37° convegno

ERT and GPR waterborne surveys on a high-elevation Alpine pond (NW Italy)

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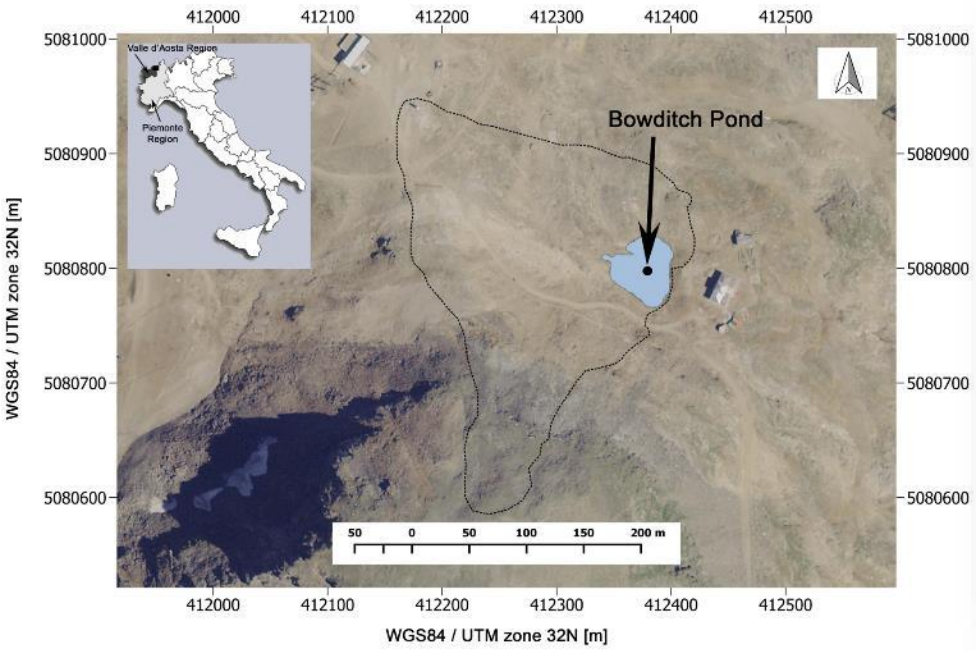
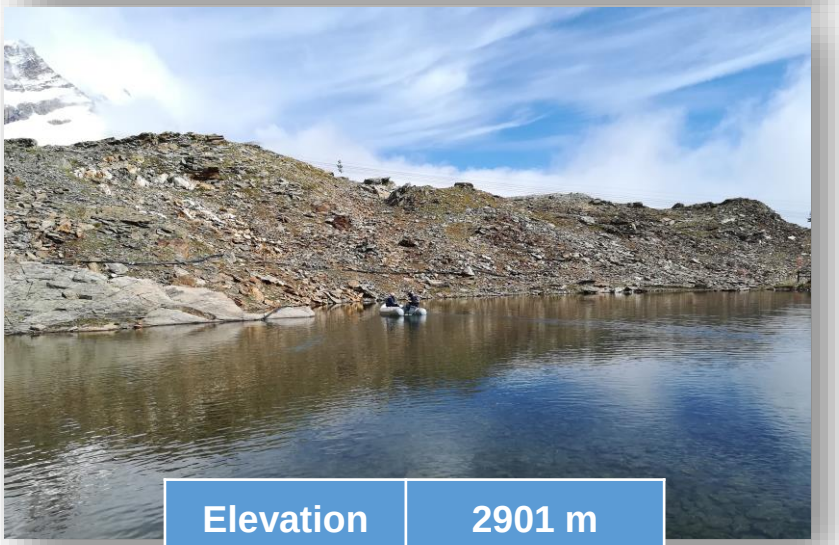
High-elevation lakes

- **Small dimensions**
- Possible **permafrost** presence
- Important role in the **hydrogeological and chemical dynamics** of mountain watersheds
- **Key reference environments for global scale processes** (*lack of direct human influence, rapid response to climate change*)

Non-seismic geophysical methods can map hydrogeological information and detect the presence of permafrost

Test site: Bowditch Pond (NW Italy)

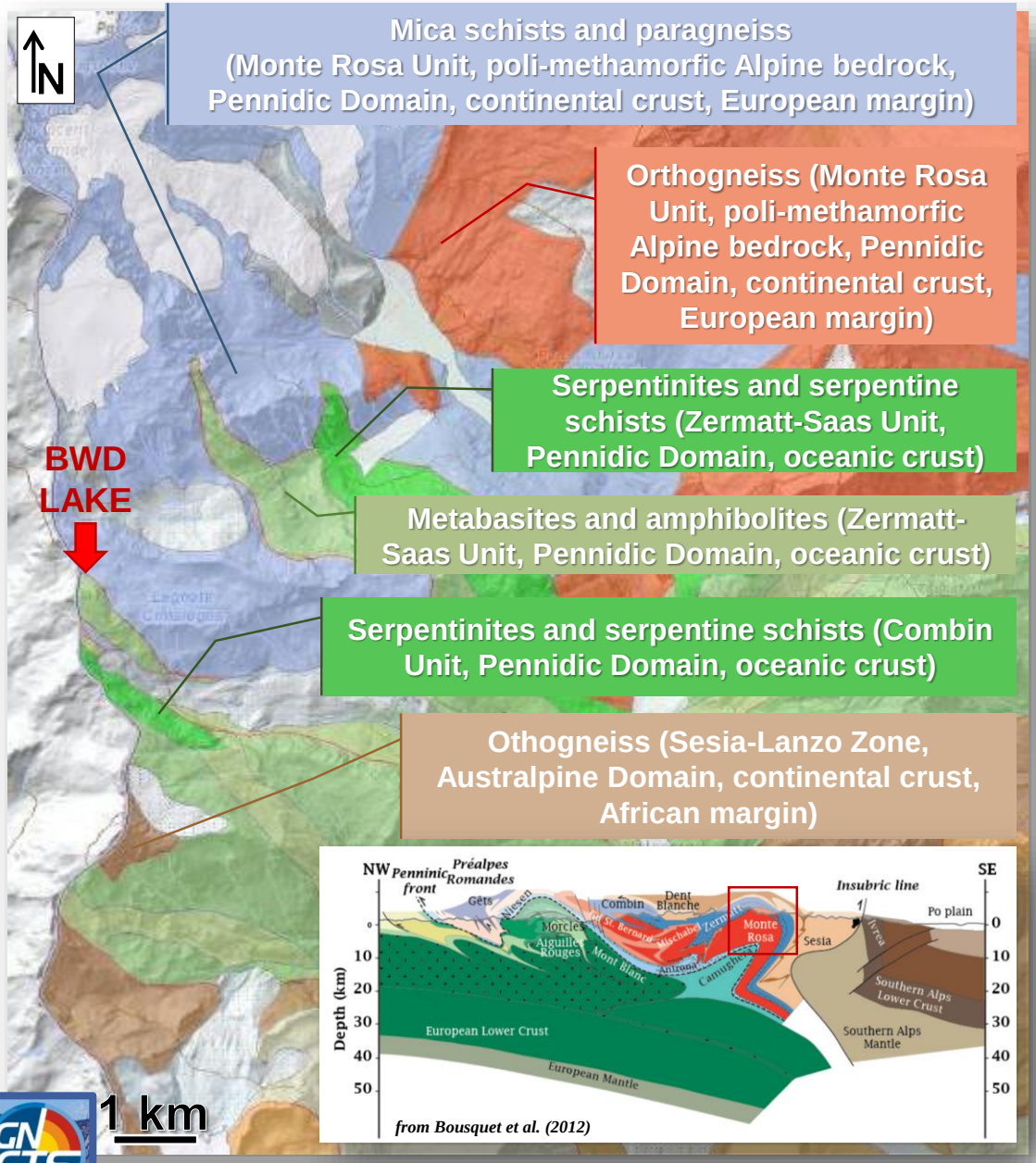




- The pond has **no surface inflows**
- A **surface outflow** is present, although it usually disappears during the ice-free season (August)
- **Permafrost** is likely to exist in the basin

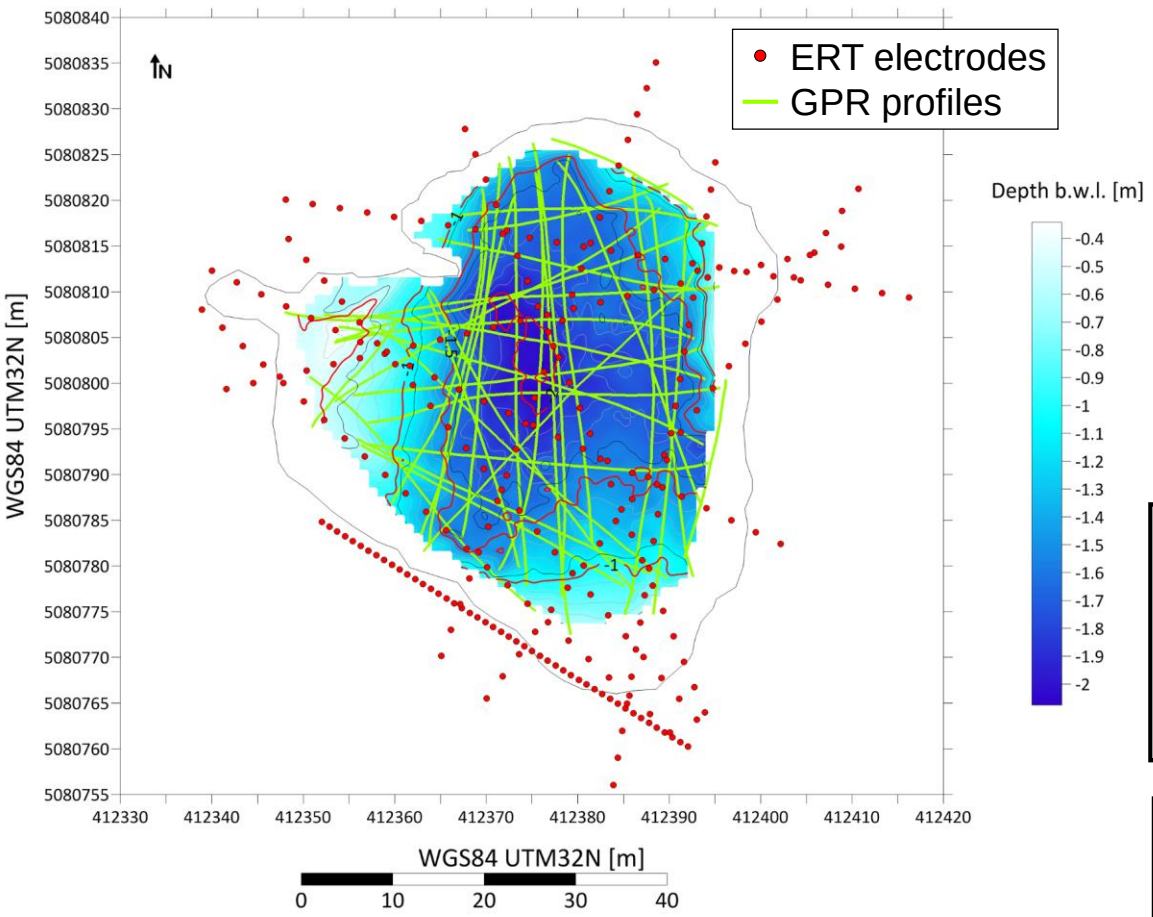
Elevation	**2901 m**
Area	**2405 m^2**

Geological background



- Different tectono-metamorphic units **folded** together
- The complex geo-structural background is partially hidden by the abundant presence of **fractured rocks** and **coarse debris covers**

Geophysical surveys



GPR

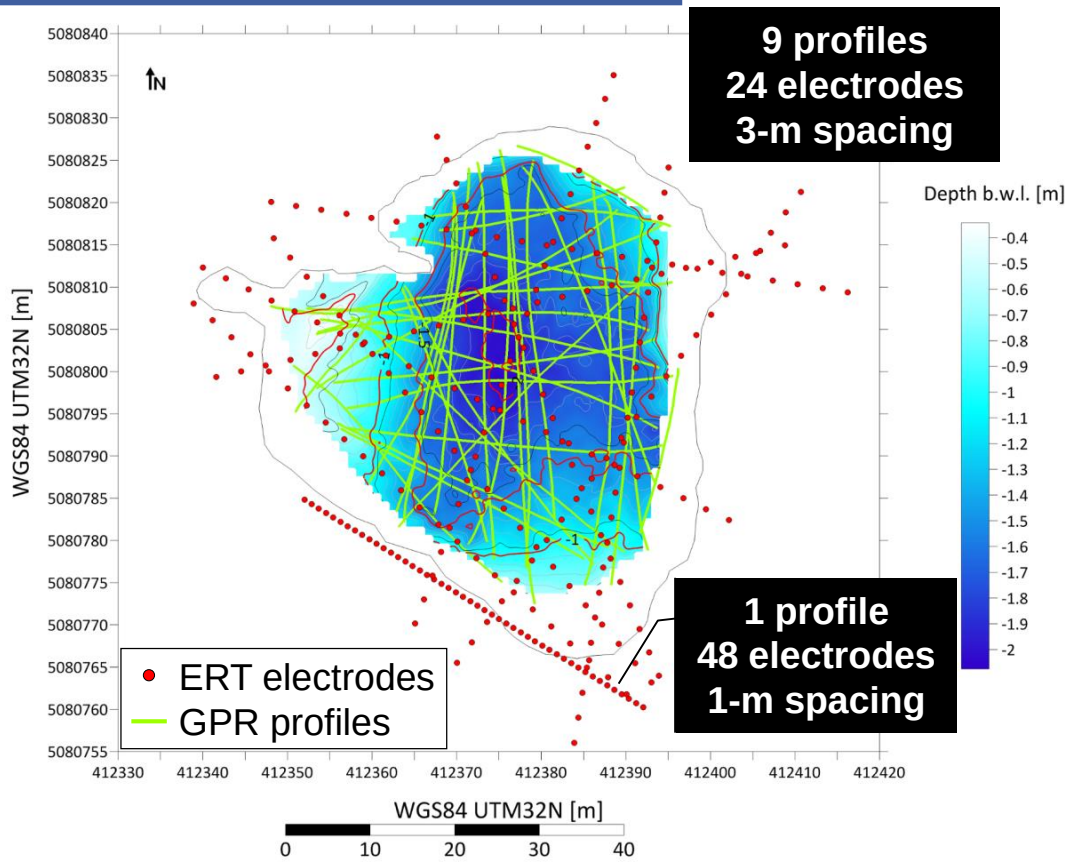
IDS **200-MHz** bistatic antenna
+ IDS K2 digital unit
Ublox EVK-5T GPS

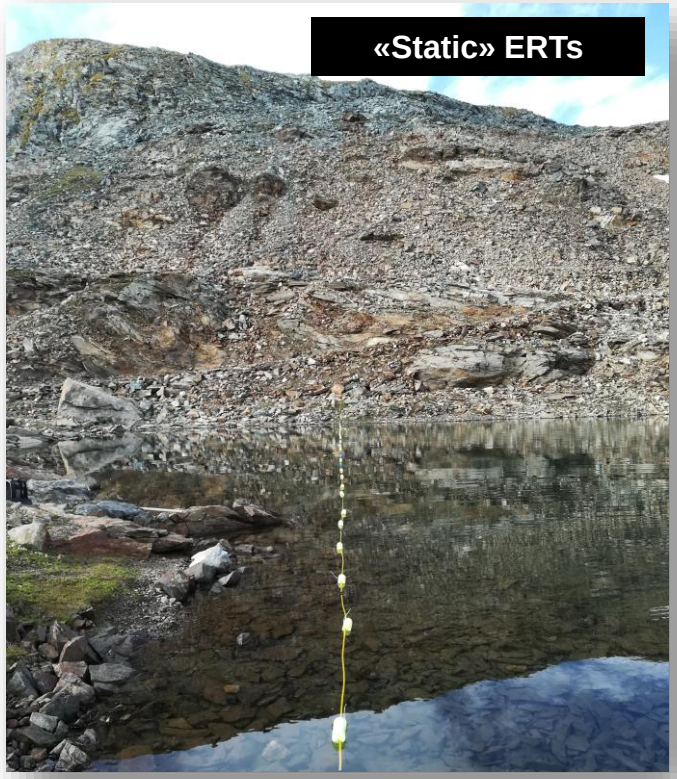
19 profiles
dt=0.48 ns
T=500 ns
1024 samples/trace

17 profiles
dt=0.48 ns
T=1000 ns
2048 samples/trace

Total Length=1331.2 m

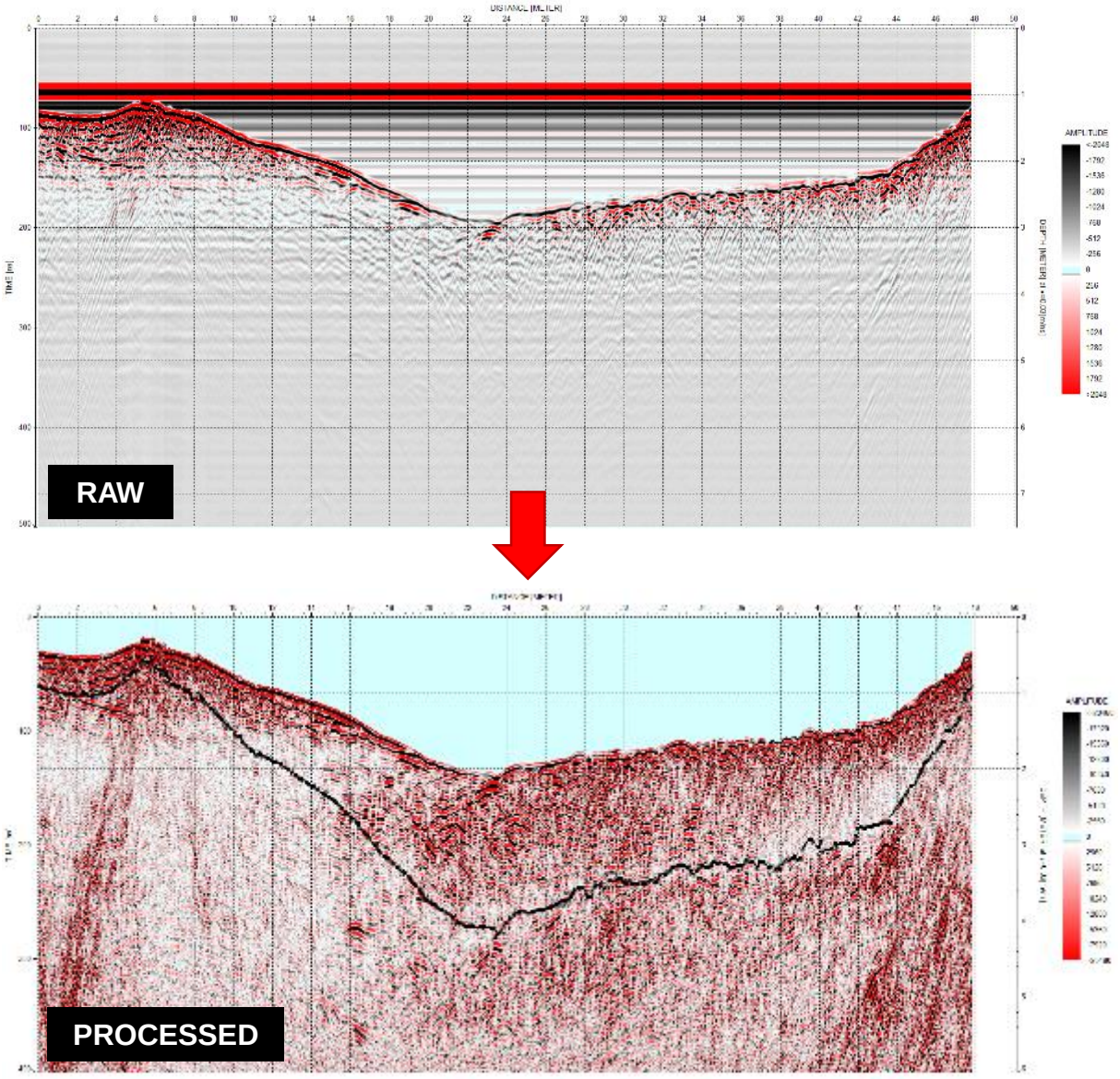
Geophysical surveys





- Floating cables with equi-spaced electrode locations stretched across the pond (stainless steel electrodes for the on-land line extremities)
- Multi-channel resistivity system (Syscal Pro – Iris Instruments) → W-S sequence
  - **SP measurement before current injection**

GPR data processing



i) **Trace regularization**, on the basis of the effective profile length and number of traces;

ii) **Time cut**, to reduce the trace length after a check of the deterioration of the S/N ratio;

iii) **Move start time**, to remove the delay introduced by the system;

iv) **Dewow**, to reduce very low frequency components;

v) **Further time cut**, to equalize the sample number within the traces of the two surveys;

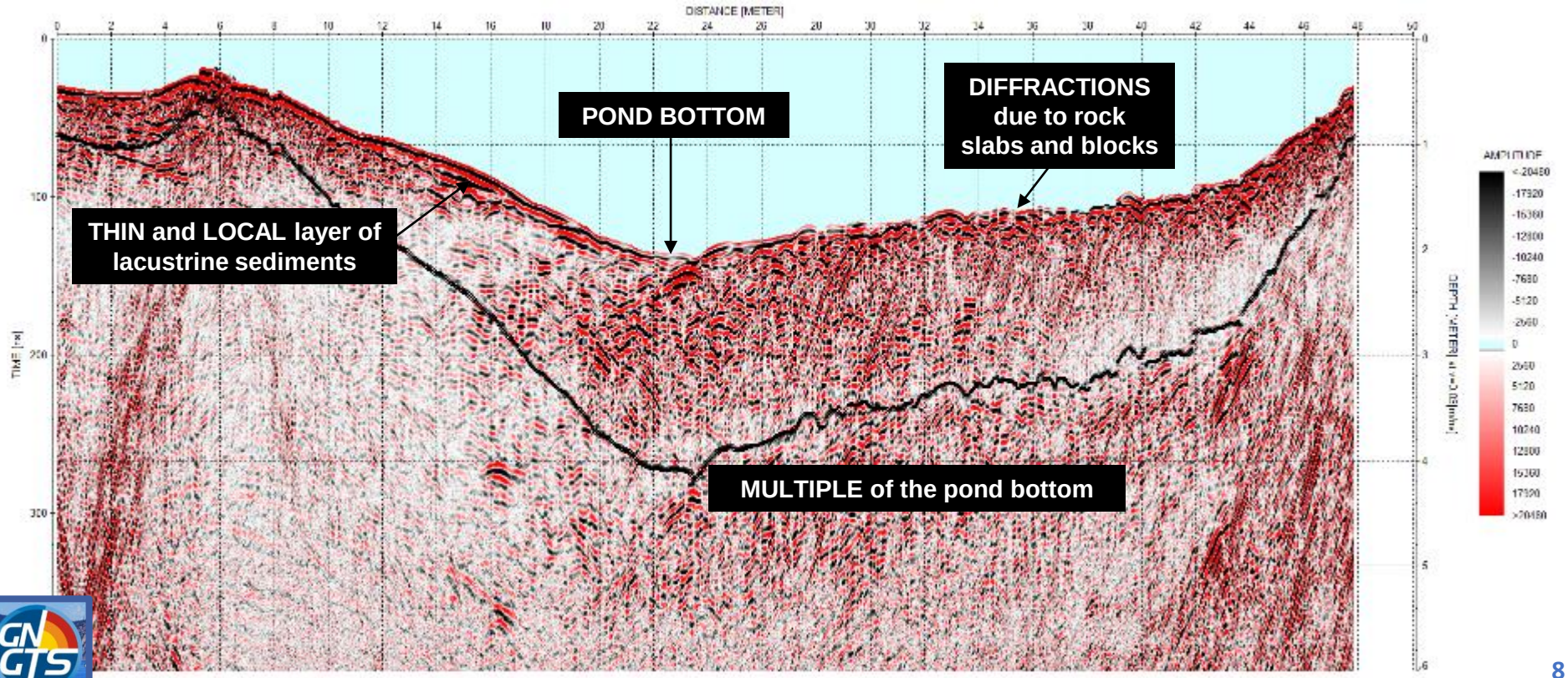
vi) **Divergence compensation**, to increase deep echoes strength;

vii) **Subtracting average**, to remove horizontal bands

viii) **Muting** above the pond-bed picking

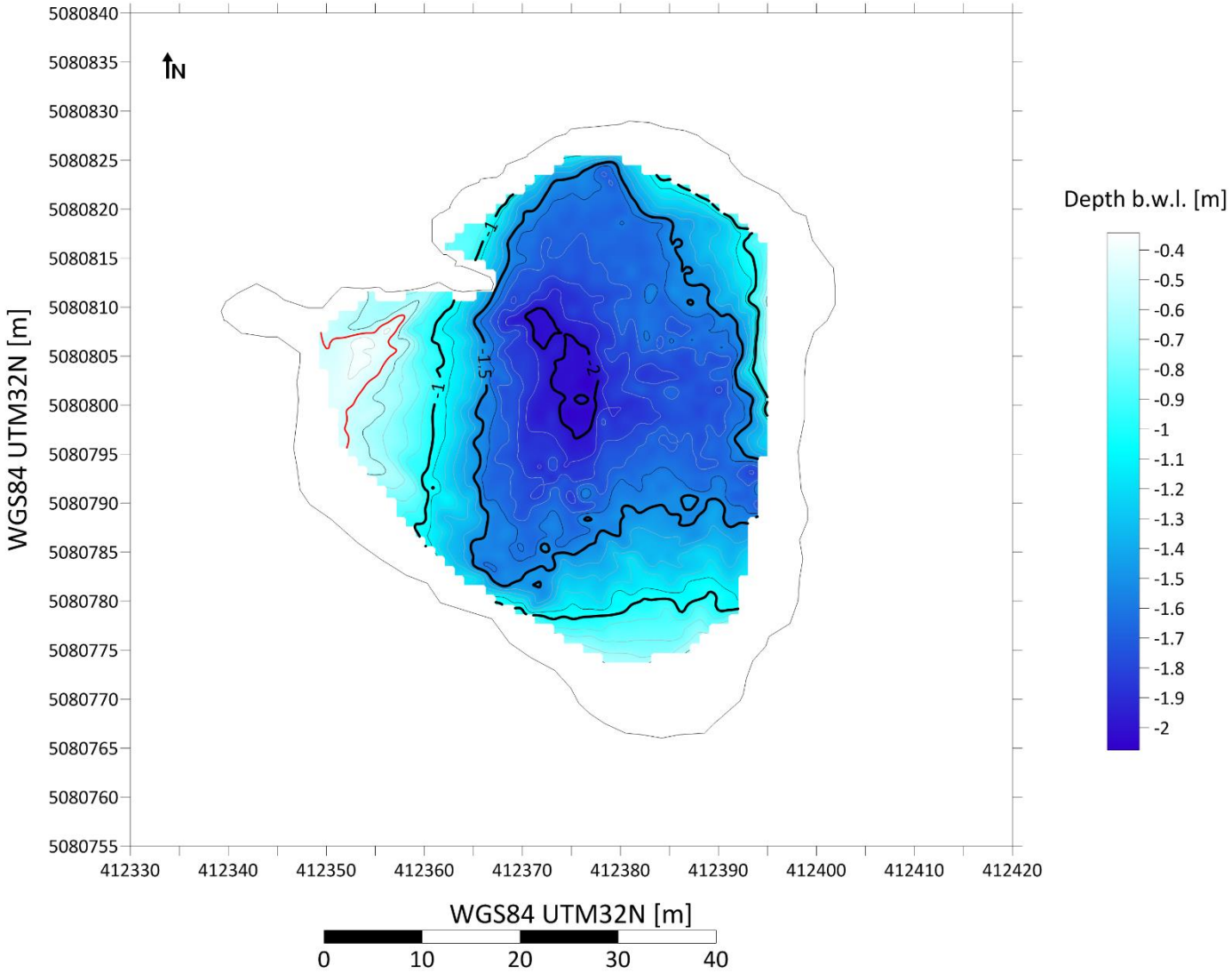
GPR results

- **Diffraction hyperbolas** are probably due to the widespread presence of **schist slabs and decimetric blocks** laying on the pond bottom. These hyperbolas showed asymptote slopes tending to 0.03 m/ns (i.e. water velocity). **Other diffraction hyperbolas showing higher velocities** (around 0.05 m/s) were also noticed and not so clearly interpretable
- Only in **restricted parts of the pond** bottom, **thin decimetric layers of lacustrine sediments** were found
- The **sedimentation** of fine materials within the basin is **almost negligible** and the pond seems to directly lie on a **rocky bedrock or** on **very coarse debris bodies**.



GPR results

- The manual picking of the pond bottom on the radargrams was further used to reconstruct the pond **bathymetry** (→ constraint for ERT inversion)
- The pond is characterized by a **thin water layer** (**max 2 m**)

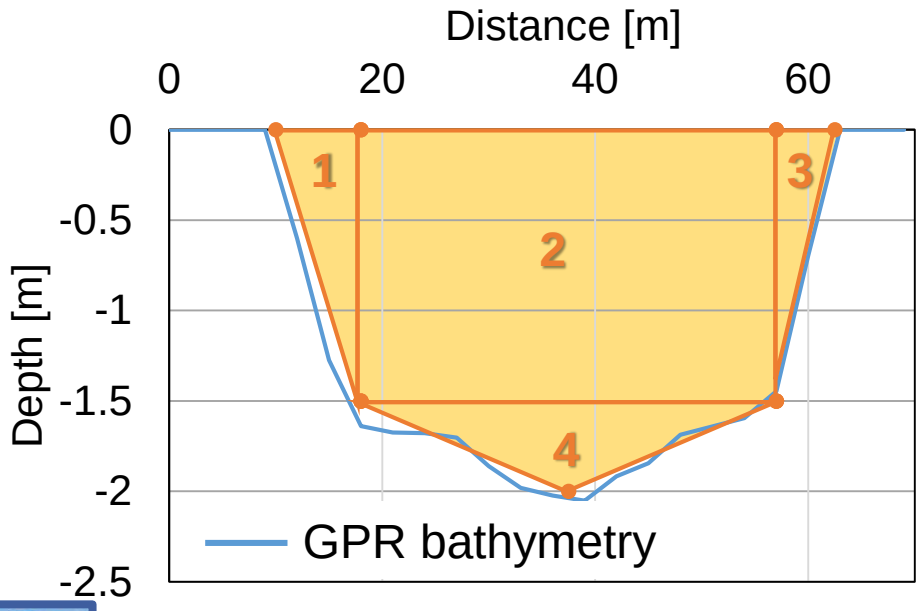


ERT and SP data processing

2D INVERSION

Due to the presence of both floating and on-land electrodes, **constraining the bathymetry** was a non-trivial issue

The most stable inversion procedure and results were obtained by **discretization of the water body with triangles and rectangles**



ERTs

i) Raw data filtering

ii) **2D INVERSION** (*Res2DInv, Geotomo*)
- No constraints
- **Bathymetry** of the pond (from GPR data) + water resistivity (**125 Ωm**)

iii) **3D INVERSION** (*ERTLab, Geostudi*) (no constraints)

SPs

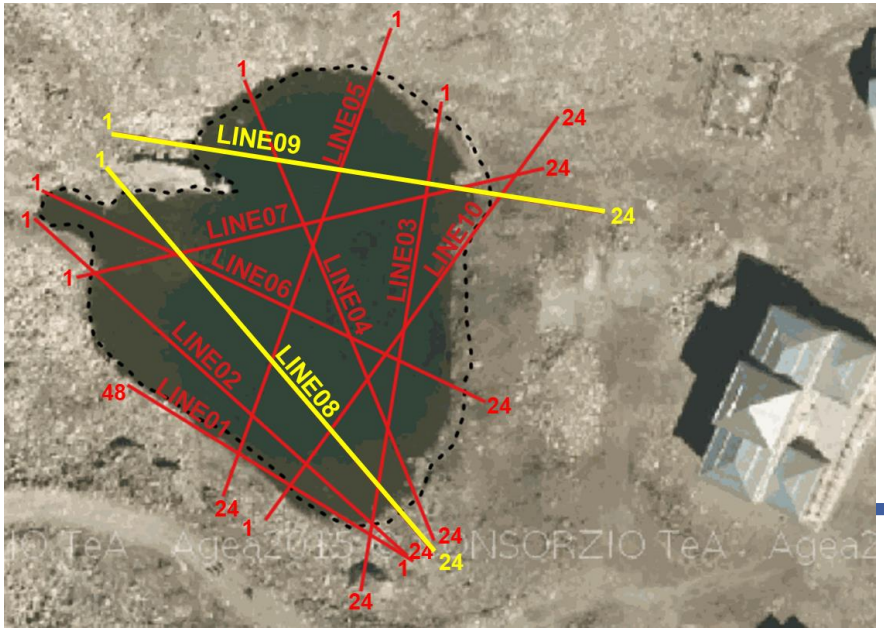
i) Extraction of the Sp measurements related to the dipoles with lower spacing (AB=9 m -> z≈AB/2 ≈4.5 m)

ii) Mapping in the center of the investigated dipole

iii) Triangular interpolation

ERT results

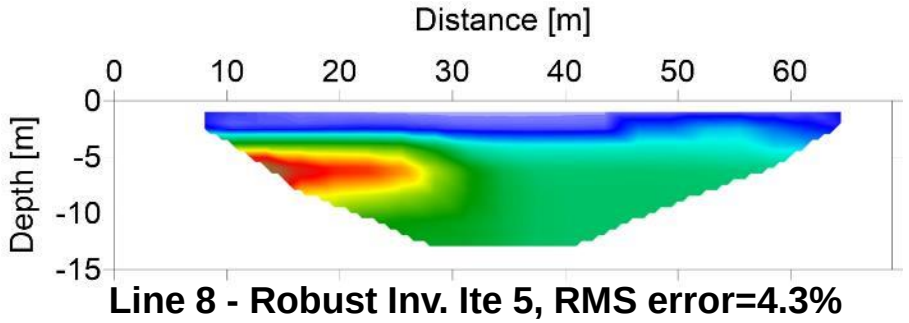
2D INVERSION



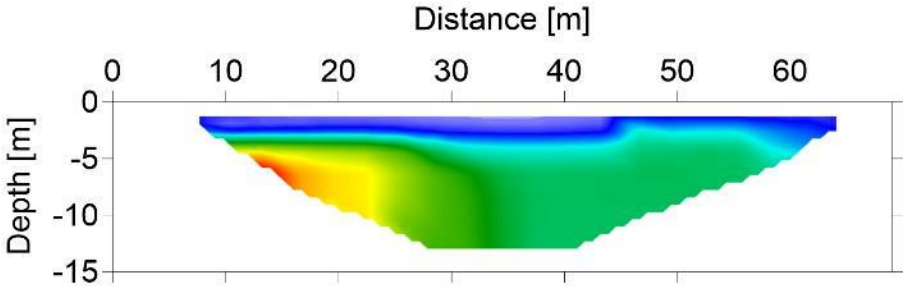
Electrical Resistivity [Ωm]

5000 10000 15000 20000 25000 30000

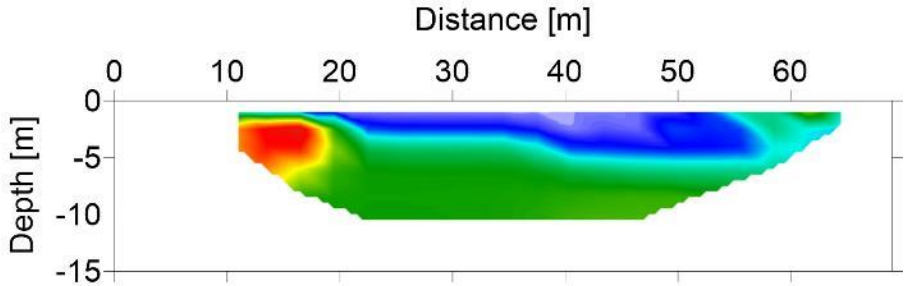
High-resistivity values in correspondence of an outcropping elongated ridge of **compact rock** (NW of the pond)



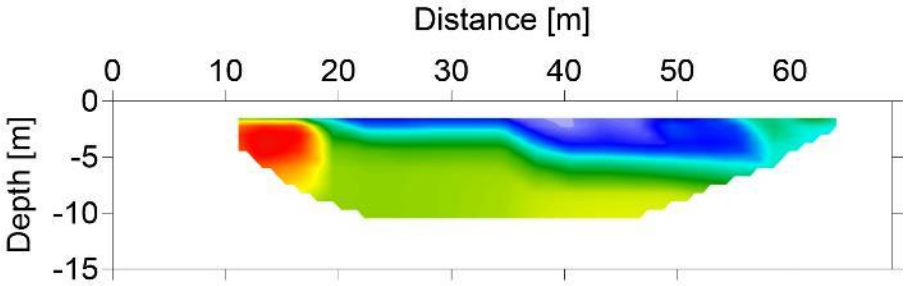
Line 8 - Robust Inv. Ite 5, RMS error=4.3%



Line 8 – Constr. Inv. Ite 5, RMS error=3.2%



Line 9 - Robust Inv. Ite 5, RMS error=6.6%

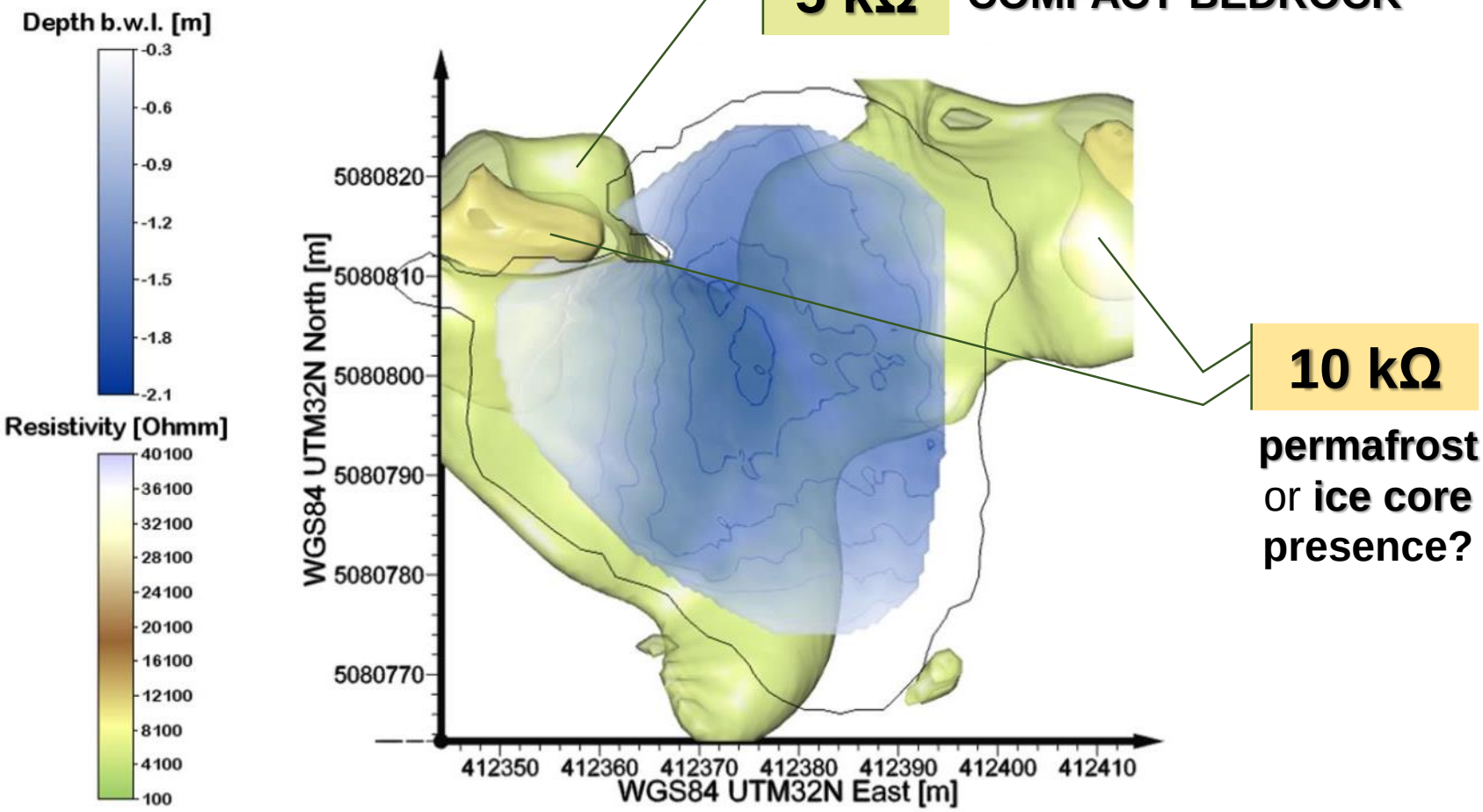


Line 9 – Constr. Inv. Ite 5, RMS error=4.9%

ERT results

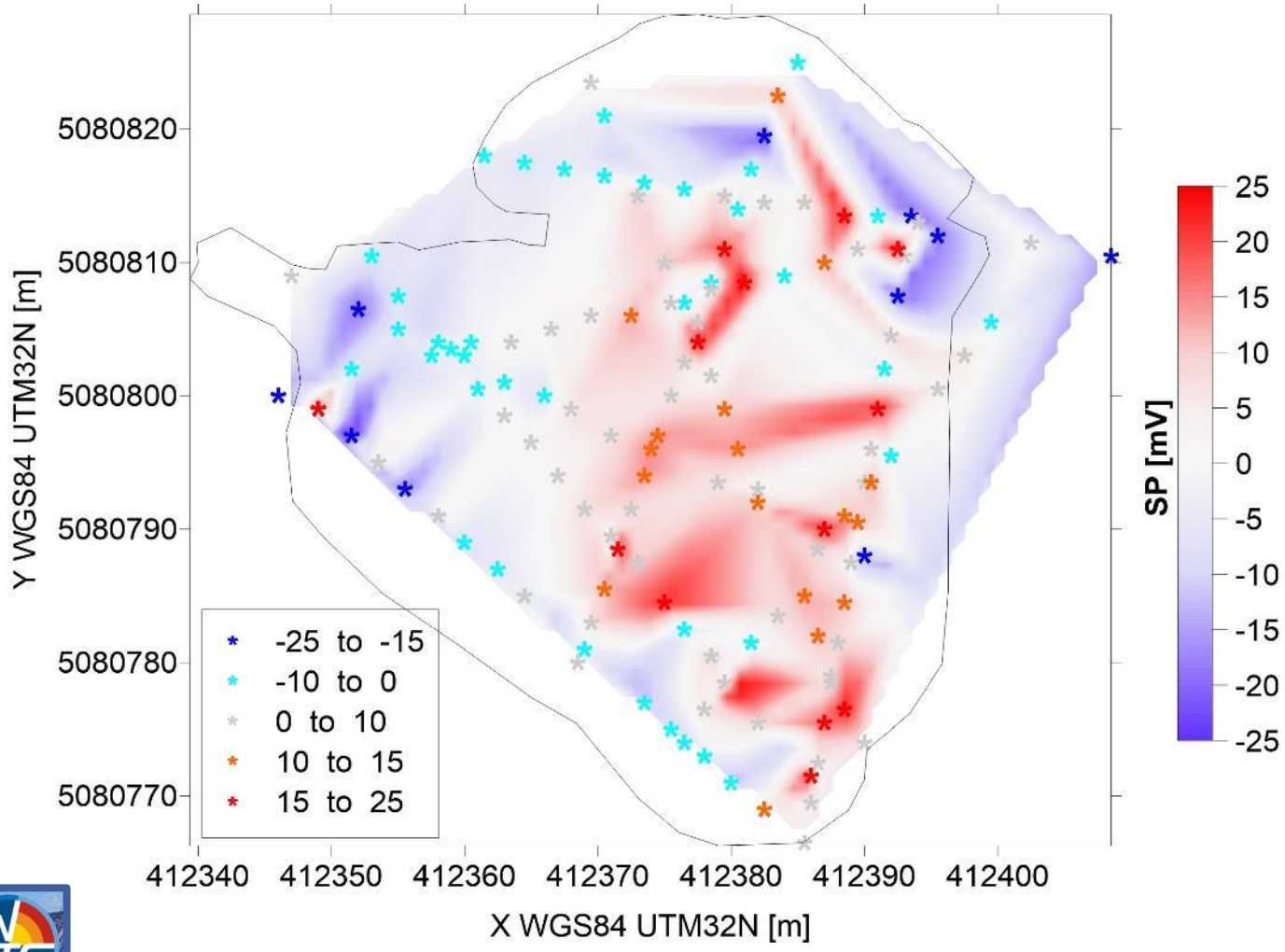
3D INVERSION

Generally **lower resistivity values** with respect to 2D results, but **analogous spatial distribution**



SP results

SPs may be diagnostic of **recharge (positive SP anomaly)**
and **seepage (negative SP anomaly)**
or other hydrodynamic processes occurring at the pond bottom



High-resistivity zones

↓

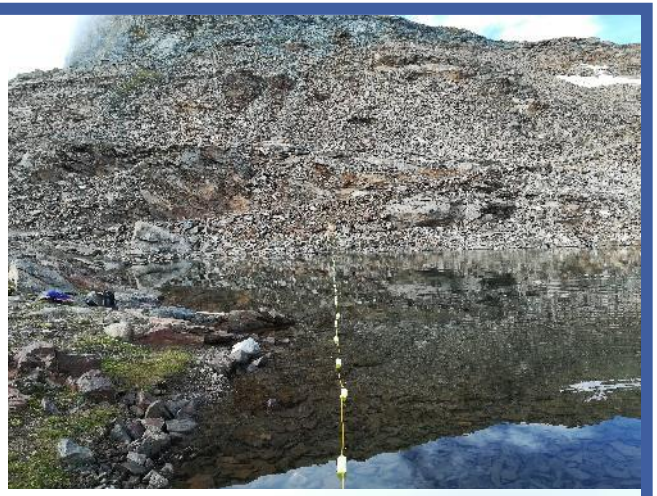
negative SP anomalies

Conclusions

- Waterborne **GPR profiles** provided the lake **bathymetry** and highlighted the absence of relevant thicknesses of **lacustrine sediments** → The lake seems to lie directly on **bedrock** or on very coarse debris material.

- **ERT results** confirm the **bedrock** presence, with different **fracturing** conditions.

- The interpretation of some results (diffraction hyperbola, inversion discrepancies, SP data) is ***still debated*** and further analysis should be done to confirm the presence of **permafrost** or ice bodies and to completely understand the **hydrodynamics** of the pond.



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