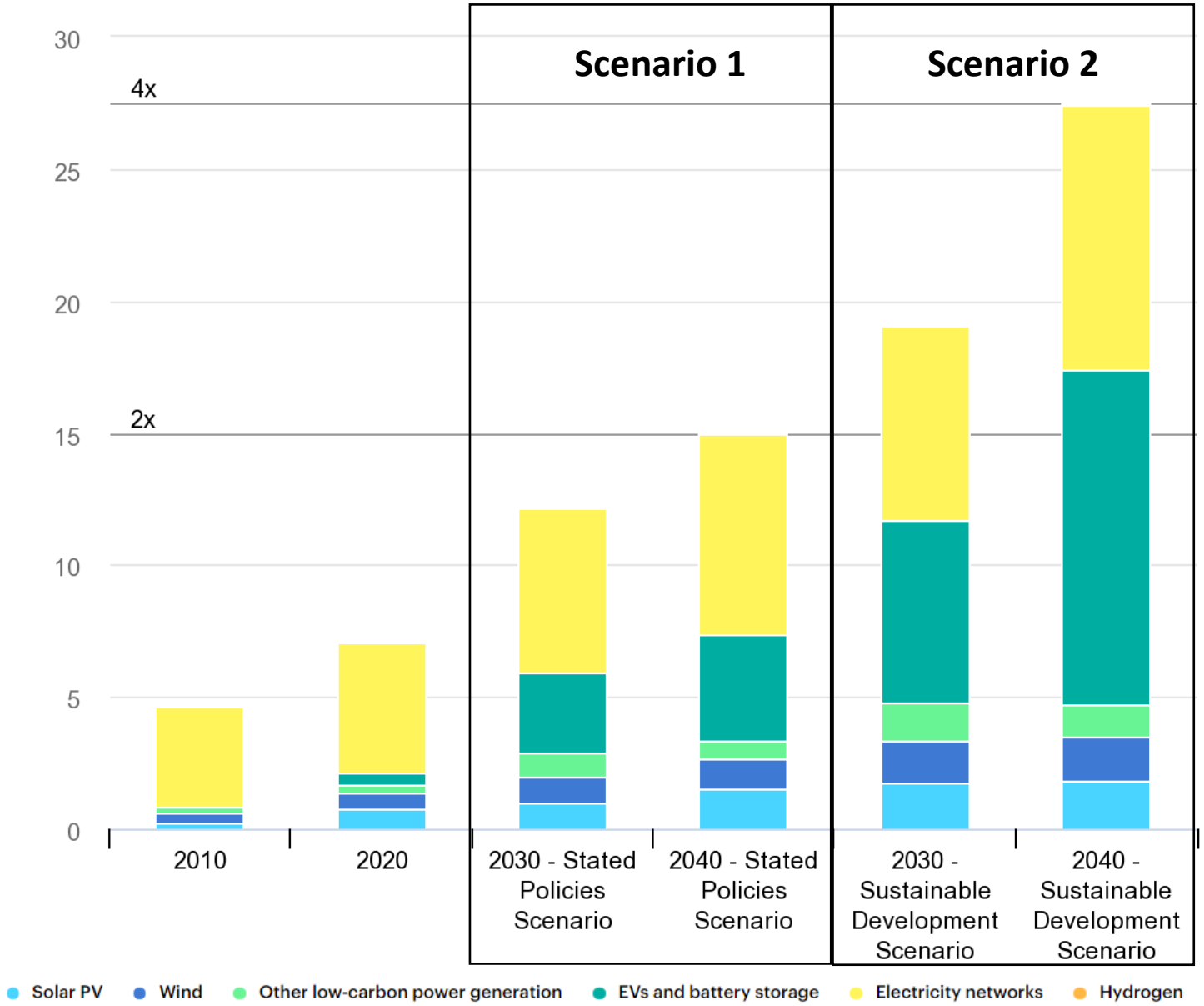


Geophysics for Deep Exploration

Jochen Kamm

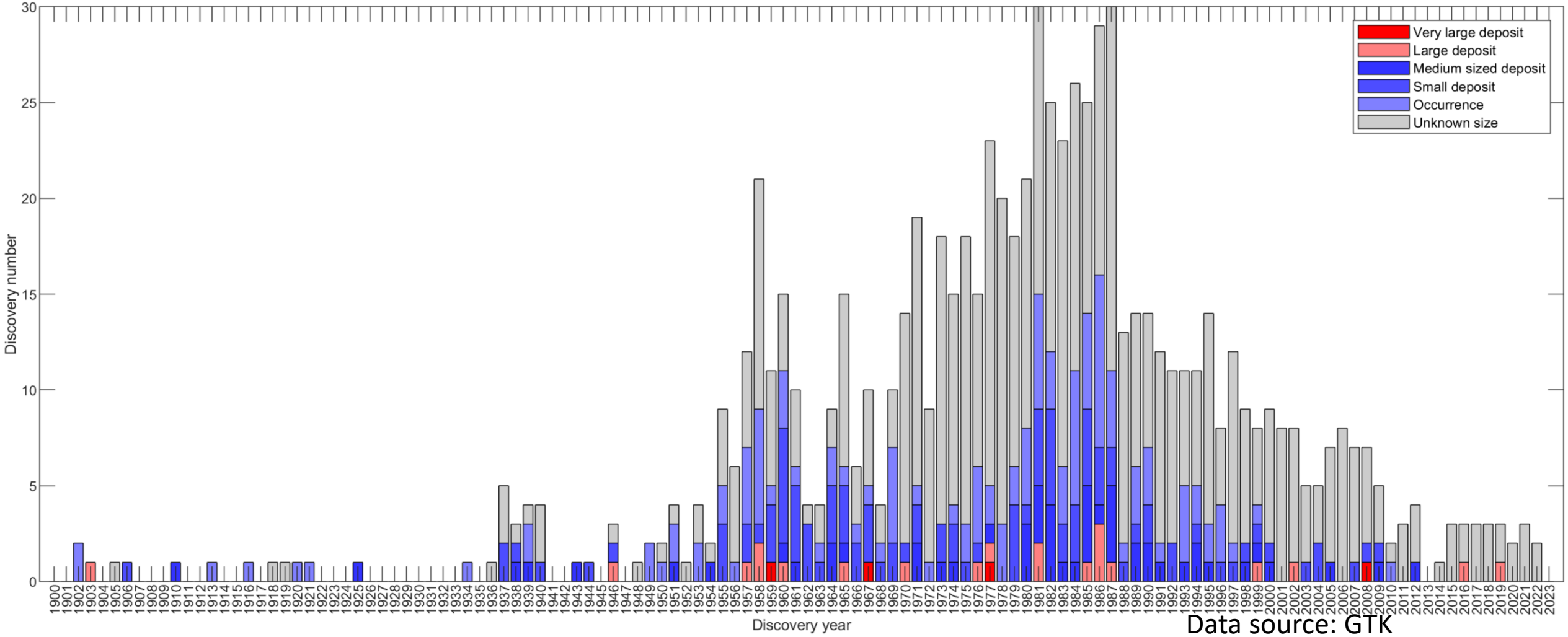
Introduction

Projected global mineral demand



IEA, Total mineral demand for clean energy technologies by scenario, 2010-2040, IEA, Paris https://www.iea.org/data-and-statistics/charts/total-mineral-demand-for-clean-energy-technologies-by-scenario-2010-2040-2, IEA. Licence: CC BY 4.0

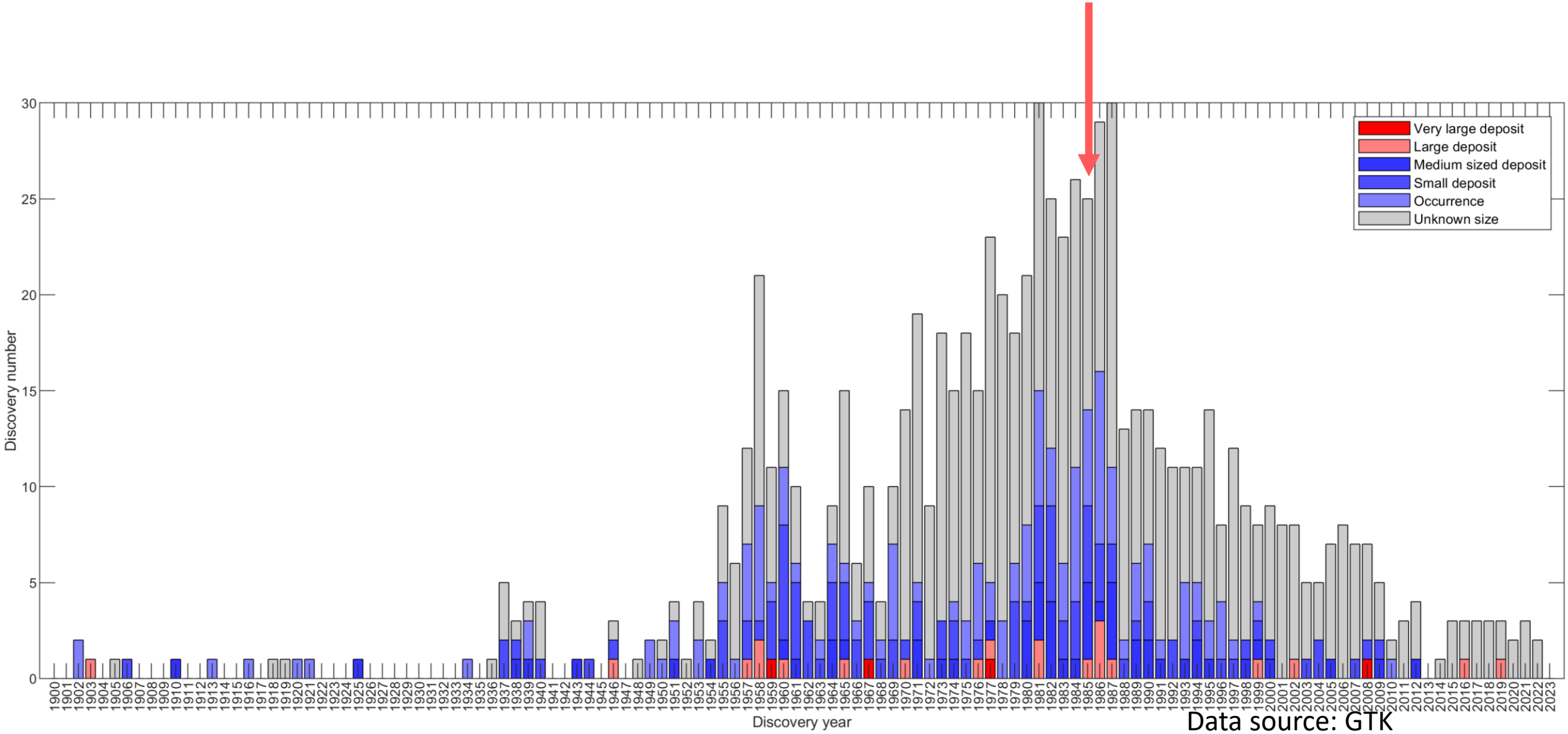
Discoveries in Finland



Data source: GTK

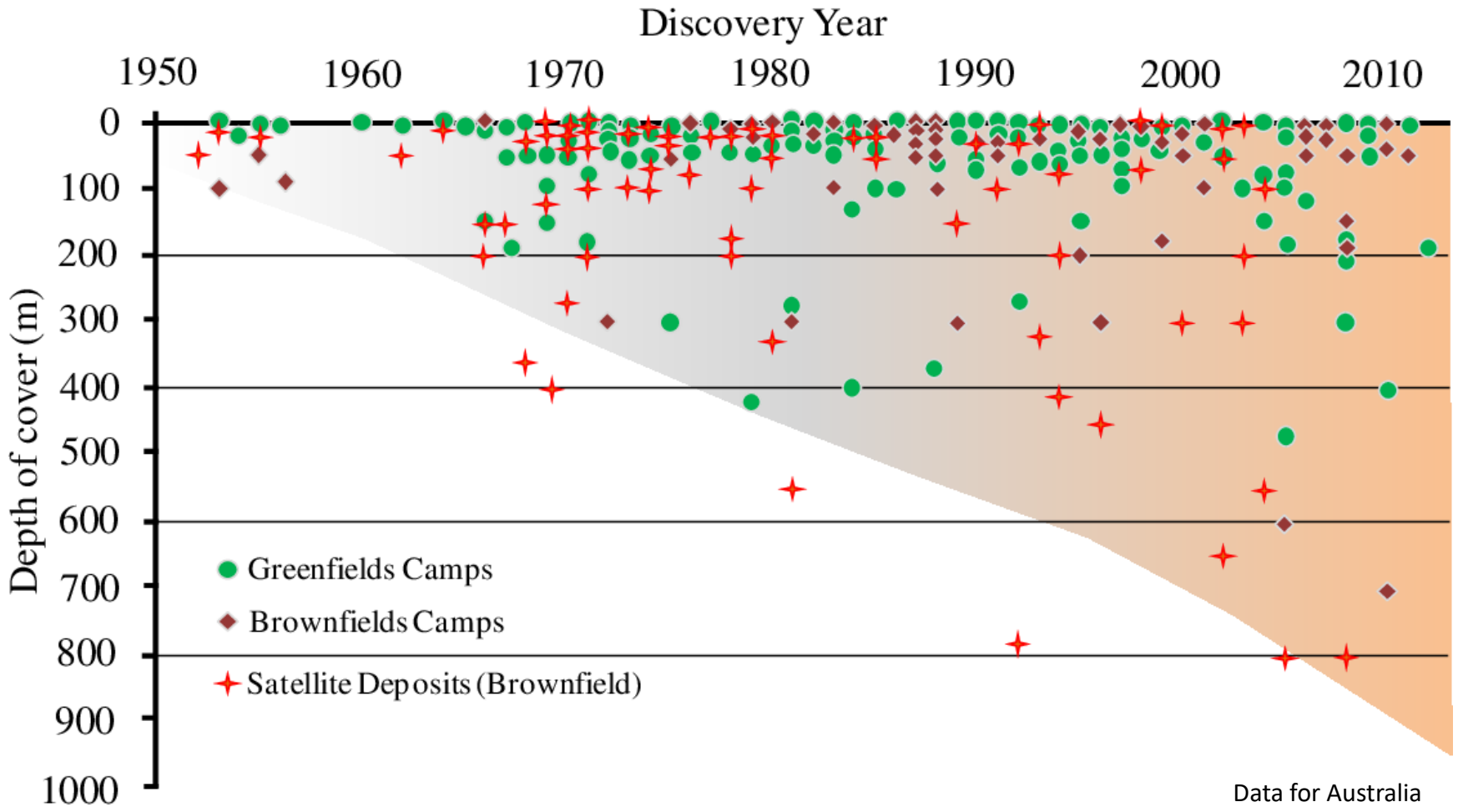
Discoveries in Finland

In 1985 **Rautaruukki Oy abandoned mineral exploration**. Personnel, data was transferred to Outokumpu Oy. At the same time **Outokumpu Oy starts to heavily decrease domestic exploration** (Haapala & Papunen, 2015).



Data source: GTK

Why Deep Mineral exploration?



Data for Australia
Nickless et al., 2014

Future large discoveries will be under cover

Finland's exploration efforts concentrated on the top 50 m below surface.

Exploring 500 m below surface increases the mineral potential tenfold.

Development focus of Deep exploration geophysics at GTK

- **Study the deep mineral potential**
  - *Increasingly expensive geophysics*
  - *Targeted*
  - *beyond currently explored depth levels*
  - *>200 m, >500 m, >1000 m*

- **Study of mineral systems**
  - *“Low-cost” geophysical methods*
  - *Regional-scale*
  - *Lithospheric depths*
  - *Understand the crust to know where to look*

Key Methods and Data

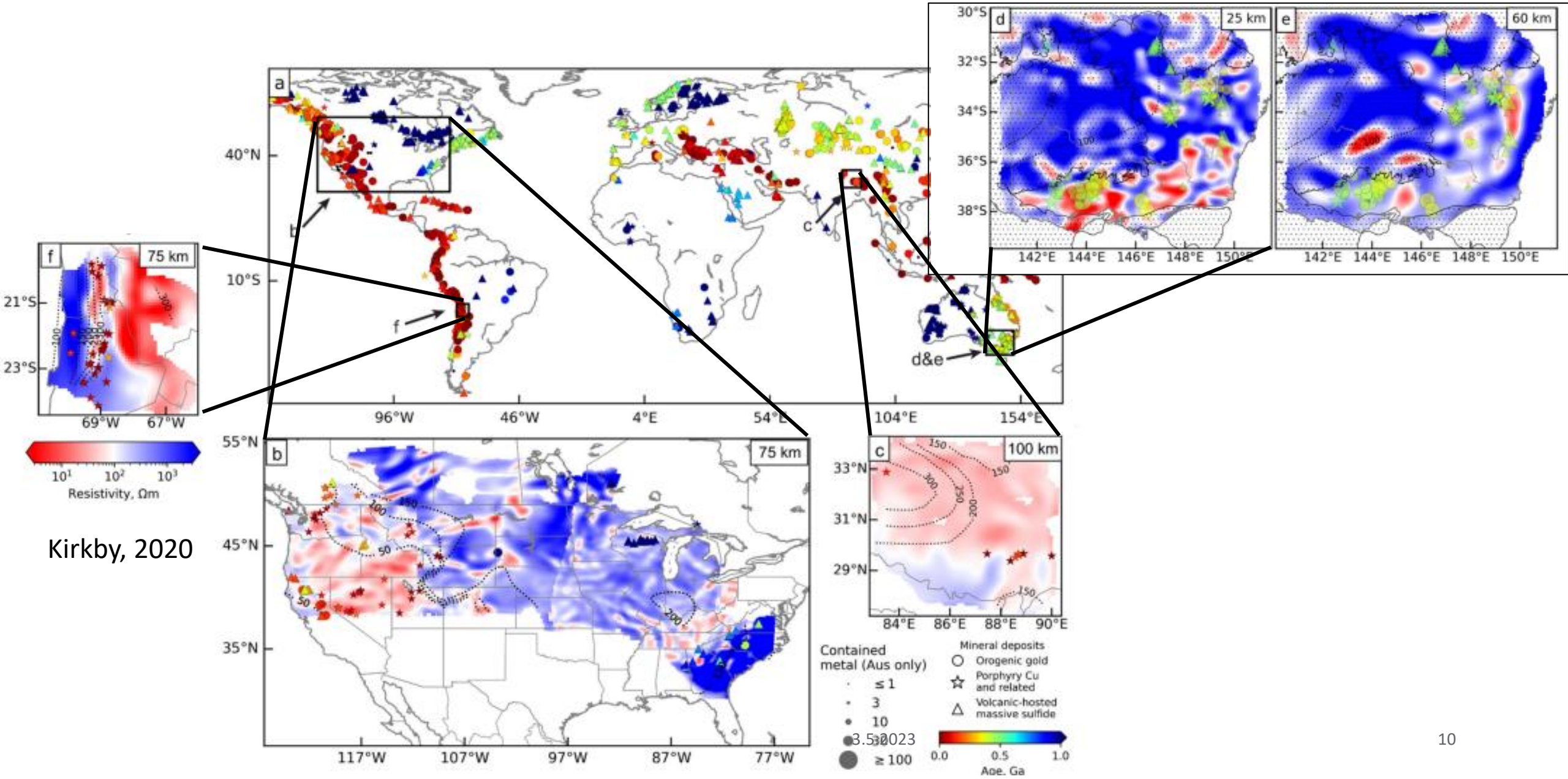
- **Electromagnetics**
- **Seismics**
- **Gravity**
- Magnetics
- **Petrophysics**
- Any other data available (geophysical, geological, geochemical…)
- **The combination of those!**

Installation of a magnetotelluric sensor on frozen lake

Seismic source in action

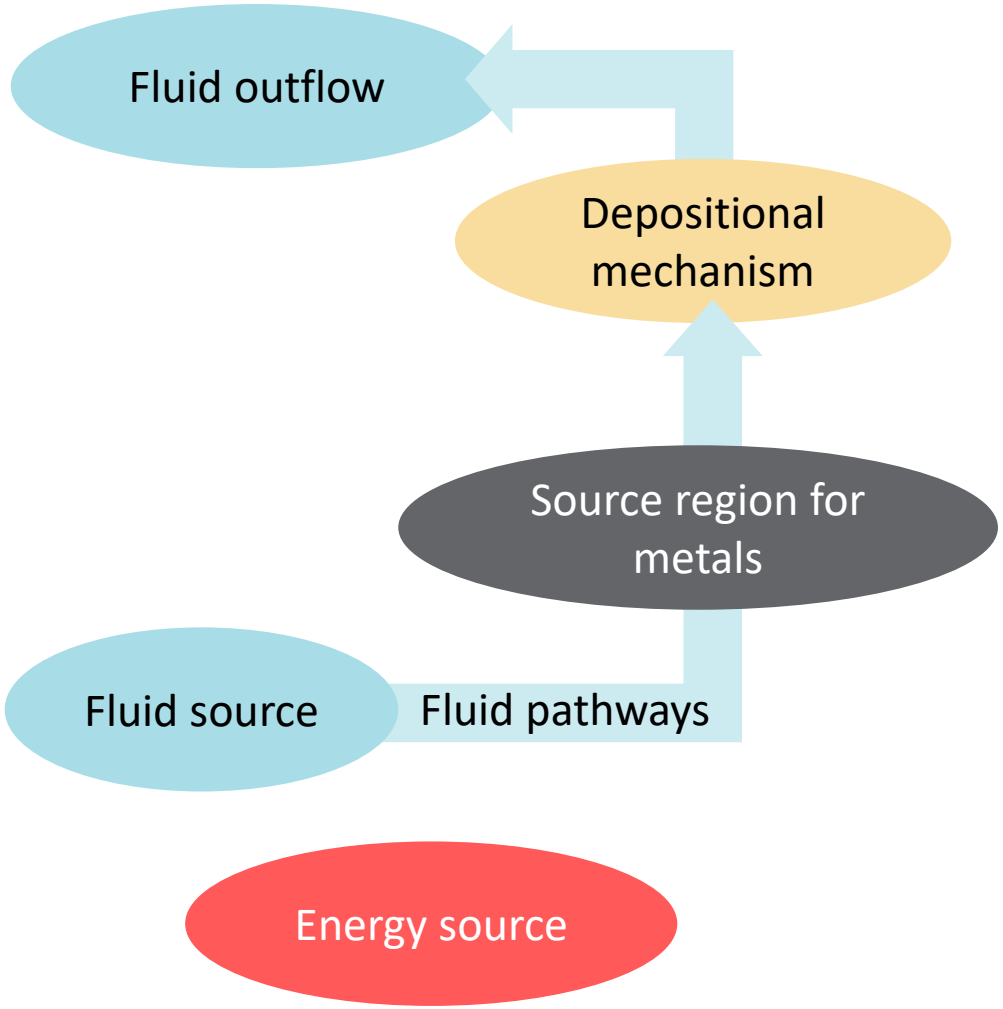
Regional geophysics and mineral systems research

Mineral deposits worldwide correlate with deep conductors



Kirkby, 2020

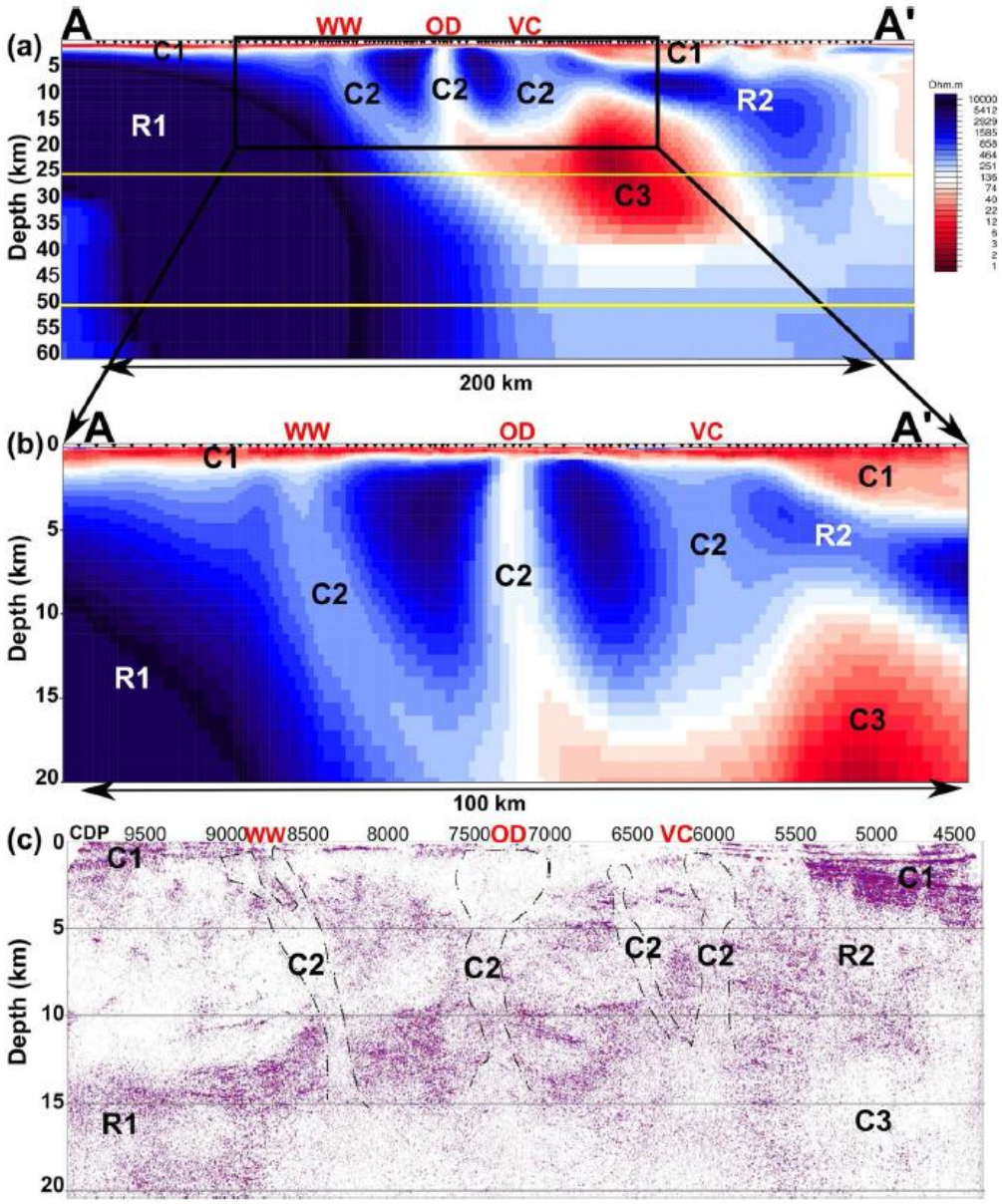
Mineral systems concept



MINERAL SYSTEMS CONCEPT

Example Olympic dam, Australia

- Mineral deposits are only small parts of a mineral system.
- Many deposits can be in the same mineral system.
- Mapping the large-scale features of mineral systems can guide targeted exploration



Olympic dam, Australia
Heinson et al., 2018

D-REX
DEPOSIT-TO-REGIONAL SCALE EXPLORATION

ERA-MIN 2
Co-funded by the Horizon 2020 programme of the European Union

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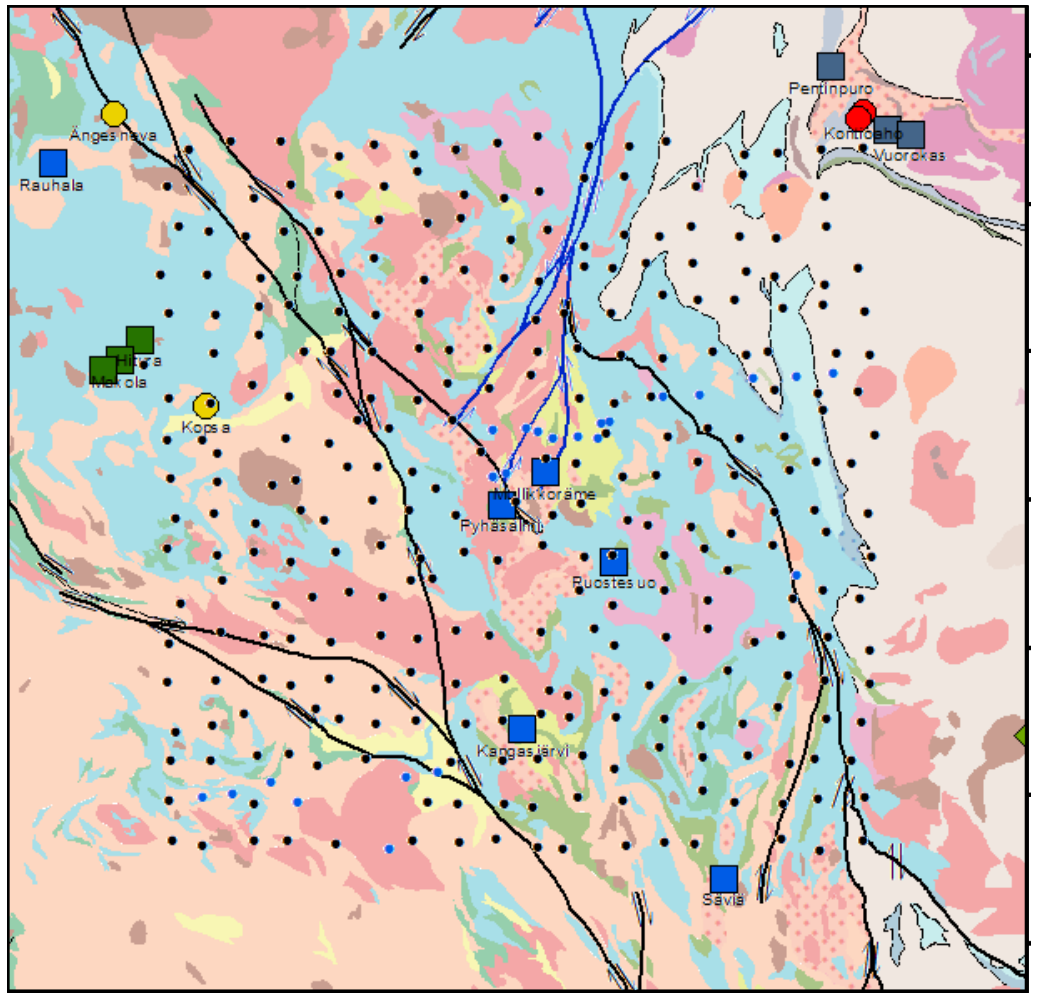
EARTH SCIENCE INSTITUTE SLOVAK ACADEMY OF SCIENCES

LoopandLine

GTK



- Mineral systems research in:
  - Northern Sweden (Malmberget, Gällivare)
  - Central Norway (Röros)
  - Finland (Pyhäsalmi): 324 MT sites at ca 6 km separation, over a 100 km x 100 km area

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[image not shared – work in progress]

- Deep and large-scale conductors help to map tectonic make-up of the crust
- Correlations with existing deposits exist

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LoopandLine

[image not shared – work in progress]

From 2D to 3D!

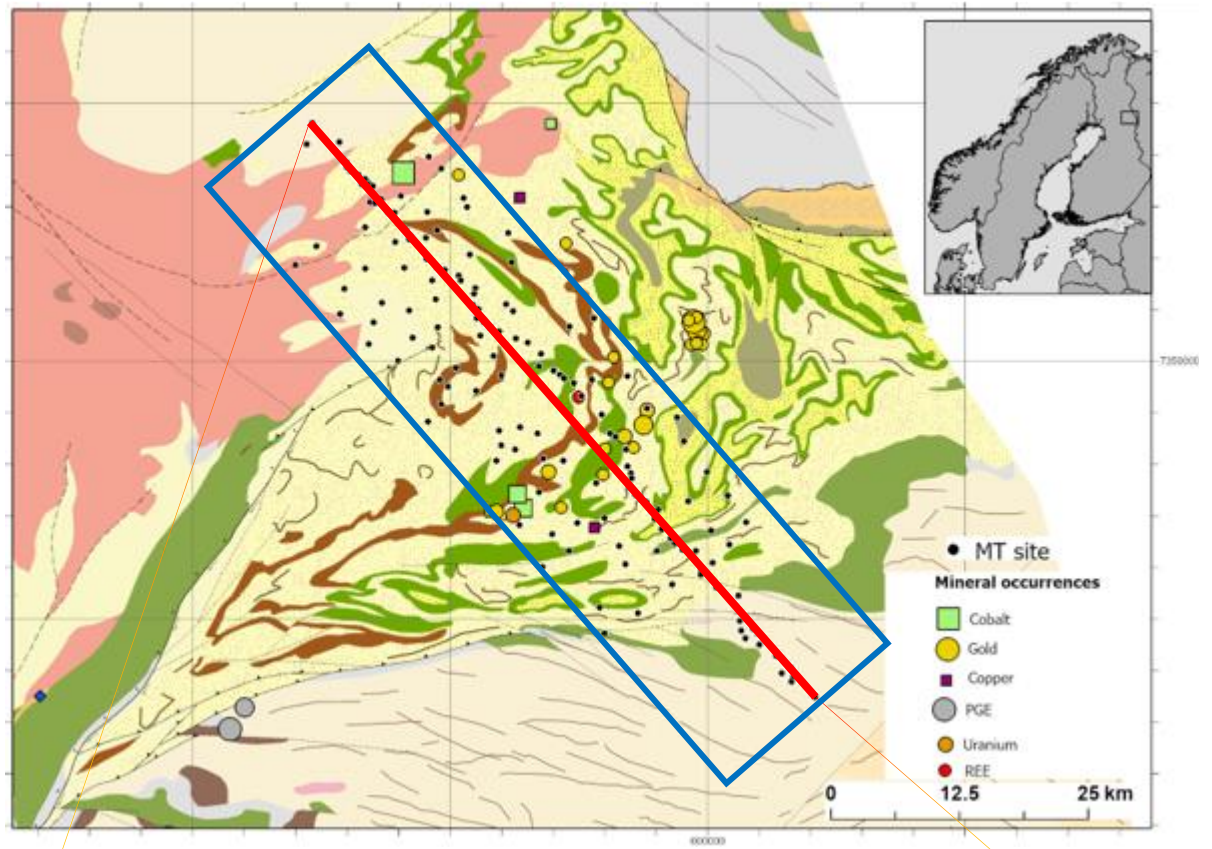
- Deep and large-scale conductors help to map tectonic make-up of the crust
- Correlations with existing deposits exist

BATCircle2.0

- Deep study of the Kuusamo belt
- Origin of Au-Co deposits?

- Magnetotellurics and gravity

- Deep underlying structures are revealed that are connected to the mineralization history of the belt



[image not shared – work in progress]

[Coordination by Aalto University. This slide concerns task 1.2.1, therefore, no full list of partners shown]

BUSINESS FINLAND

LATITUDE COBALT

GTK

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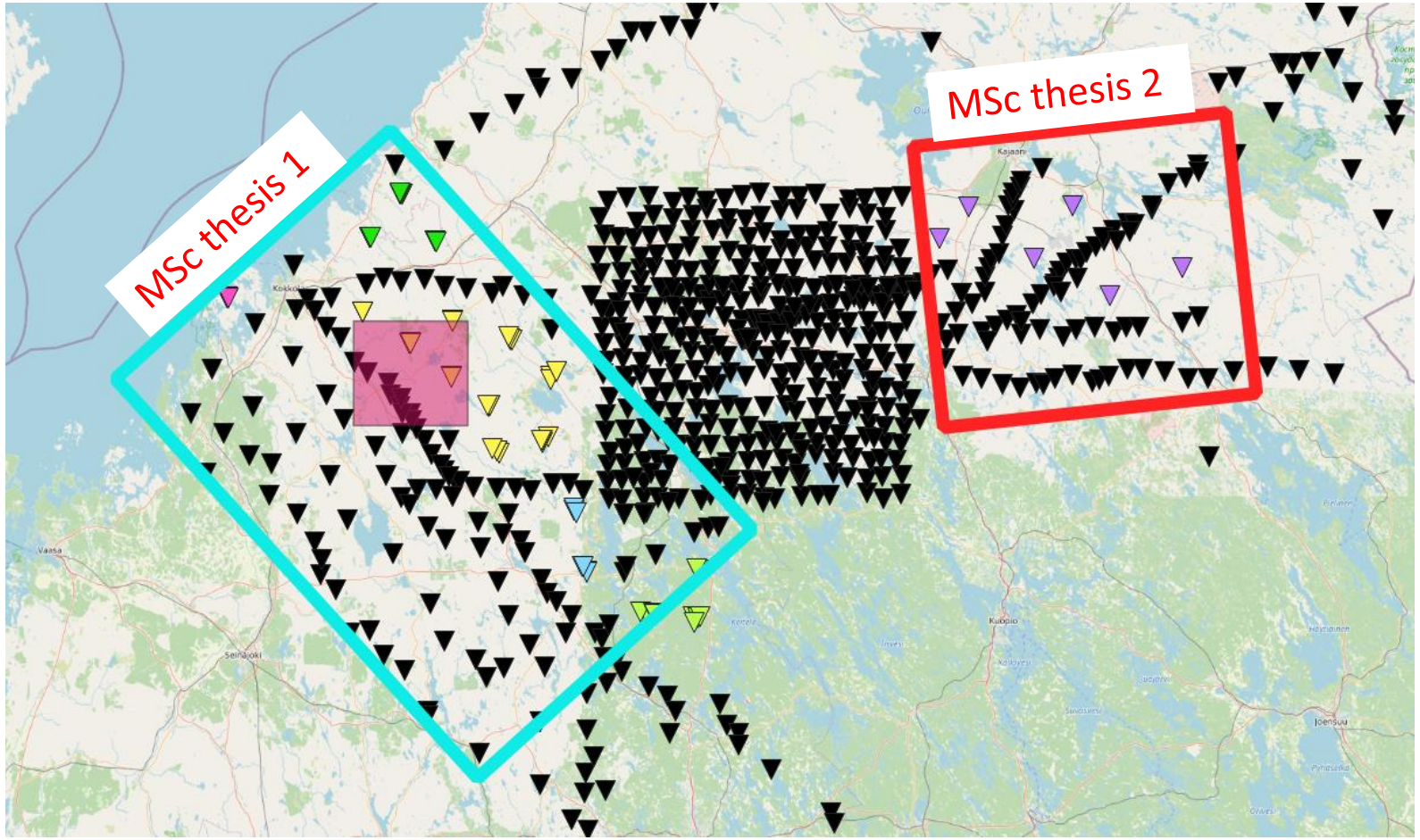
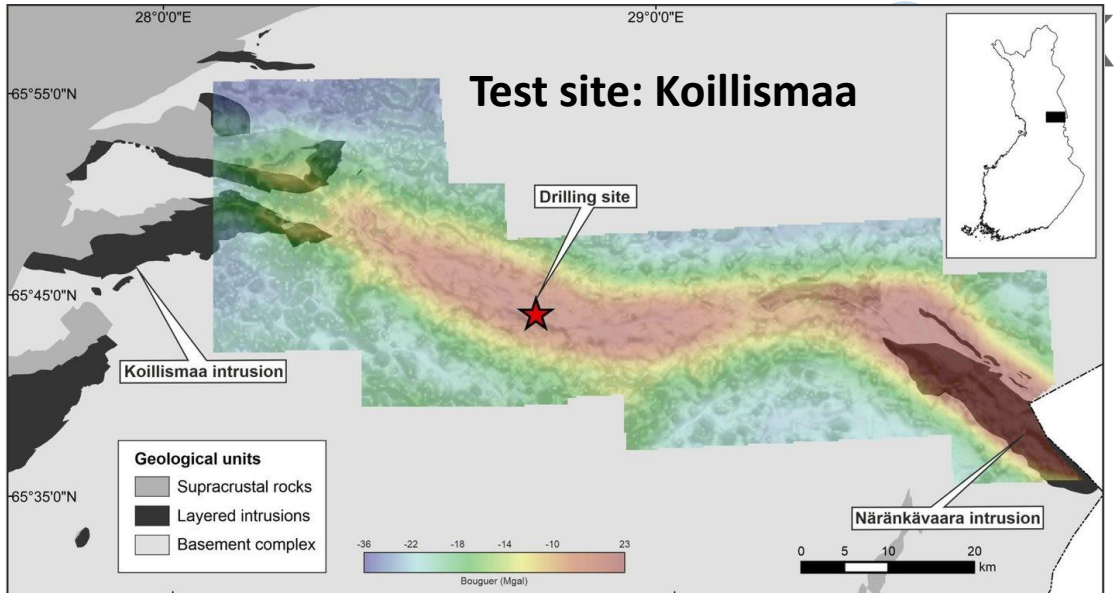
MSc projects to bring existing data together and extend to 3D

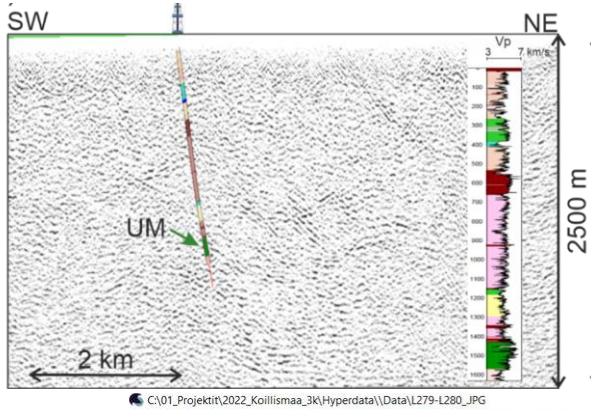


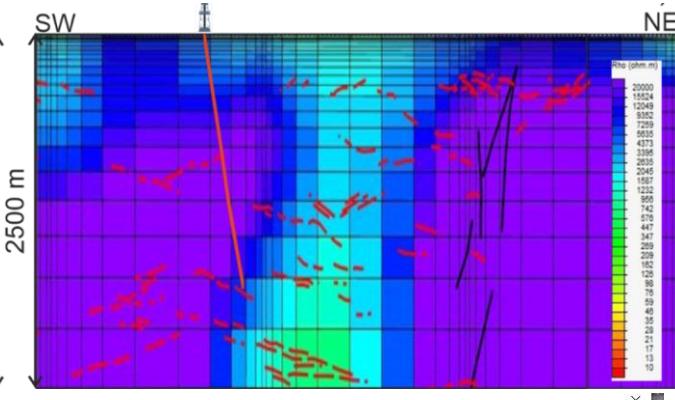
Developing New Geophysical Methods for Targeted Deep Mineral Exploration

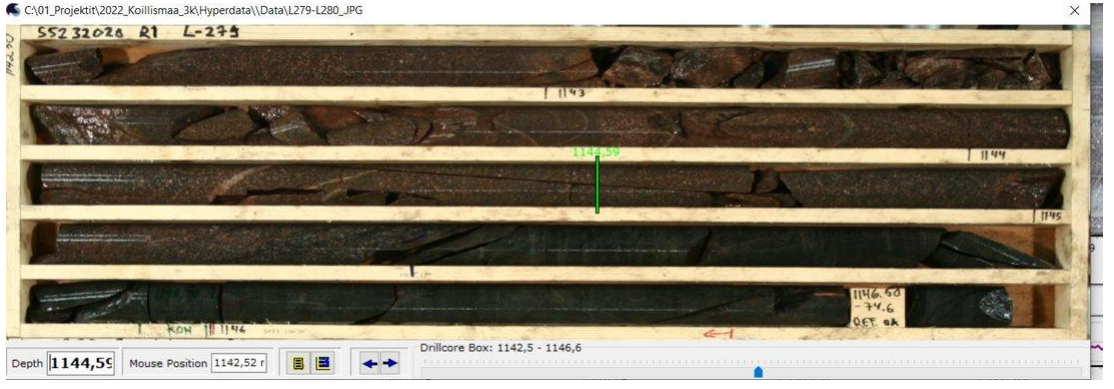
SEIS DEEP

- Joint seismic and electromagnetic data acquisition and interpretation
- Measurements to be carried out later 2023









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SEIS DEEP

Strydes

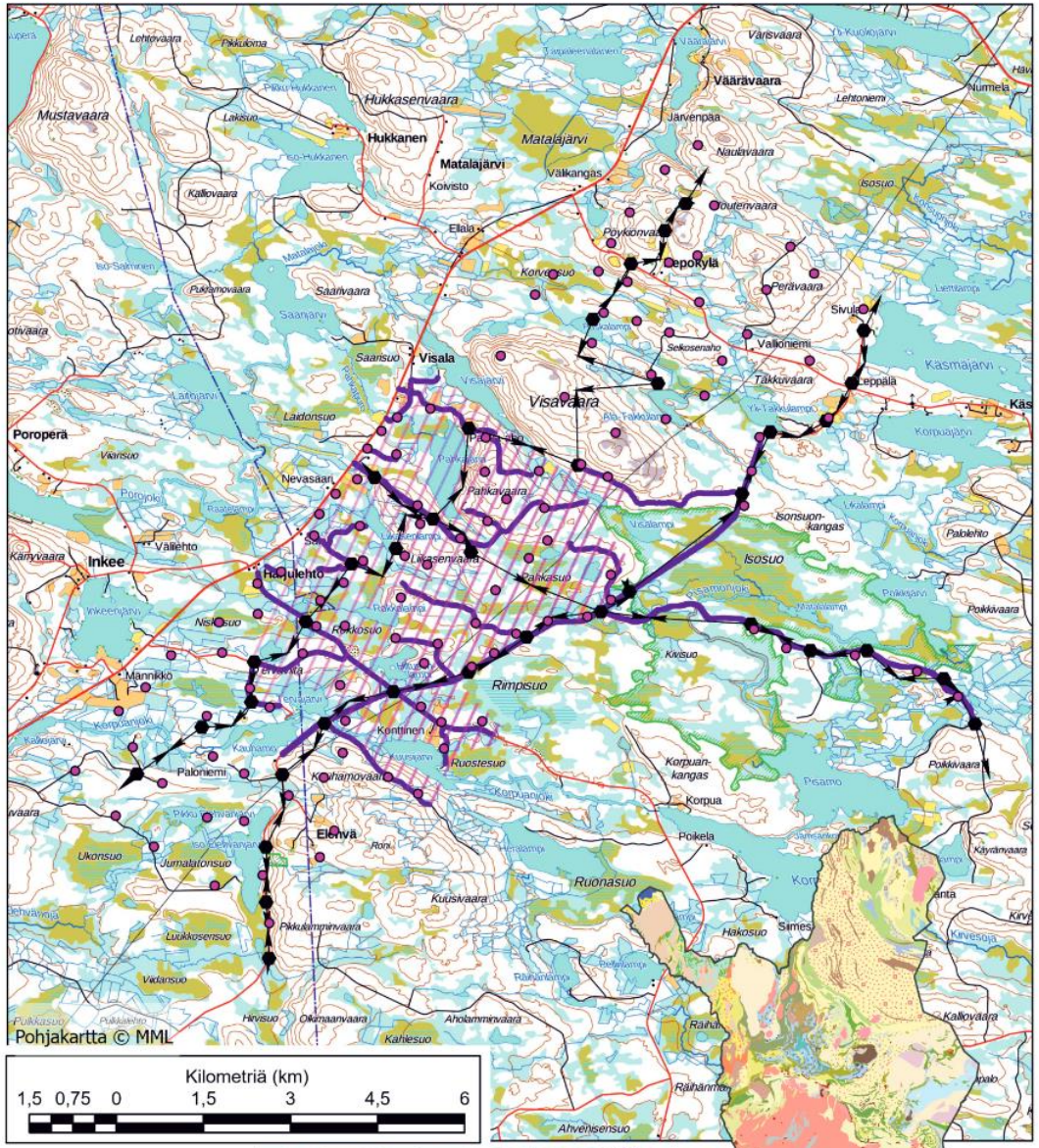
CSEM-Tx

Wireless seismics

CSEM/MT-Rx

EM-Tx

Vibroseis trucks



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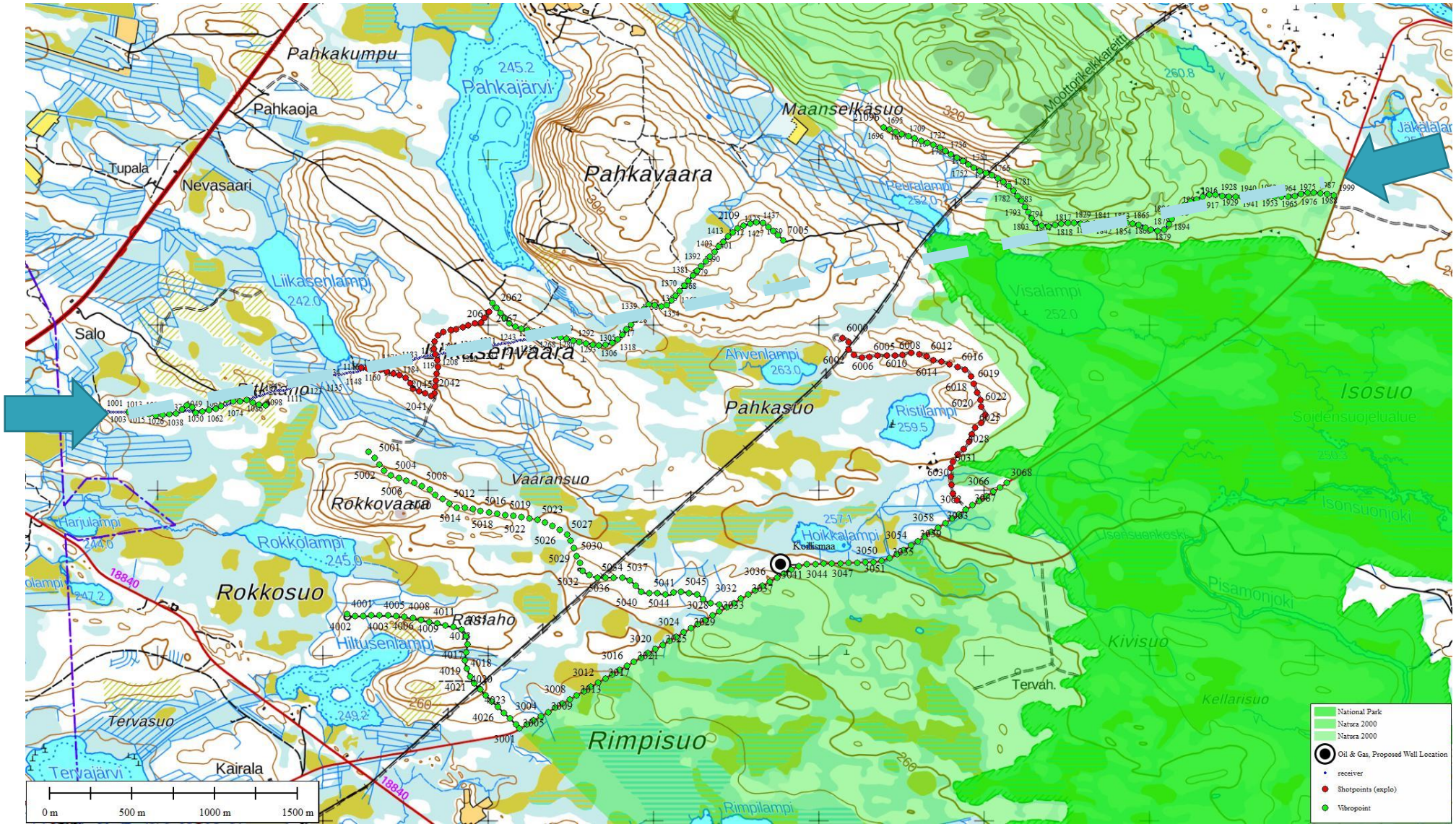
28.4.2023

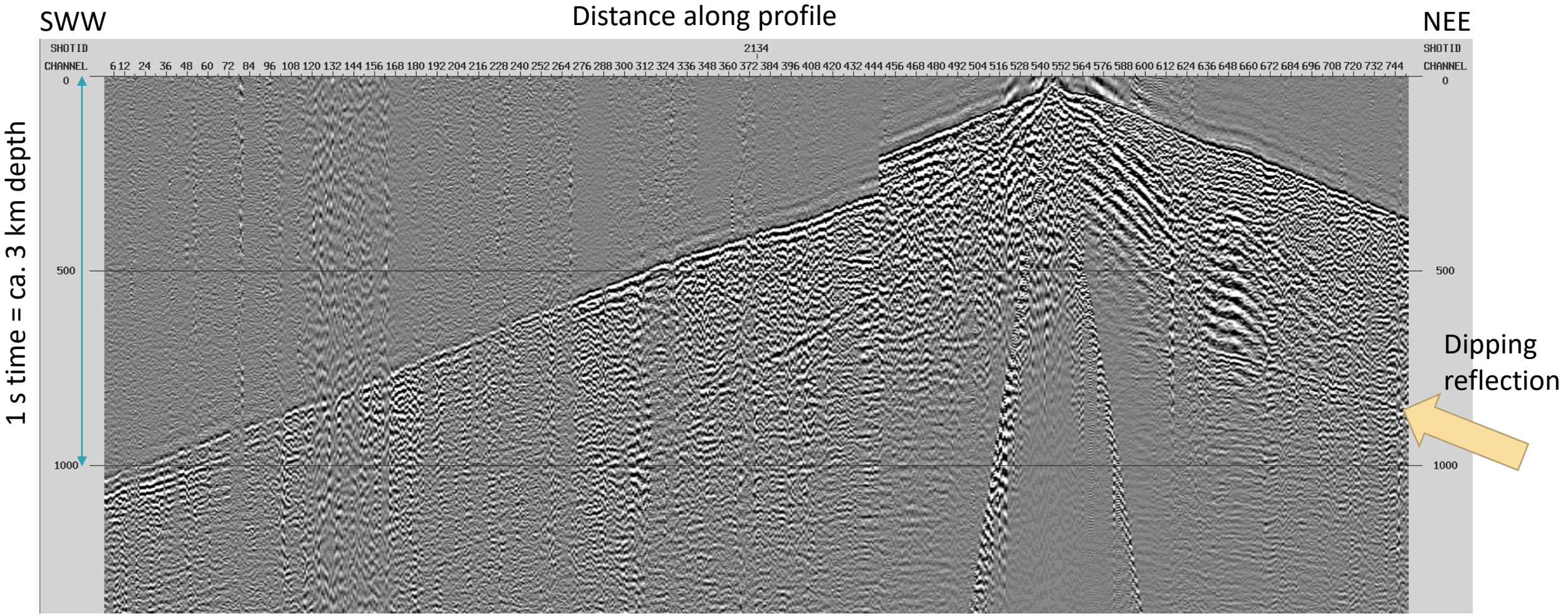
2D seismic profile



ca. 7.5 km long

750 receivers @ 10 m
187 shotpoints @ 40 m
(Vibroseis and explo)

2D Shot-gather example



Distributed Acoustic Sensing (DAS)

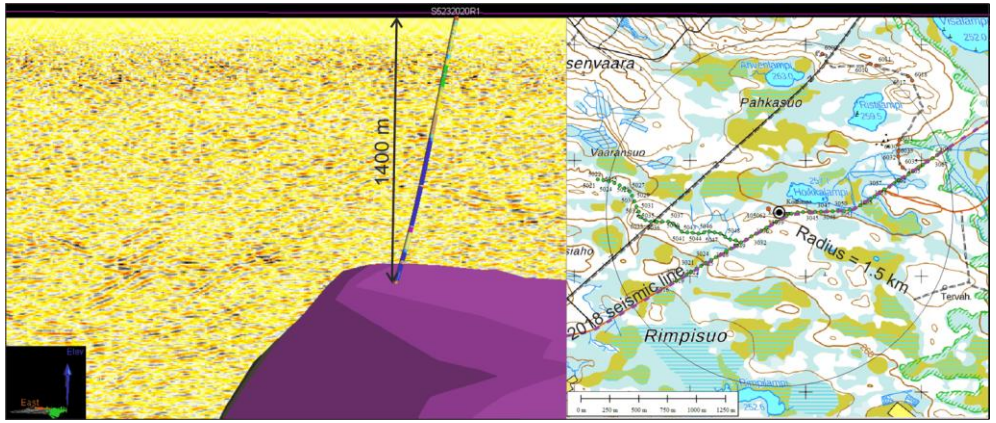
DAS is a new seismic recording method

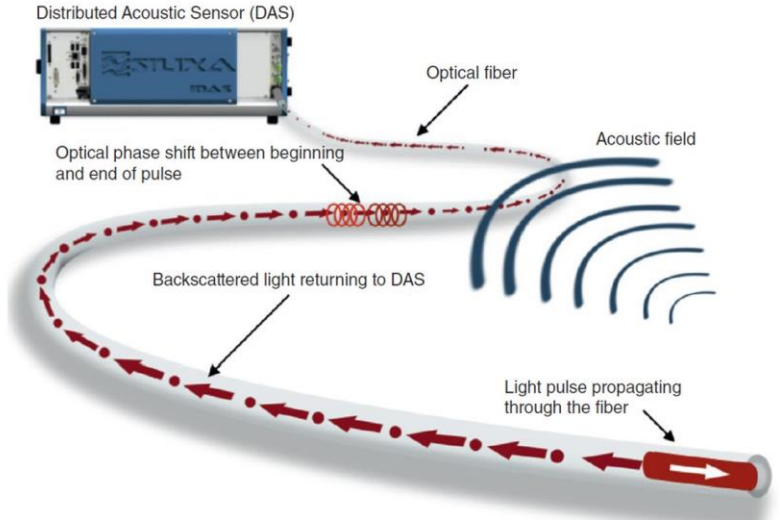
Very dense sampling along the cable

Extremely useful for borehole seismics (VSP)

Also in surface seismics, our latest experiments show applicability of DAS (not shown here)

First test: Experiment in the Koillismaa Deep Hole

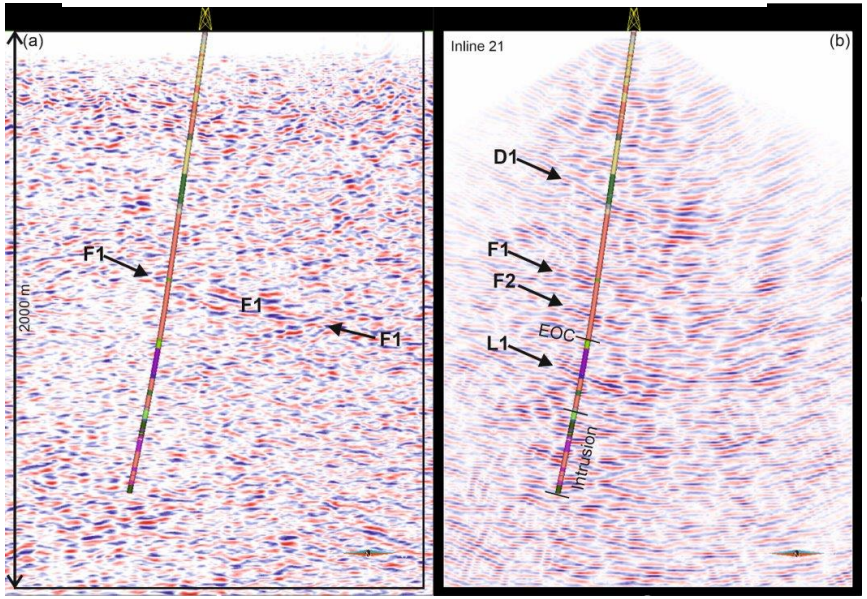




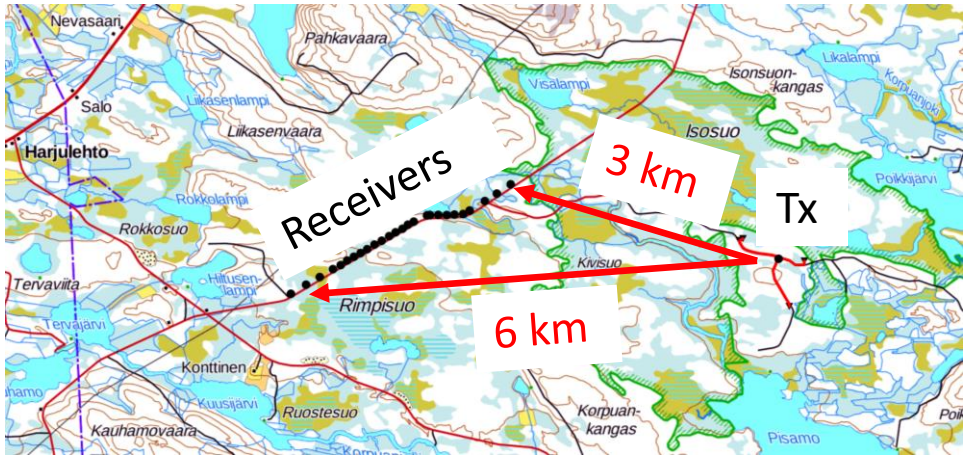
DAS cable in the borehole

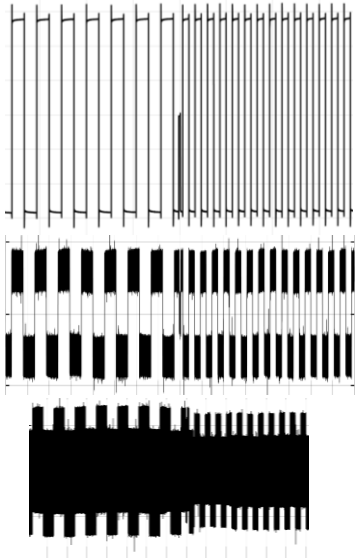
Data incoming

Comparison with surface seismic



First CSEM test (Koillismaa 2022)

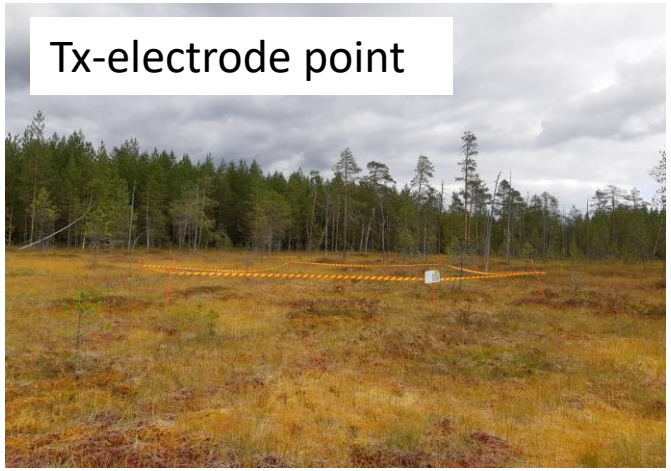


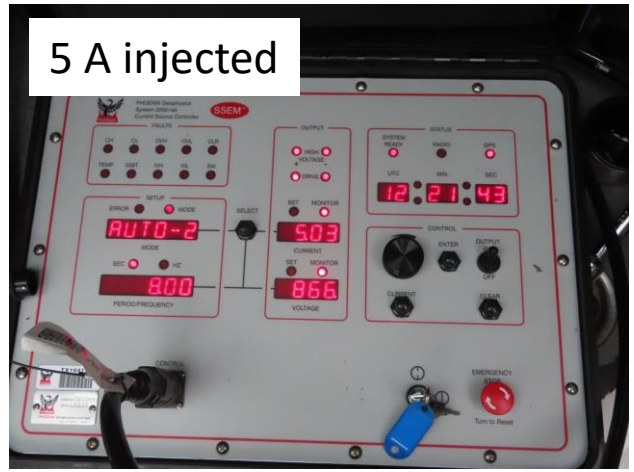


At Tx — Good conditions

3 km — Signal visible over large distances

6 km — High data quality





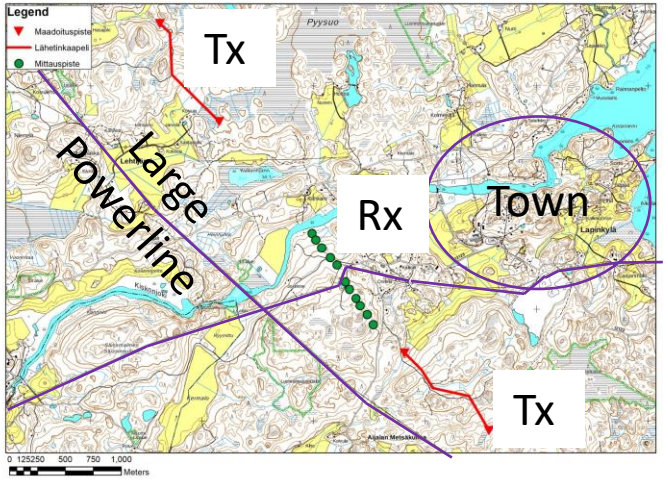
Second CSEM test (Aijala 2023)

Southern Finland:

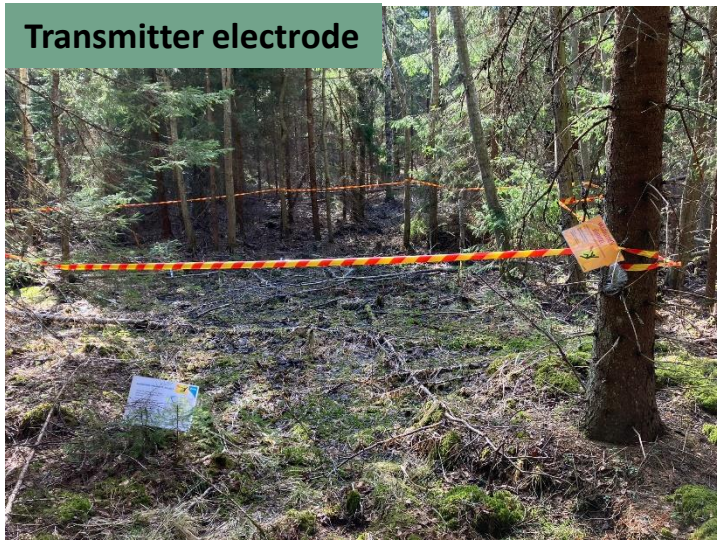
Challenging conditions, noise from power lines, cultural activity

The method still performs well

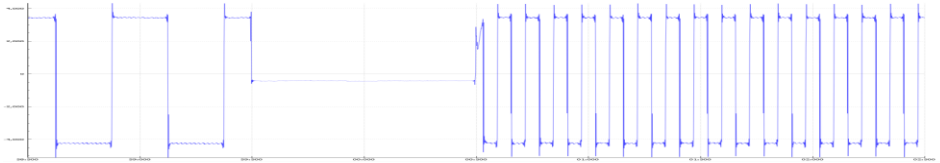
Modelling in 3D is being developed: results expected end of 2023



Transmitter electrode

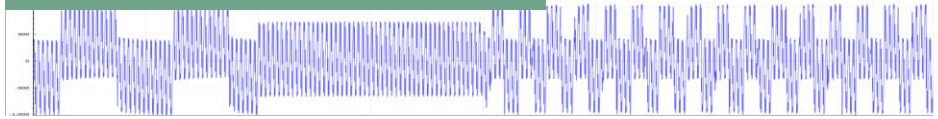


Current recording

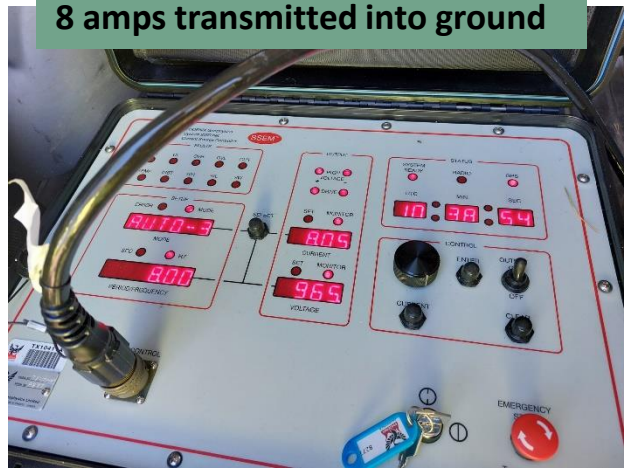


Receiver close to transmitter

Receiver far from transmitter

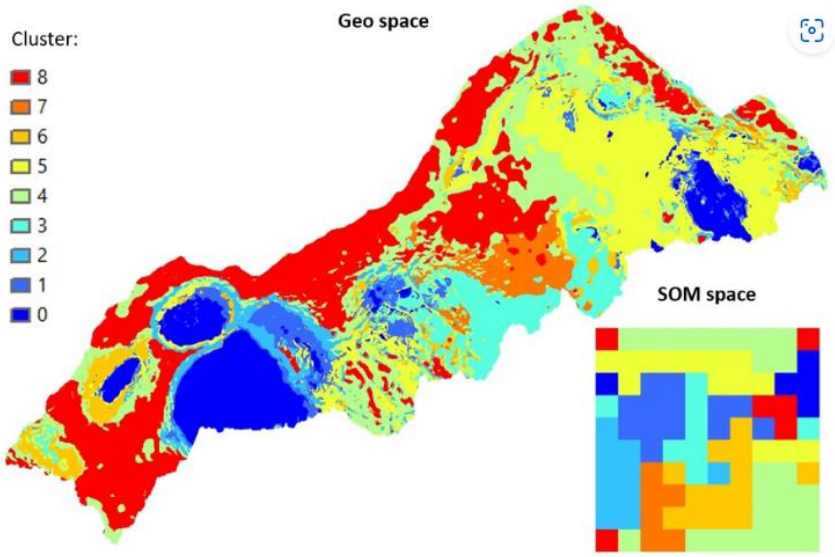


8 amps transmitted into ground



DroneSOM

- Development of new drone systems:
  - Gravity (DTU)
  - Electromagnetics (RADAI)
- Development of data interpretation software
  - 2D&3D SOM (BEAK & GTK)
  - 3D geophysical inversion (GTK)



Supported by

eit RawMaterials
Connecting matters

radai

DTU

beak CONSULTANTS

GTK

Summary and Outlook

Summary and Outlook

- Future targets are deep (100s of m)
- Finding deep targets needs highly developed geophysics

- For deeper mineral exploration
  - Suitable new geophysical methods must further developed
  - These are typically expensive and logistically more intense

- For targeting such intensive studies we need
  - Transition from anomaly-hunting to understanding geological systems
  - Deep data sets (Magnetotellurics, Seismics, Gravity) to build extensive regional and mineral systems models for targeting exploration

- Interpretations become complex
  - Petrophysics supported multi-method approaches
  - Integration of many data types (Geophysics, Geochemistry, Geology)
  - Developing computational interpretation/modelling techniques: joint inversion, machine learning, ...

Kiitos!

GTK

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