Interreg North-West Europe
RAWFILL
European Regional Development Fund

EUROPEAN UNION

Co-funded by the Walloon region

CONTRIBUTION OF GEOPHYSICAL METHODS TO THE STUDY OF OLD LANDFILLS:

A CASE STUDY IN ONOZ (BELGIUM)

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RAWFILL project

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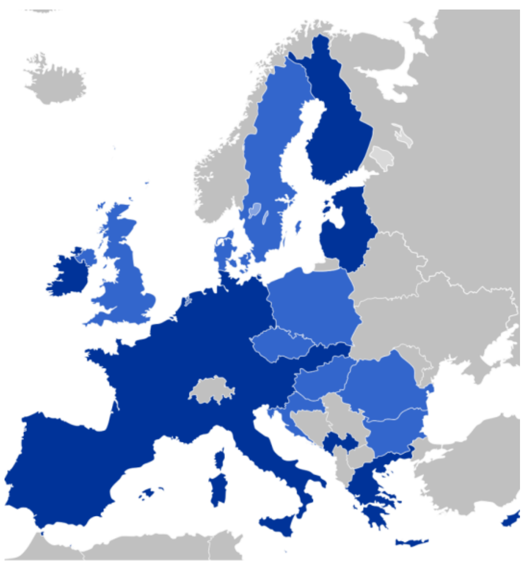
EUROPEAN UNION
North-West Europe
RAWFILL
European Regional Development Fund



100,000 –
500,000 landfills

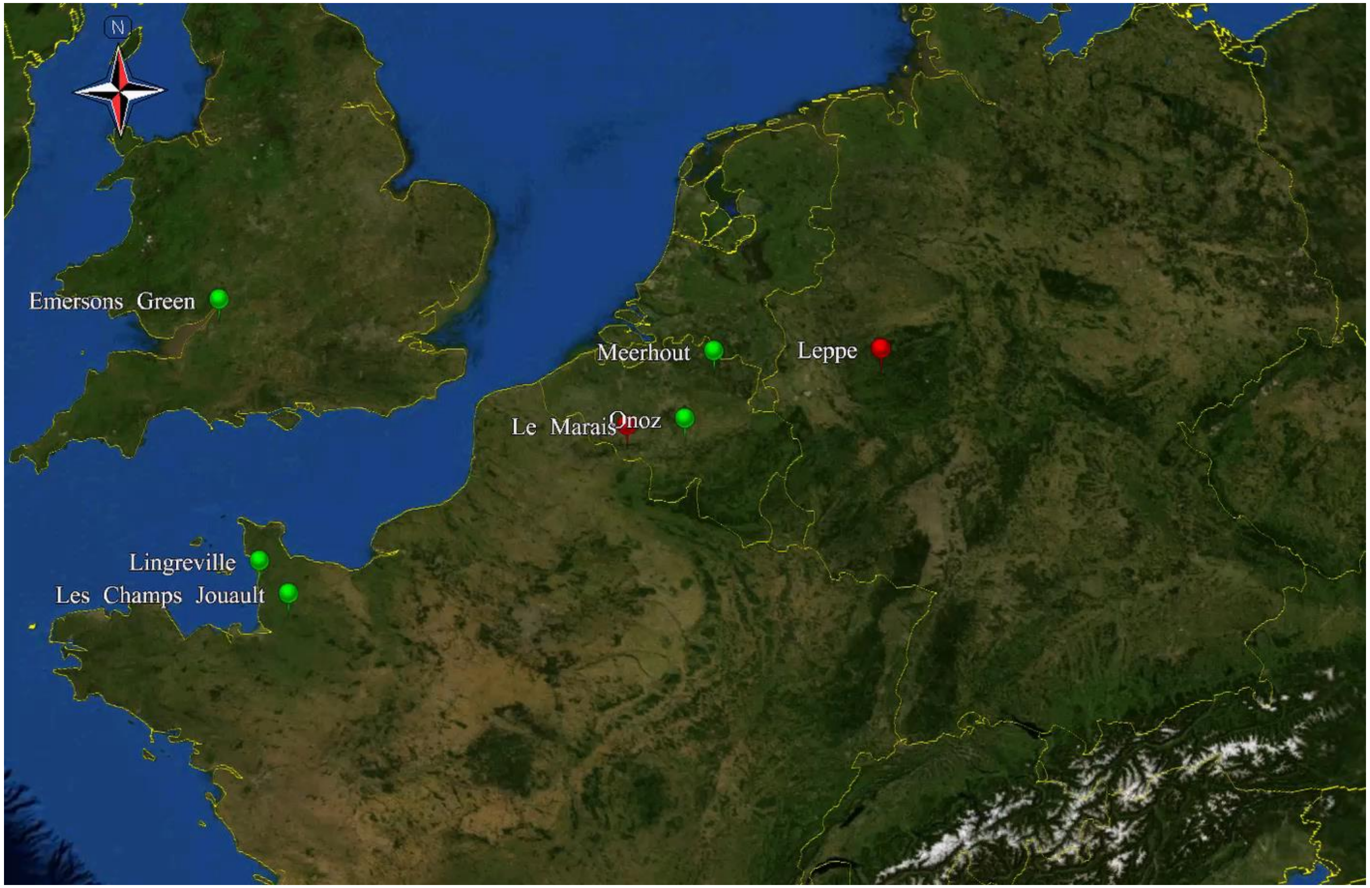
Landfill mining

Needs:
- Raw materials
- Energy sources
- Land

(Jones et al. 2013)

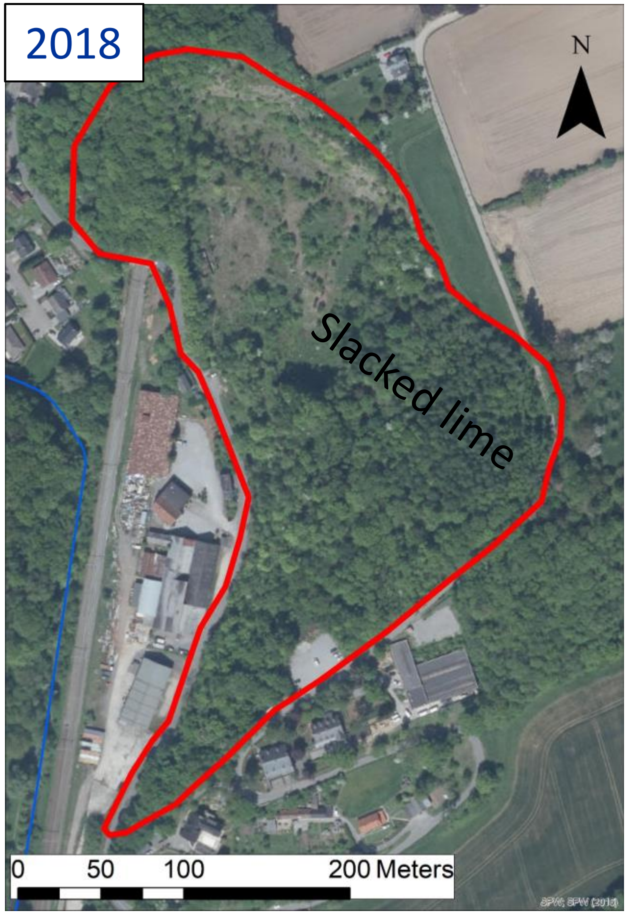
RAWFILL = Raw materials recovered from landfills
- focus on developing new methods to reduce the economic risk of LFM projects

Geophysics within RAWFILL



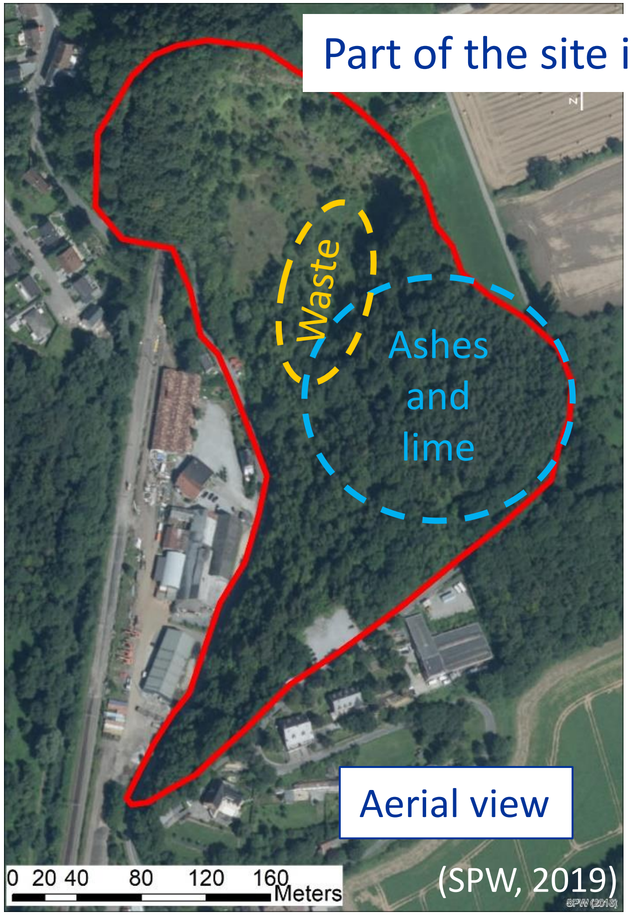
Context: history

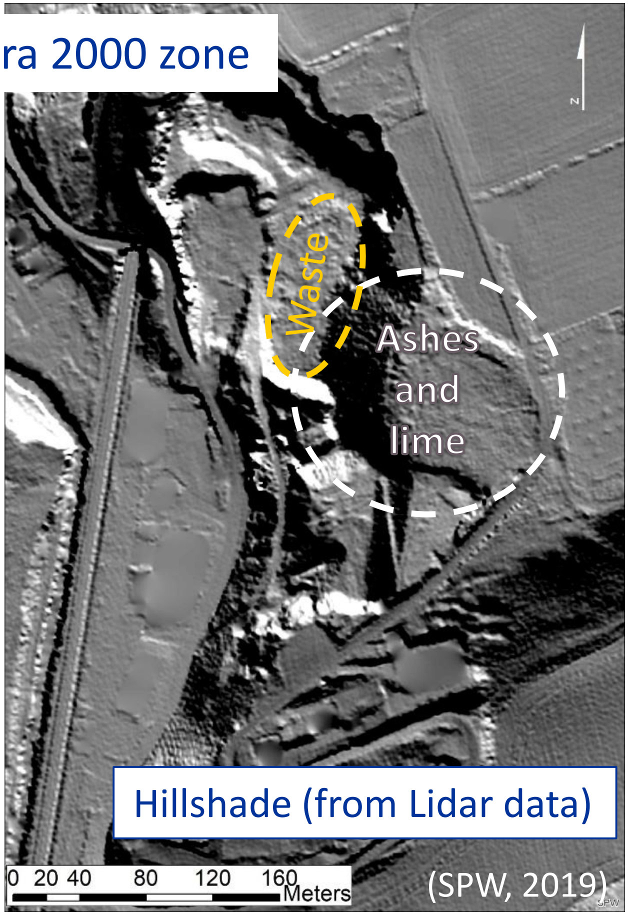
- 1902-1967:
  - quarry (limestone extraction)
- 1967-1976:
  - slacked lime deposits followed by ashes deposits
- 1982-1987:
  - heterogeneous wastes (inert, tires, rubber, plastic, car parts, household…)



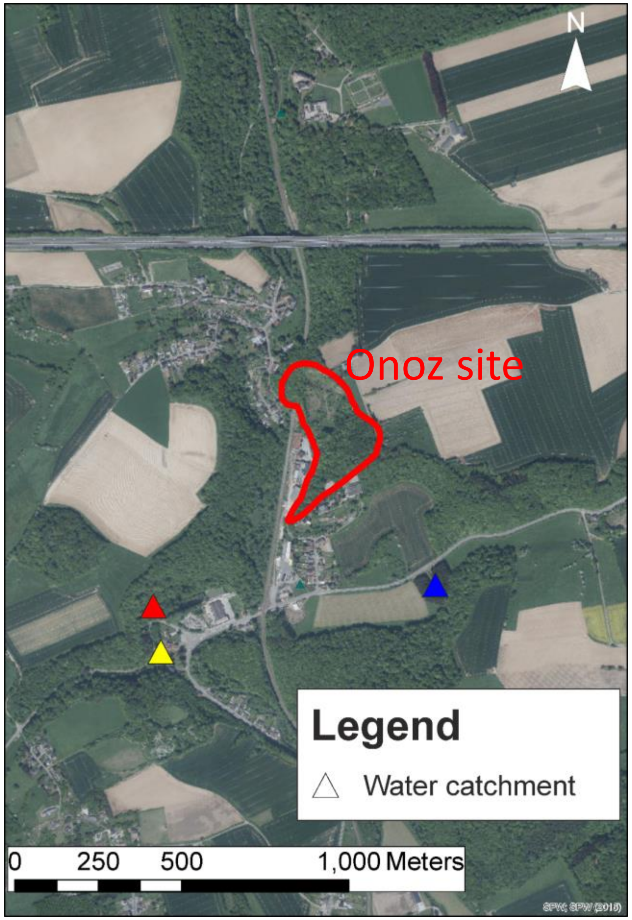
Context: current state

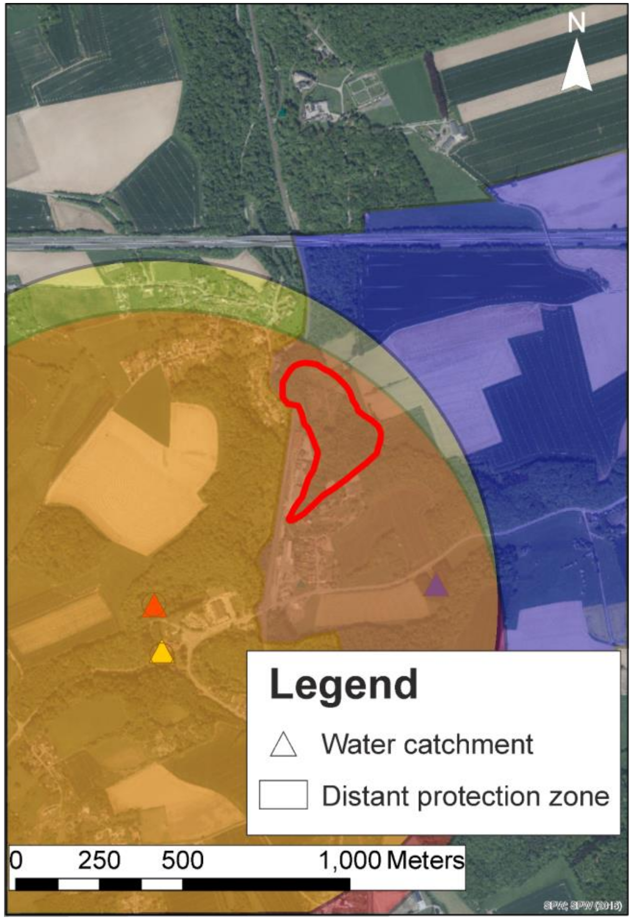
Part of the site is in a Natura 2000 zone





Context: water catchment





- Landfill is in the vicinity of three water catchments… and is located inside their distant protection zone

Selected methods

- Electromagnetic induction (EM)
- Magnetometry (MAG)
- Electrical Resistivity Tomography (ERT) and Induced Polarization (IP)
- Seismic method
  - Horizontal to Vertical Noise Spectral Ratio (HVNSR or H/V)

Mapping

Imaging

Soundin

Spatial coverage: EM & MAG

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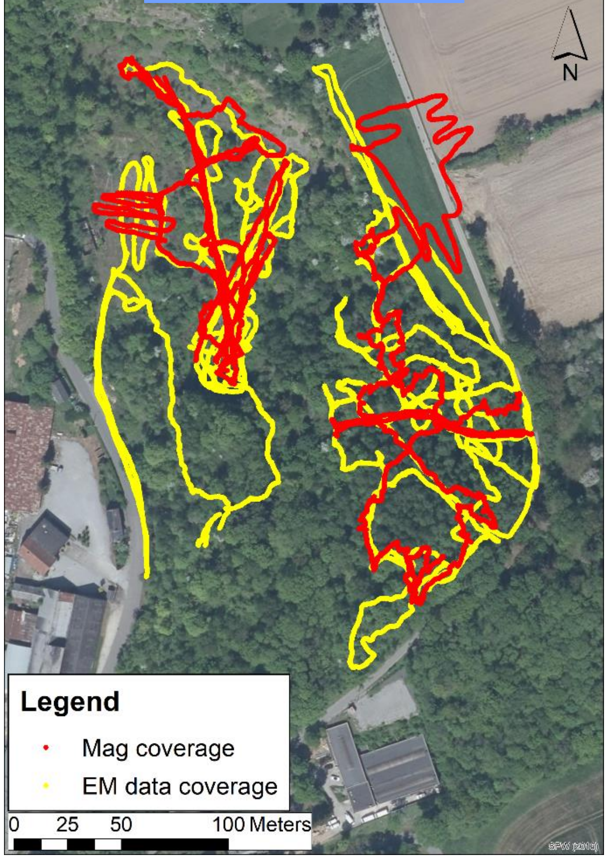
EM + MAG

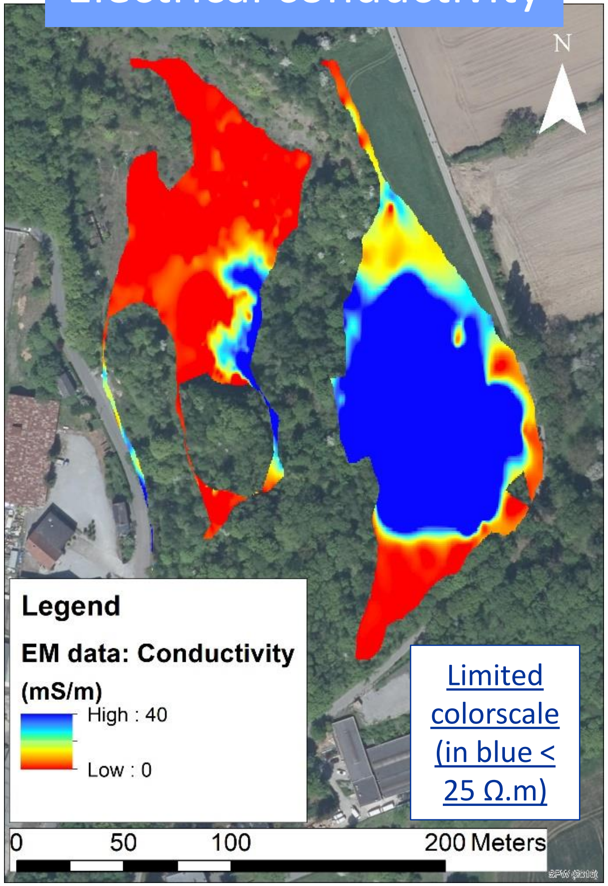


EM

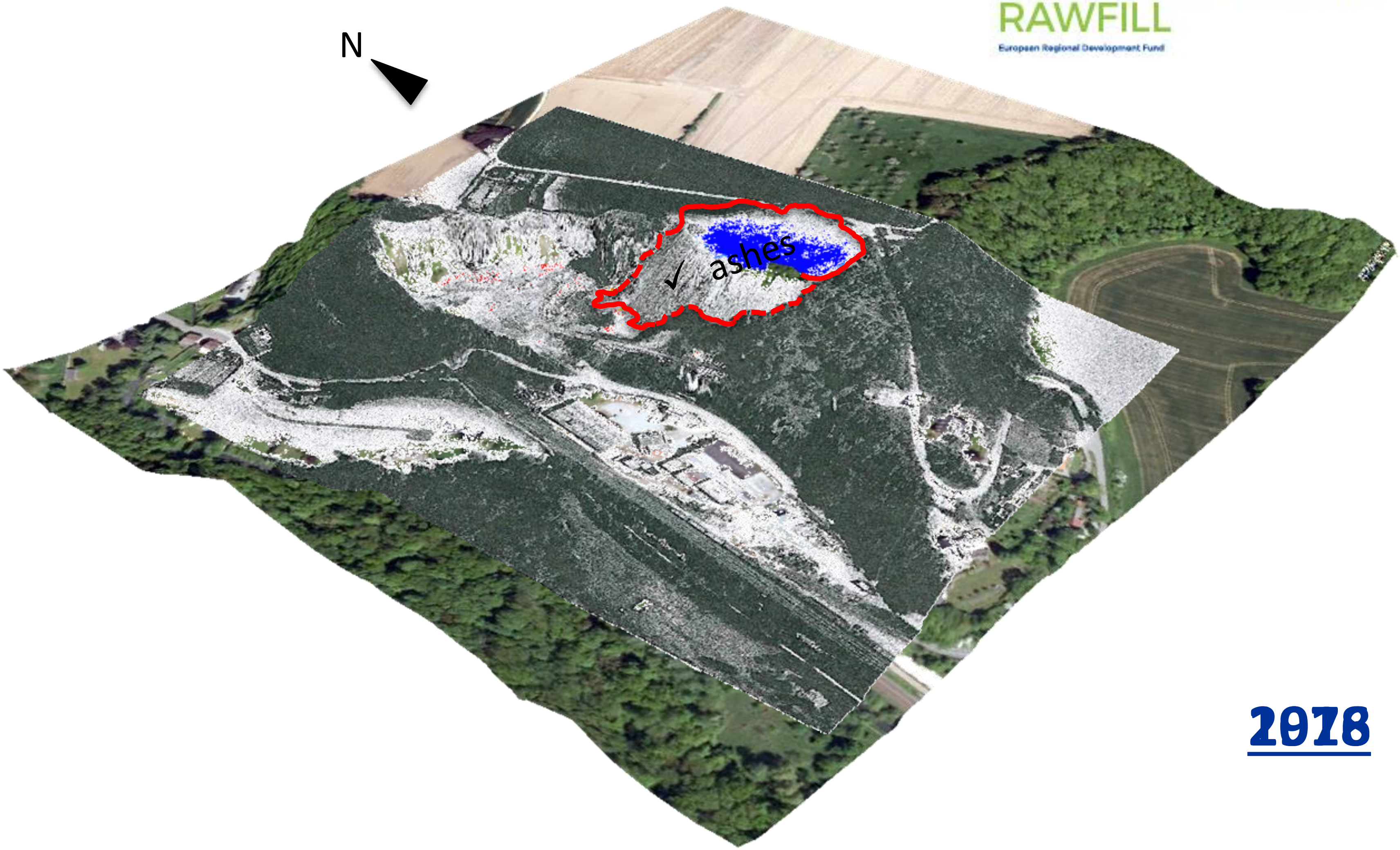
MAG

Results: EM at around 6 m depth

Electrical conductivity



Interpretation: EM



2018

Results: Magnetometry

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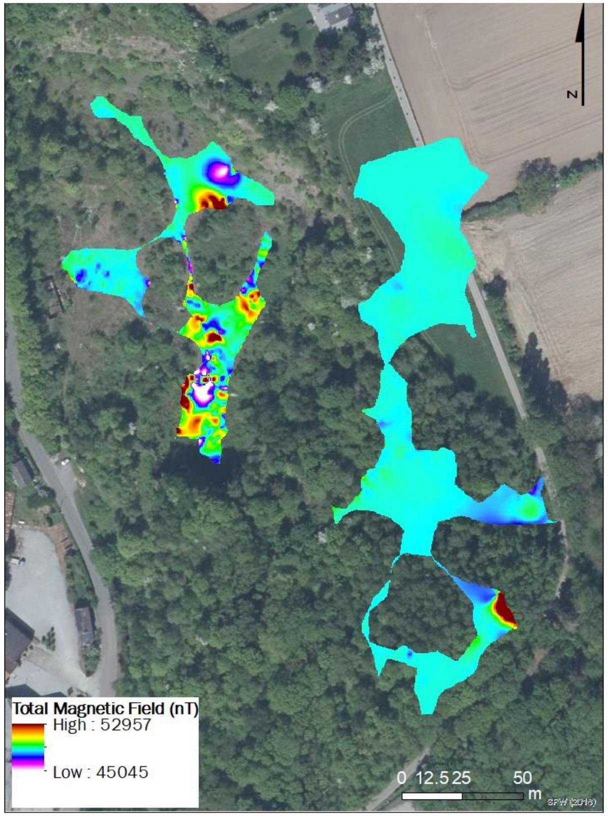
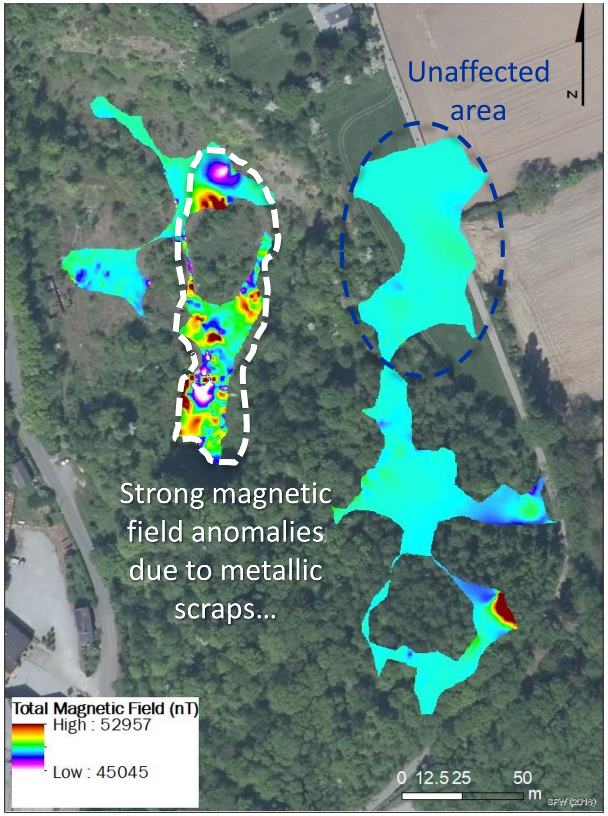
Total magnetic field



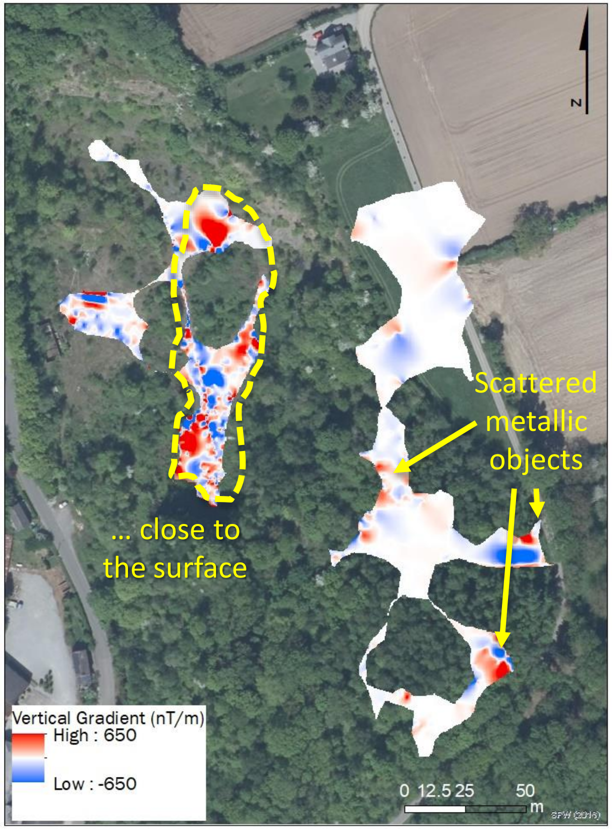
Vertical magnetic field

Interpretation: Magnetometry

Total magnetic field

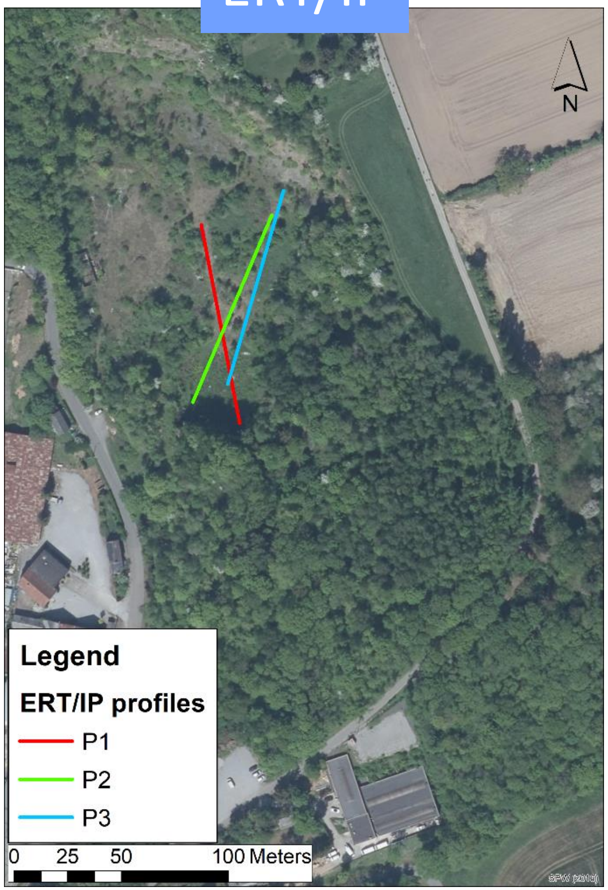


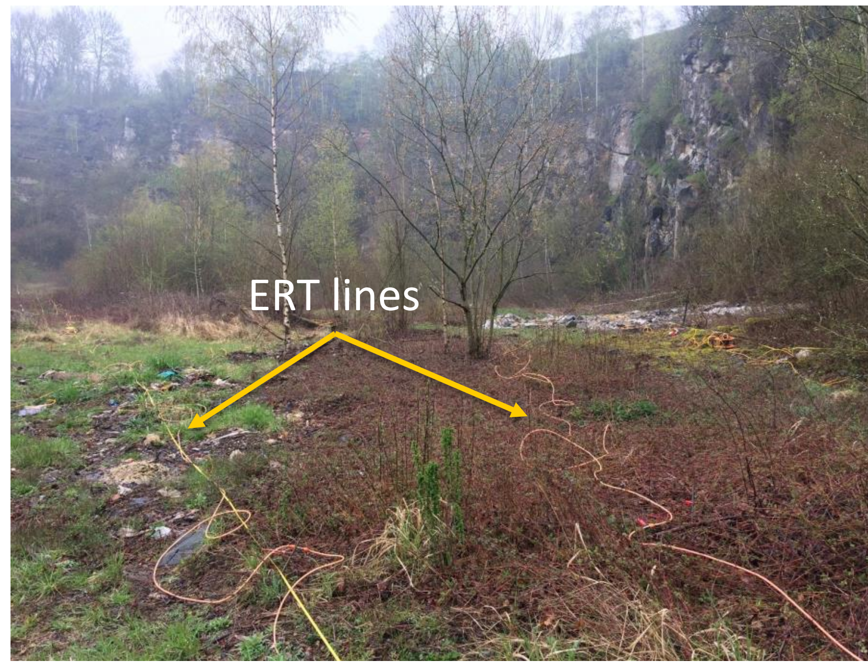
Vertical magnetic field



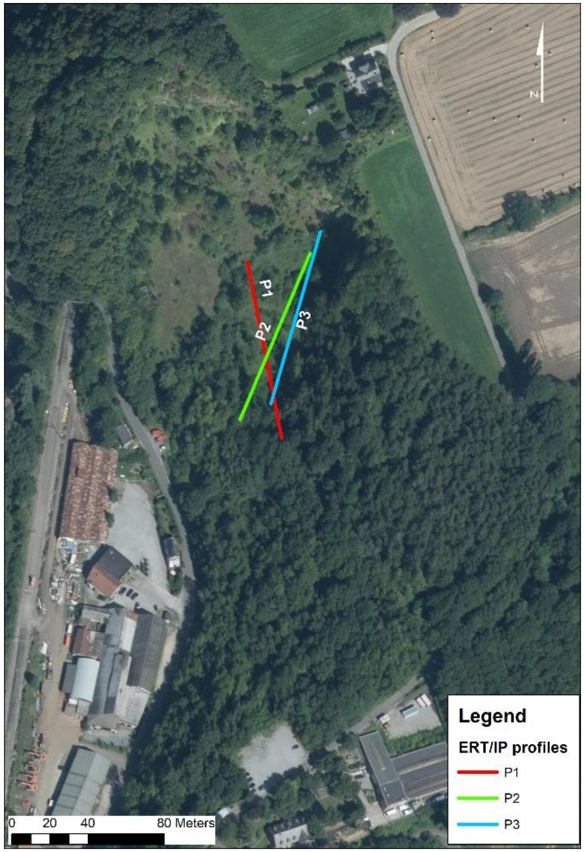
Spatial coverage

ERT/IP

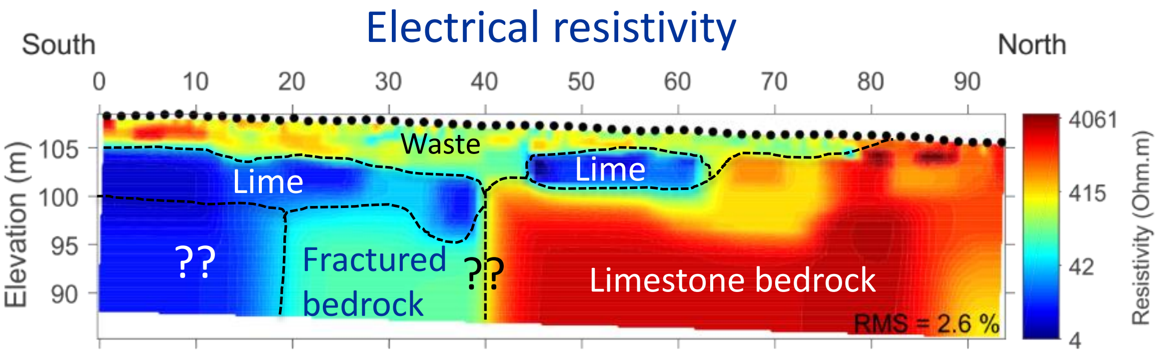




Results: ERT/IP



P1



Validation with ground truth data

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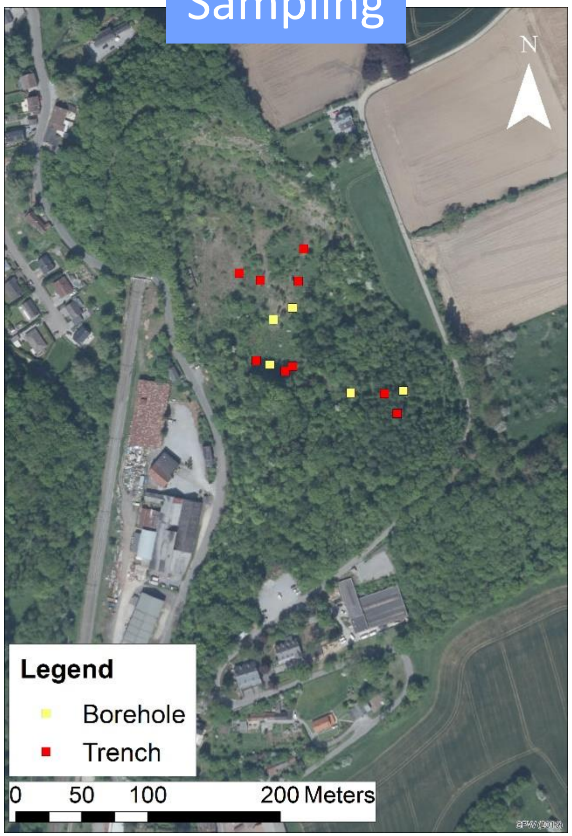
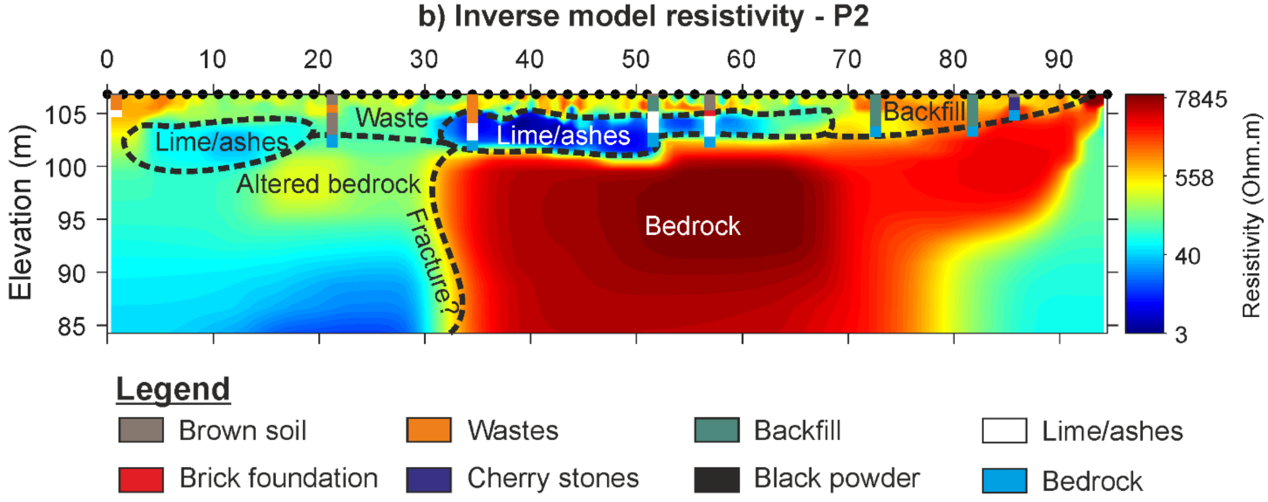
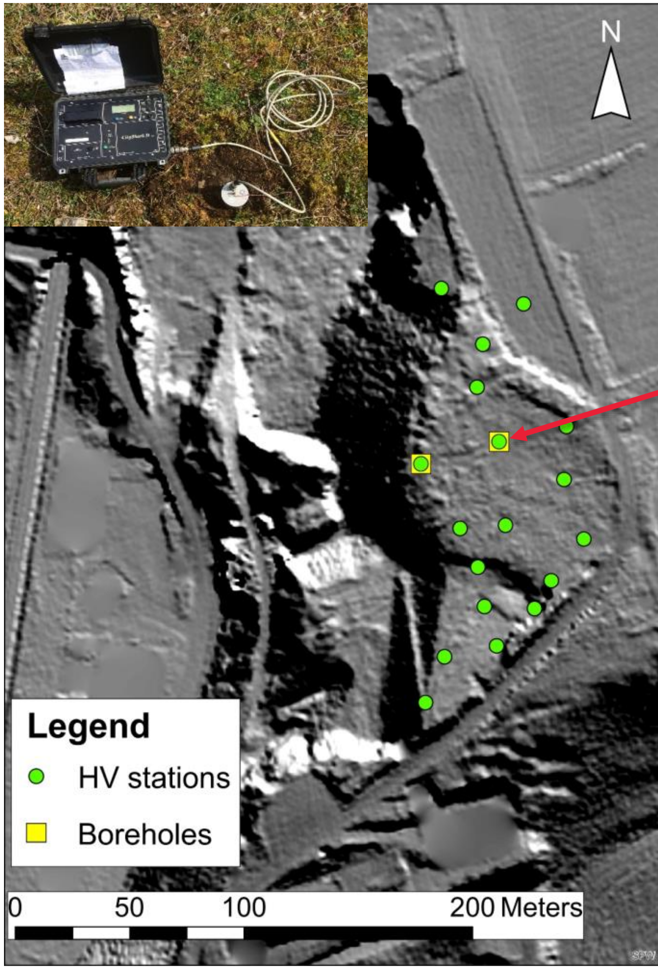
Sampling



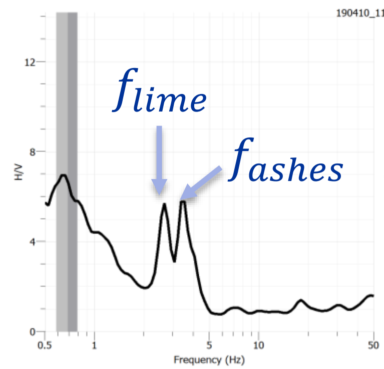
P2



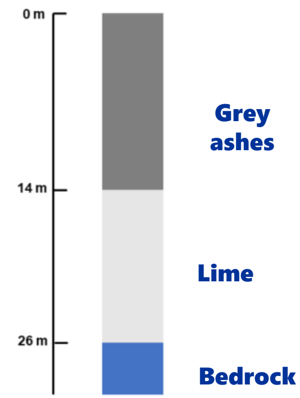
H/V measurements



H/V measurement



Borehole log



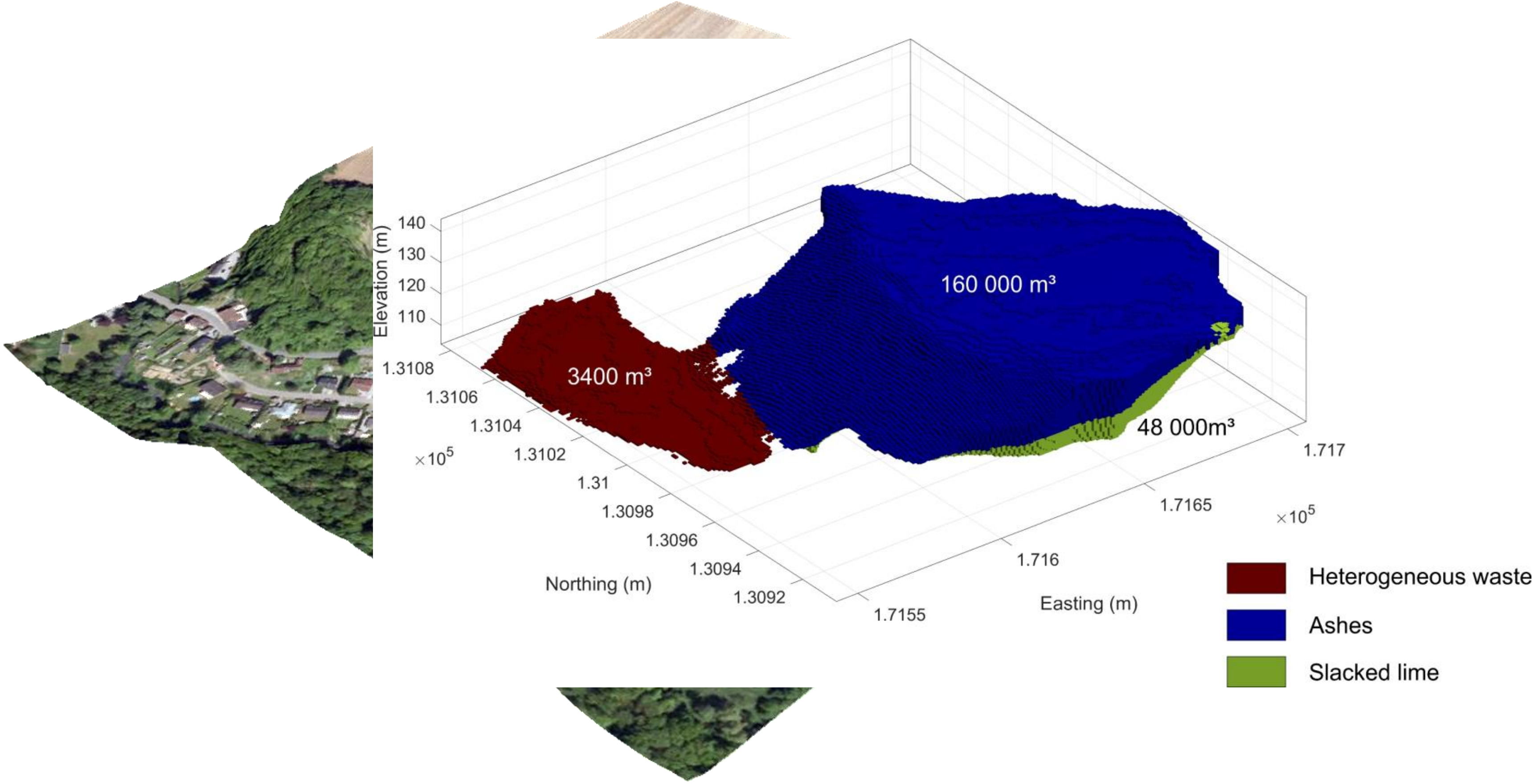
$$V_{s\,lime} = 318\,\frac{m}{s}$$

$$V_{s\,ashes} = 271\,\frac{m}{s}$$

Possible to estimate the thickness of ash and lime at other HV stations

(Debouny, 2019)

Resource distribution model



Summary: RAWFILL approach

1) Gather all available information
2) Use mapping methods (e.g. EM & Mag) to quickly delineate landfill extent, identify anomalies and decide upon location for more detailed 2D or 3D-surveys (ERT/IP, seismic)
3) Define a sampling plan based on geophysical results
4) Use ground truth data to calibrate and verify geophysical data
5) Build resource distribution model

In Onoz, this approach allowed to save up to 50% of characterization costs

Q&A

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Raw materials recovered from landfills

The Interreg North-West Europe Project is coordinated by SPAQuE and unites 8 partners from 4 EU regions.

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EUROPEAN UNION
North-West Europe
RAWFILL
European Regional Development Fund

Thank you!

Context

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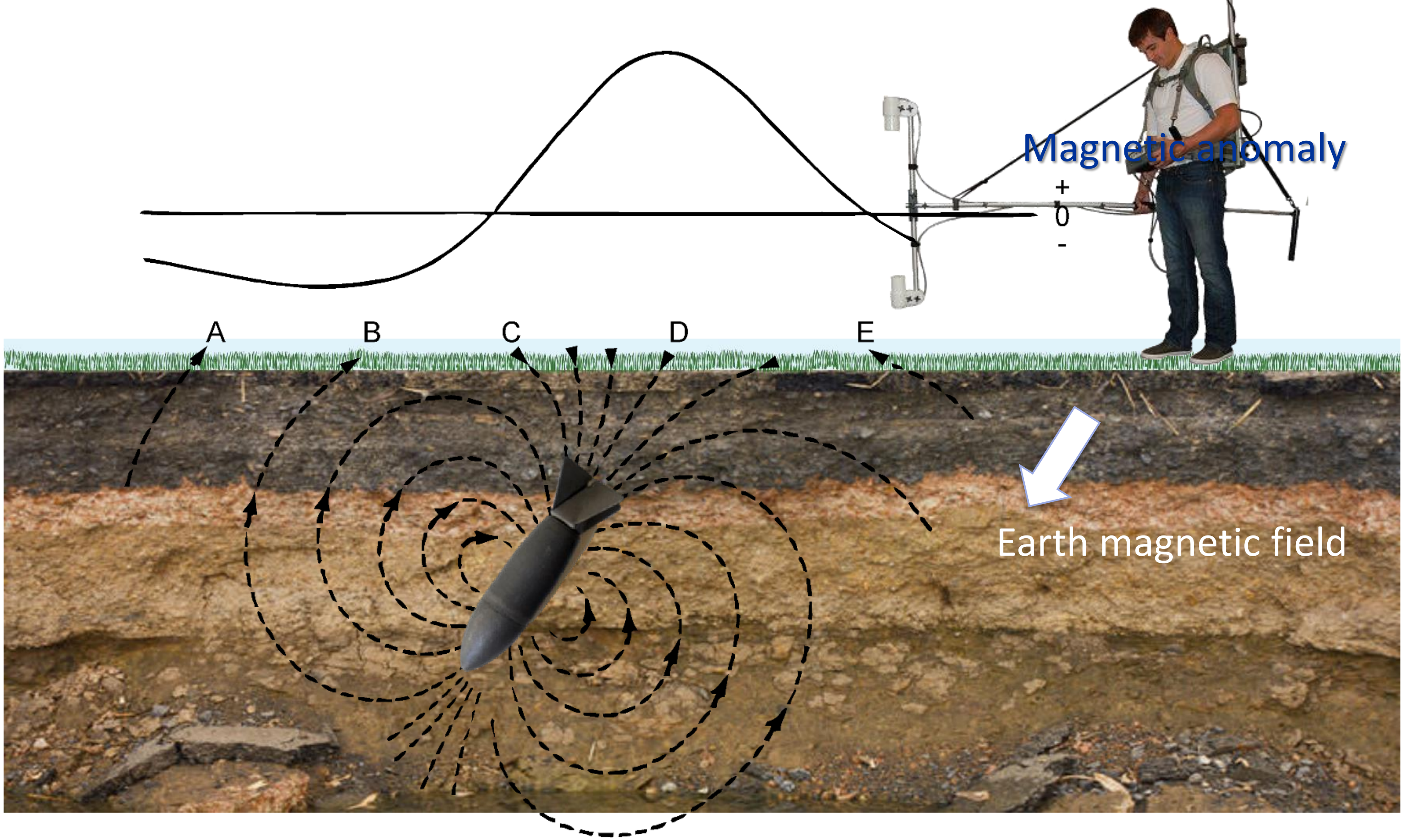
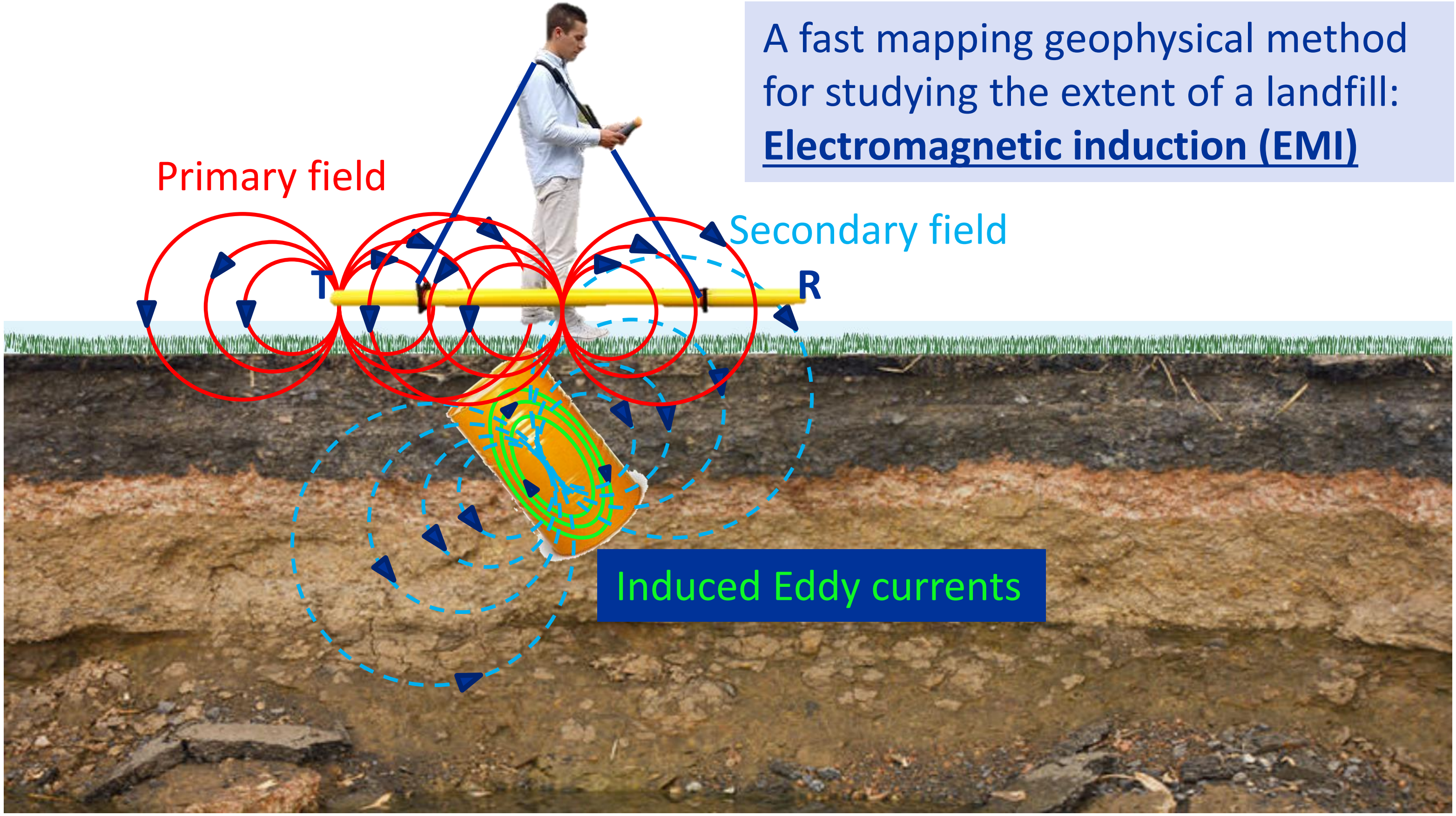
Methods

- Magnetometry



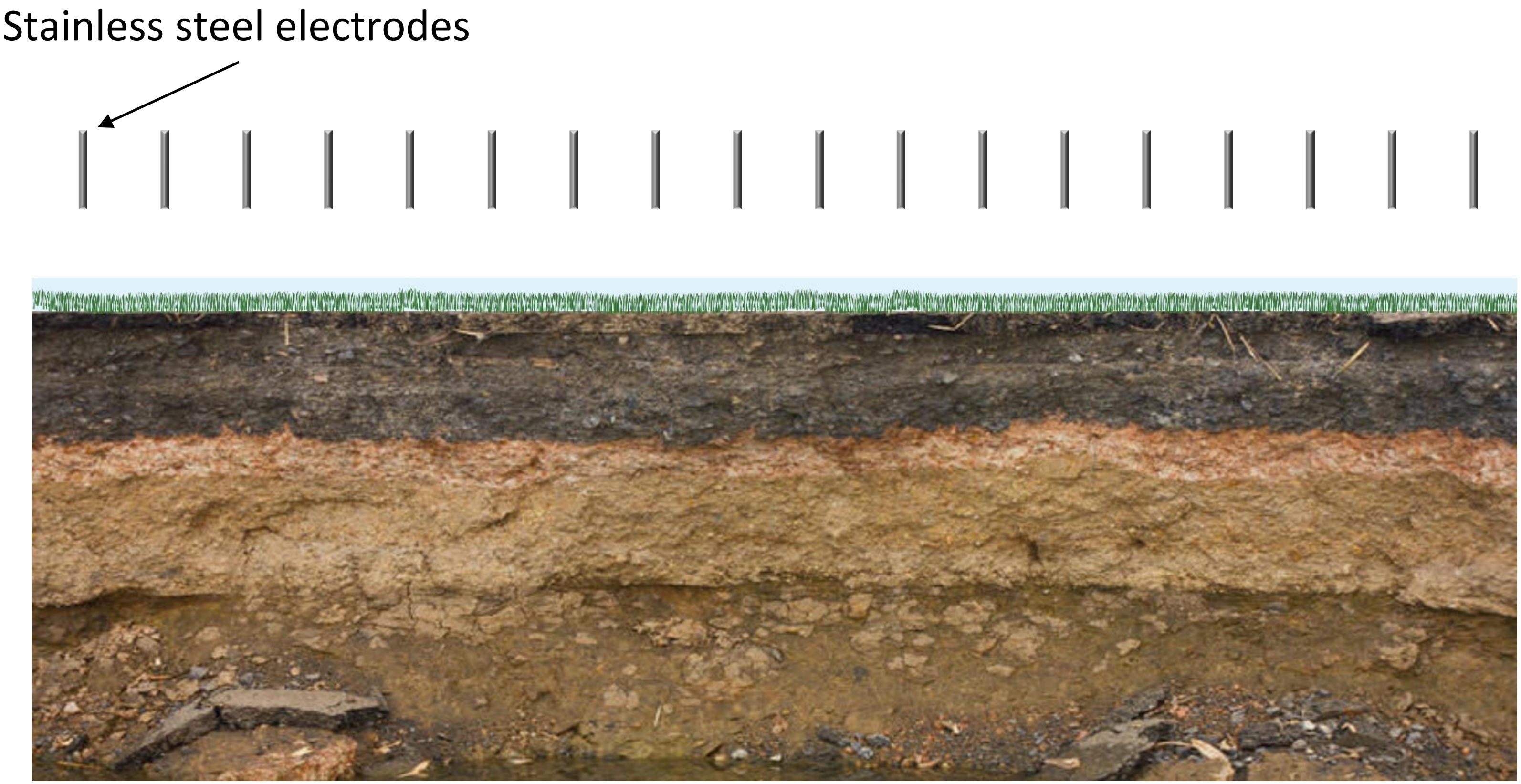
Methods

A fast mapping geophysical method for studying the extent of a landfill: **Electromagnetic induction (EMI)**



Methods

- ERT/IP



Methods

- ERT/IP

Methods

- ERT/IP

Méthodes utilisées

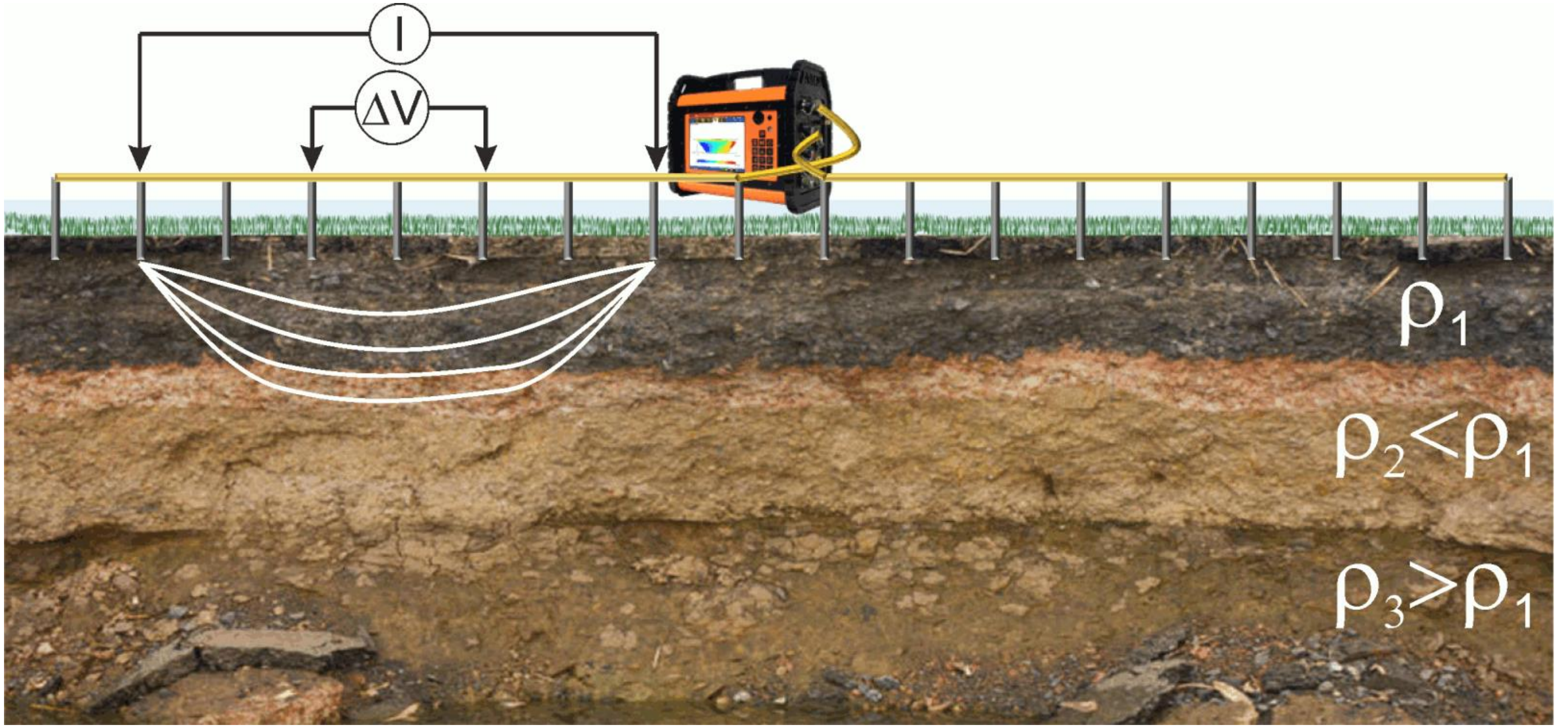
- ERT/IP

Methods

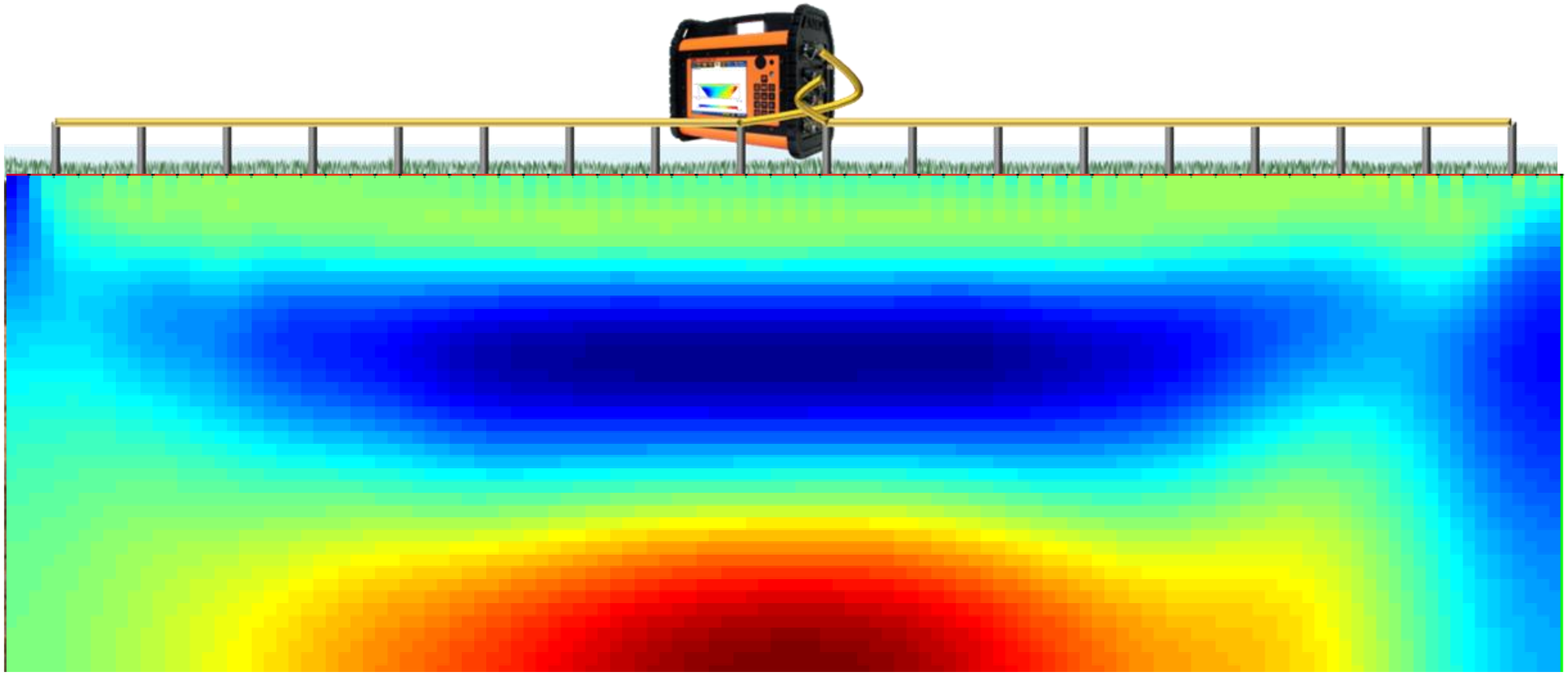
- ERT/IP

Methods

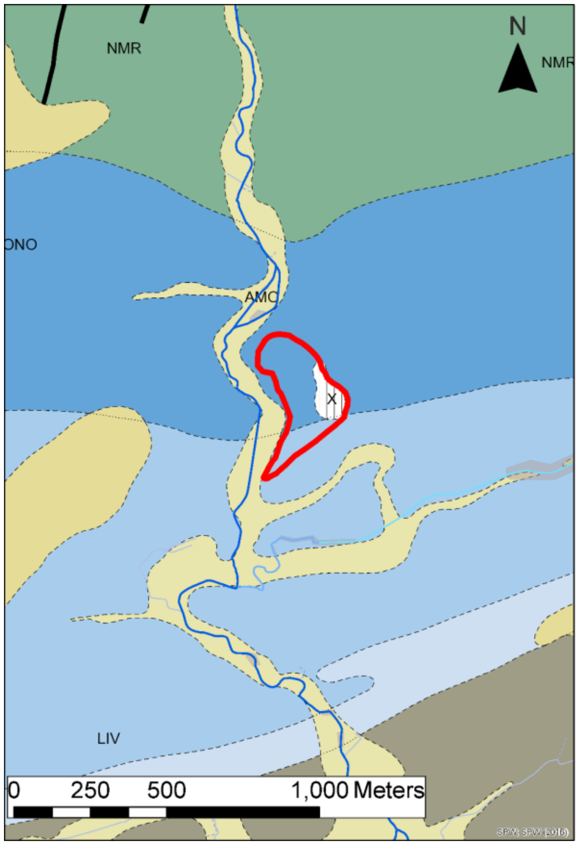
- ERT/IP



Methods



Site overview: geology

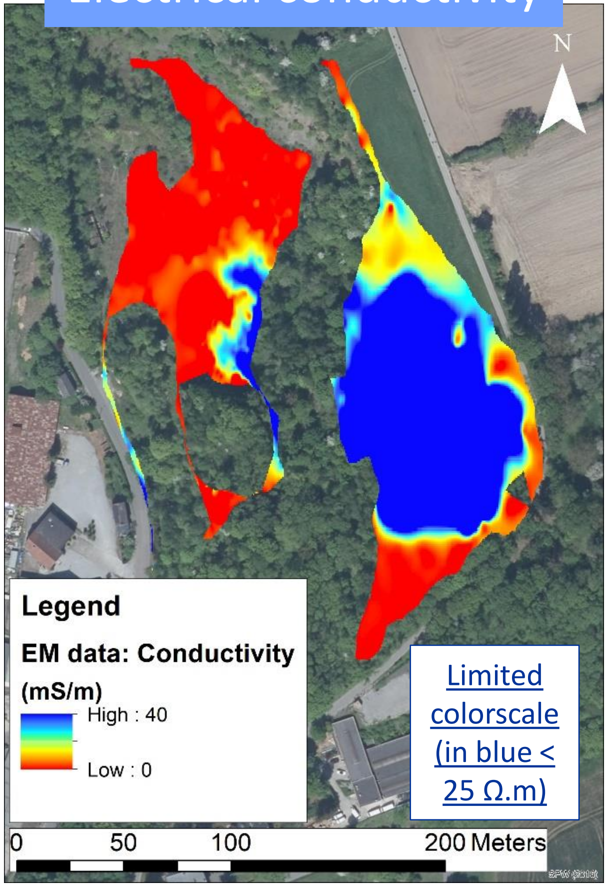


Legend

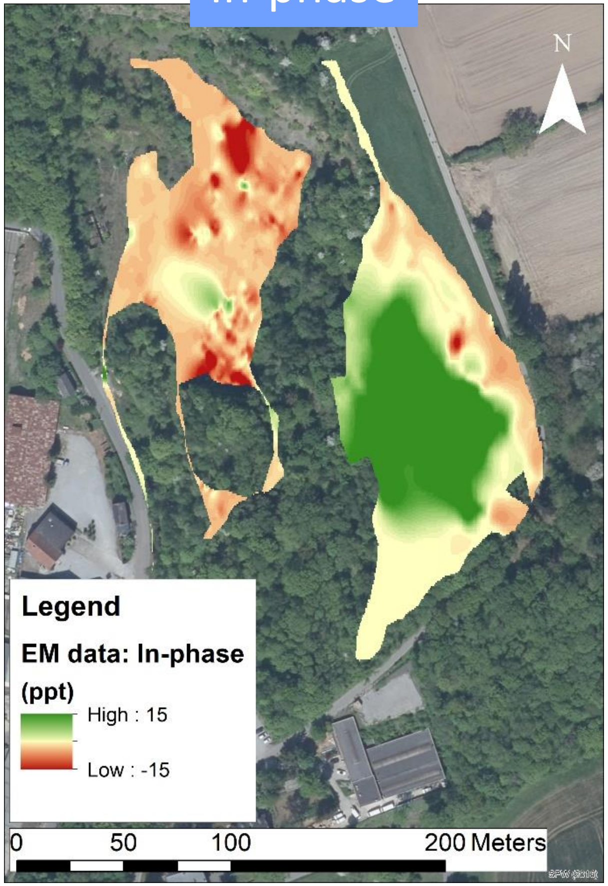
- Orneau river
- Modern alluvium - AMO
- Bruxelles formation - BXL
- Houiller group - HOU
- Hoyoux group - HOY
- **Lives Formation -LIV: Well-bedded limestones**
- **Onoz Formation - ONO: Thin- to thick-bedded limestones**
- Namur Formation - NMR

Results: EM at around 6 m depth

Electrical conductivity



In-phase



Results: ERT/IP

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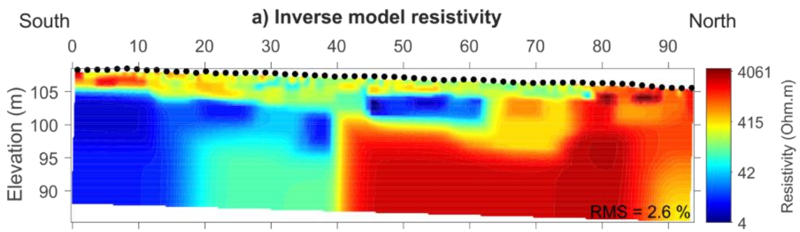
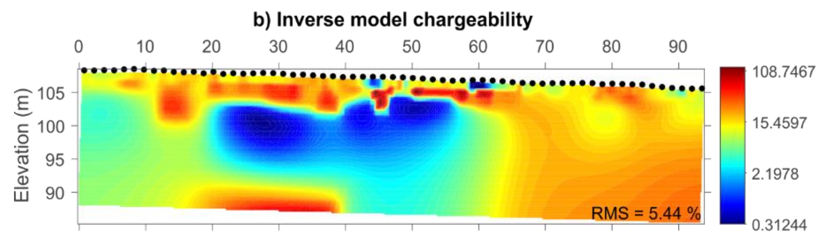
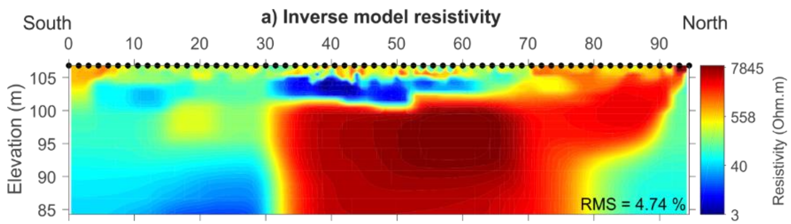
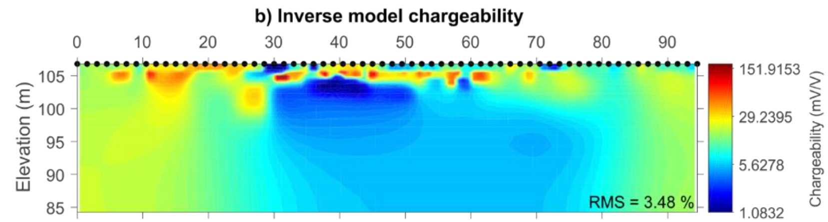
P1



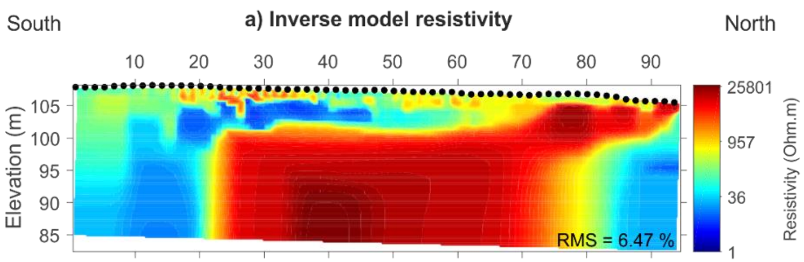


P2



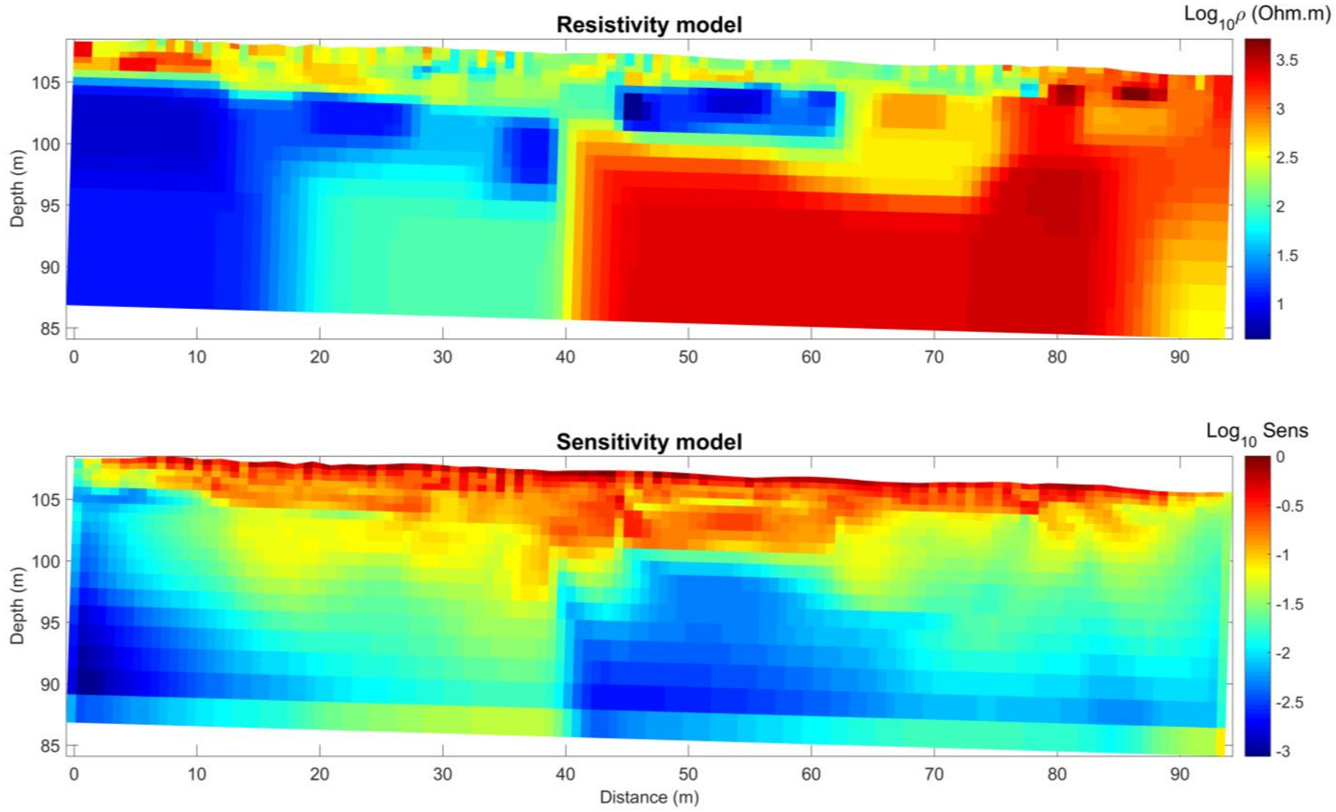


P3



Similar structures observed in P2 and P3

Sensitivity



DOI

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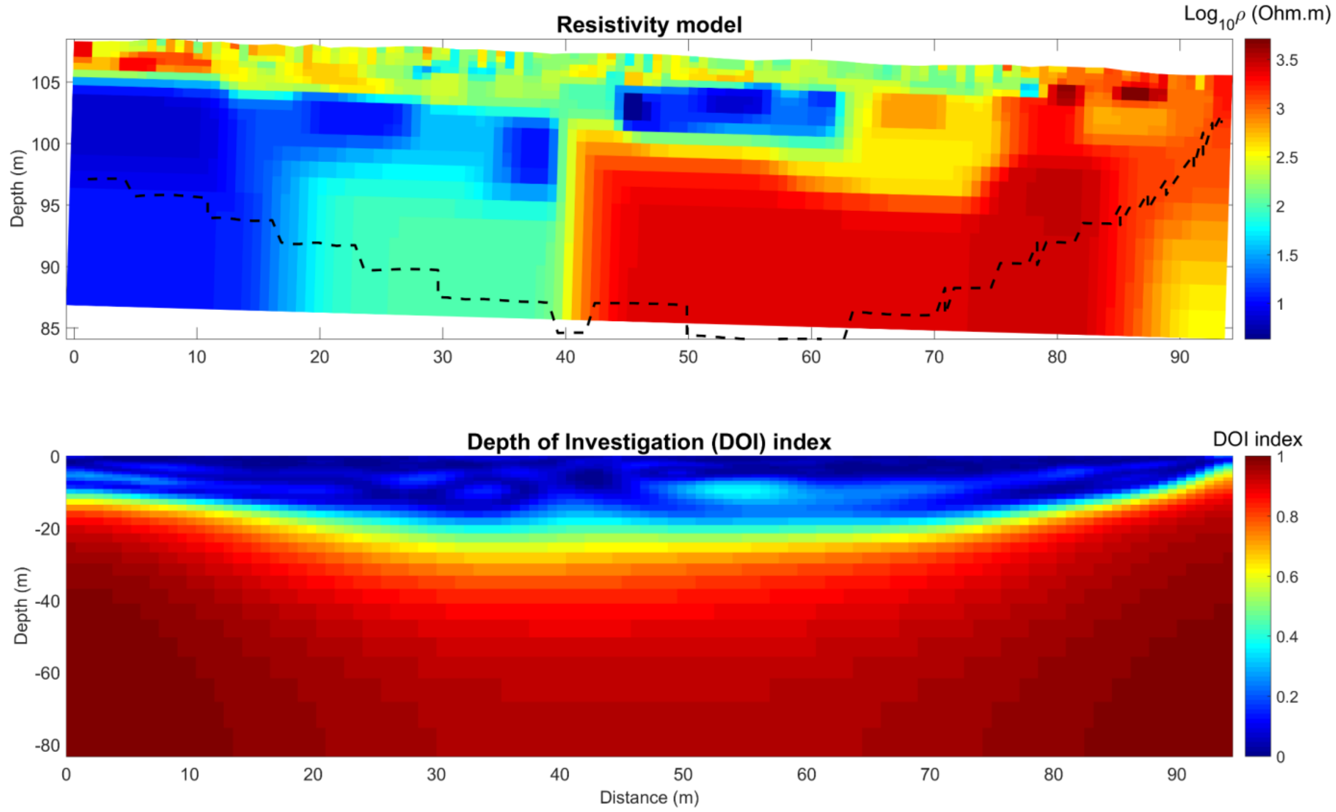
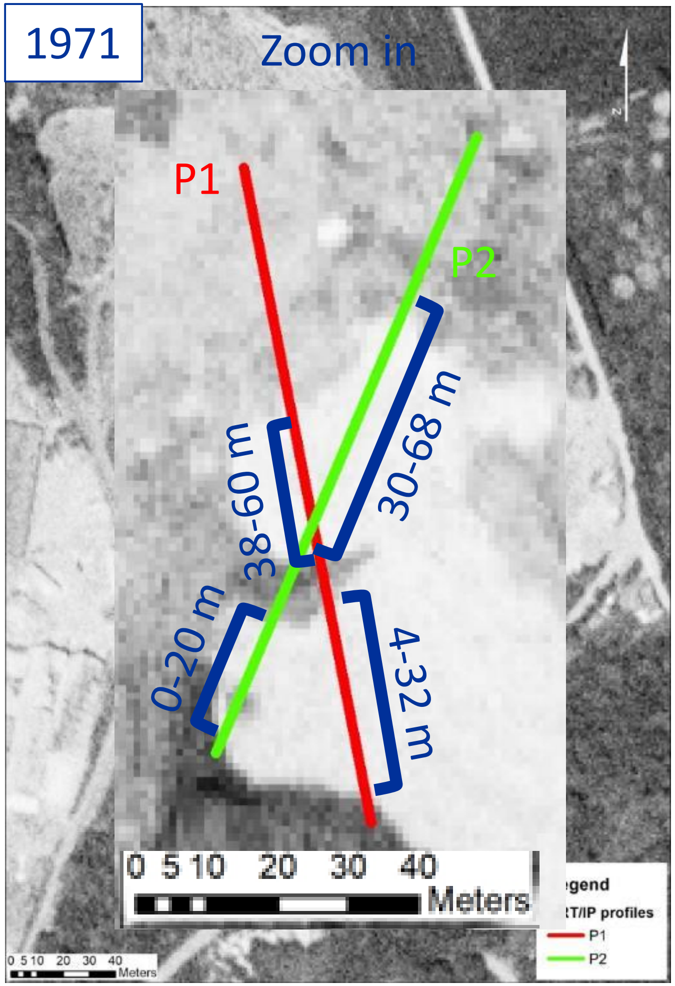
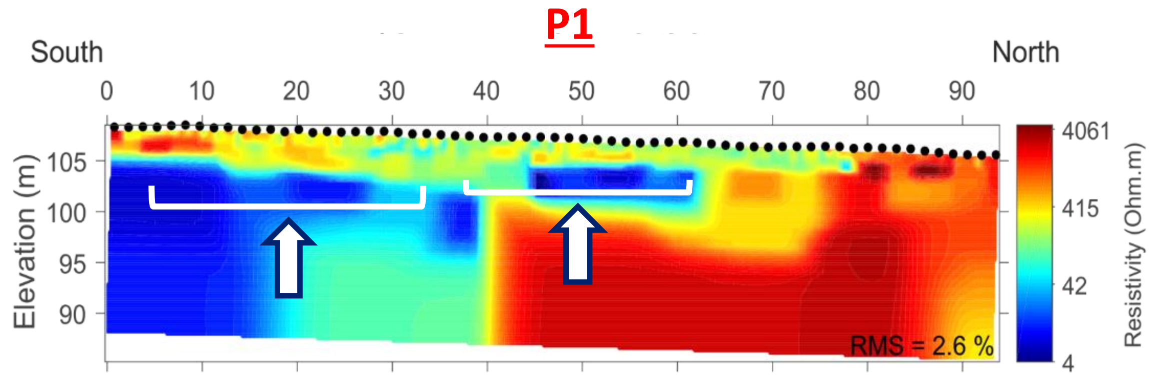
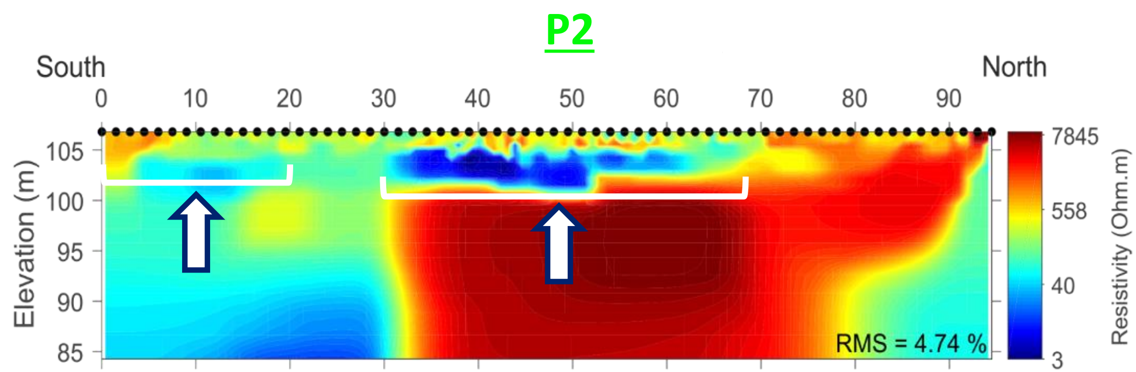


Interpretation: ERT/IP

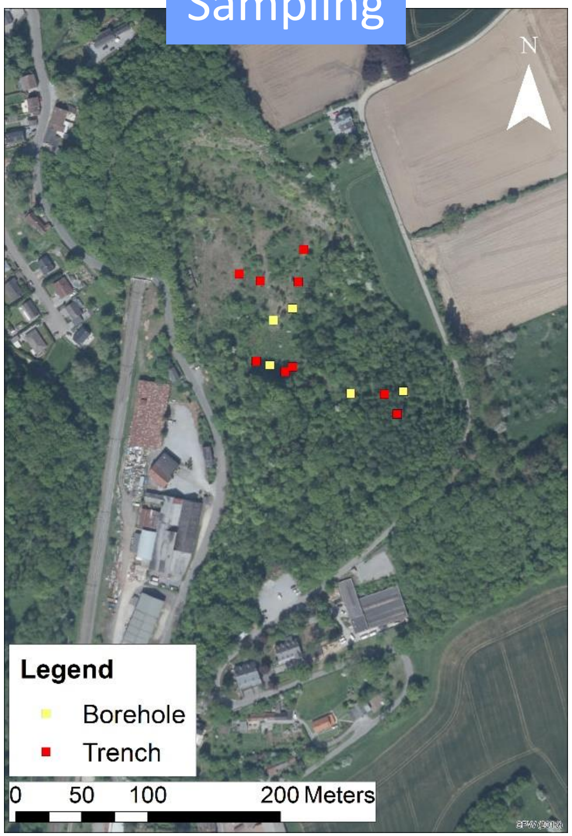


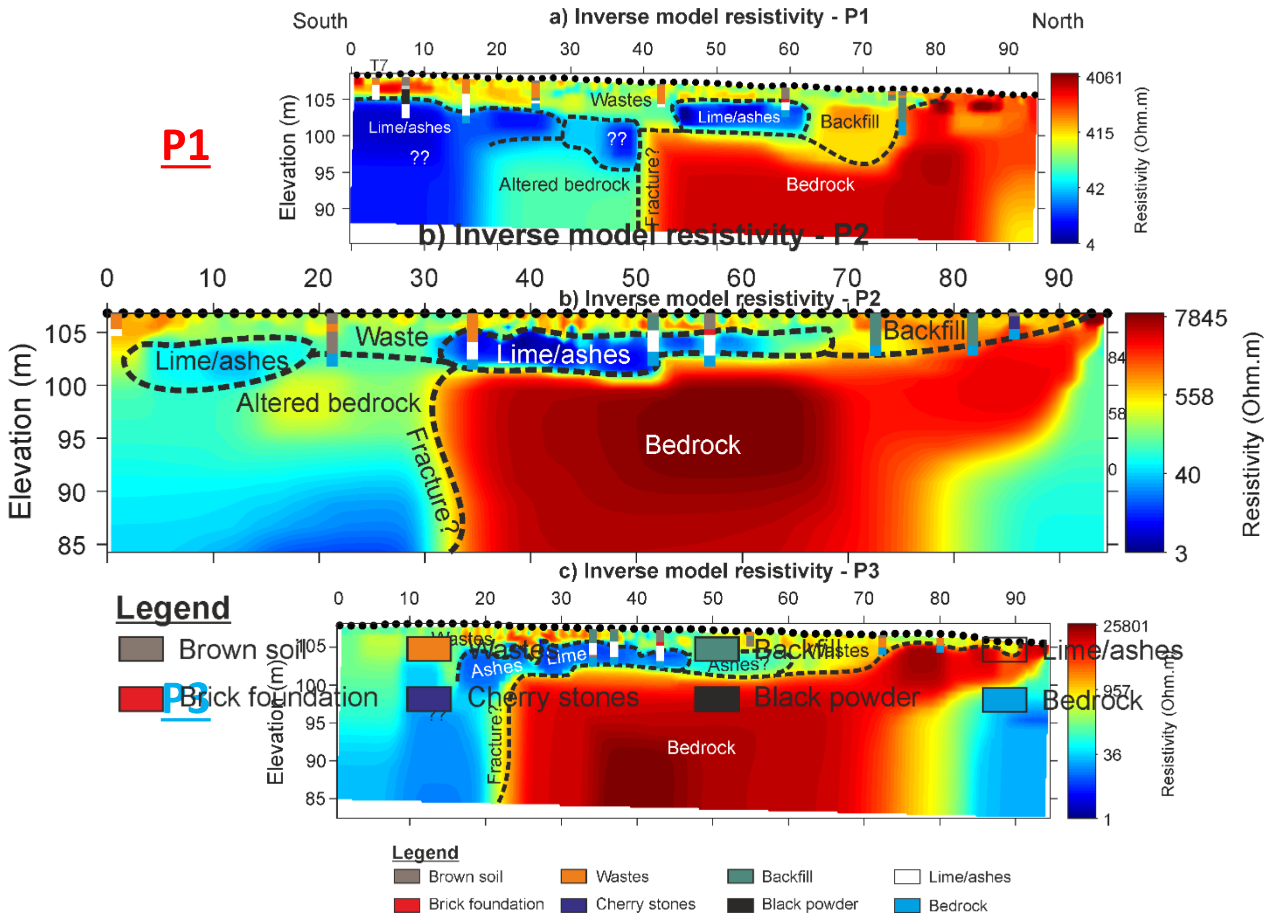




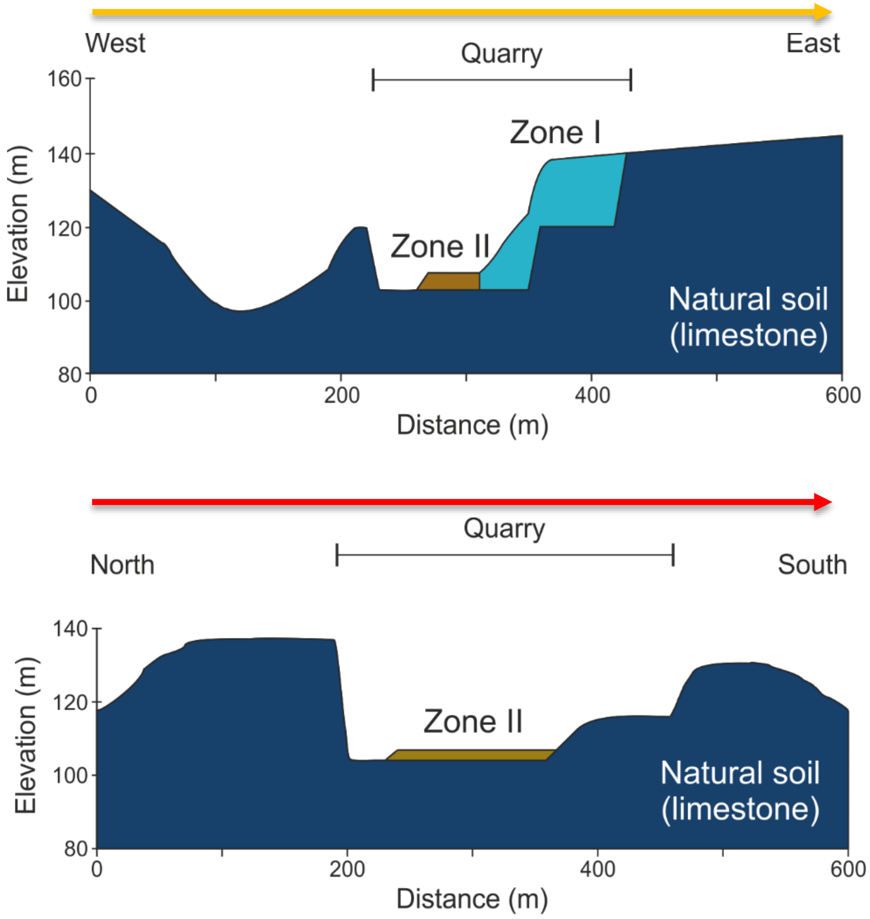
Validation with ground truth data

Sampling





Site overview: current state



3D ERT results

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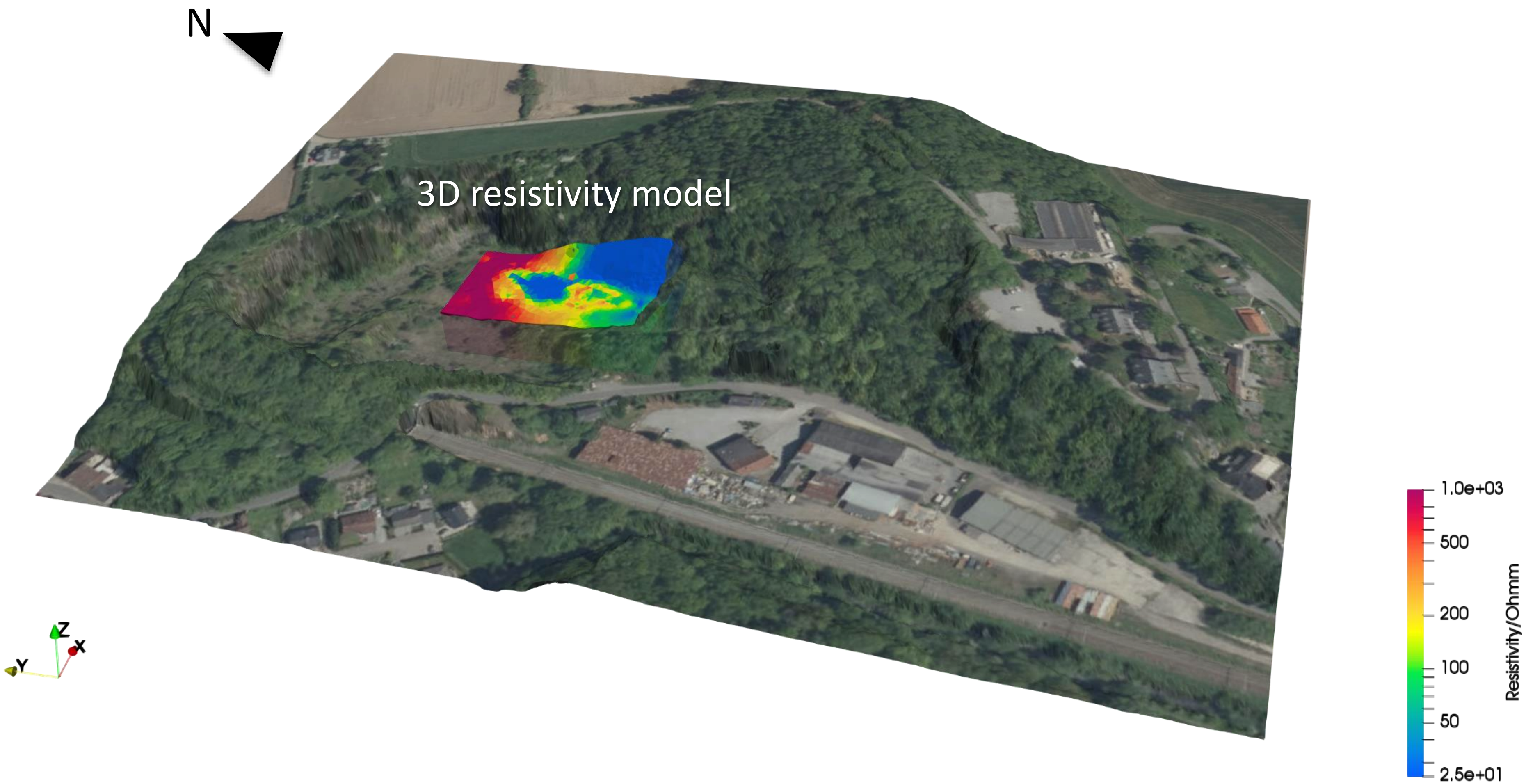
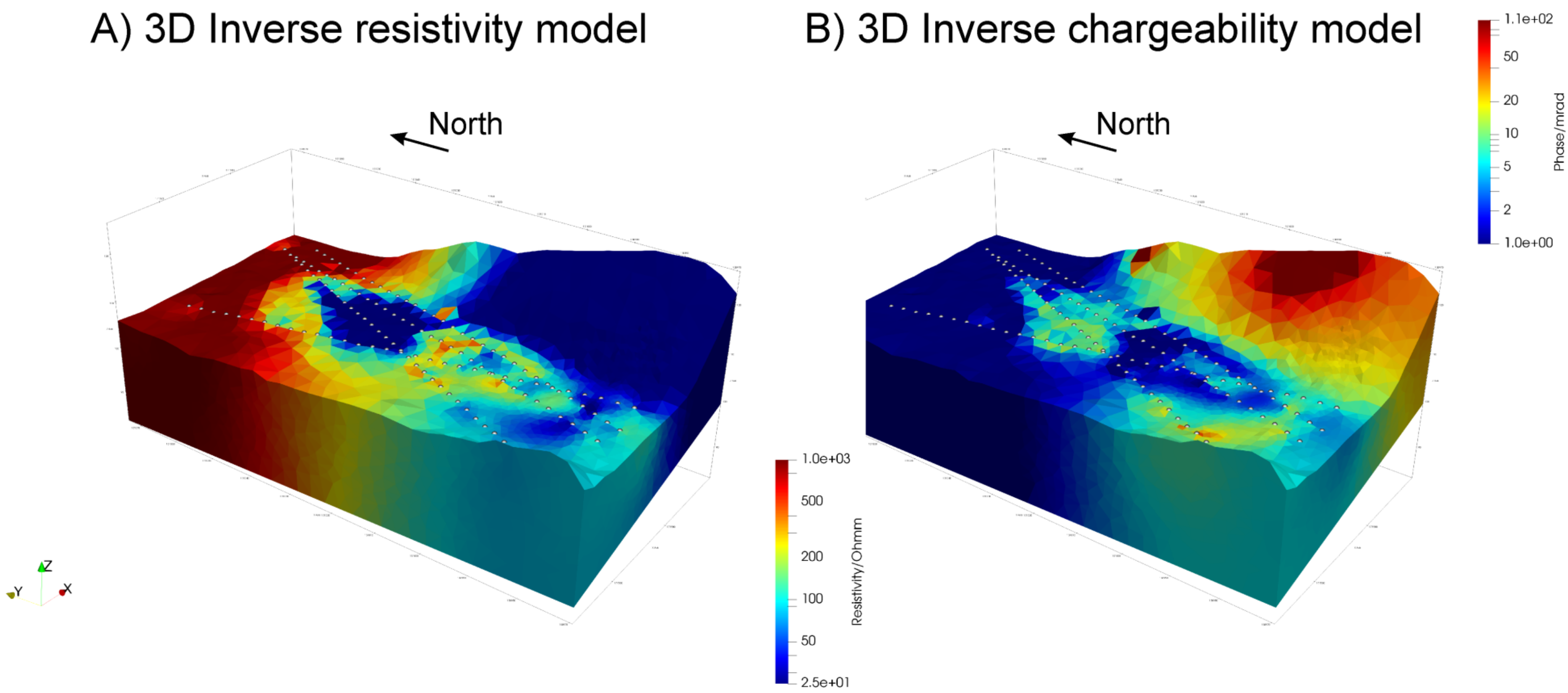


3D ERT/IP



A) 3D Inverse resistivity model
B) 3D Inverse chargeability model
North
North
1.0e+03
500
200
100
50
2.5e+01
Resistivity/Ohmm
1.1e+02
50
20
10
5
2
1.0e+00
Phase/mrad
Z
Y
X

Soil contamination

ZONE	LAYER	TEST	POLLUTING ELEMENTS AND NORM EXCEEDANCE*
Lower	Waste	**Chemical**	▪ PAH > **TV** (T1,T2,T4,T6, F2), **VI** (T1, T4, F2) ▪ VOHC > **TV** (T1,T6, F2) ▪ Heavy metals > **TV**,**LV**, **VI** (T1 to T7 F2) ▪ Mineral oils > **TV** (T1,T2,T5,T6,T7, F2), **VI** (T1,T3,T4,T6, F2) ▪ Polychlorinated biphenyl (PCB) > **LV** (T1,T6)
		Leaching	▪ Heavy metals > **TV** (Pb), VI (Cu), **LV** (Al, Sb) ▪ Mineral Oils > **TV**, **VI** ▪ Total Organic Carbon (TOC) > Signal value ▪ …
	Lime	**Chemical**	▪ Heavy metals > **TV** (T1,T6), **VI** (T6, F2), **LV** (T6, F3) ▪ Mineral oils > **TV** (T1, T6, F2, F3) ▪ PCB > **LV** (T1) ▪ VOHC > **TV** (T1, F3), **VI** (T6, F2, F3) ▪ Hydrocarbons > **LV** (F2, F3) ▪ …
		Leaching	▪ VOHC > **TV** ▪ Heavy metals > **TV** (Pb), **LV** (Al, Ba) ▪ TOC > Signal value
Upper	Lime	**Chemical**	▪ Mercury > **TV** (F4, F5), **VI** (F4) ▪ Aluminium > **LV** (F4) ▪ Mineral oils > **TV** (F4, F5), **VI** (F5) ▪ VOHC > **TV** (F4), **VI** (F4, F5) ▪ Hydrocarbons > **LV** (F4, F5) ▪ …
		Leaching	▪ VOHC > **TV** ▪ Heavy metals > **TV** (Pb), **LV** (Al, Ba) ▪ TOC > Signal value
	Ashes	**Chemical**	▪ Aluminium > **LV** (T8, F4, F5) ▪ Mineral oils > **TV** (F4, F5) ▪ PAH > **TV**, **VI** (F5) ▪ VOHC > **VI** (F4, F5)
		Leaching	▪ Arsenic > **TV** ▪ Aluminium > **VL** ▪ Fluorides > **VL**

(Debouny, 2019)

HVNSR theory

Bimodal model

$$f_0 = \frac{V_s}{4\ H}$$

Trimodal model

$$f_1 = \frac{1}{4\left(\frac{H_0}{V_{s0}} + \frac{H_1}{V_{s1}}\right)}$$