Evaluating the resource recovery potential of fly ash deposits using electrical and electromagnetic methods

David Caterina[1], Itzel Isunza Manrique[1], Hadrien Michel[1,2,3], Christin Bobe[4], Hugo Lucas[5], Frédéric Nguyen[1], and Ellen Van De Vijver[4]

[1]Urban and Environmental Engineering, Université de Liège, Belgium
[2]F.R.S.-FNRS (Fonds de la Recherche Scientifique), Brussels, Belgium
[3]Department of Geology, Ghent University, Ghent, Belgium
[4]Department of Environment, Ghent University, Ghent, Belgium
[5]Department of Process Metallurgy and Metal Recycling, RWTH Aachen University, Aachen, Germany

What is Fly Ash?

Fly Ash (FA) is a particle from the combustion chamber or formed within the flue-gas stream that is transported in the flue-gas

Bottom Ash (BA) is a granular material removed from the bottom of dry boilers, which is much coarser than FA though also formed during the combustion of coal or other materials.

Why is it important ?

- Several hundred megatonnes of combustion waste are produced each year worldwide, 80 to 85% of which is FA
- FA can be reused advantageously as structural filling material, binder material (partially replacing portland cement), sand substitute, geopolymers…

BUT only 15% of FA produced is actually reused, the rest is landfilled

Why is it important ?

- Coal FA contains a wide number of heavy metals such as As, Pb, Ni, Cu, Cd, Cr and Hg
- FA coming the combustion of solid waste may contain a higher amount of contaminants
- When landfilled, heavy metals and other contaminants present in FA may leach out and contaminate surrounding soil and groundwater

Reusing FA from landfills is not only good for the economy but also for the environment.

Context of the study

Better understand the geophysical identity of FA deposits

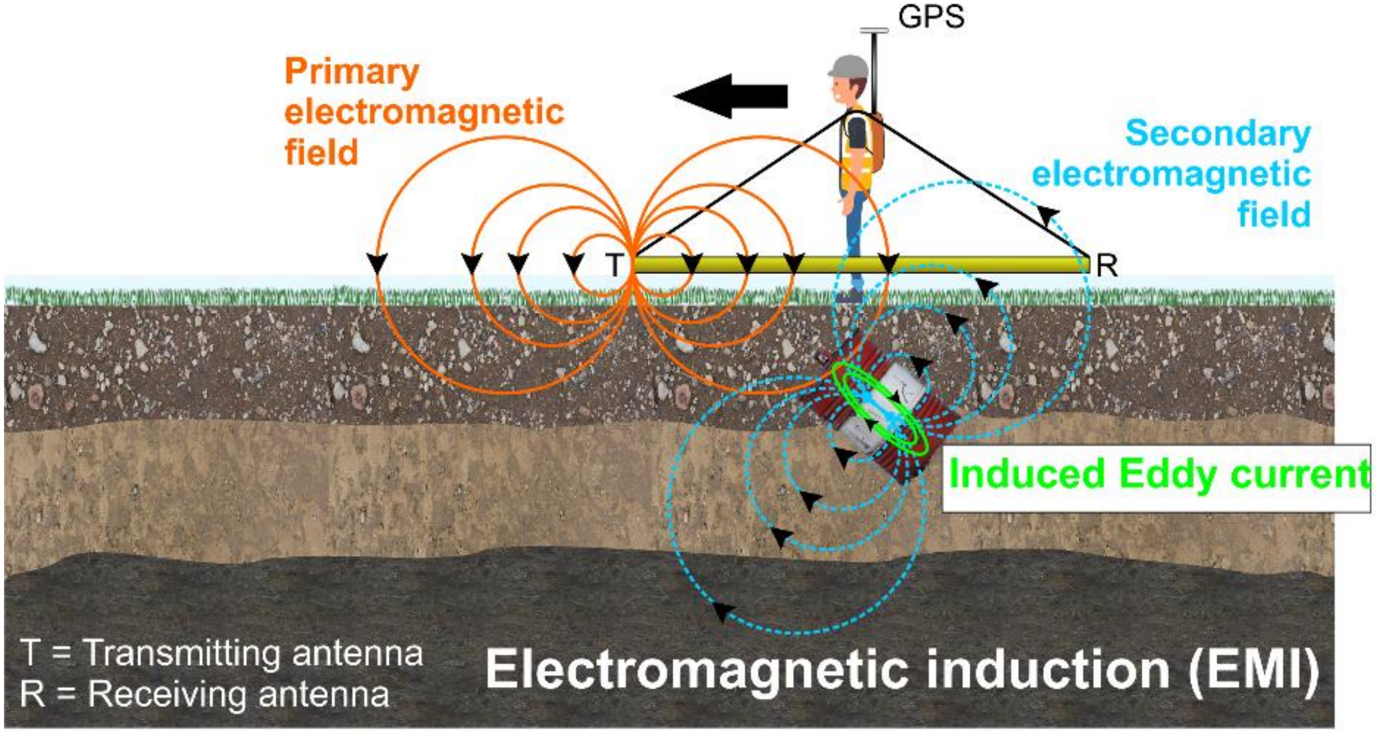
Improve estimation of volume and quality of recoverable resources from geophysics

How?

Test different geophysical techniques on 3 sites in Belgium where FA were deposited

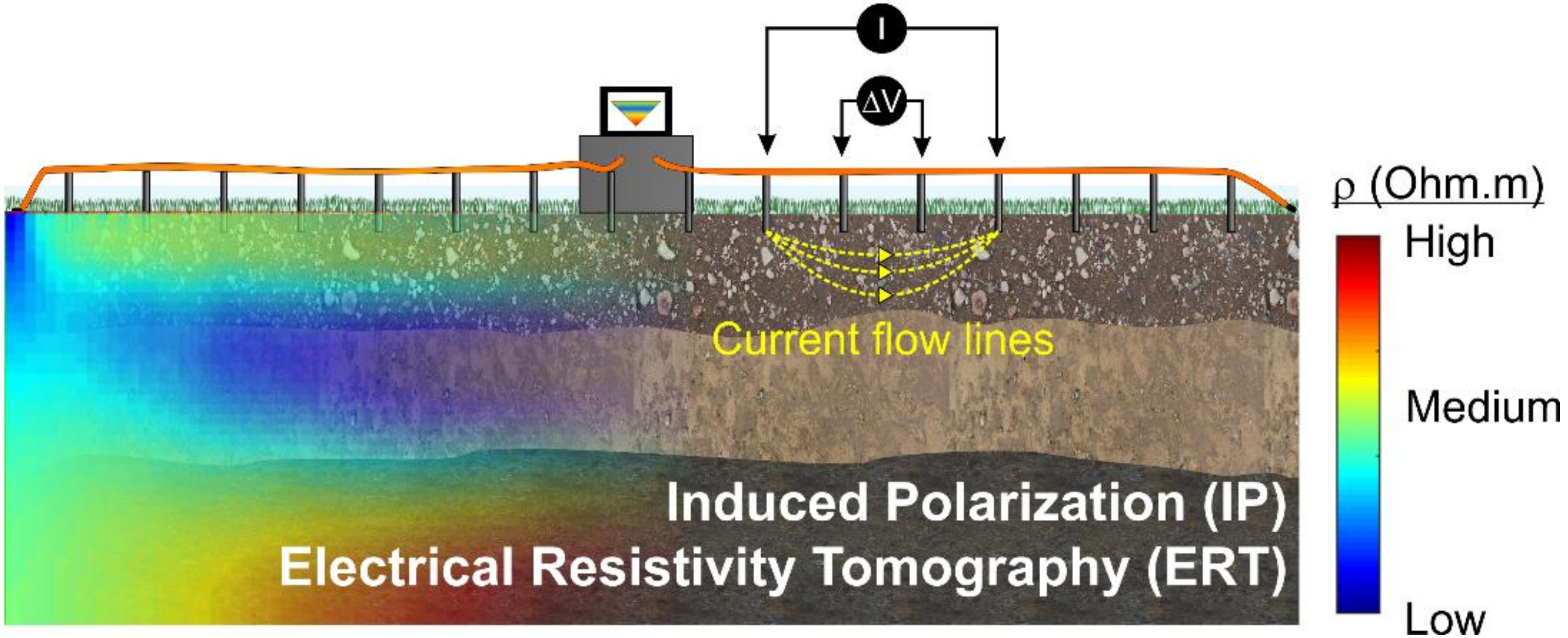
Geophysical methods used

Geophysical mapping



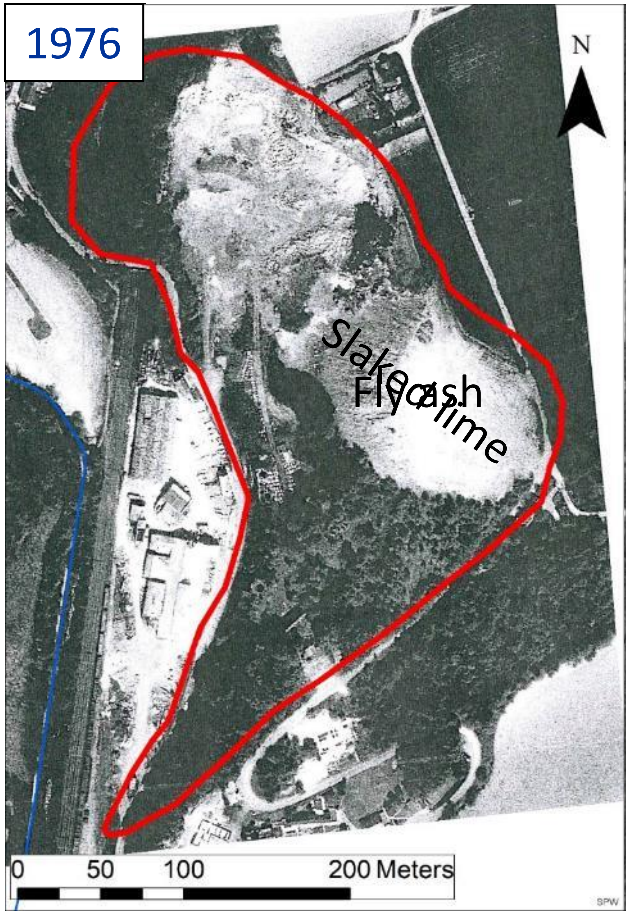
Geophysical methods used

Geophysical profiling



Site 1: Limestone quarry

- 1902-1967:
  - quarry (limestone extraction)
- 1967-1976:
  - slaked lime deposits
    followed by fly ash deposits
- 1982-1987:
  - heterogeneous wastes (inert, tires, rubber, plastic, car parts, household…)



(SPW, 2019)

Site 1: Limestone quarry

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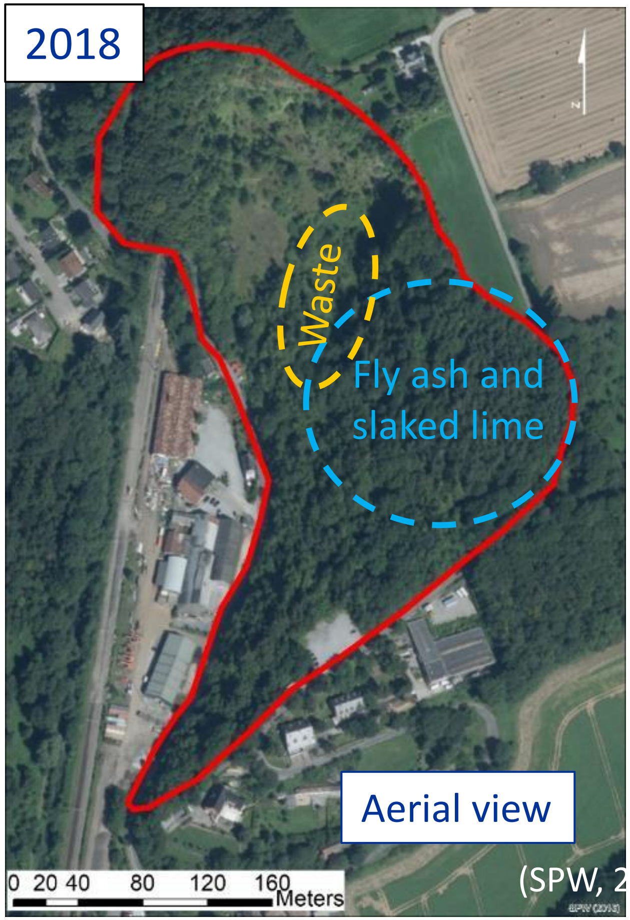
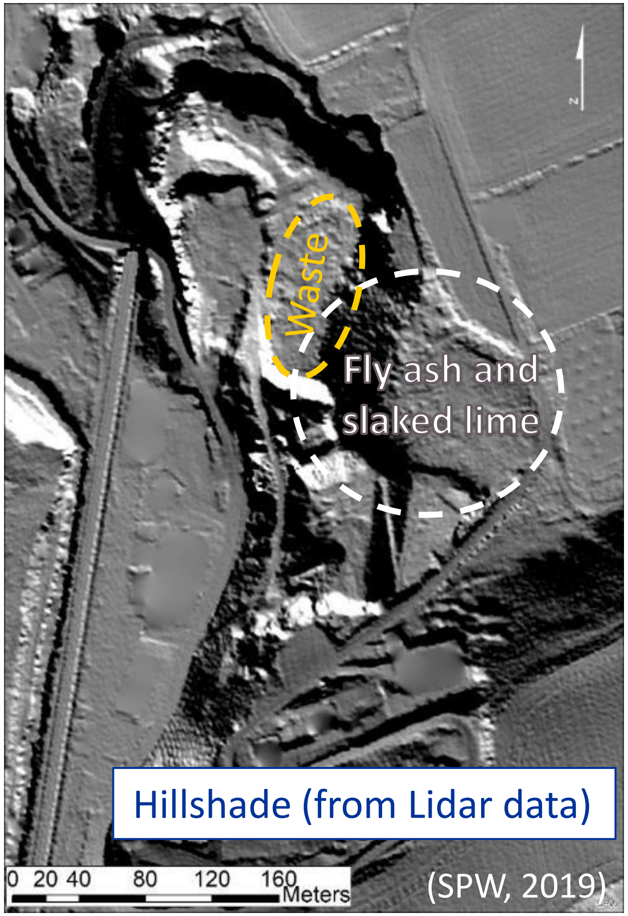
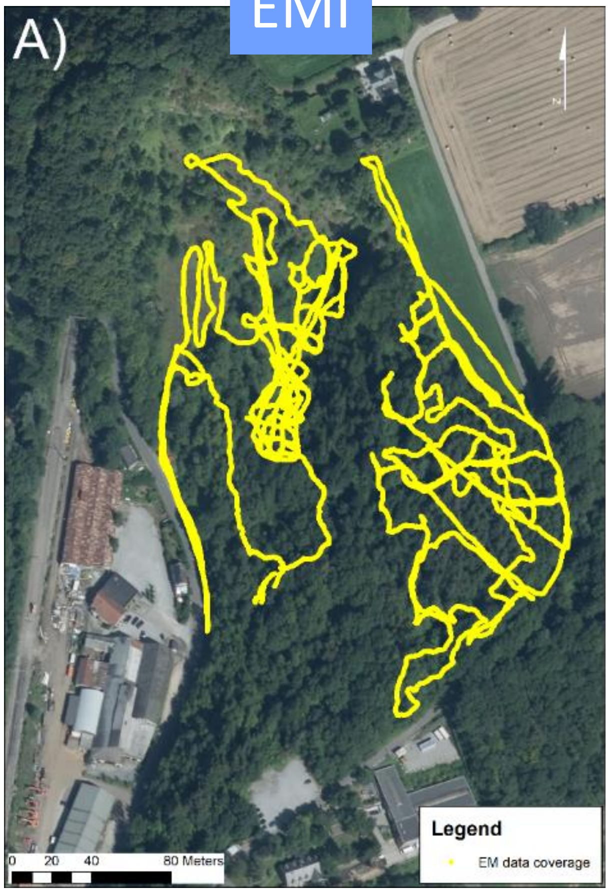
European Regional Development Fund



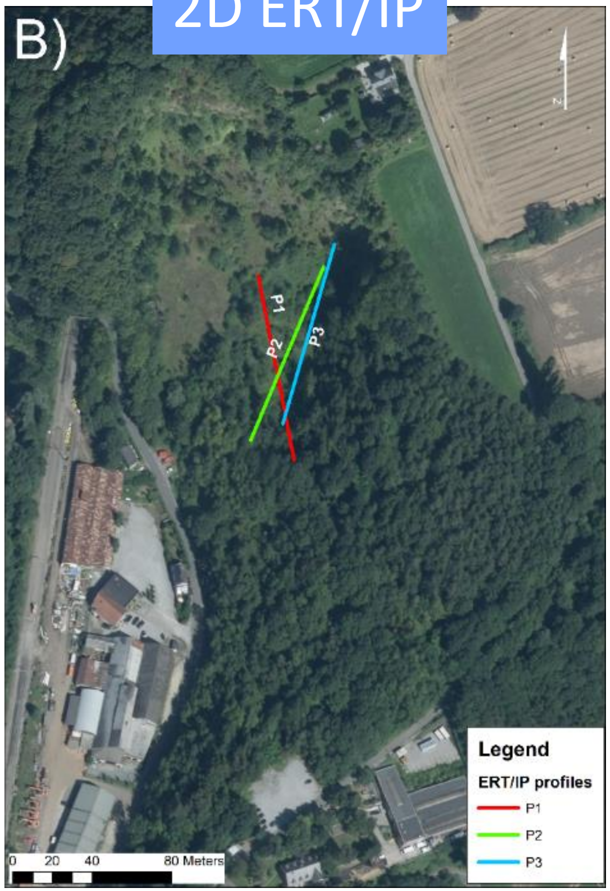


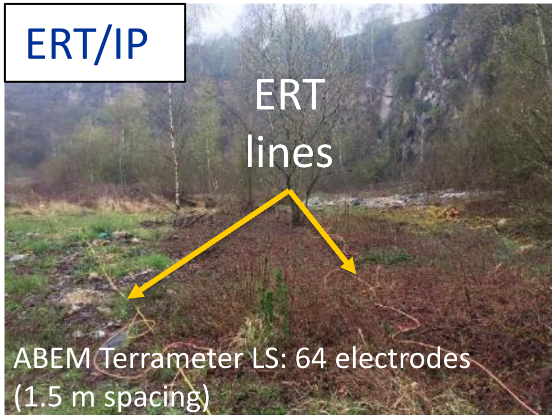
Spatial coverage: EMI & ERT/IP

EMI

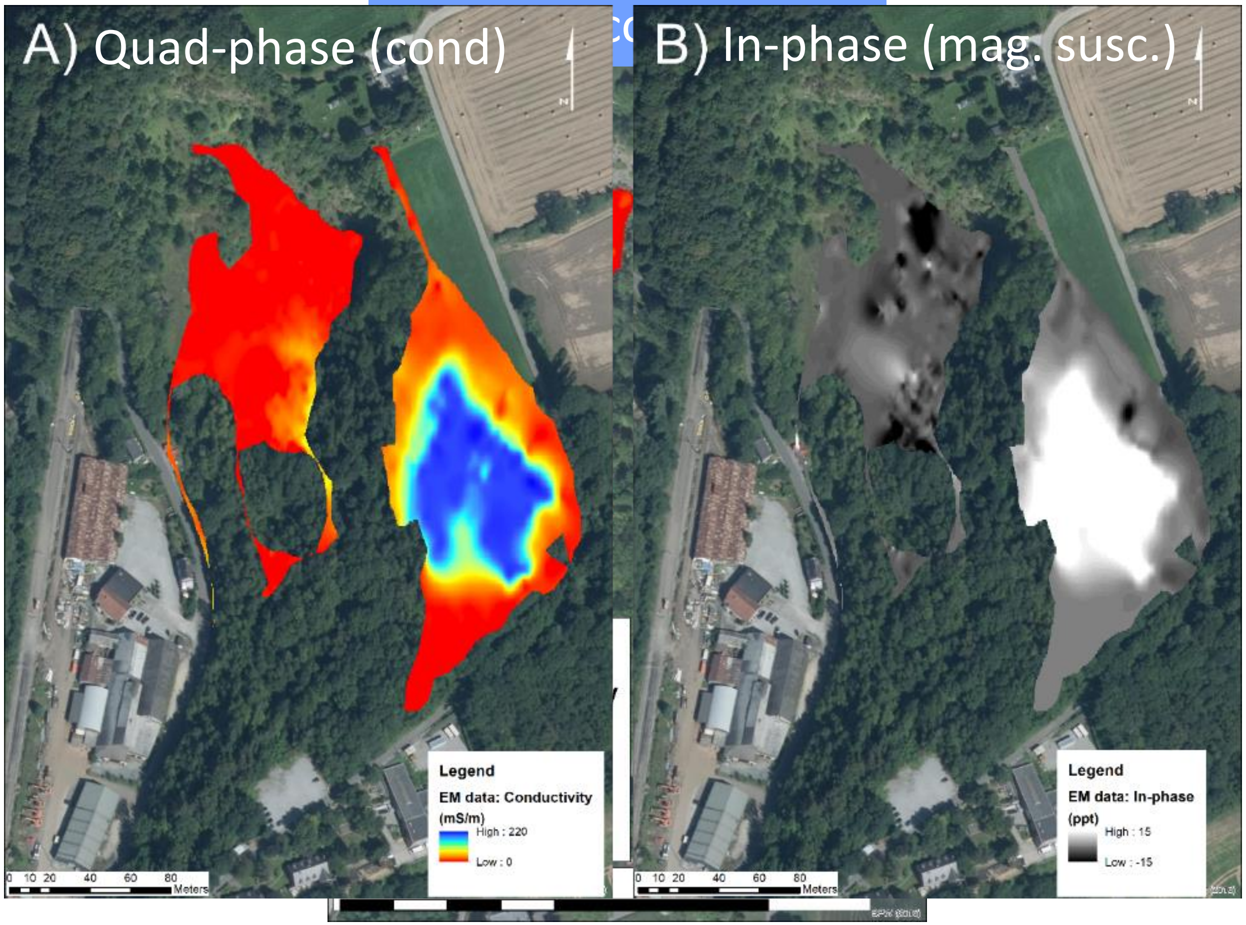


2D ERT/IP





Results: EMI


A) Quad-phase (cond)
B) In-phase (mag. susc.)
Legend
EM data: Conductivity (mS/m)
High : 220
Low : 0
0 10 20 40 60 80 Meters
Legend
EM data: In-phase (ppt)
High : 15
Low : -15
0 10 20 40 60 80 Meters

Interpretation: EMI

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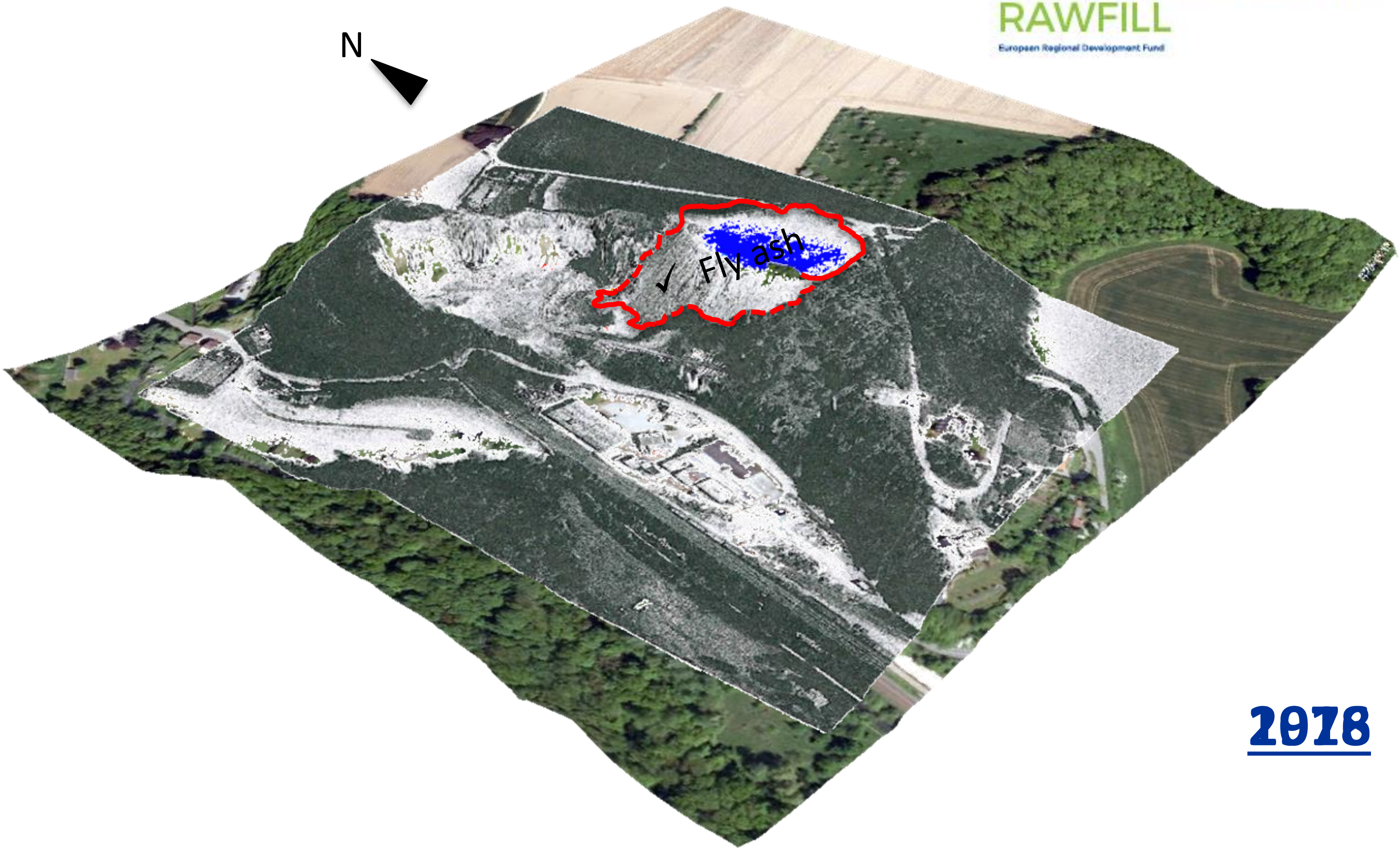

2018

Results: ERT/IP

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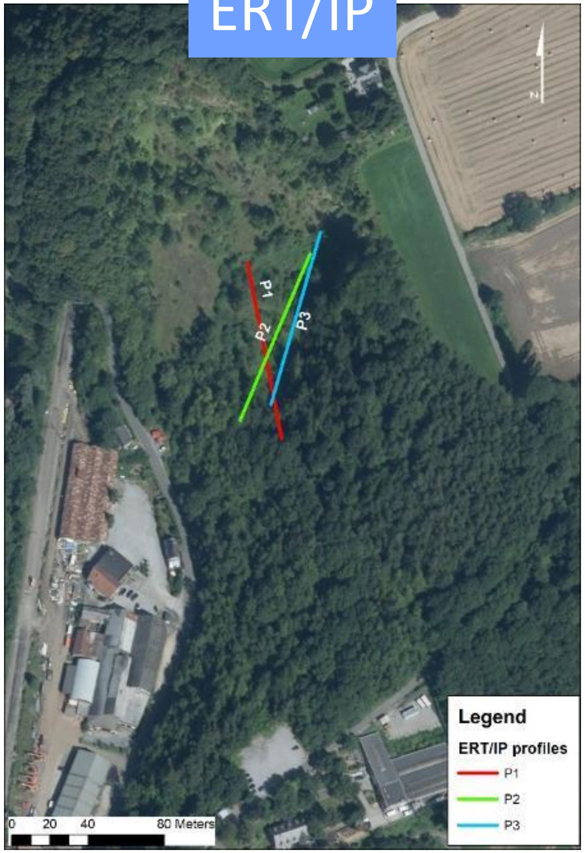
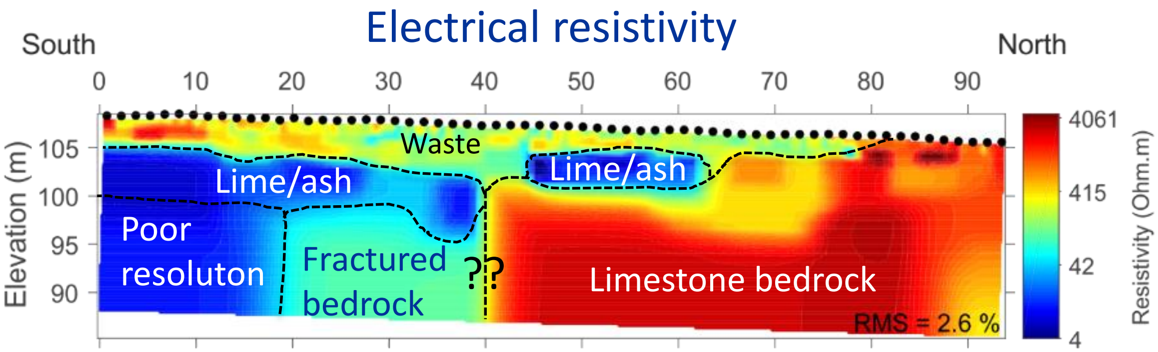
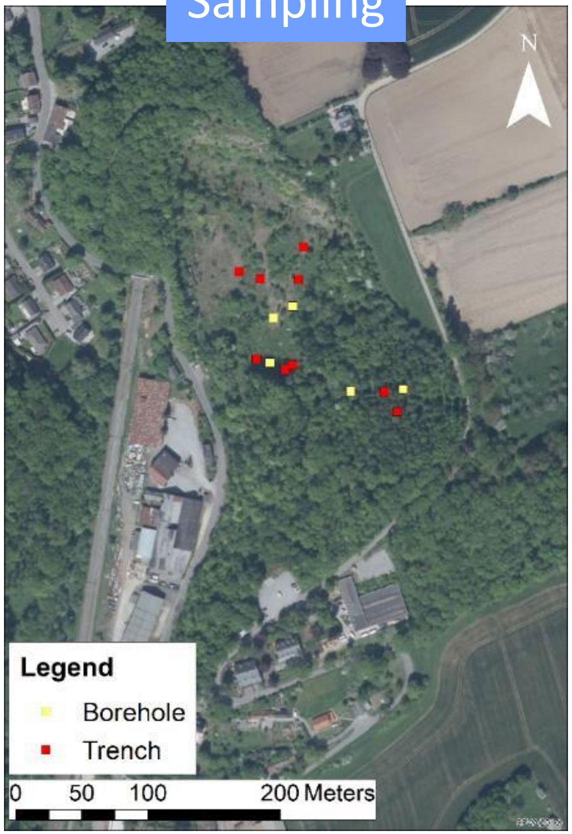
ERT/IP

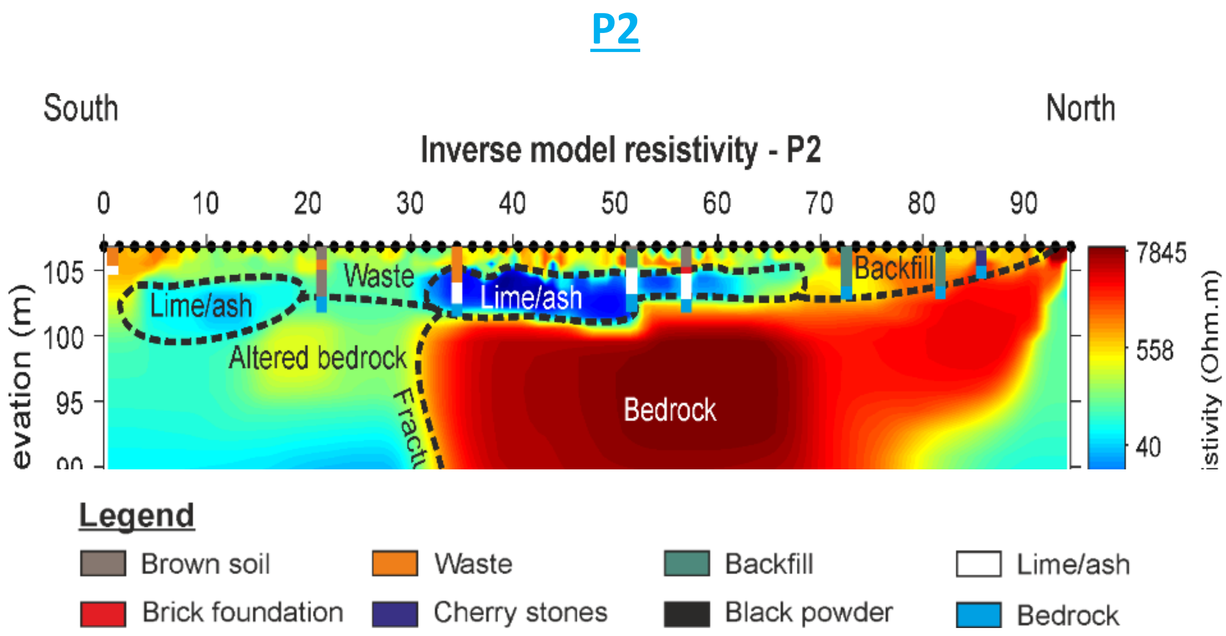


P1

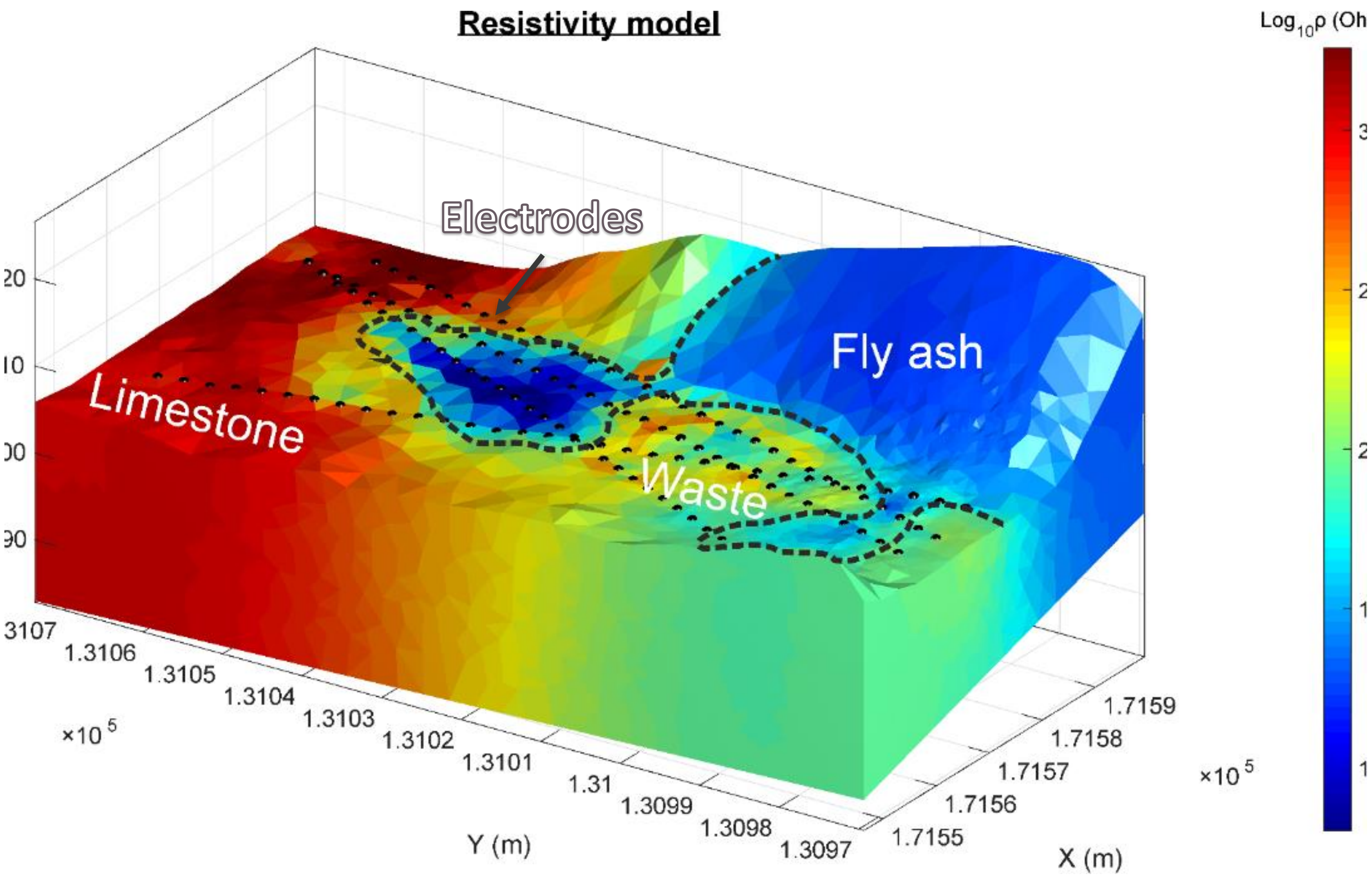


Validation with ground truth data



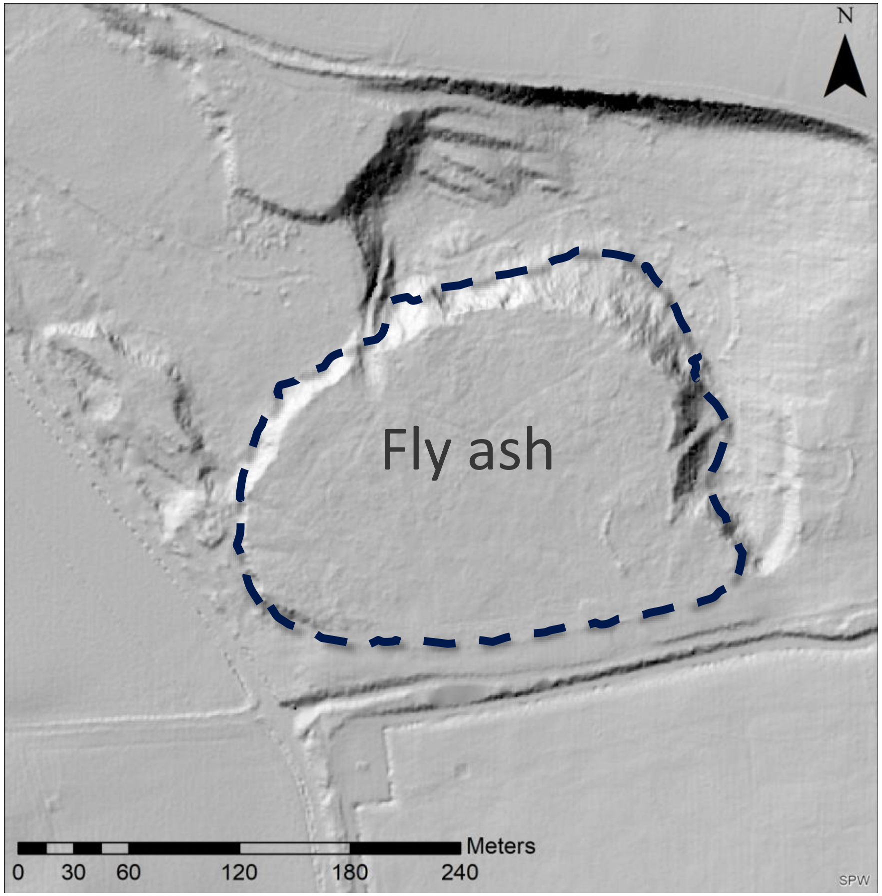


Refinement: 3D ERT



Site 2: Chalk quarry

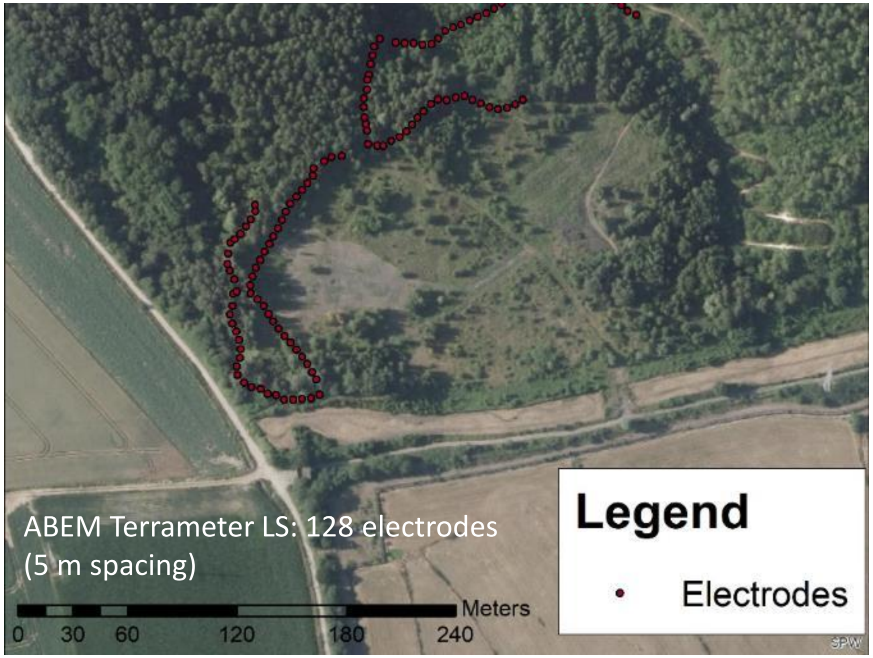
- Former chalk quarry
- Partially filled with fly ash
- Unknown thickness of fly ash deposits (>20 m expected)



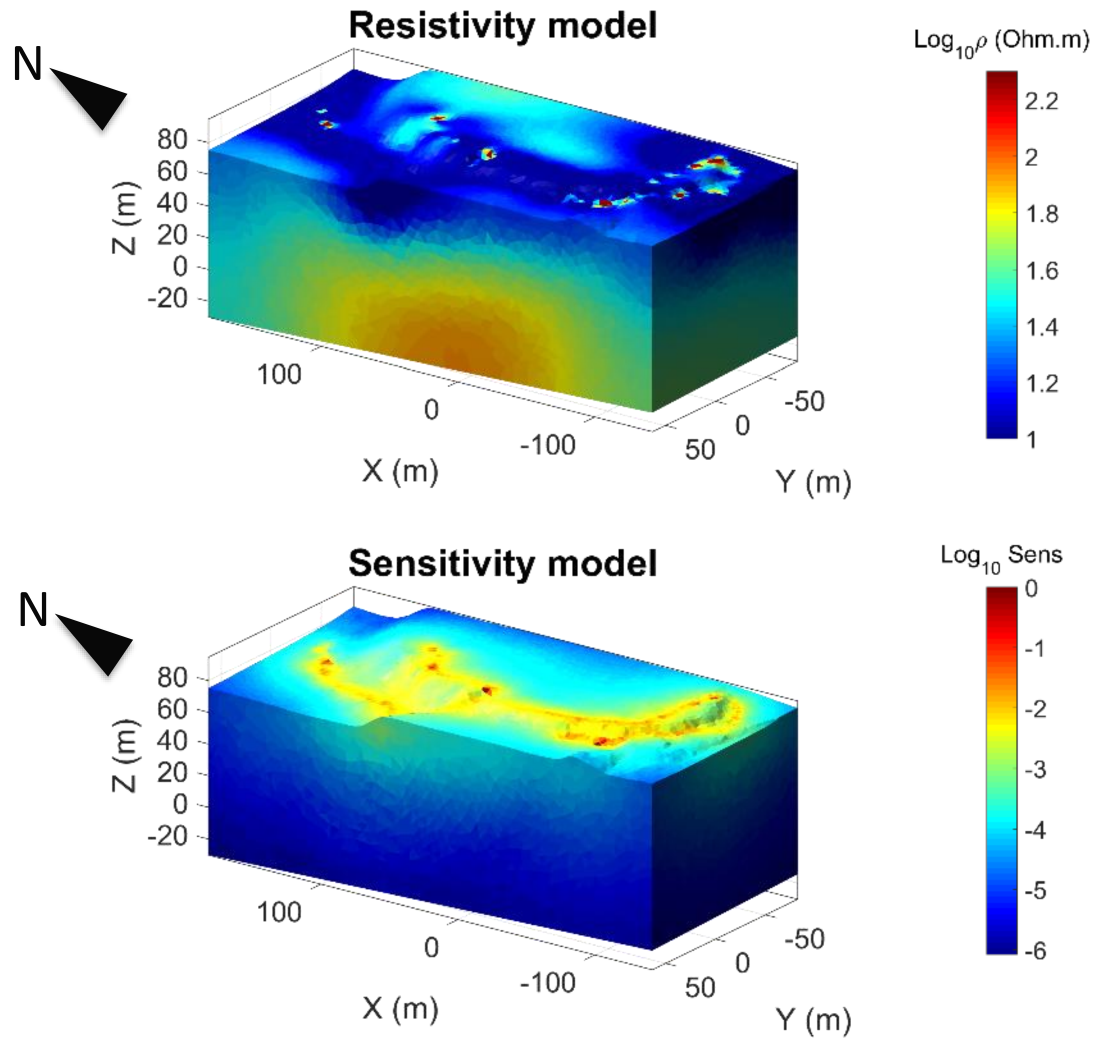
Spatial coverage: ERT

- Only ERT measurements
- 128 electrodes spaced by 5 meters
- « Random » electrode configuration with a constraint on the geometrical factor k

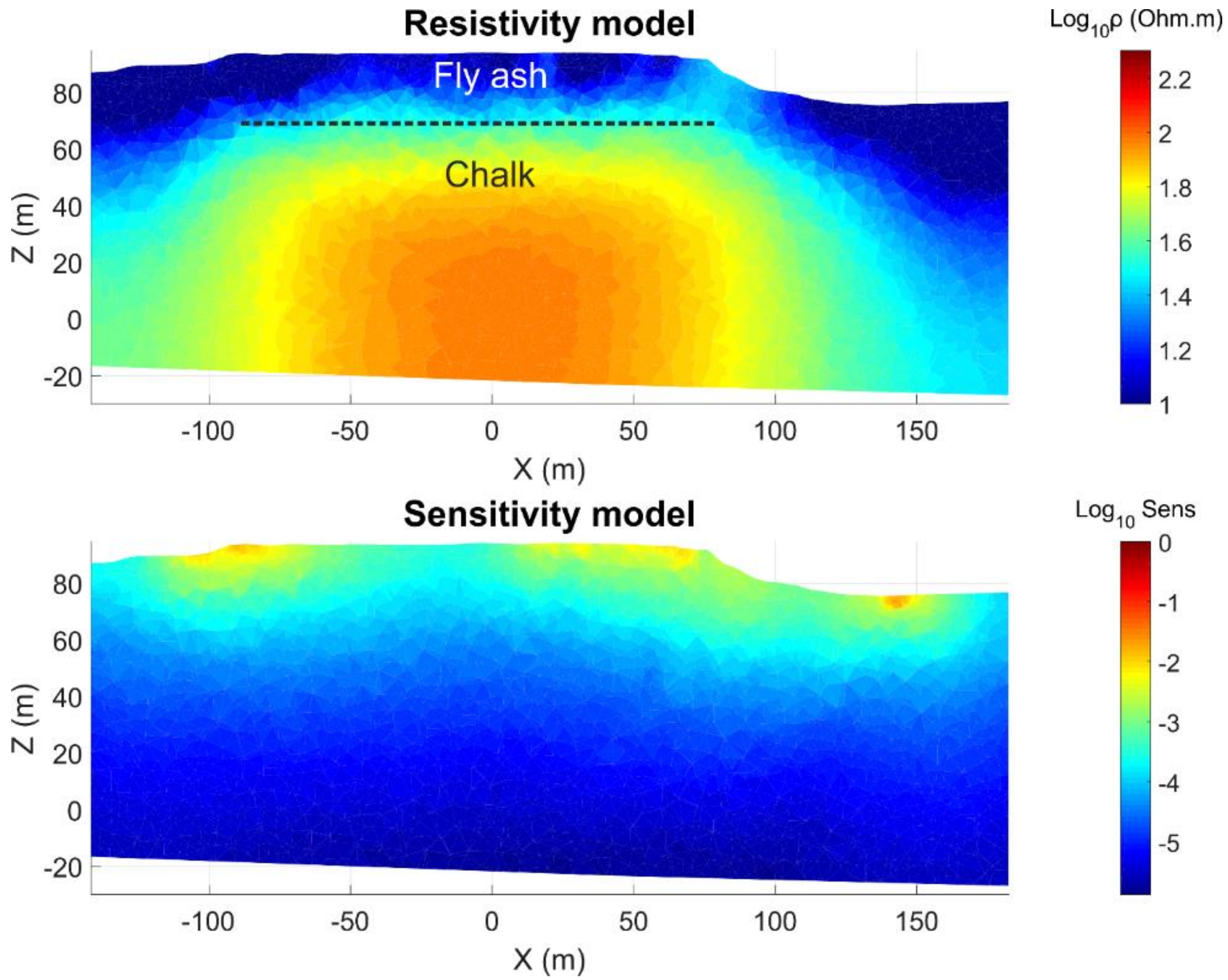
200 < k <4000



Results: ERT


Resistivity model
N
Log10ρ (Ohm.m)
2.2
2
1.8
1.6
1.4
1.2
1
Z (m)
80
60
40
20
0
-20
100
0
-100
X (m)
50
0
-50
Y (m)
Sensitivity model
N
Log10 Sens
0
-1
-2
-3
-4
-5
-6
Z (m)
80
60
40
20
0
-20
100
0
-100
X (m)
50
0
-50
Y (m)

Results: ERT



Resistivity model
Fly ash
Chalk
Z (m)
X (m)
Log10ρ (Ohm.m)
Sensitivity model
Z (m)
X (m)
Log10 Sens

<u>Site 3</u>: Clay pit

- before 1950s:

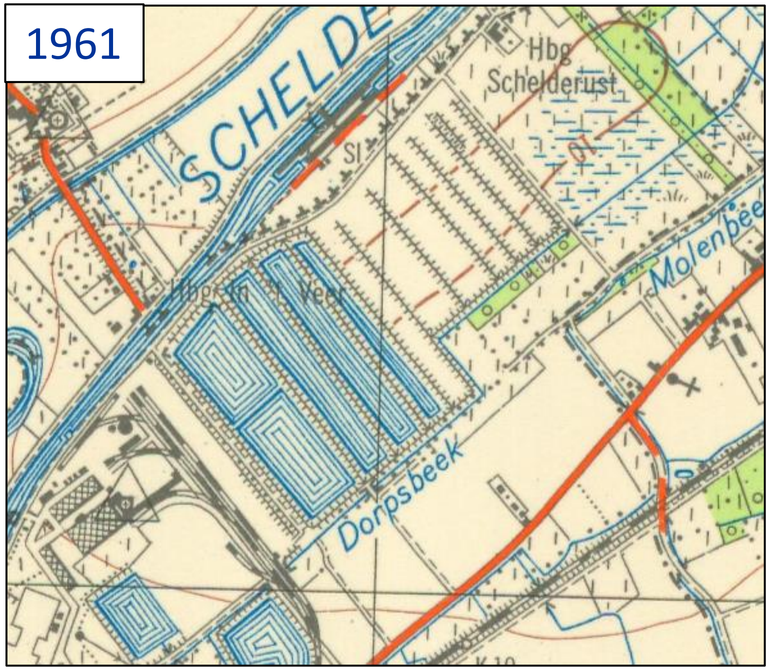
  Clay pit

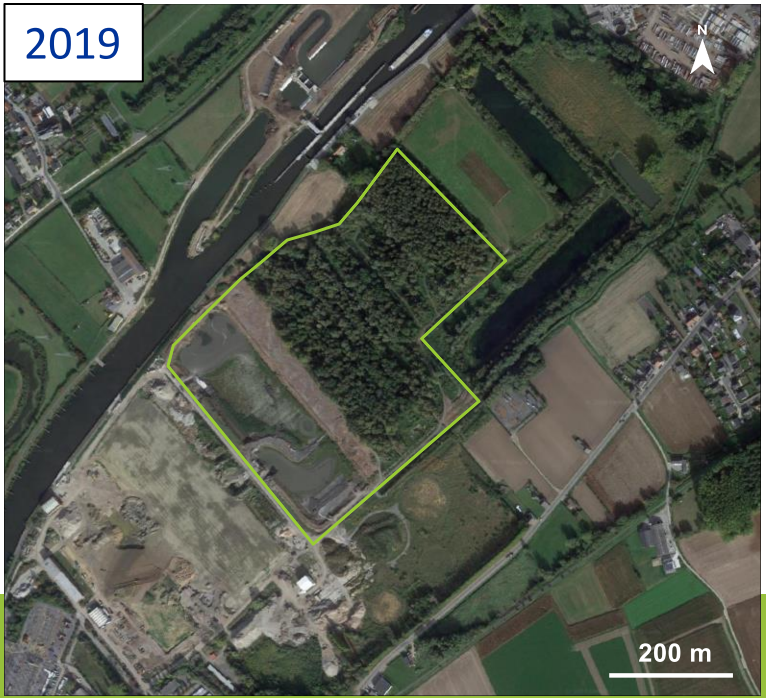
- 1958-1969:

  Fly ash landfill coal-fired power plant: hydraulic transportation to sediment basins

- 1970-1995:
  - Fly ash landfill
  - Commercial and public waste landfill (east)

→ *Unknown thickness fly ash deposits (2–5 m)? Underlying clay?*

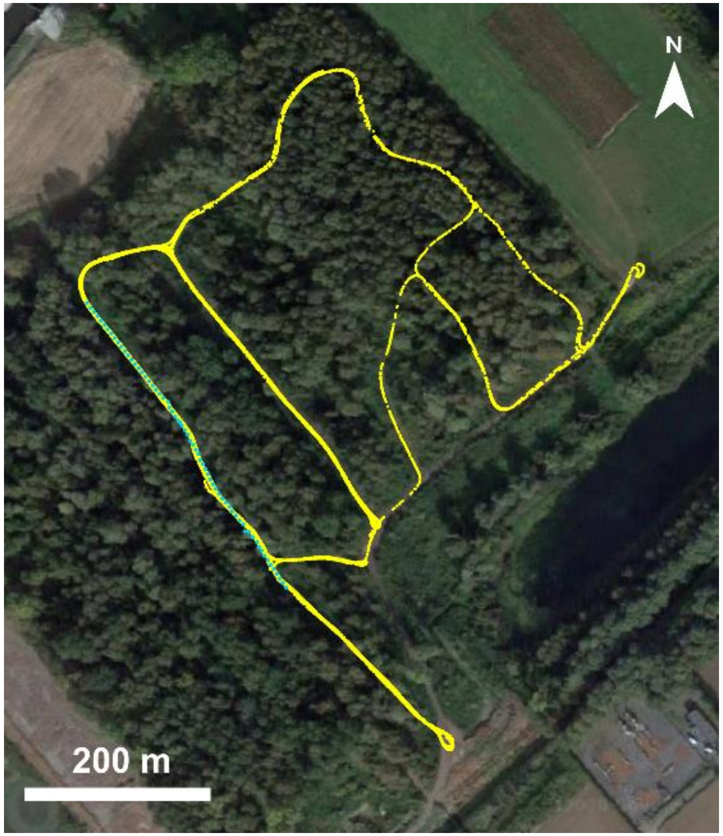




Spatial coverage: EMI & ERT/IP

2D ERT/IP

ABEM Terrameter LS: 64 electrodes at 3 m spacing



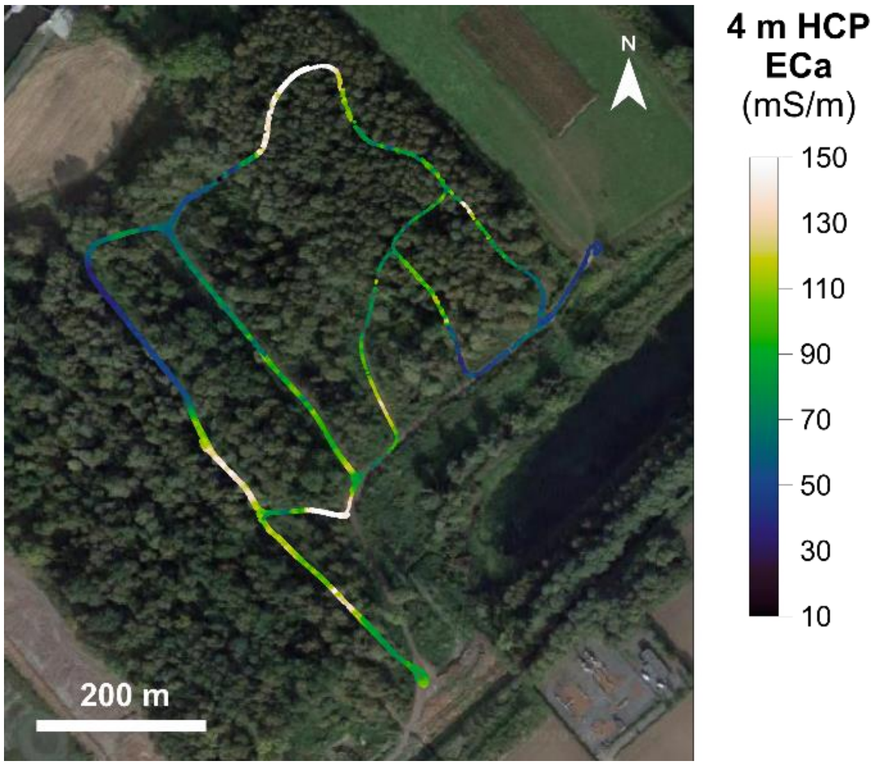
- ERT/IP lectrodes
- EMI measurement points

EMI

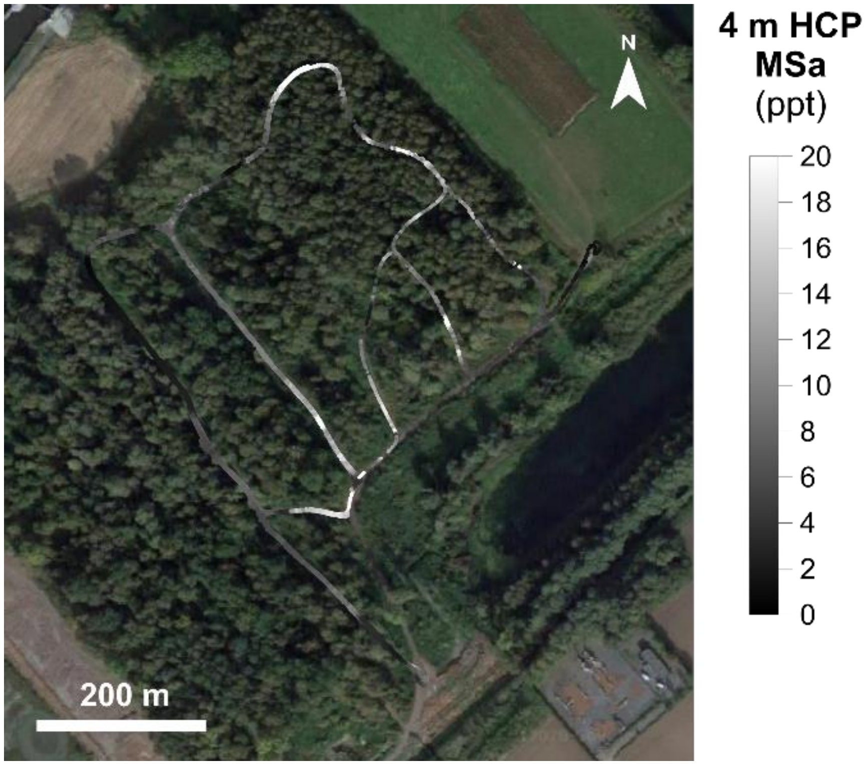
Mobile survey with DUALEM-421S: sampling rate 5 Hz, avg. driving speed 8.6 km/h, avg. sampling interval 0.5 m

Results: EMI

Apparent electrical conductivity



Apparent magnetic susceptibility



Note: Apparent measurement values assuming conditions of low induction number

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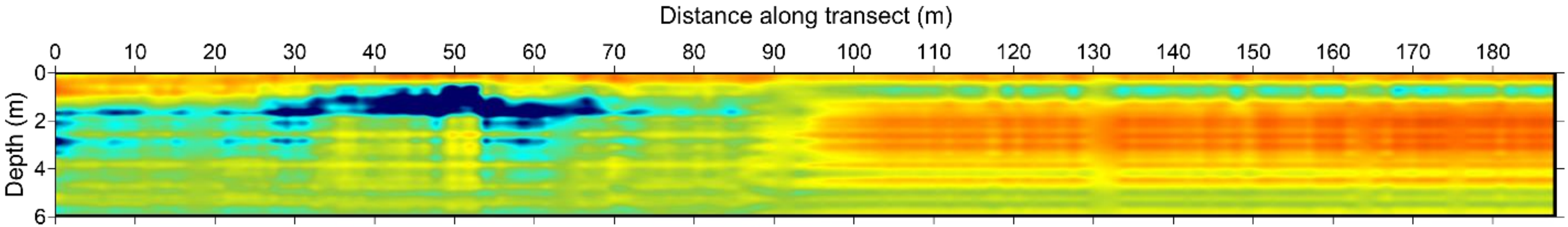
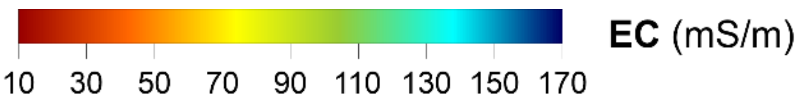
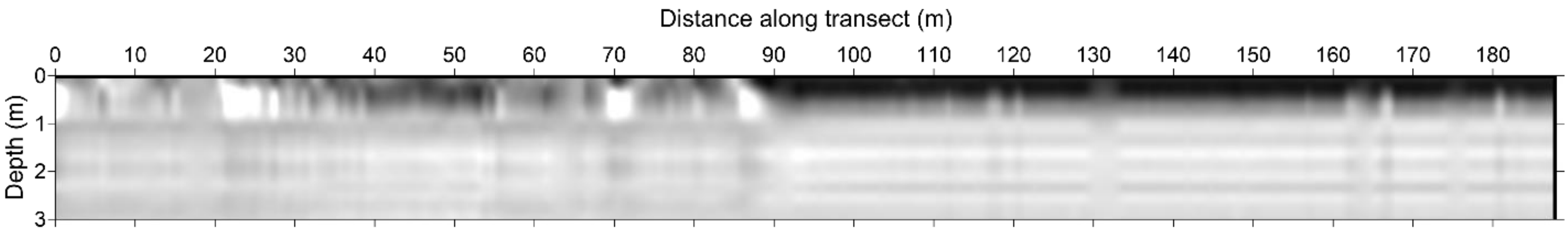
Results: EMI

Preliminary results of a non-calibrated **1D inversion** using a **Kalman ensemble generator** (Bobe et al., 2019) along the transect covered by ERT/IP

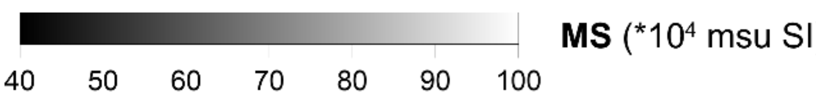


Note the strongly exaggerated depth scale used in both plots!



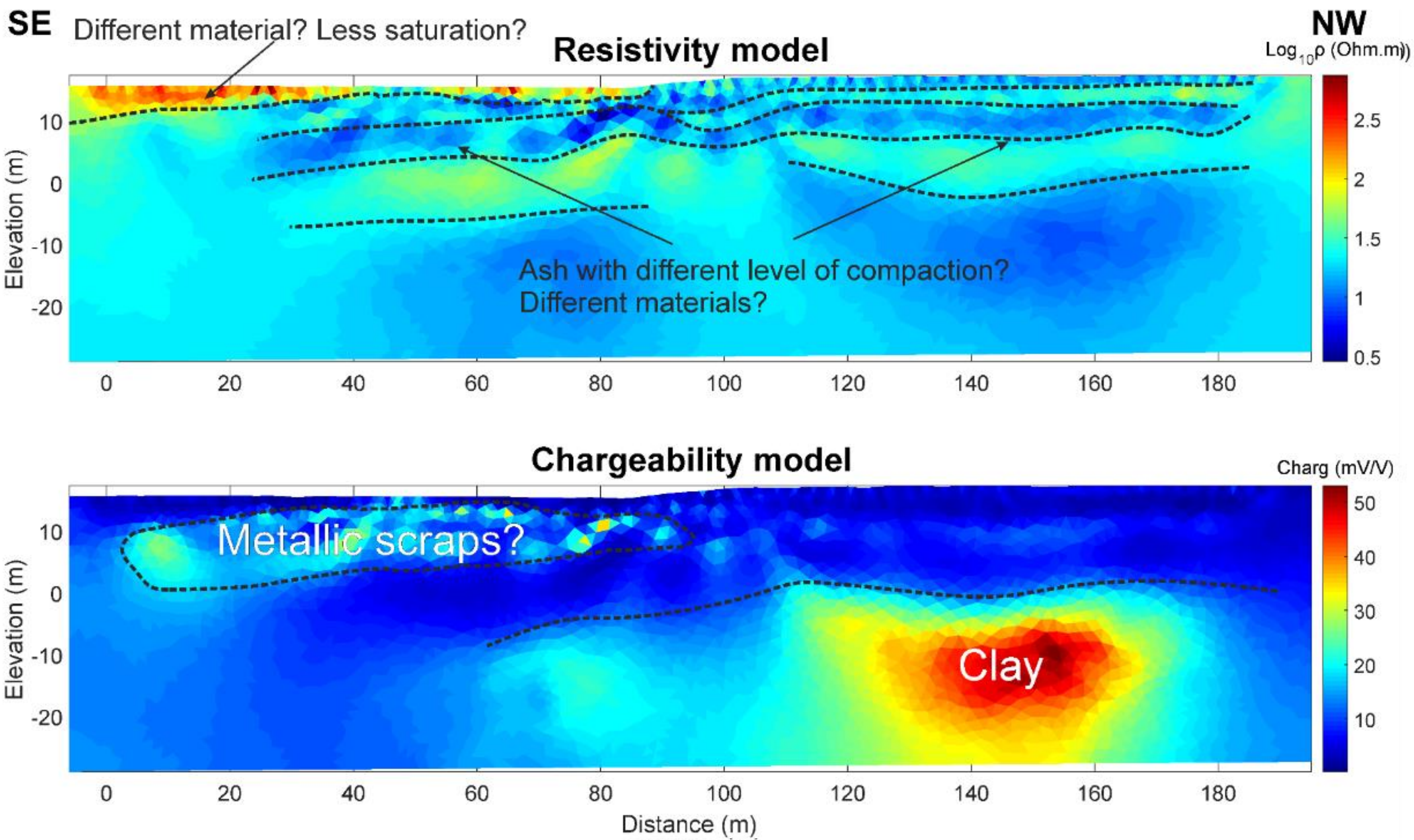


Very shallow depth of investigation for MS!



Bobe, C., Van De Vijver, E., Keller, J. Hanssens, D., Van Meirvenne, M., & De Smedt, P. (2019). Probabilistic inversion of frequency-domain electromagnetic data using a Kalman ensemble generator. *IEEE Transactions on Geoscience and Remote Sensing*, 58(5), 3287-3297. https://doi.org/10.1109/TGRS.2019.2953004

Results: ERT/IP



Preliminary conclusions and perspectives

- FA deposits investigated generally exhibit high electrical conductivity (resp. low electrical resistivity) presumably due to high specific surface and the presence of conductive minerals
- High magnetic susceptibility observed presumably explained by the presence of magnetic oxides in FA (± 30% of iron oxides in FA are magnetic)

Further field and laboratory experiments required to validate these first results and identify the main factors explaining the observed geophysical response

Thank you for reading this presentation!

David, Itzel, Hadrien, Christin, Hugo, Fred, and Ellen

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