ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Electrical Surveying
Part I: Resistivity method
Lecture B

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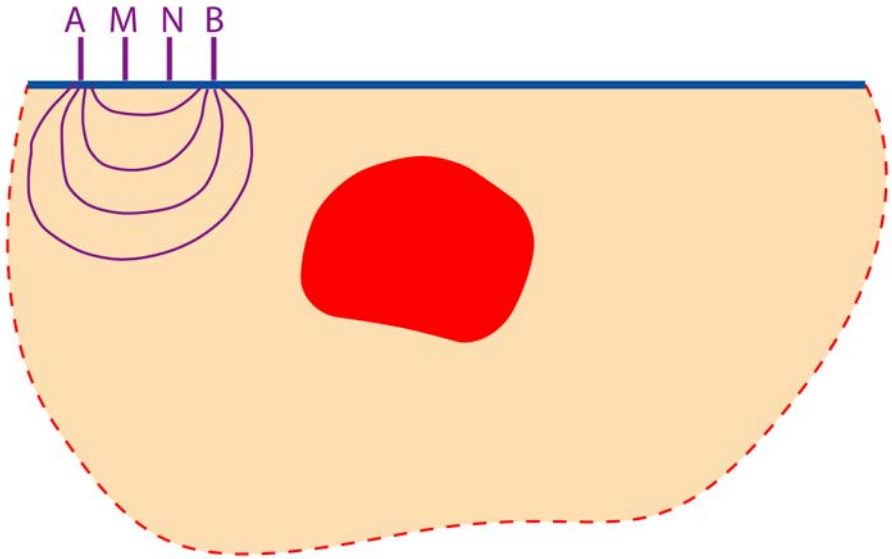
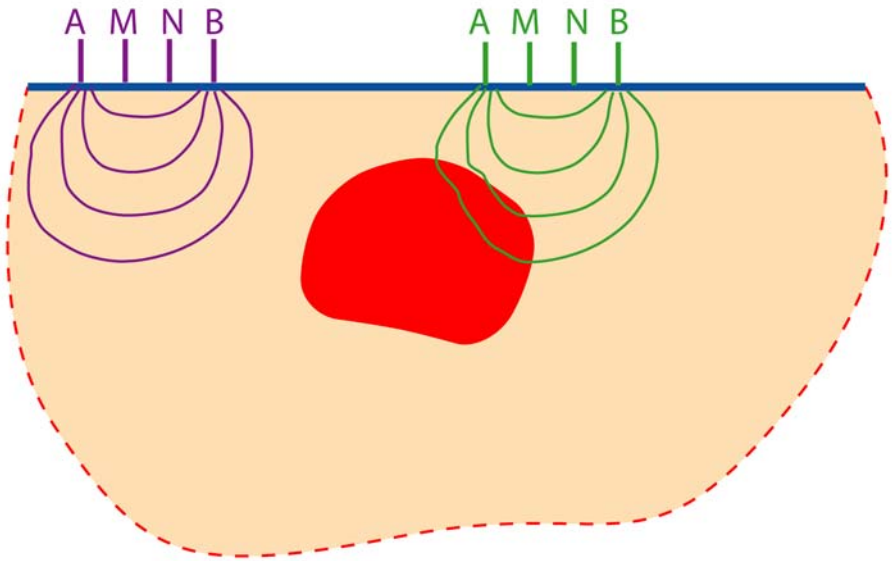
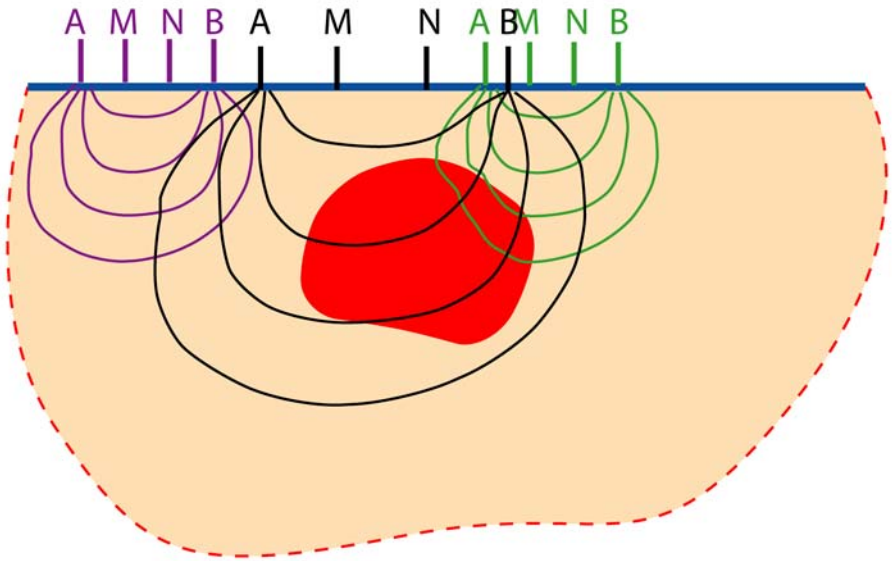
Resistivity tomography



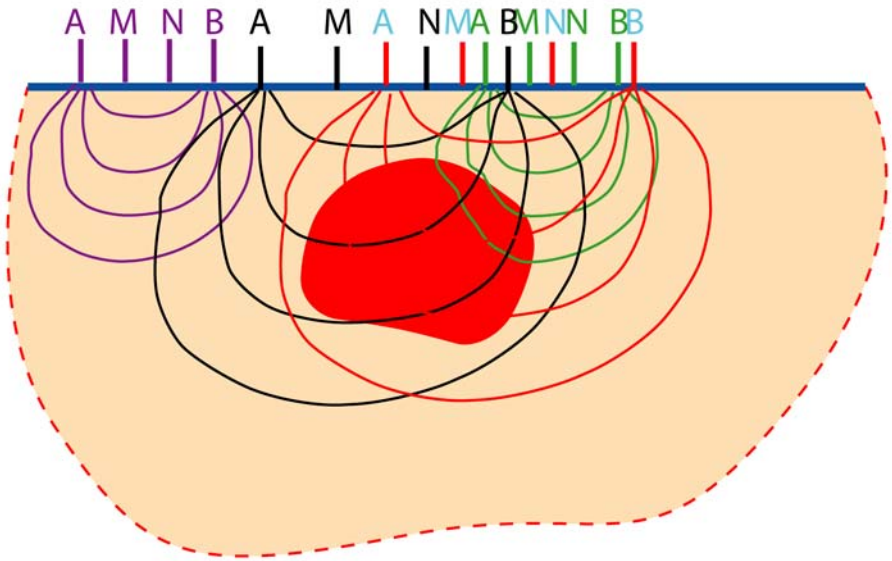
Resistivity tomography



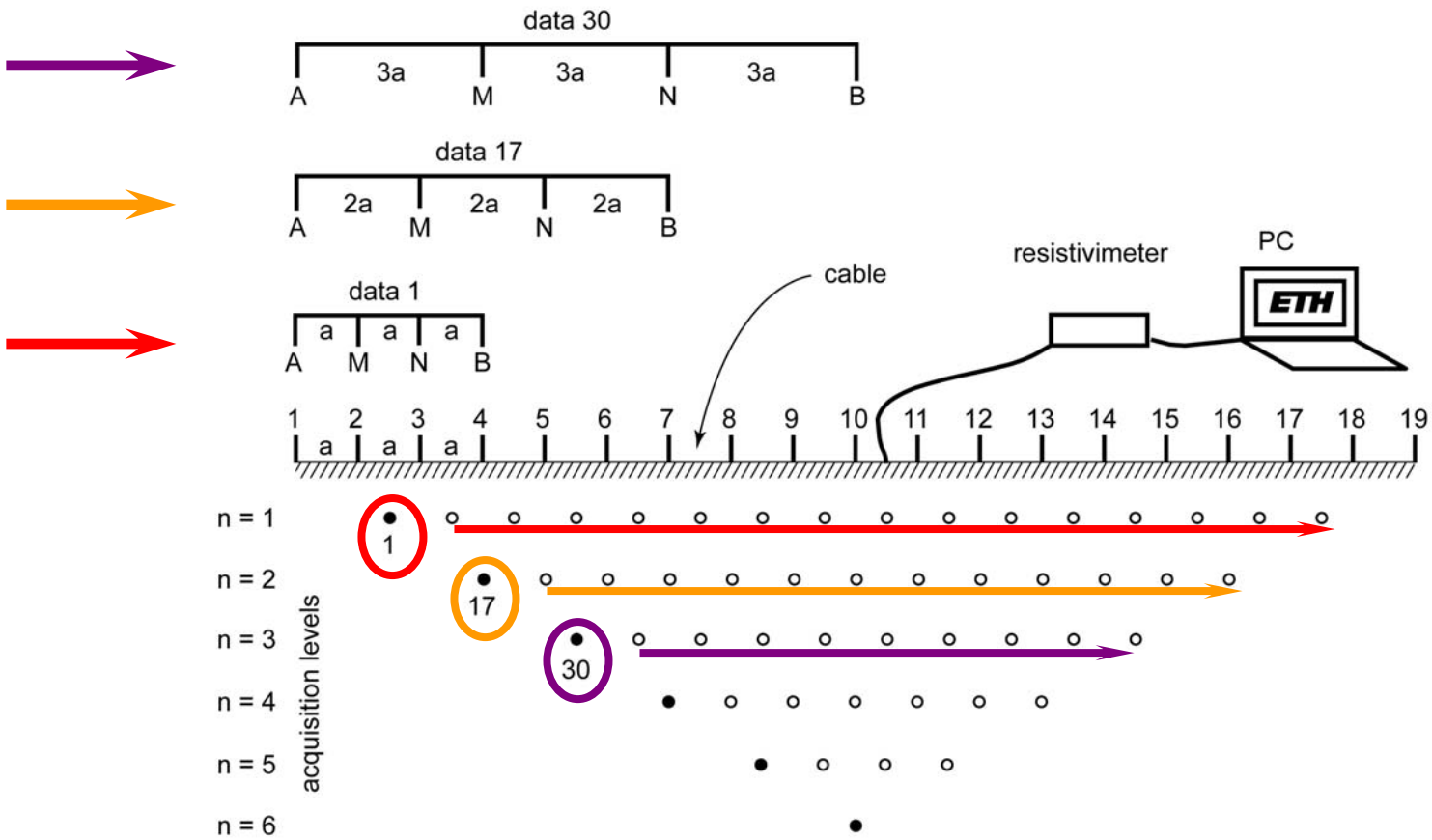
Resistivity tomography



Resistivity tomography

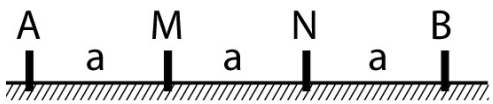


Resistivity tomography



2D electrode configurations

Wenner

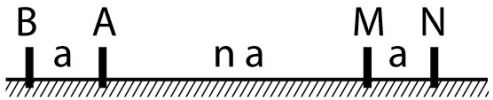


$K=2\pi a$

Wenner-Schlumberger

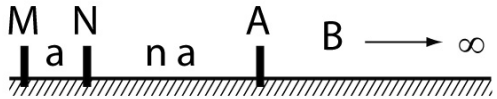
$K=\pi n (n+1) a$

dipole-dipole



$K=\pi n (n+1) (n+2) a$

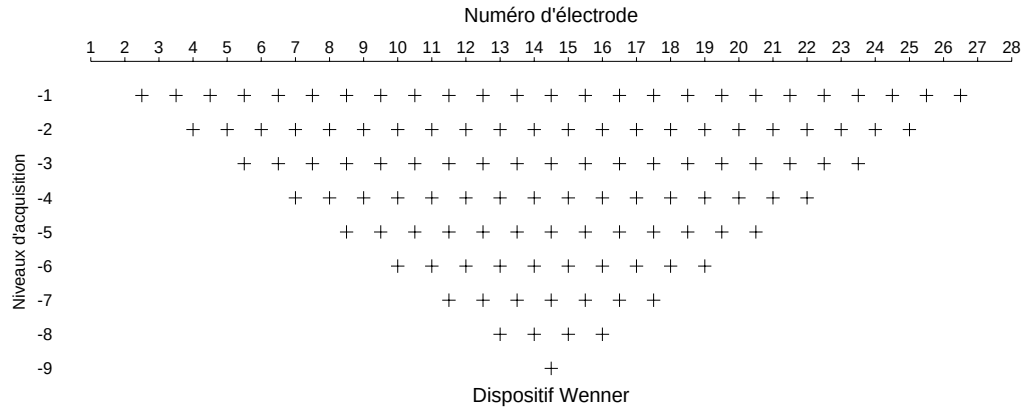
pole-dipole



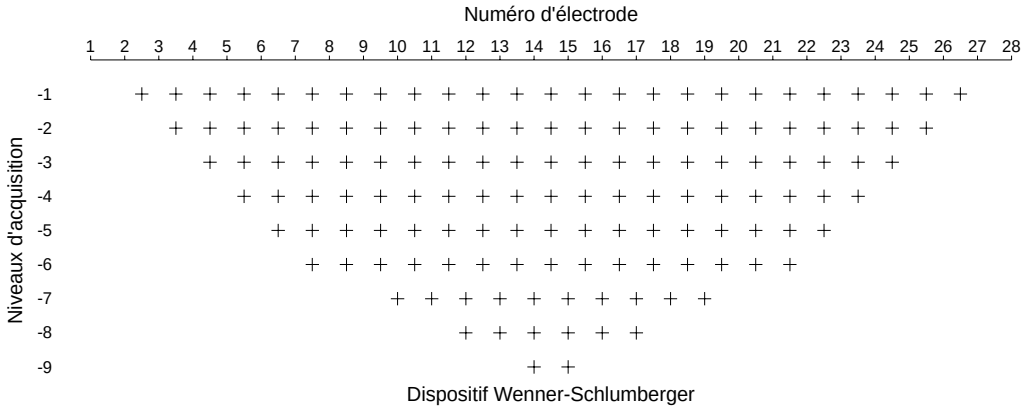
$K= 2\pi n (n+1) a$

pole-pole

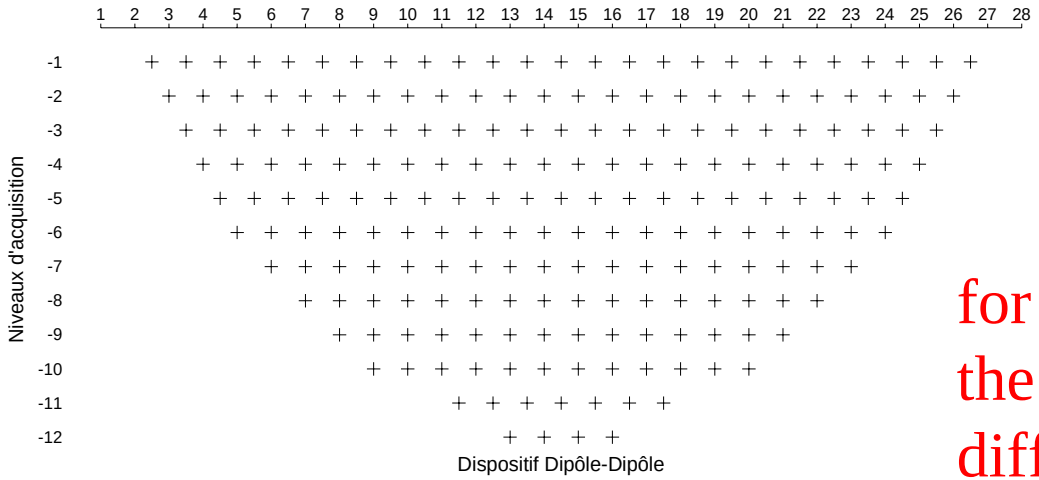
$K=2\pi a$



Wenner array



Schlumberger array



dipole-dipole array

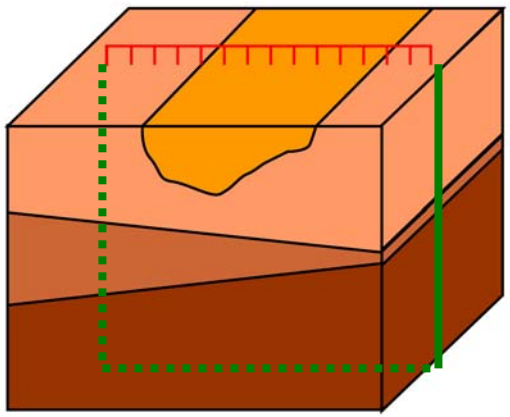
for a same number of electrodes the number of data points is different!

DAIHATSU
adidas

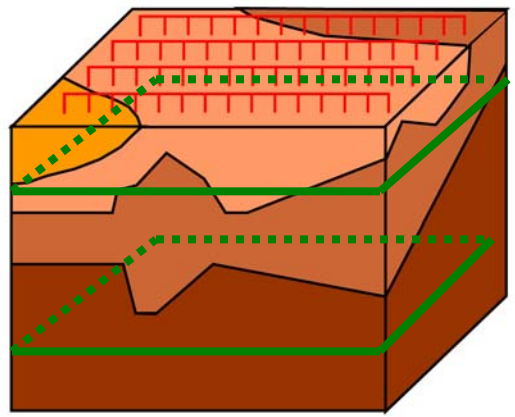
Source: P. Martínez Pagán, Universidad Politécnica de Cartagena

2D versus 3D

2D



3D

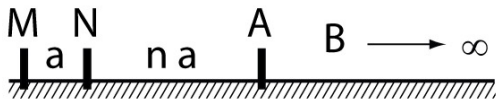


3D electrode configurations

dipole-dipole

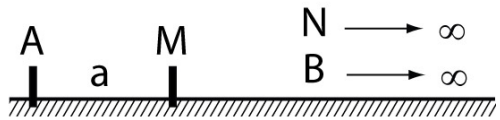
$K=\pi\, n\, (n+1)\, (n+2)\, a$

pole-dipole

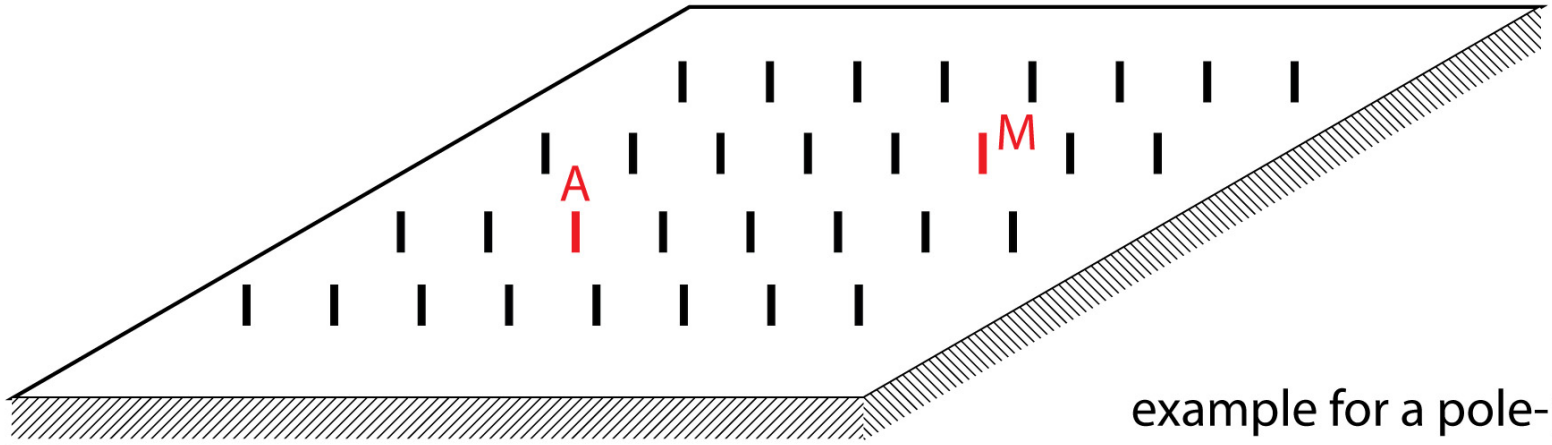


$K= 2\, \pi\, n\, (n+1)\, a$

pole-pole



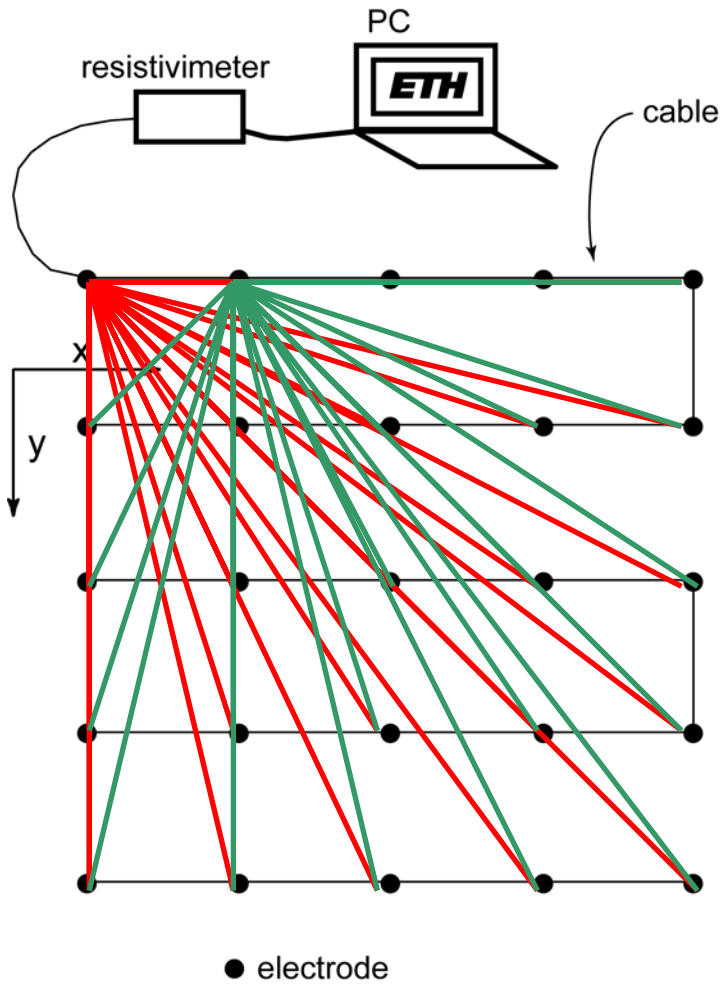
$K=2\, \pi\, a$

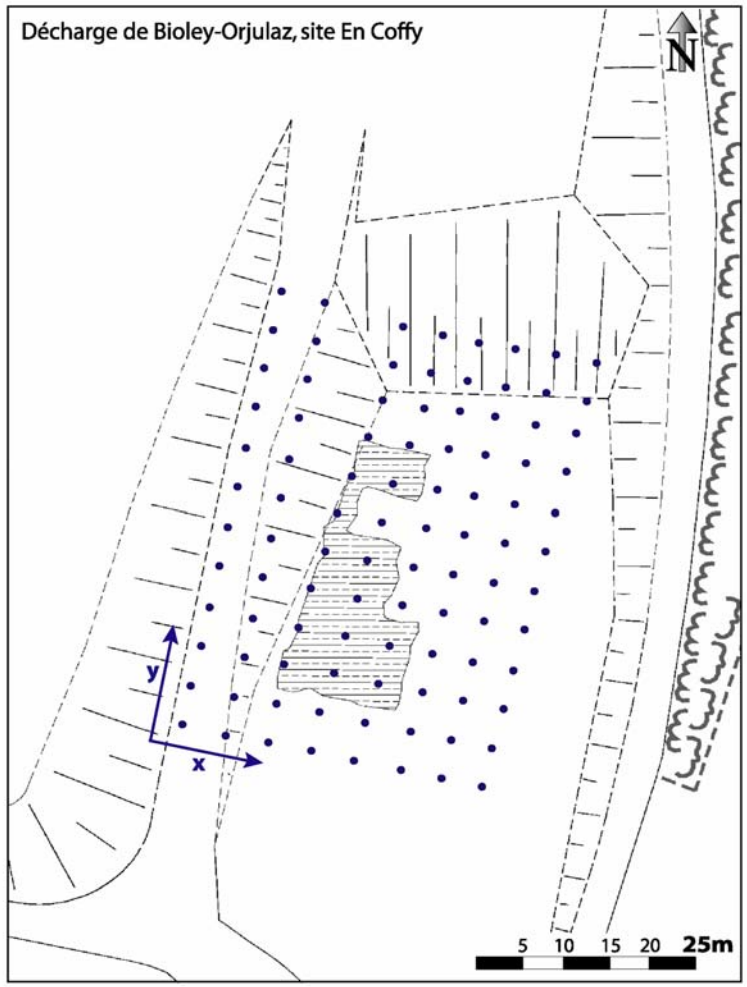


example for a pole-pole

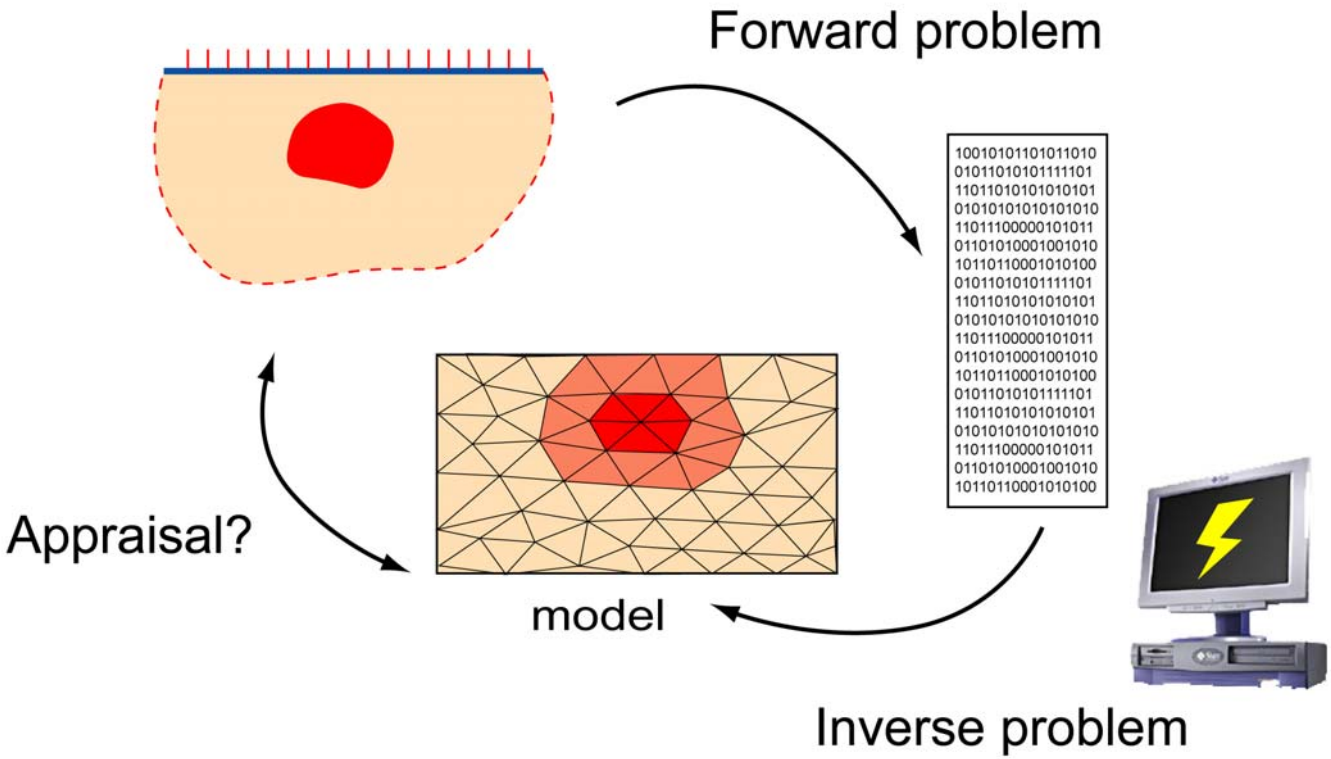
ETH

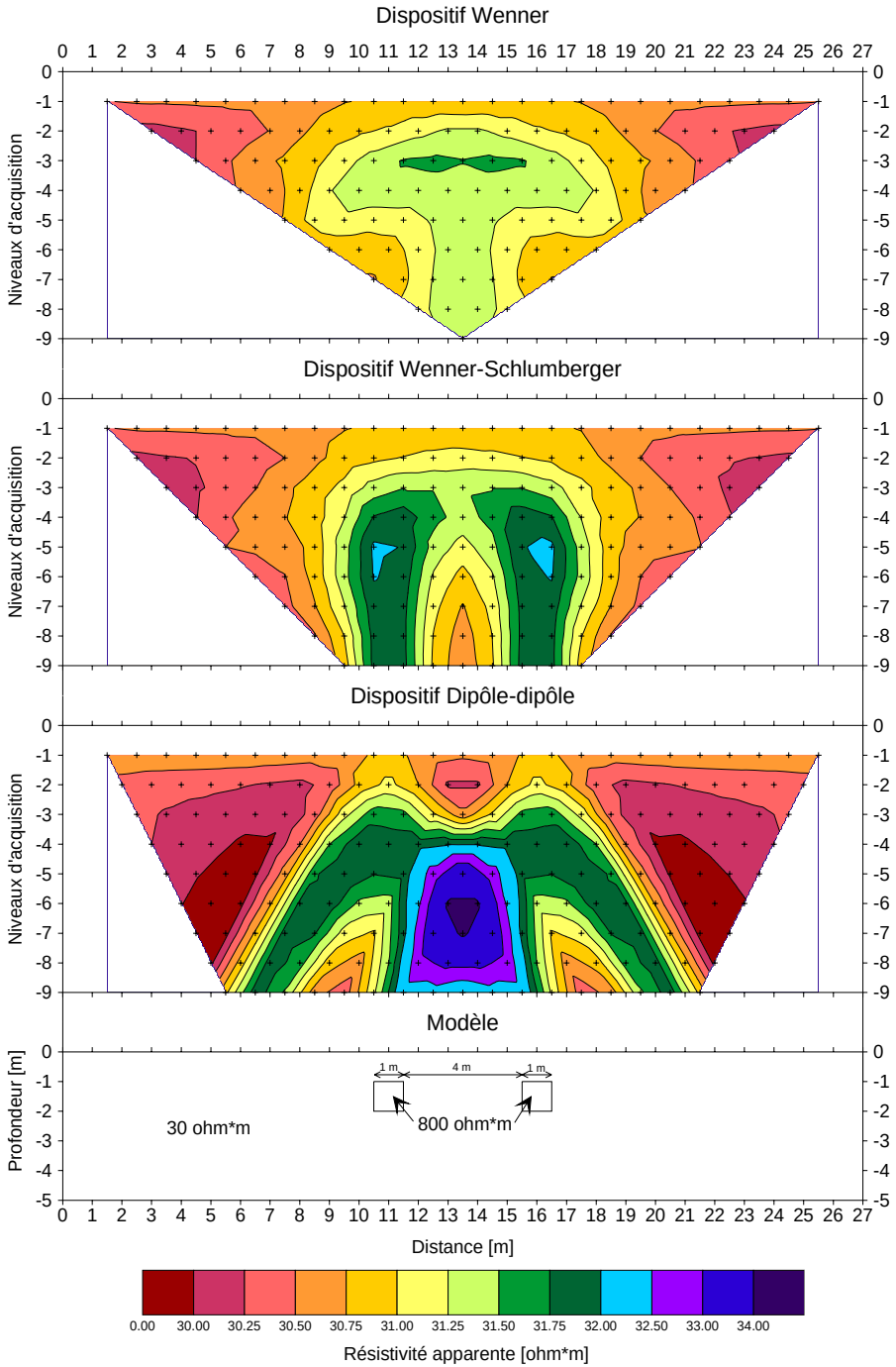
3D resistivity survey





Tomography inversion

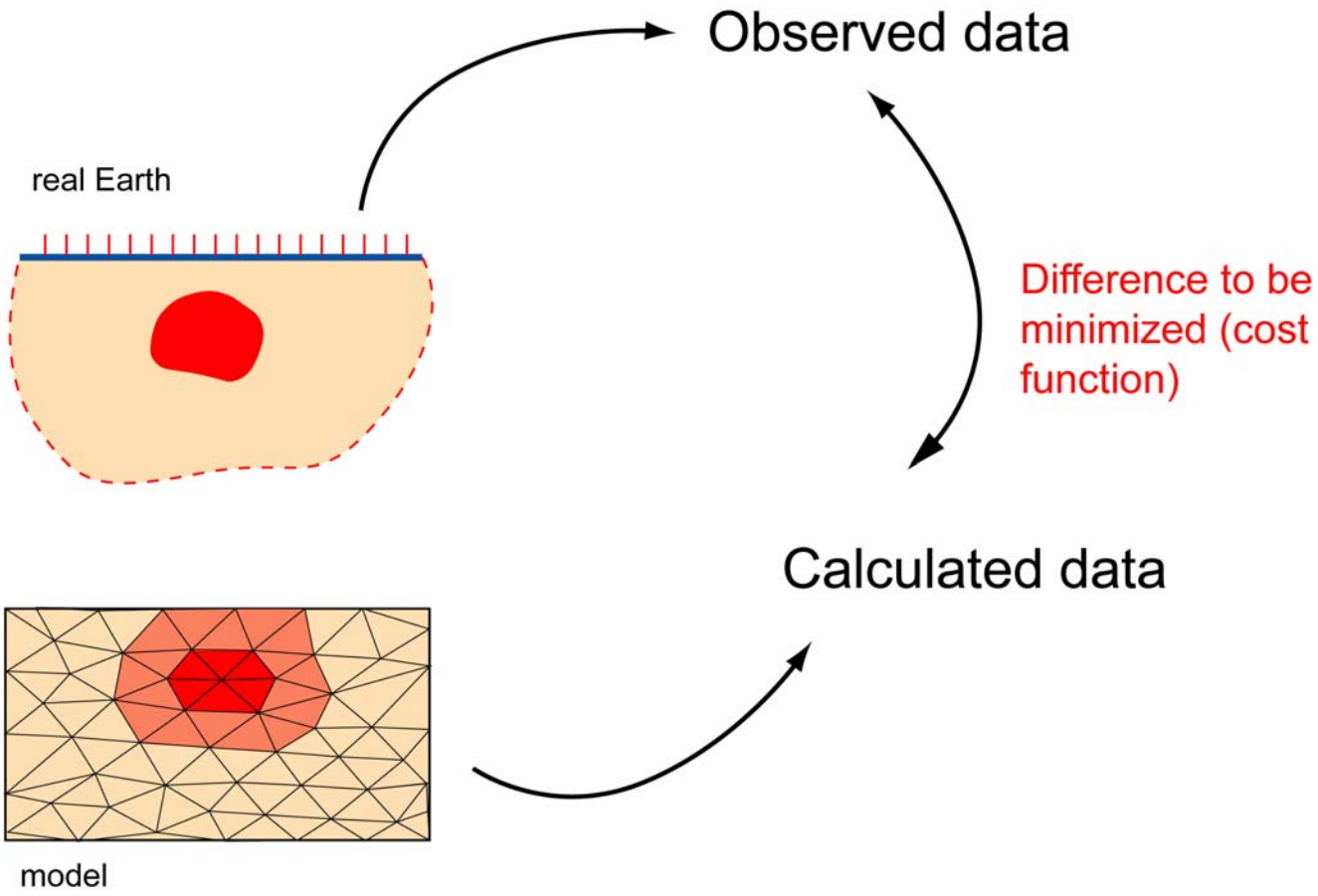




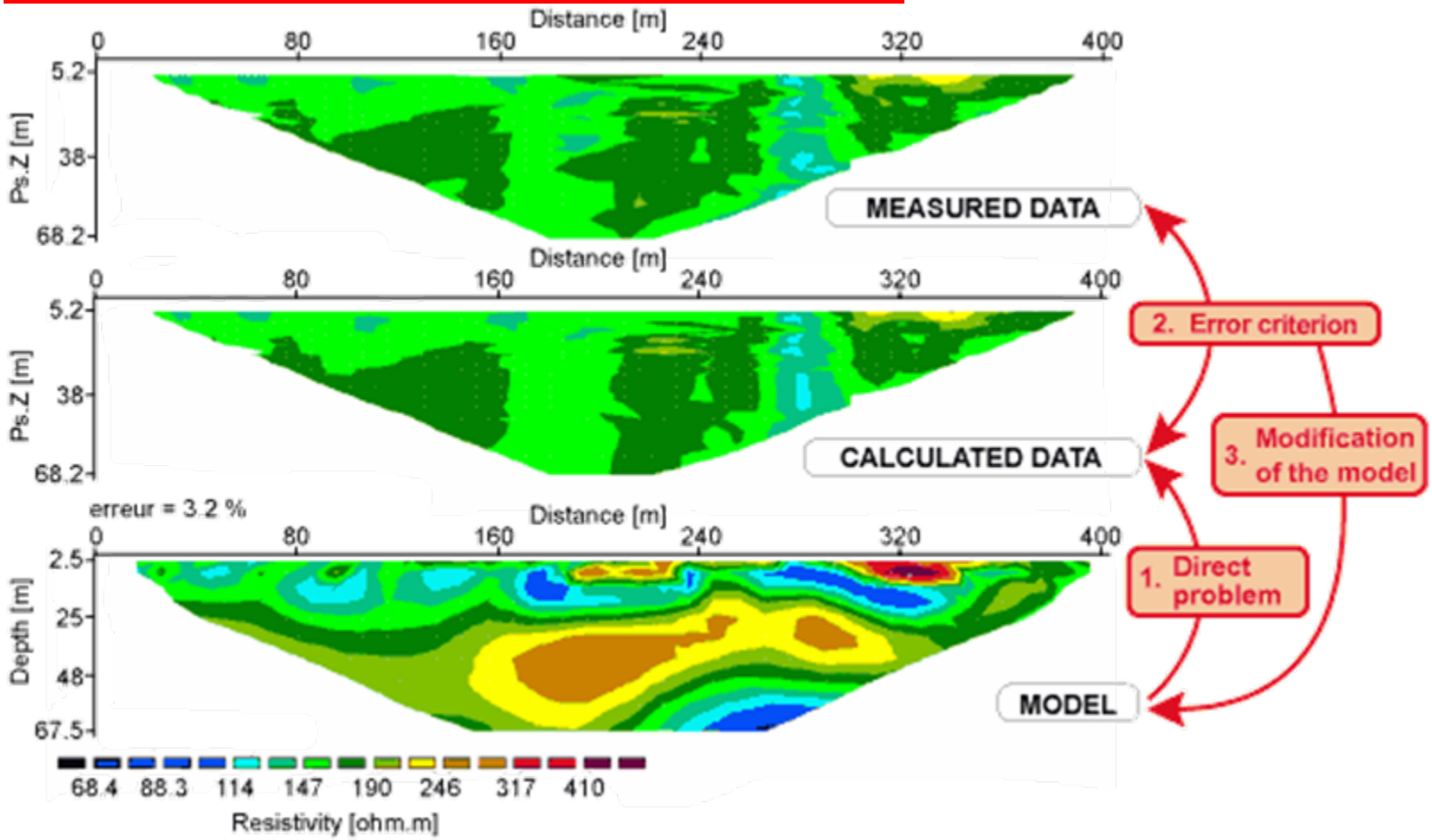
The apparent resistivity pseudosection is different depending on the array used!

Need for inversion…

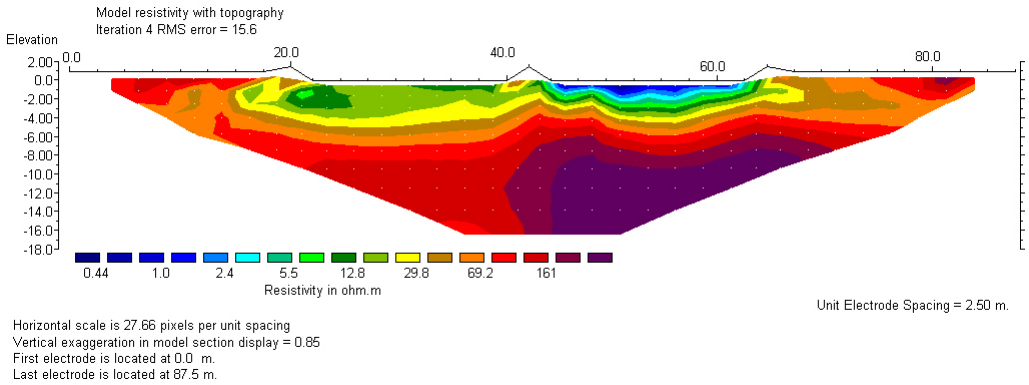
Tomography inversion

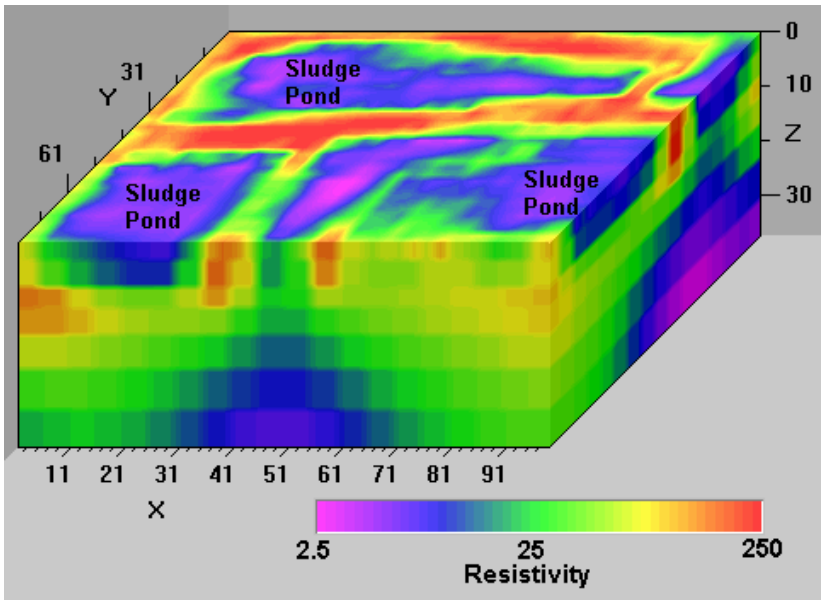


Tomography inversion

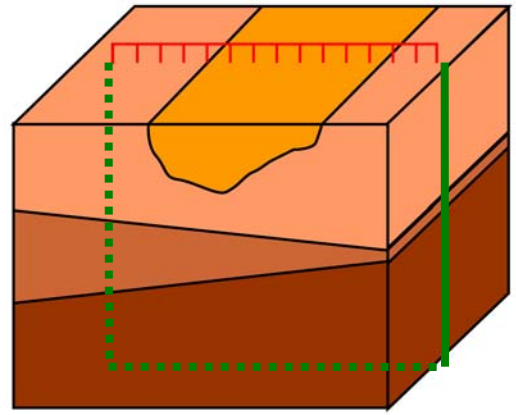


2D and 3D inversion results

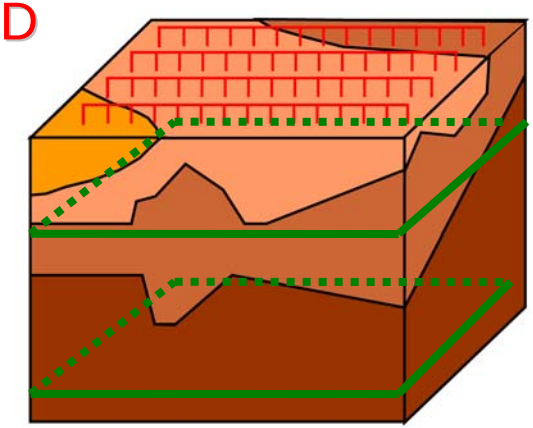




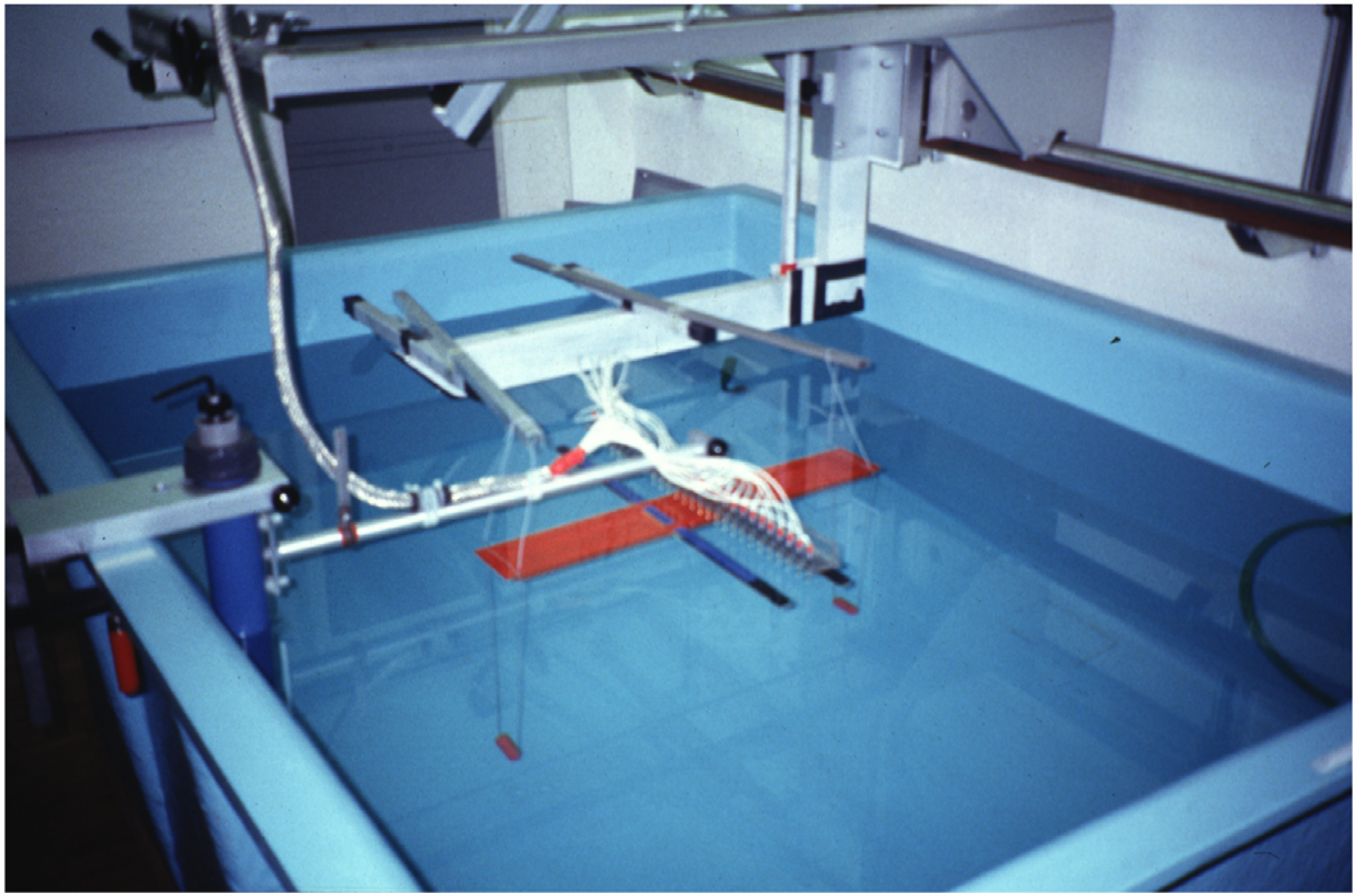
2D



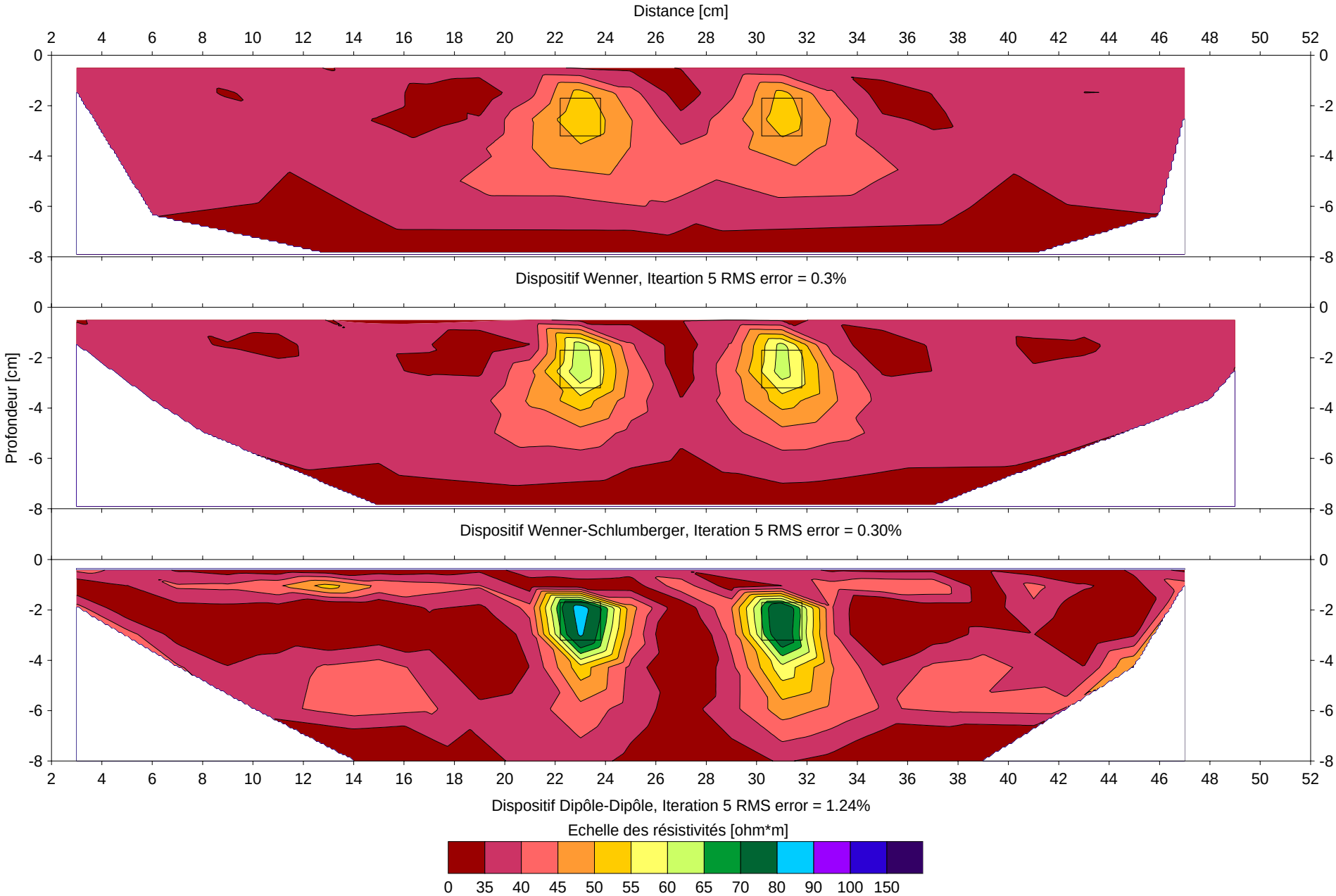
3D



Tank examples



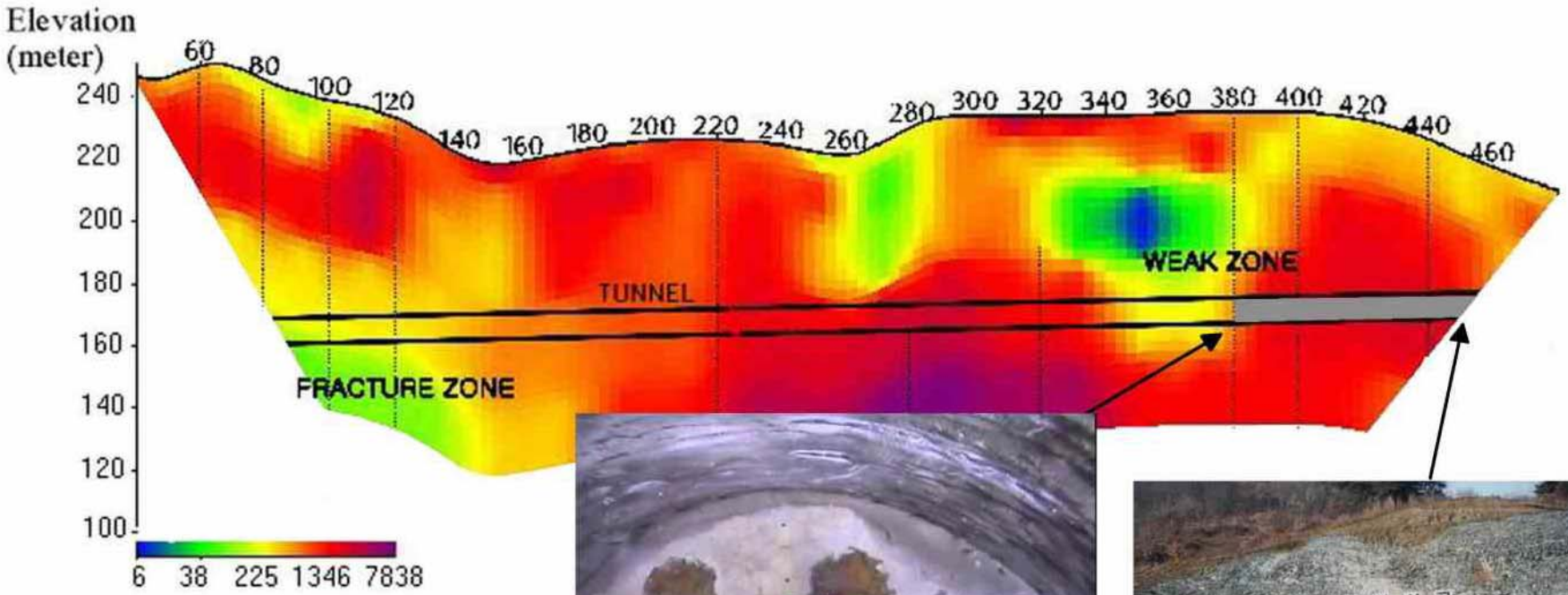
Effect of different electrode arrays



Some examples

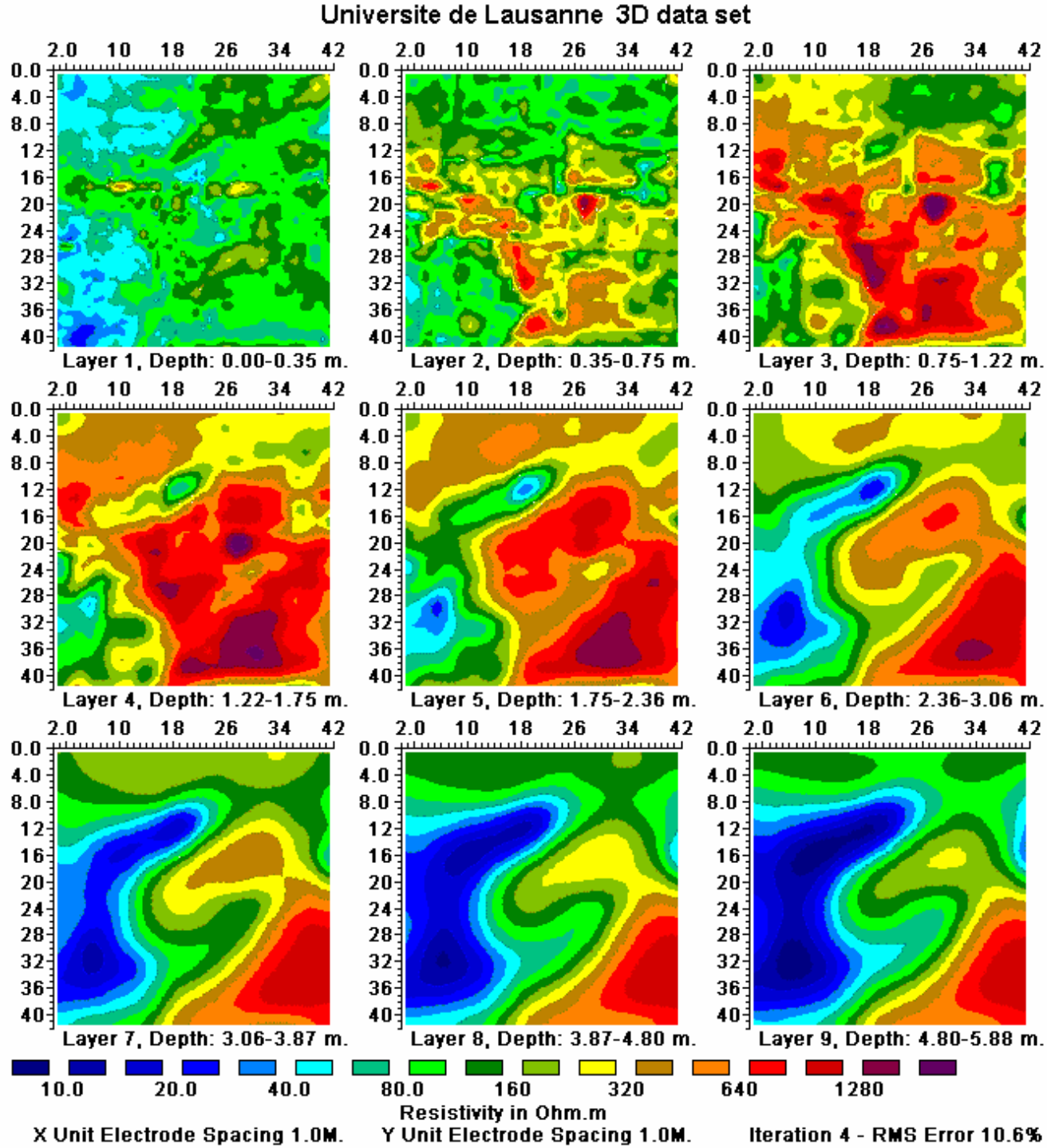
Here follow some examples of 2D and 3D resistivity imaging for environmental and civil and engineering applications…

Tunnel engineering

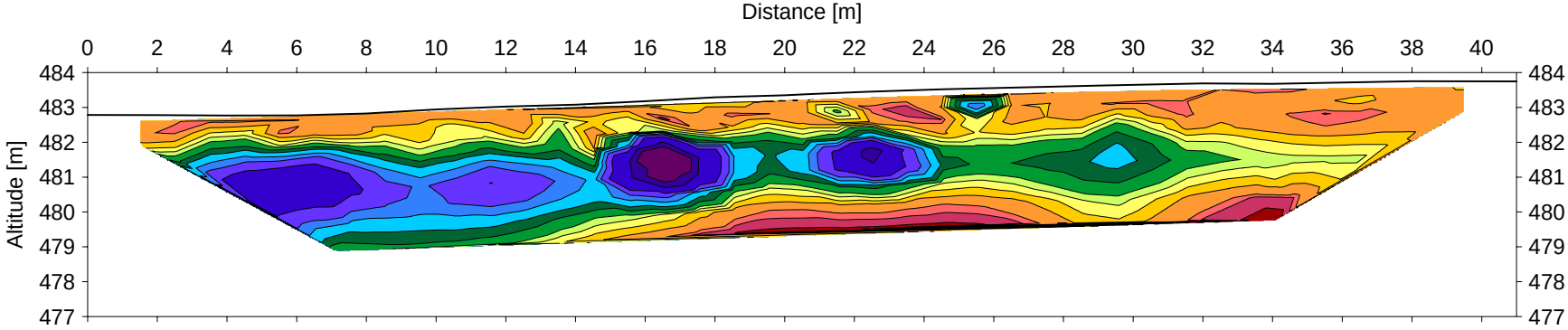


The tunnel front at the weak zone was shot-creted and three windows left open for the engineers to study the weak-zone material.

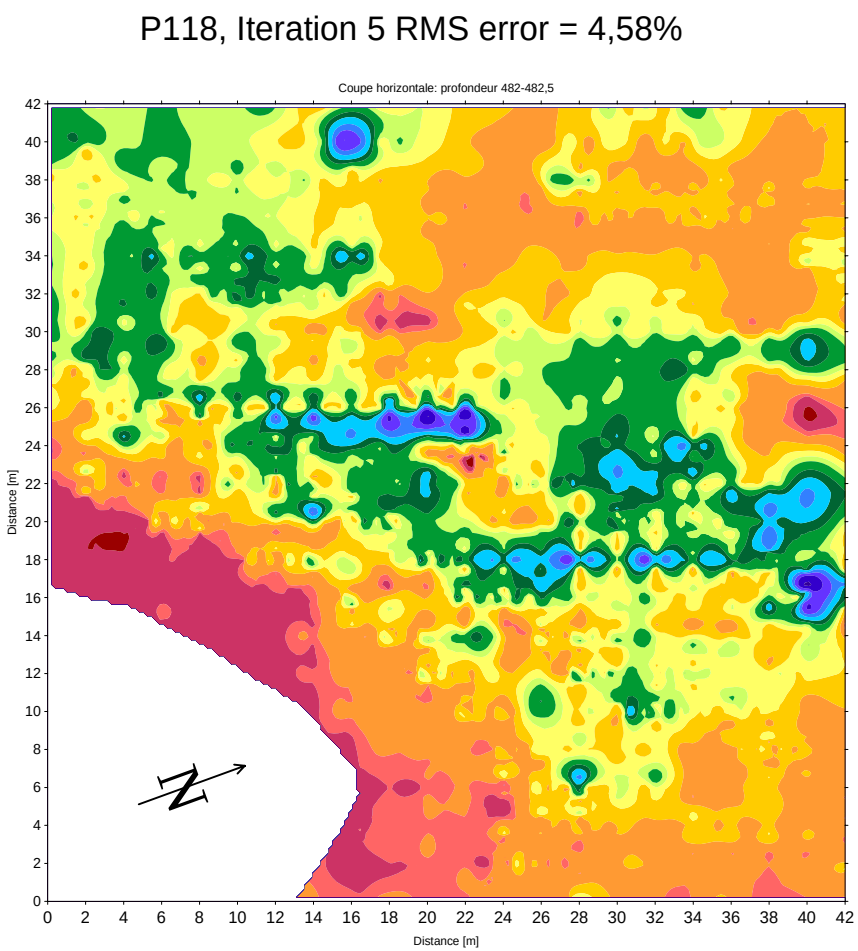
The entrance to one of the two parallel tunnels

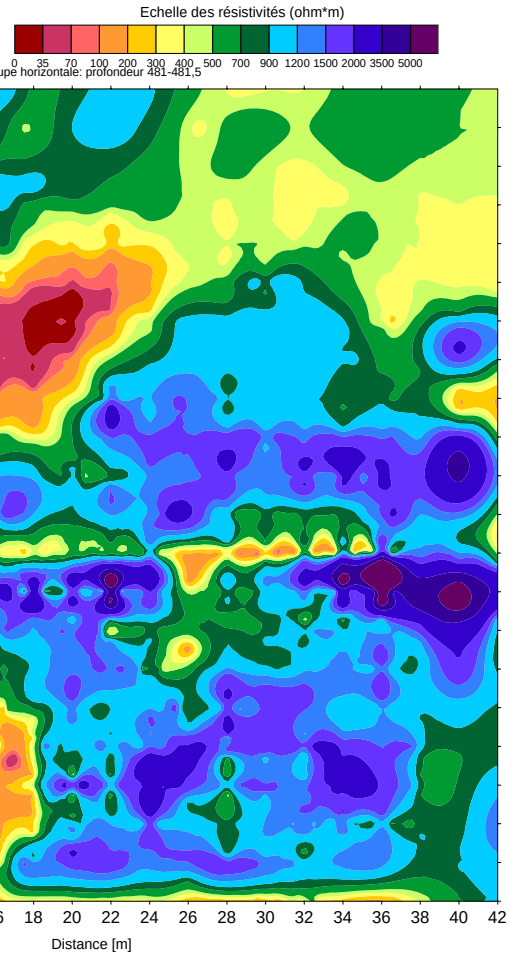


3D archaeological survey



P118, Iteration 5 RMS error = 4,58%

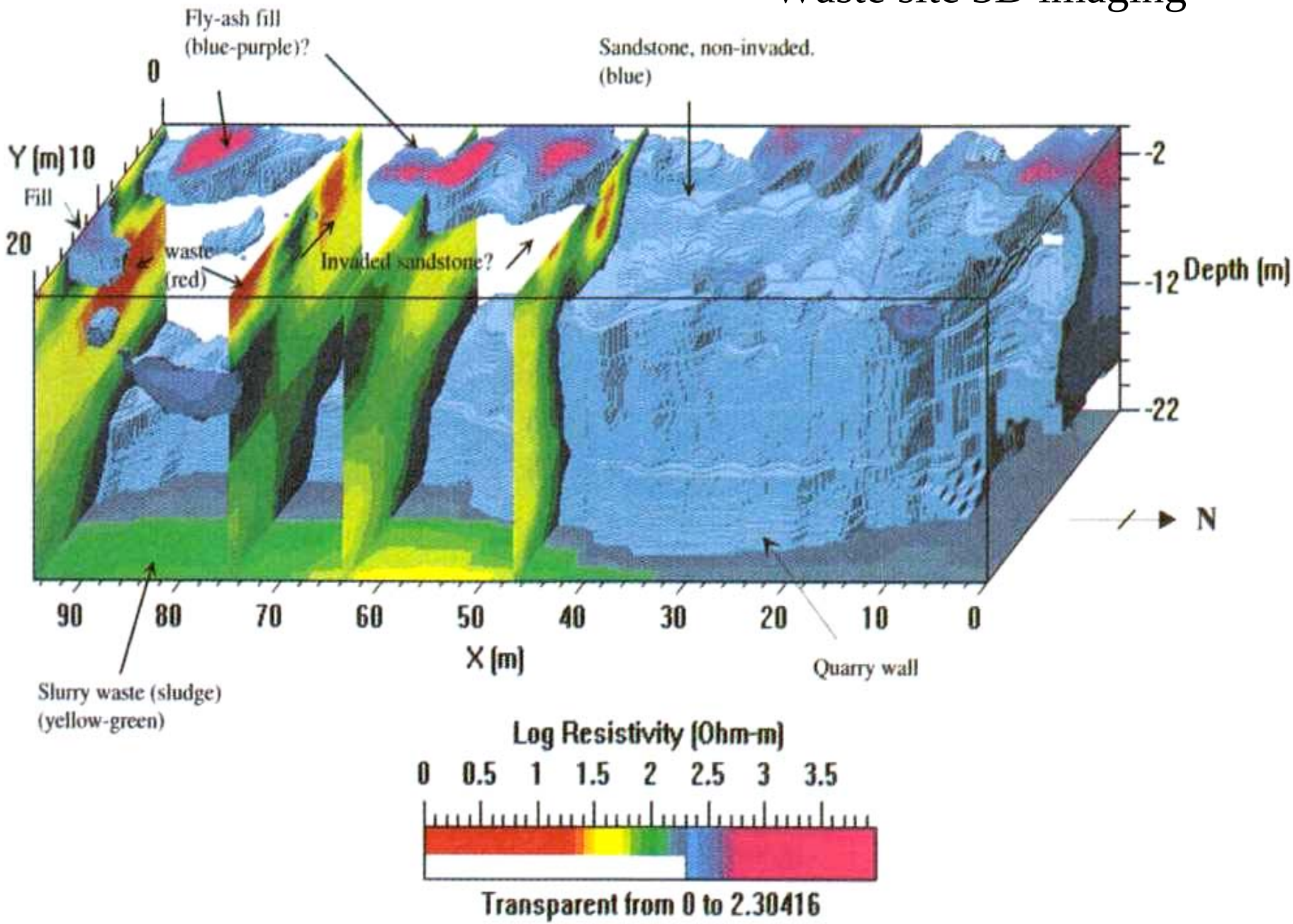




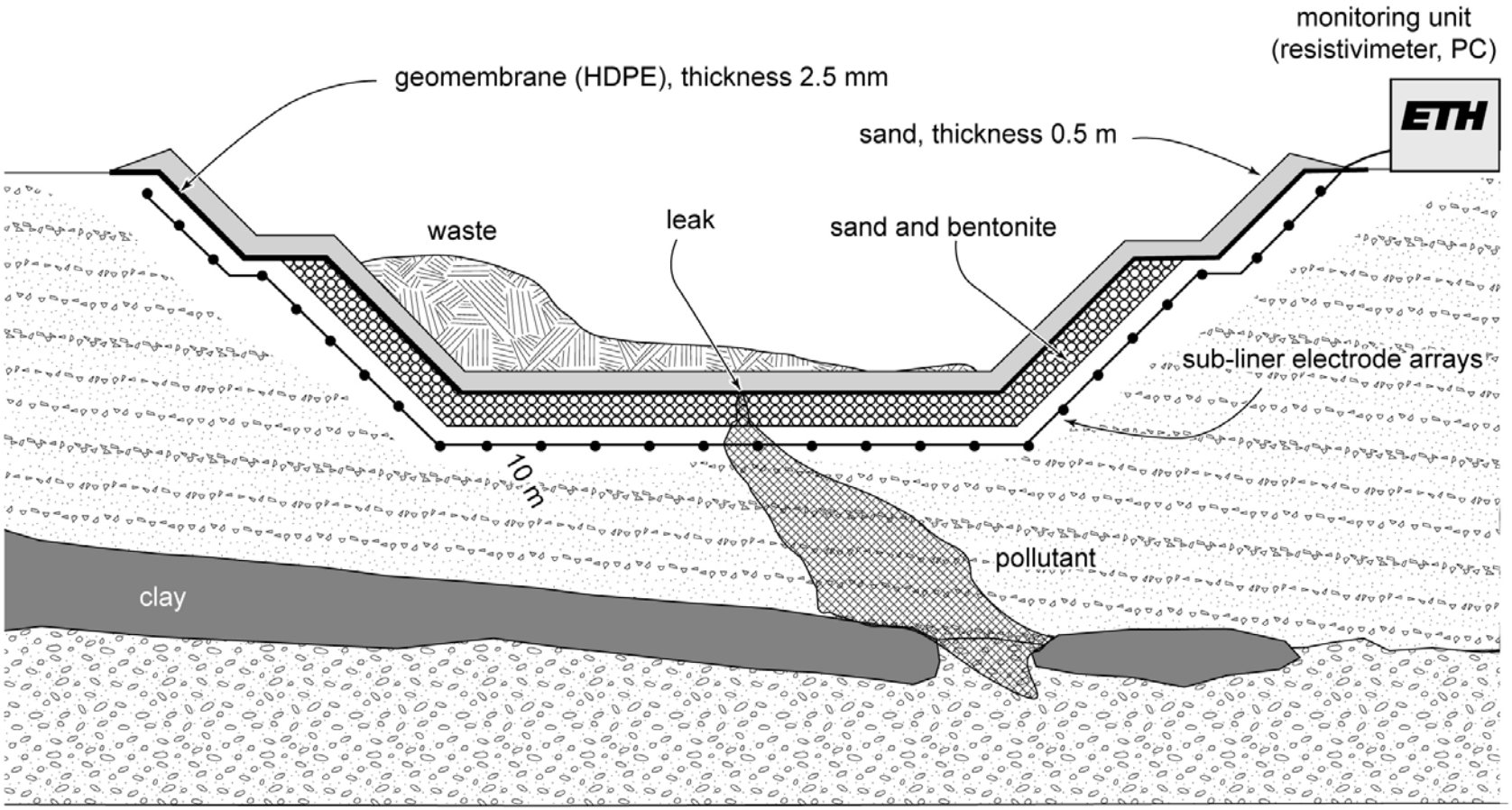
Depth slice 482 to 482.5 m

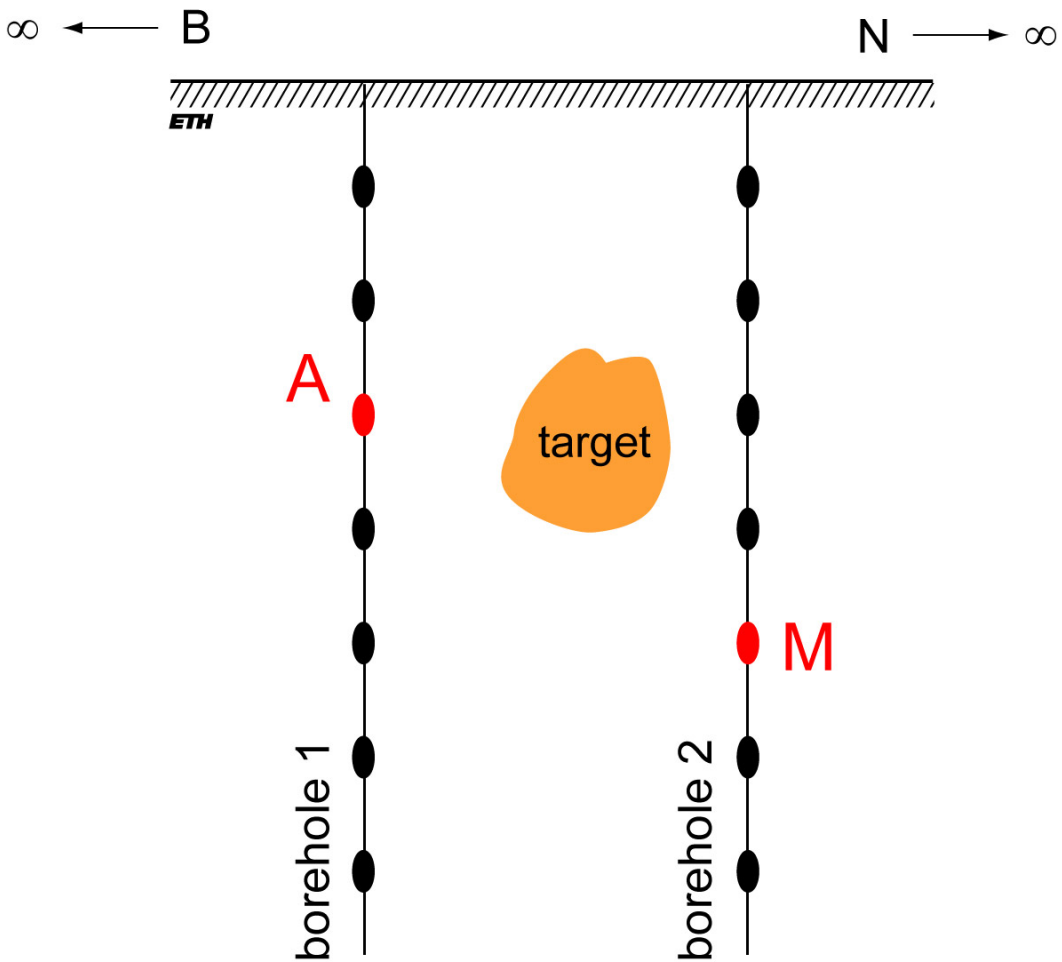
Depth slice 481 to 481.5 m

Waste site 3D imaging



Monitoring


monitoring unit
(resistivimeter, PC)
geomembrane (HDPE), thickness 2.5 mm
ETH
sand, thickness 0.5 m
waste
leak
sand and bentonite
sub-liner electrode arrays
10 m
pollutant
clay

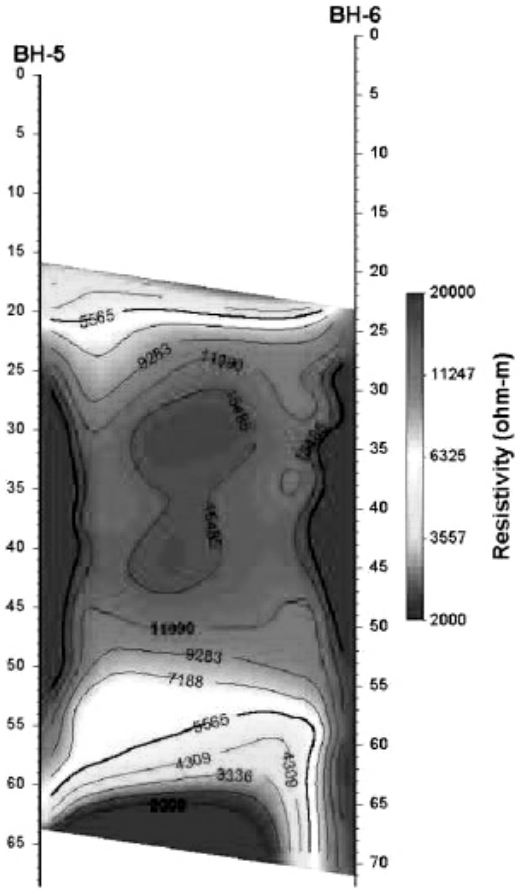


example of a pole-pole survey

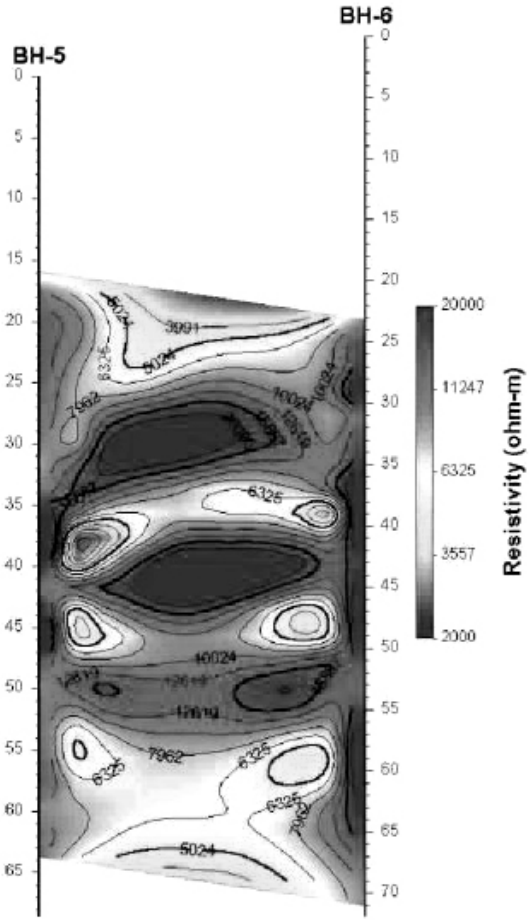
Resistivity imaging is also possible in boreholes.

The boreholes must be filled with water.

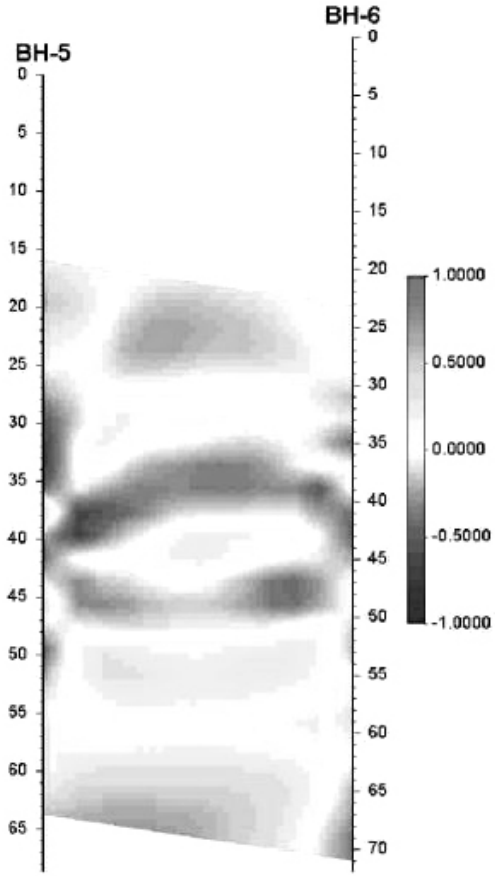
Borehole to borehole measurements



Tomographie avant injection

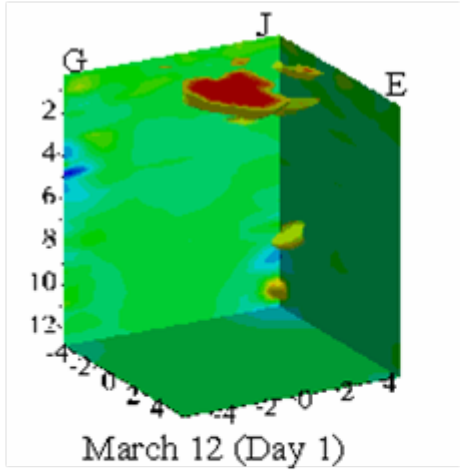


Tomographie après injection

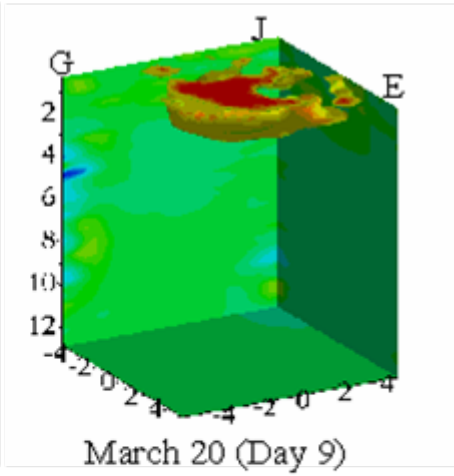


Différence

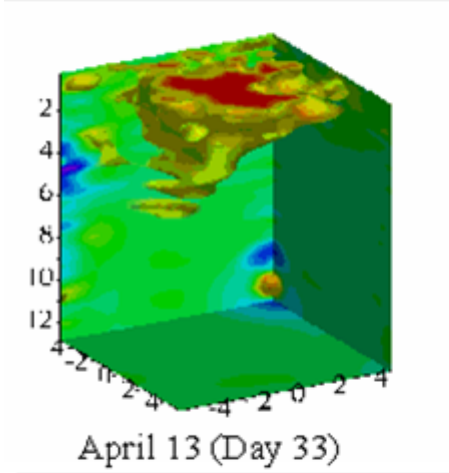
Monitoring water injection



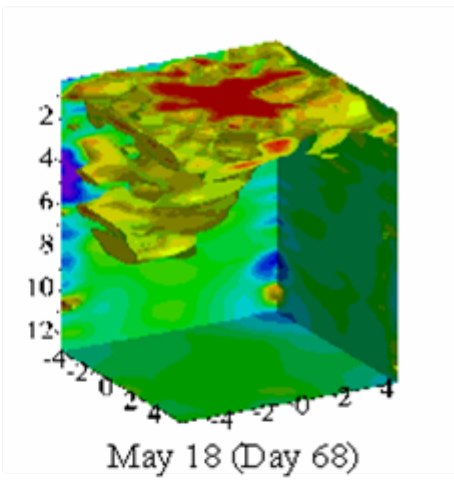
March 12 (Day 1)



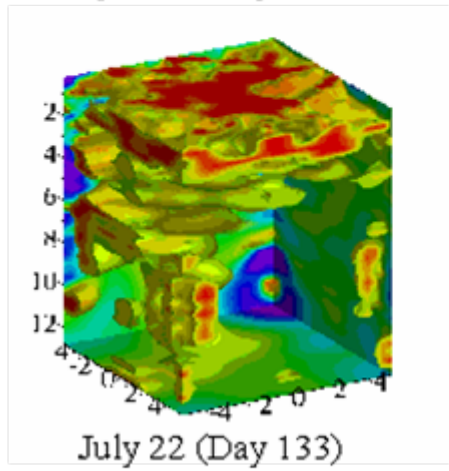
March 20 (Day 9)



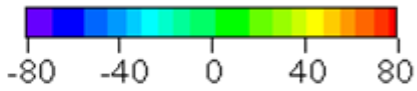
April 13 (Day 33)



May 18 (Day 68)



July 22 (Day 133)



Percent Difference of Conductivity,

Infiltration started on 3/11/1999 (Day 0)

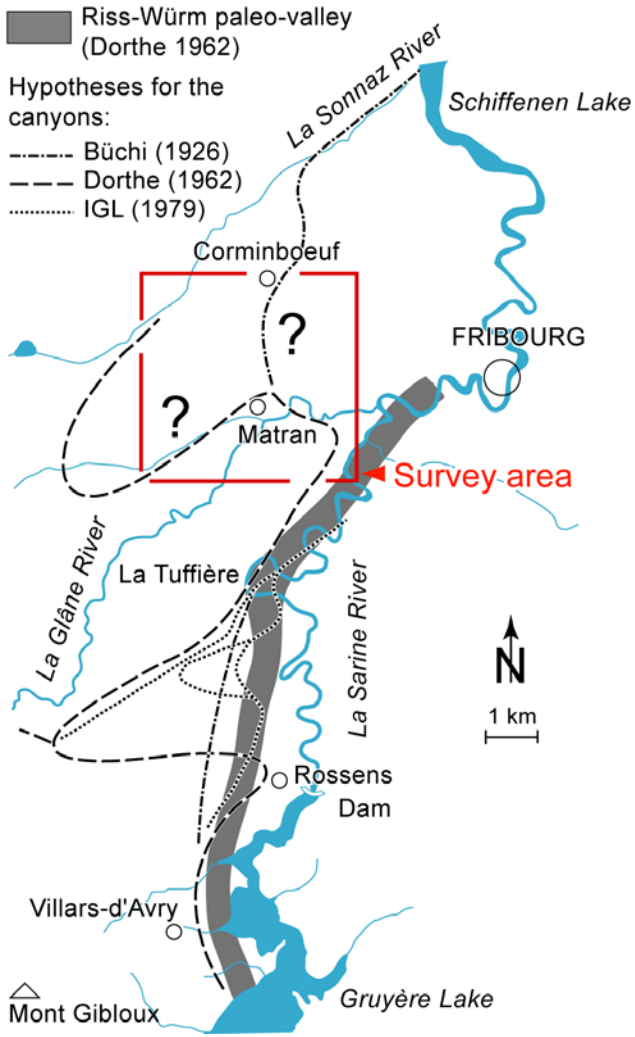
4. Summary of resistivity methods: two case histories

References:

MARESCOT, L., LIACI, S., CHAPELLIER, D., 2003. Etude géoélectrique des cours d'eau interglaciaires à l'Ouest de la ville de Fribourg (Suisse). Eclogae Geologicae Helvetiae, 96, 261-273.

MARESCOT, L., LOKE, M.H., CHAPELLIER, D., DELALOYE, R., LAMBIEL, C., REYNARD, E., 2003. Assessing reliability of 2D resistivity imaging in mountain permafrost studies using the Depth Of Investigation index method. Near Surface Geophysics, 1, 57-67.

Case history 1: Looking for paleo-valleys



Parametrical resistivity determination…

Quaternary

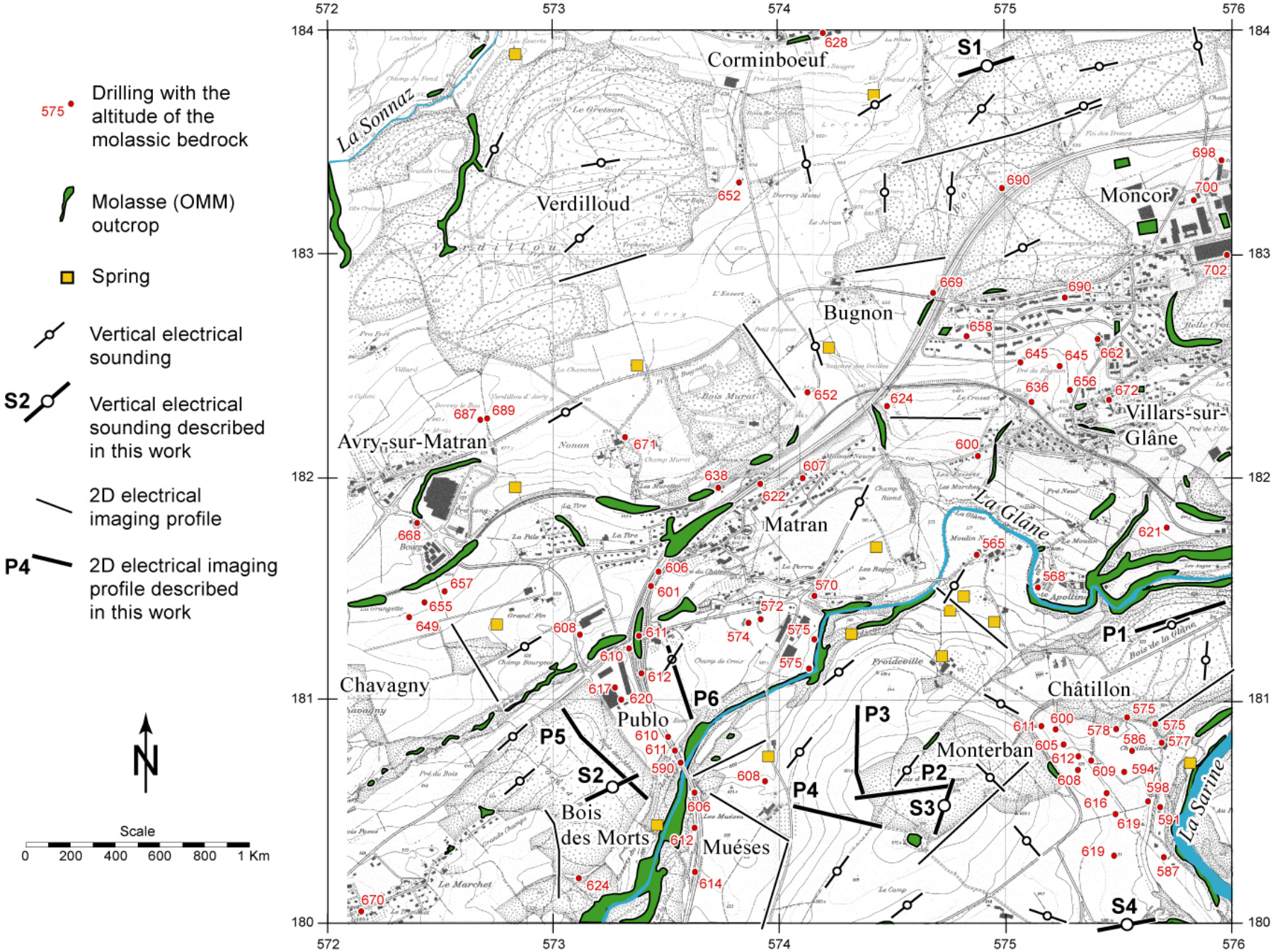
Post glacial sediments:		200 - 300 ohm.m
Moraine (with clay)	:	60 – 150 ohm.m
Gravel (with water)	:	160 – 250 ohm.m
Gravel (dry)	:	500 – 1000 ohm.m
Sand	:	60 – 100 ohm.m
« Complexe rissien »	:	30 – 60 ohm.m

Tertiary

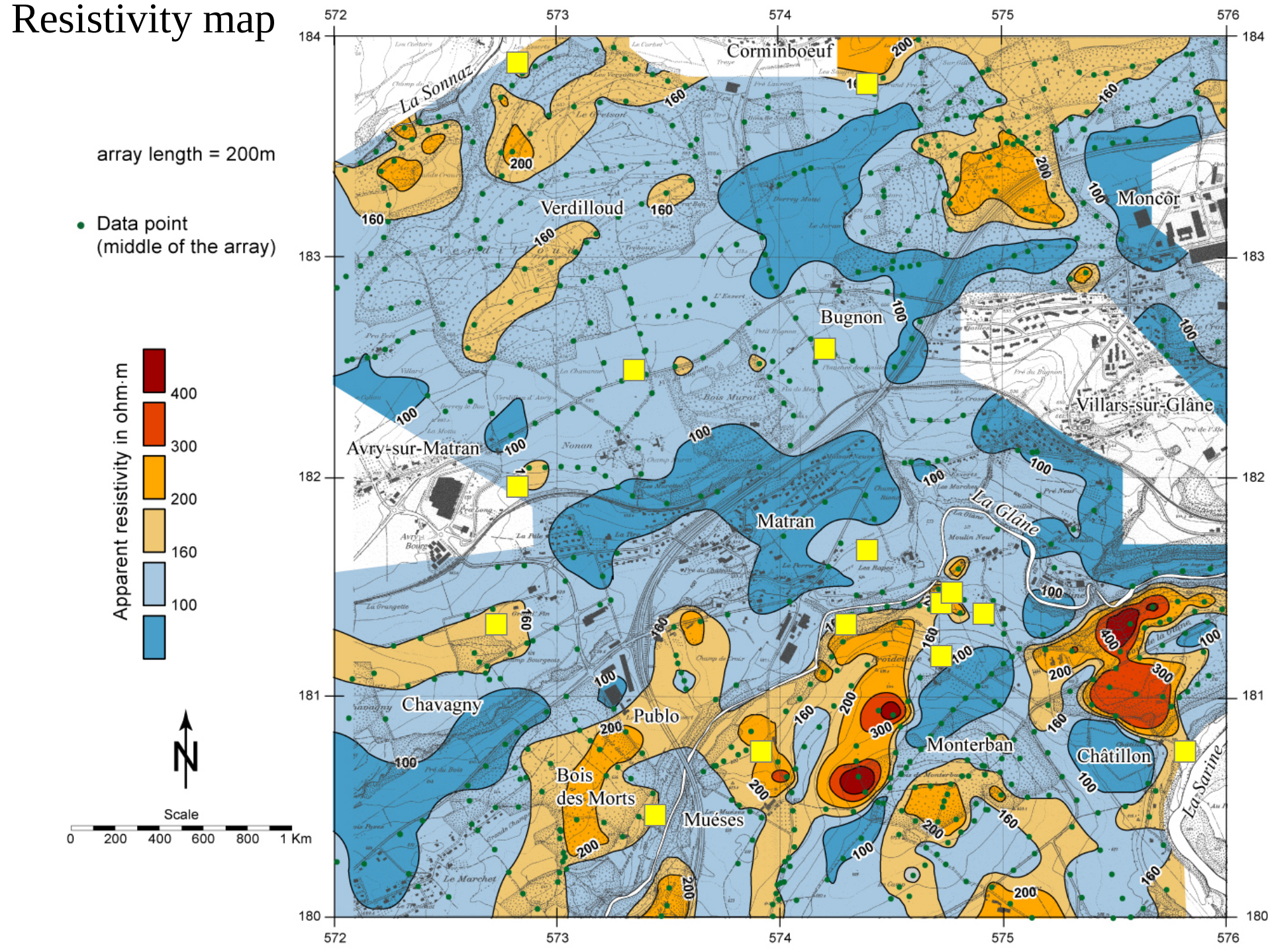
Molasse (bedrock)	:	110 – 170 ohm.m

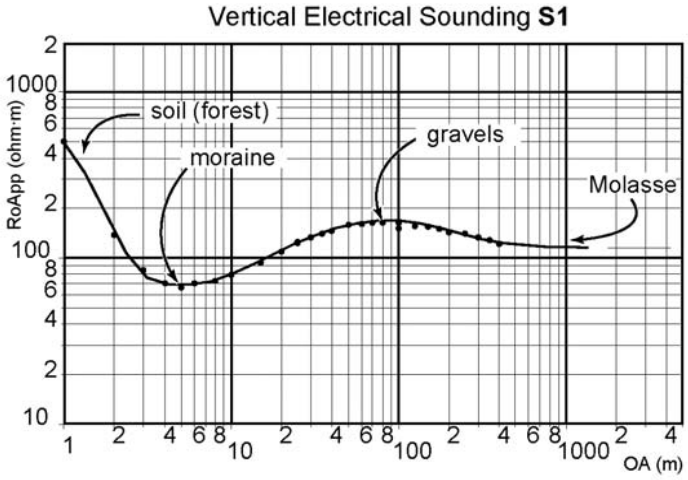
!!! Resistivity contrast must exist

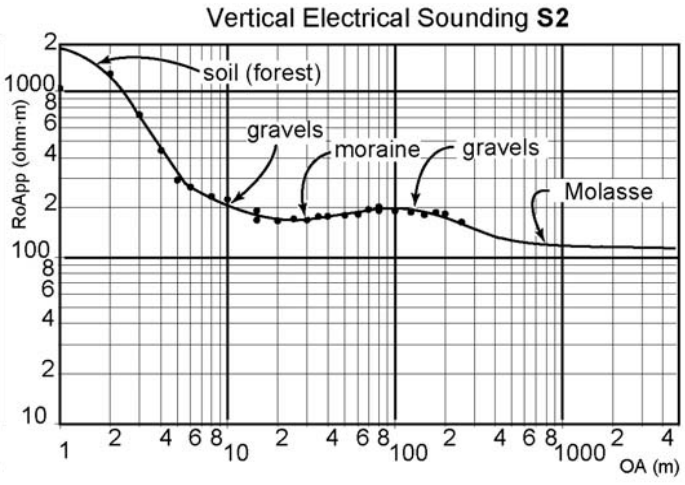
Available information

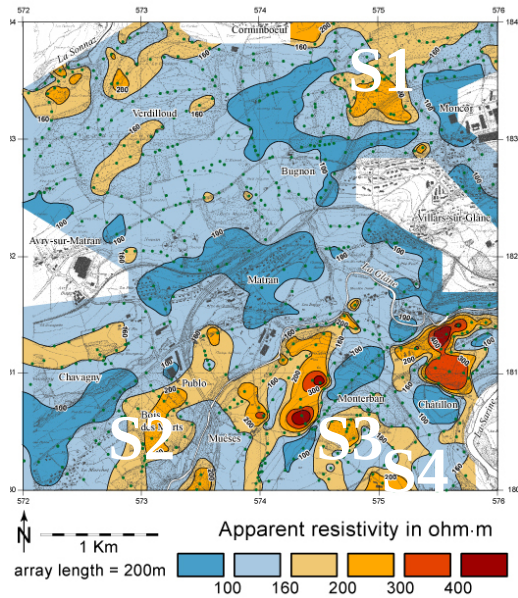


Resistivity map



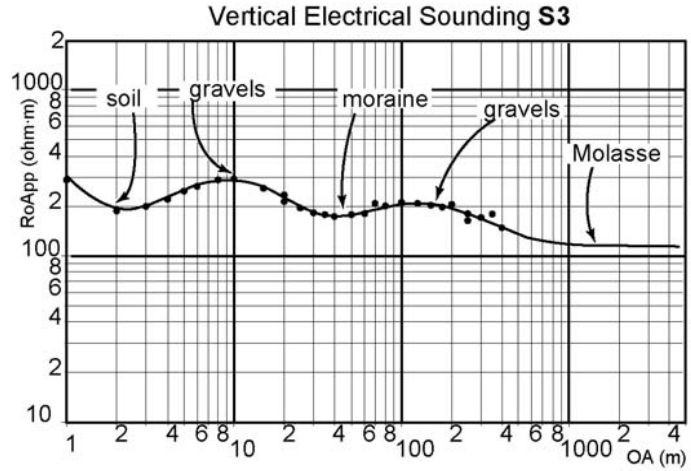


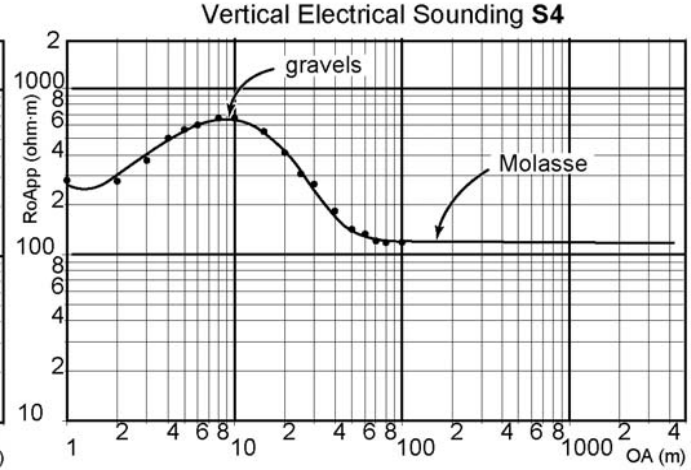




Layer N°	Resistivity (ohm·m)	Thickness (m)	Depth (m)	Altitude
1	900	0.6		670
2	63	6.8	0.6	669.5
3	300	2	7.4	662.7
4	200	58	9.4	660.7
5	115		67.3	602.7

Layer N°	Resistivity (ohm·m)	Thickness (m)	Depth (m)	Altitude
1	2000	1.2		635
2	215	7.5	1.2	633.8
3	101	9.2	8.7	626.3
4	281	47.5	17.9	617.1
5	117		65.4	569.6



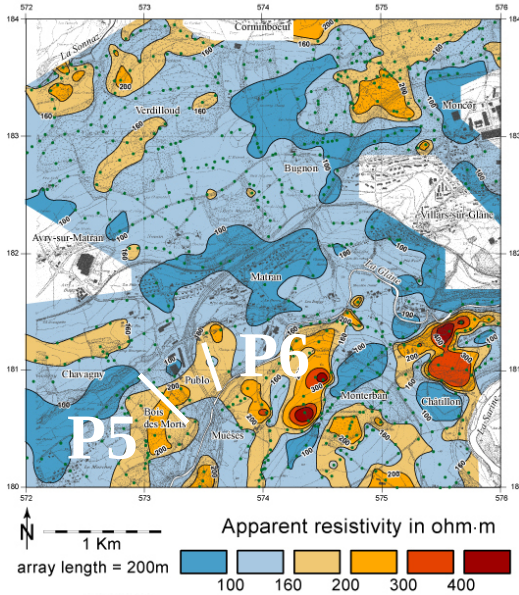


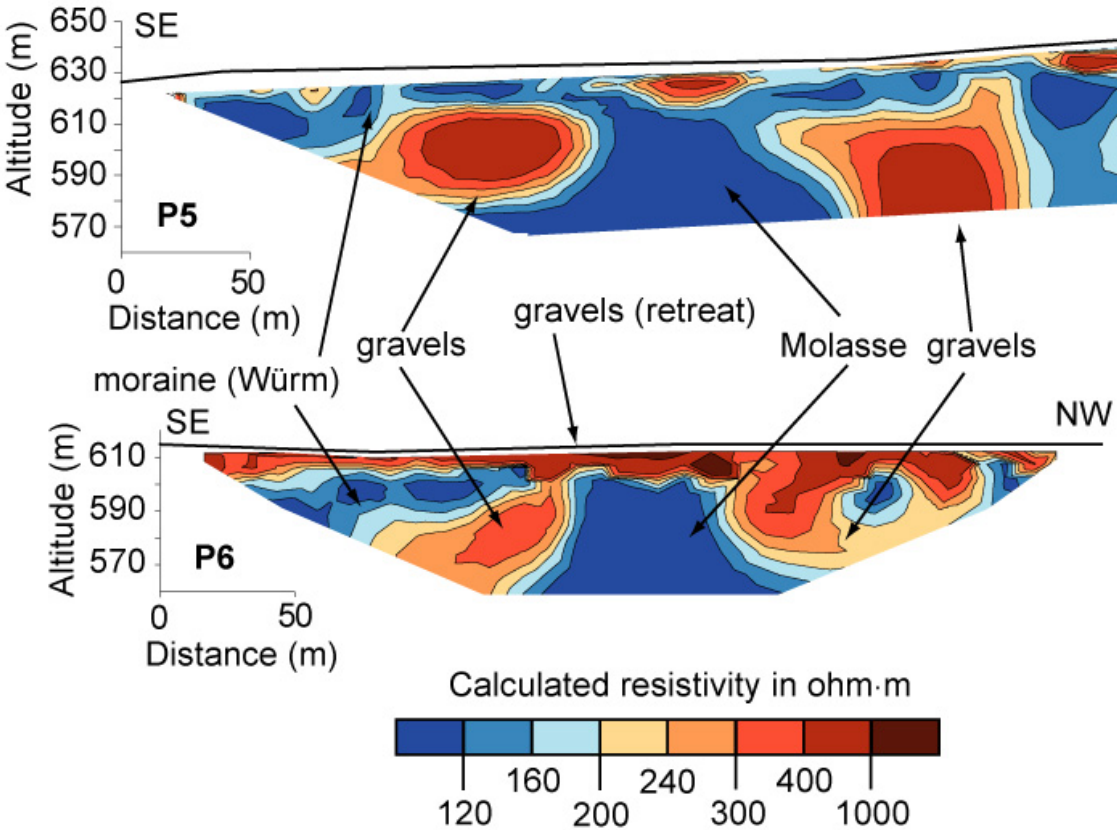
Layer N°	Resistivity (ohm·m)	Thickness (m)	Depth (m)	Altitude
1	460	0.5		677
2	92.5	0.9	0.5	676.5
3	475	4.8	1.4	675.6
4	102	15	6.2	670.8
5	303	53.5	21.2	655.8
6	123		74.7	602.3

Layer N°	Resistivity (ohm·m)	Thickness (m)	Depth (m)	Altitude
1	266	0.7		621
2	119	0.3	0.7	620.3
3	1175	5.5	1.0	620
4	84	14	6.5	614.5
5	124		20.5	600.5

VES survey

2D resistivity tomography





Profile P5
Wenner-Schlumberger array,
829 data points,
iteration 4, error RMS: 7.7%

Profile P6
Wenner-Schlumberger array,
386 data points,
iteration 4, error RMS: 3.9%

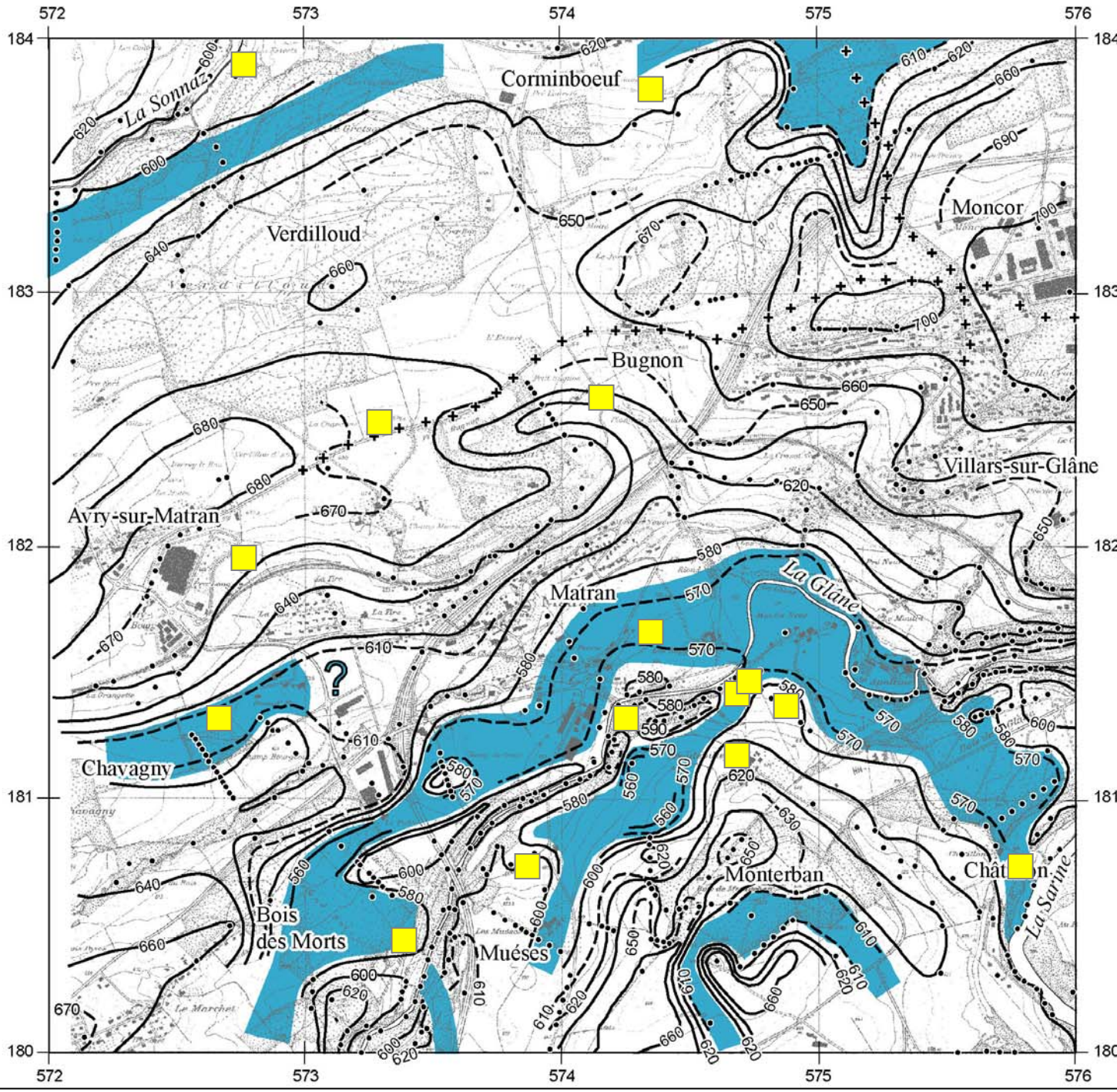
Result…

660 Altitude of the Tertiary bedrock (main equidistance 20 m)

Depth to bedrock measurement (drilling, outcrops, geoelectrical survey)

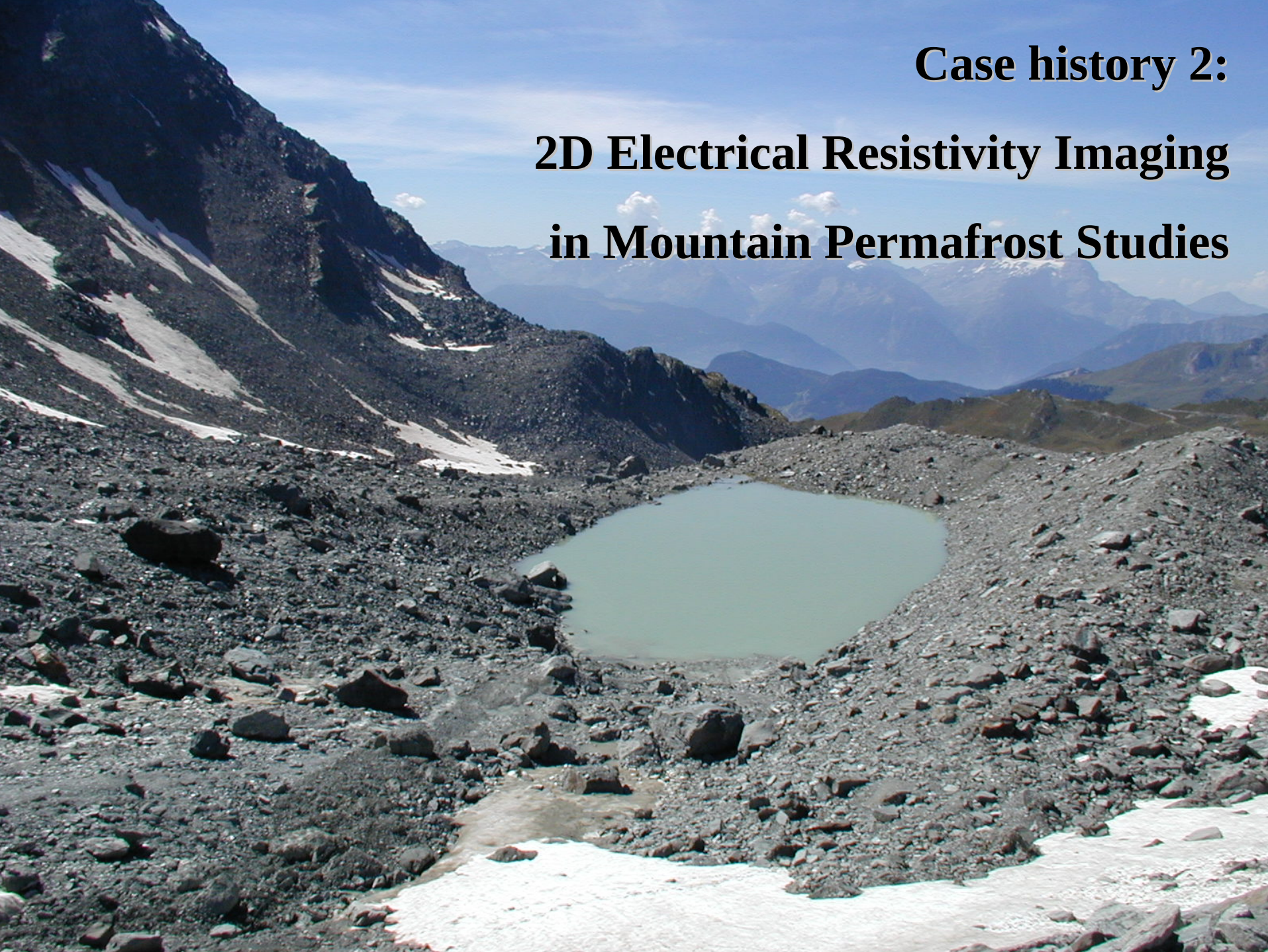
Gravimetry measurement station

The imaged paleo-valley framework.
The blue color symbolizes the bottom of the valleys



N

Scale
0 200 400 600 800 1 Km



Case history 2:

2D Electrical Resistivity Imaging in Mountain Permafrost Studies

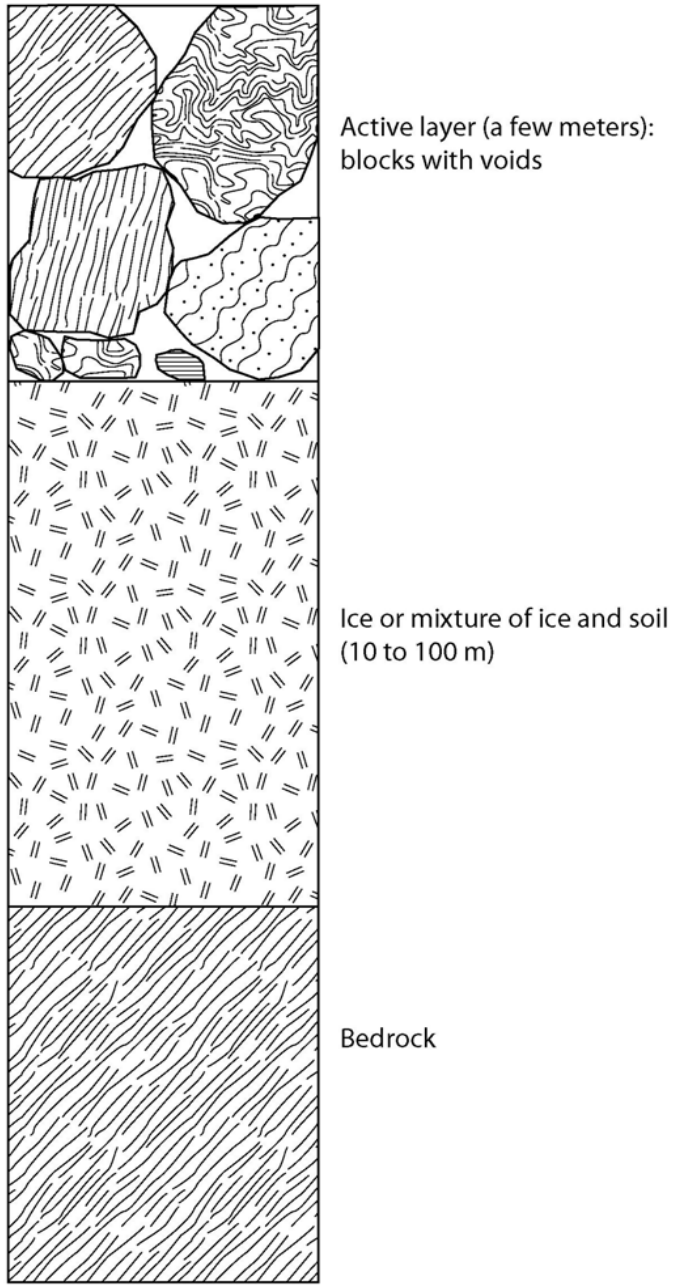
What is permafrost?

Lithological material with a temperature below 0°C during at least one whole year.

What is a rock glacier?

A mass of blocks cemented with ice. The velocity of an active rock glacier can reach a few centimetres per year.

A schematic lithology of a rock glacier:



Methodology

Long (> 1 m) steal stakes.

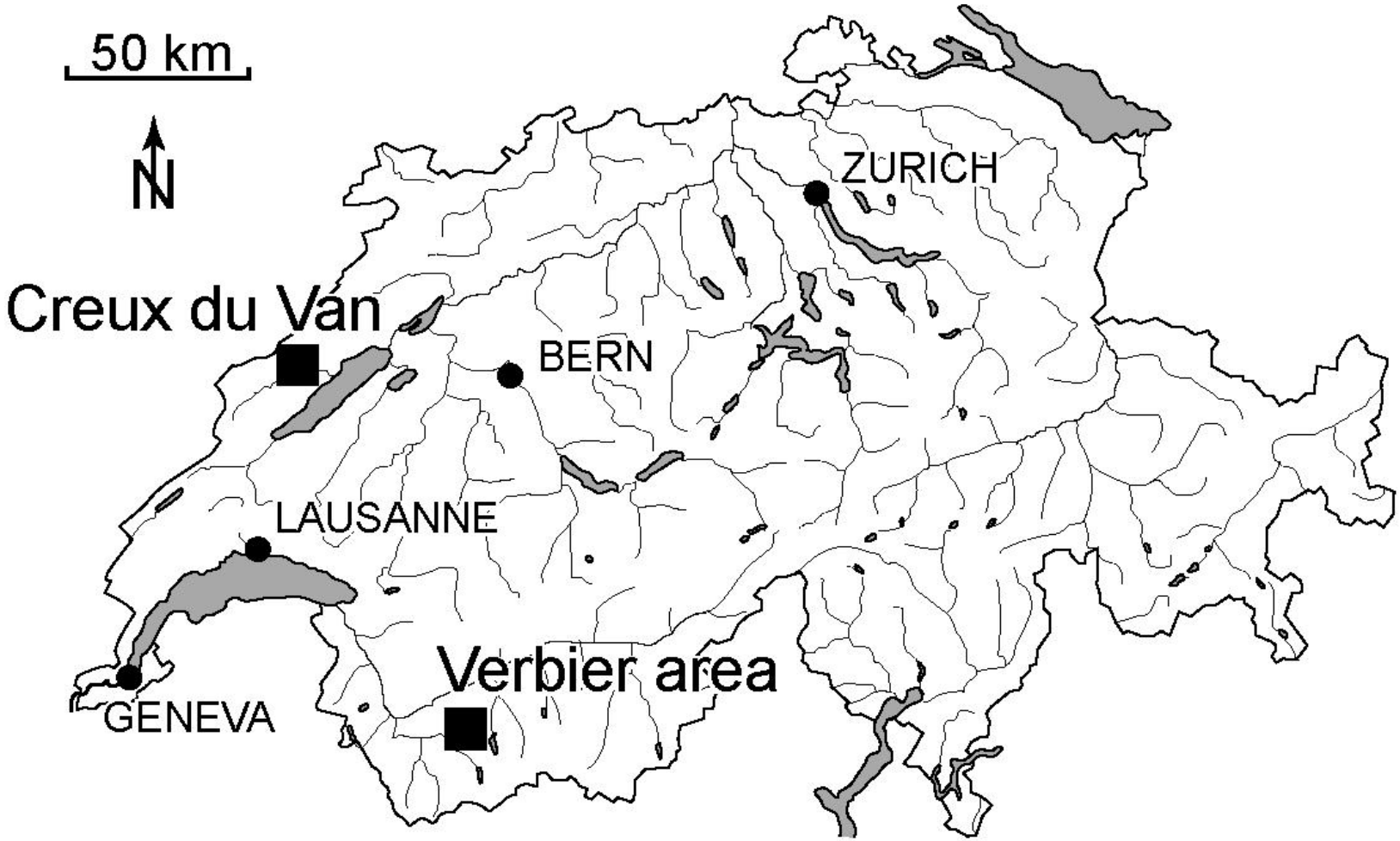
Sponges with salt water.

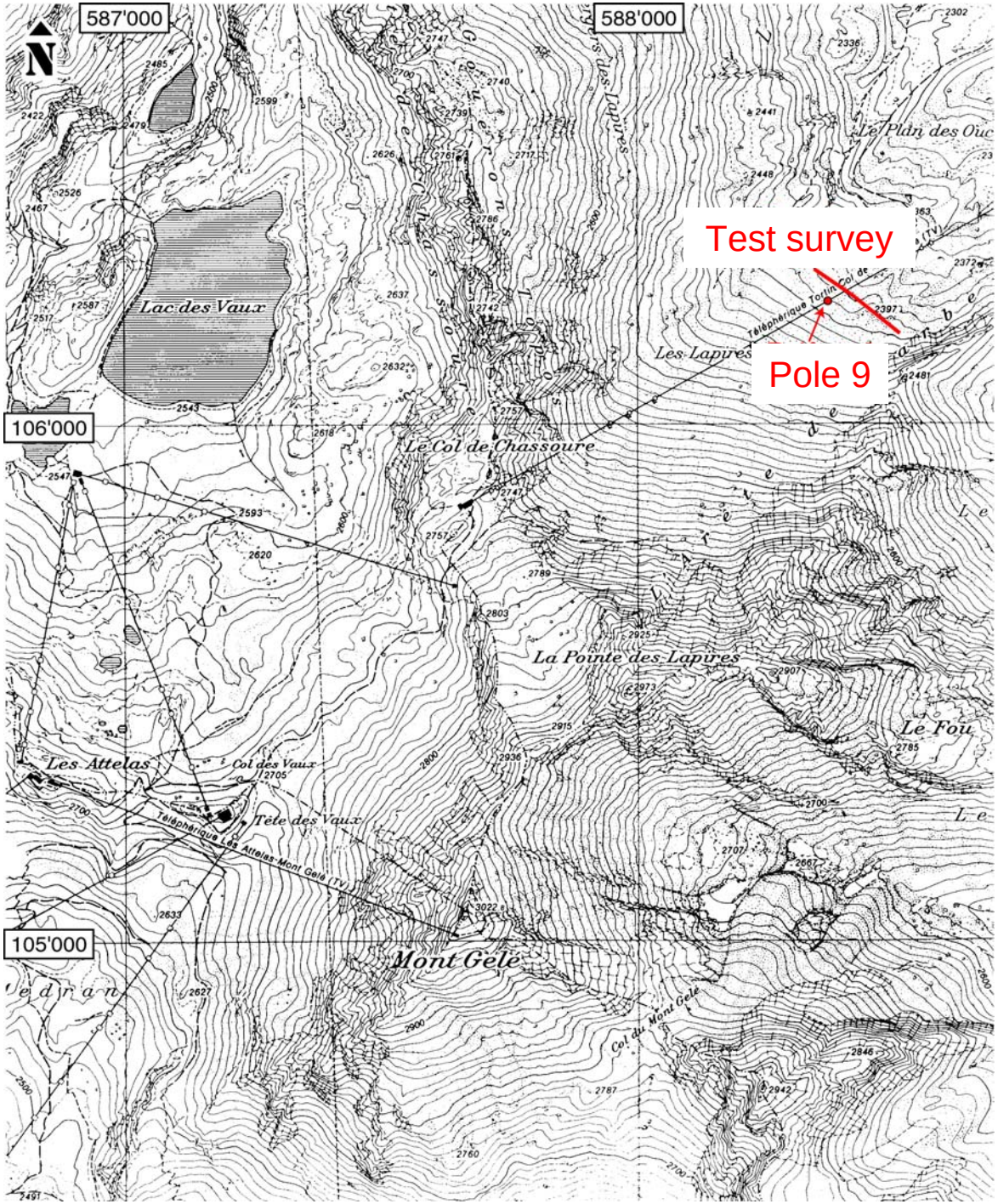
Acquisition characteristics

Contact resistance: about 80’000 Ohm

Injected current: about 2 to 5 mA

The research sites location





The test survey:

Les Lapires, Tortin

(2400 m a.s.l.)

Occurrence of mountain permafrost:

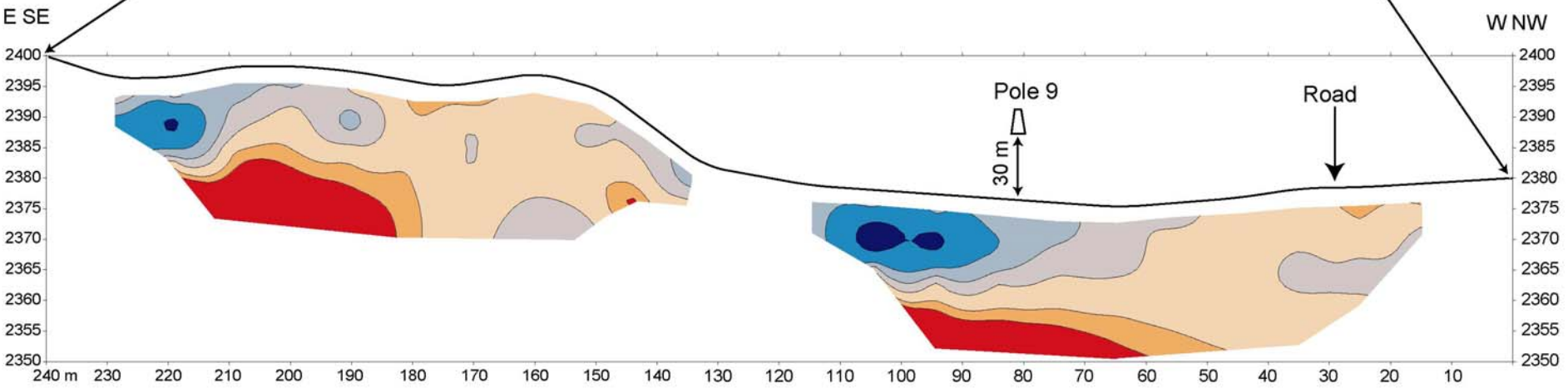
A problem for civil engineering…

Permafrost occurs in a drilling along the pole 9:

Permafrost from -3.5 m to -20 m

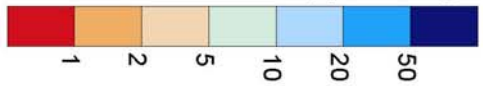
DAIHATSU
adidas

A dangerous job …



Wenner-Schlumberger array
unit electrode spacing 10 m
iteration 10
RMS error 6.3%

Calculated resistivity [Kohm.m]



Wenner-Schlumberger array
unit electrode spacing 10 m
iteration 5
RMS error 4.8%

5. Conclusions

Advantages

- Survey simple and robust
- Non expensive
- Method mainly sensitive to the fluid in rocks
- Allows for a rapid qualitative mapping of the underground

Drawbacks

- Sensitive to non-unicity in the modeling solutions
- Quantitative aspects still need to be developed but progresses have been currently made