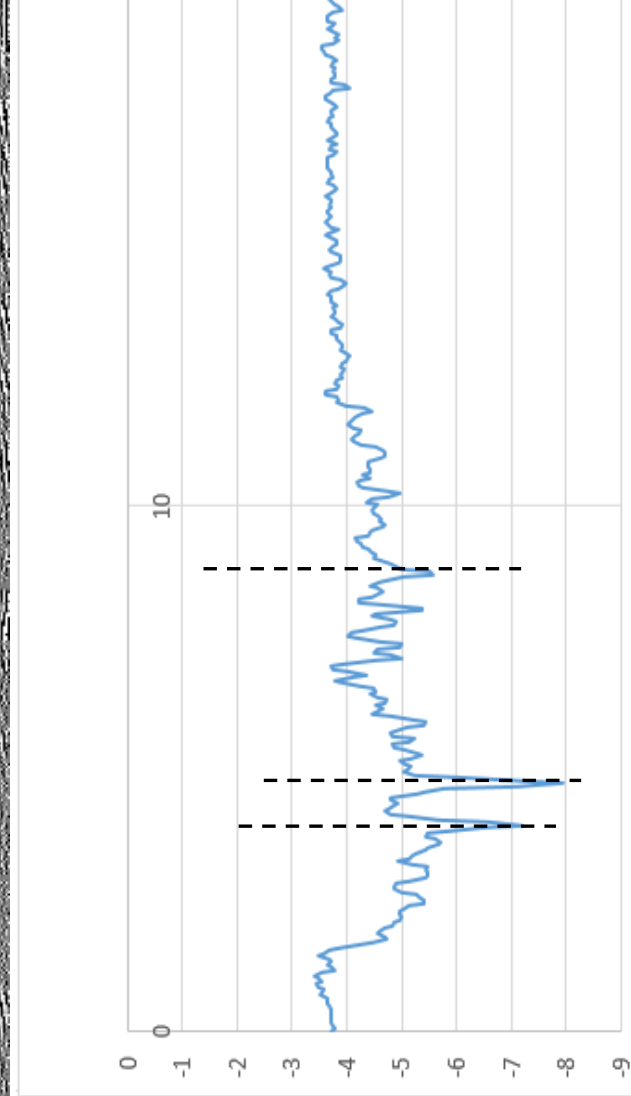
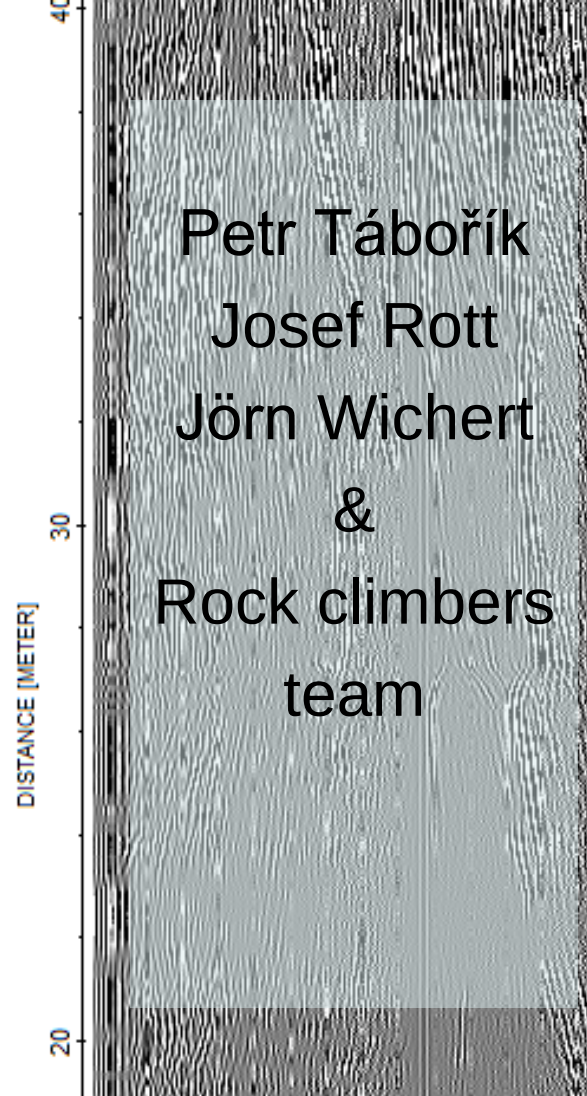




FACULTY OF SCIENCE
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INSTITUTE OF
HYDROGEOLOGY
ENGINEERING GEOLOGY
AND APPLIED GEOPHYSICS



GEOPHYSICAL SURVEY OF THE RELAXED ZONES IN THE SANDSTONE ROCK MASS

Neuber's tower

MOTIVATION

... to study rock stability



Neuber's tower



Neuber's tower

1981 collapsed!!!



Doga Tower



Solitary (lone-standing) rock towers

Doga Tower



Potential rock collapse hazard





Janusova hlava (Janus Head)

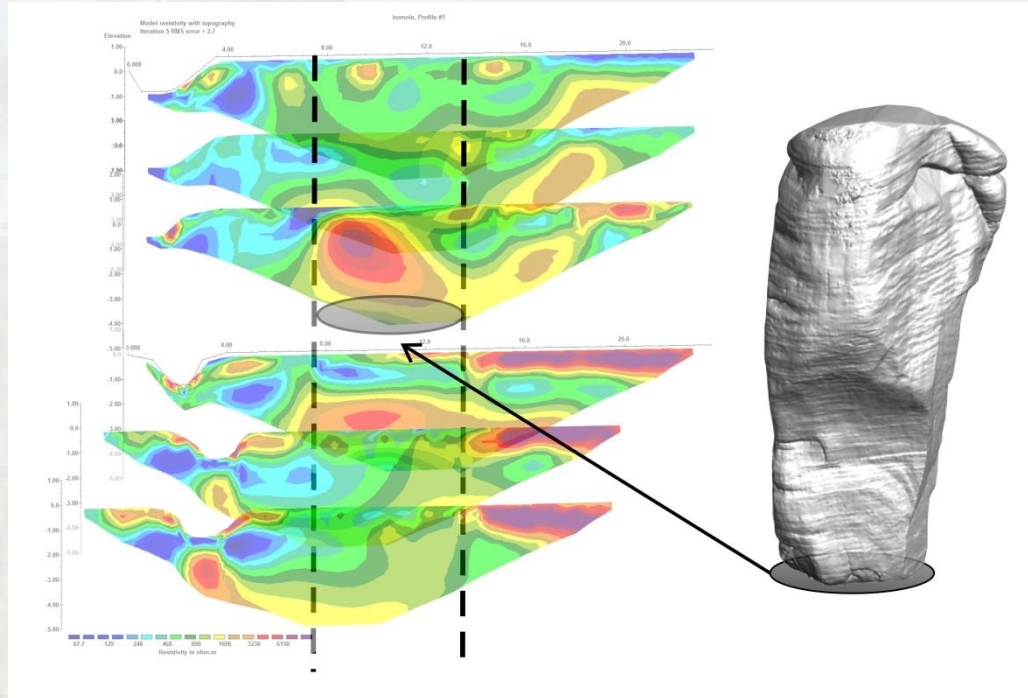
Malé Tiské Stěny





...
m
k

since 2015



Geophysical insight into the rock towers stability

Petr TÁBOŘÍK ^{1,2}, Filip HARTVICH ^{1,2}, Jan Blahůt ^{1,2}, Otakar KRÁSNÝ ³, Petr KUNA ⁴



FACULTY OF SCIENCE
Charles University



INSTITUTE OF ROCK STRUCTURE AND MECHANICS
Academy of Sciences of the Czech Republic, v.v.i.

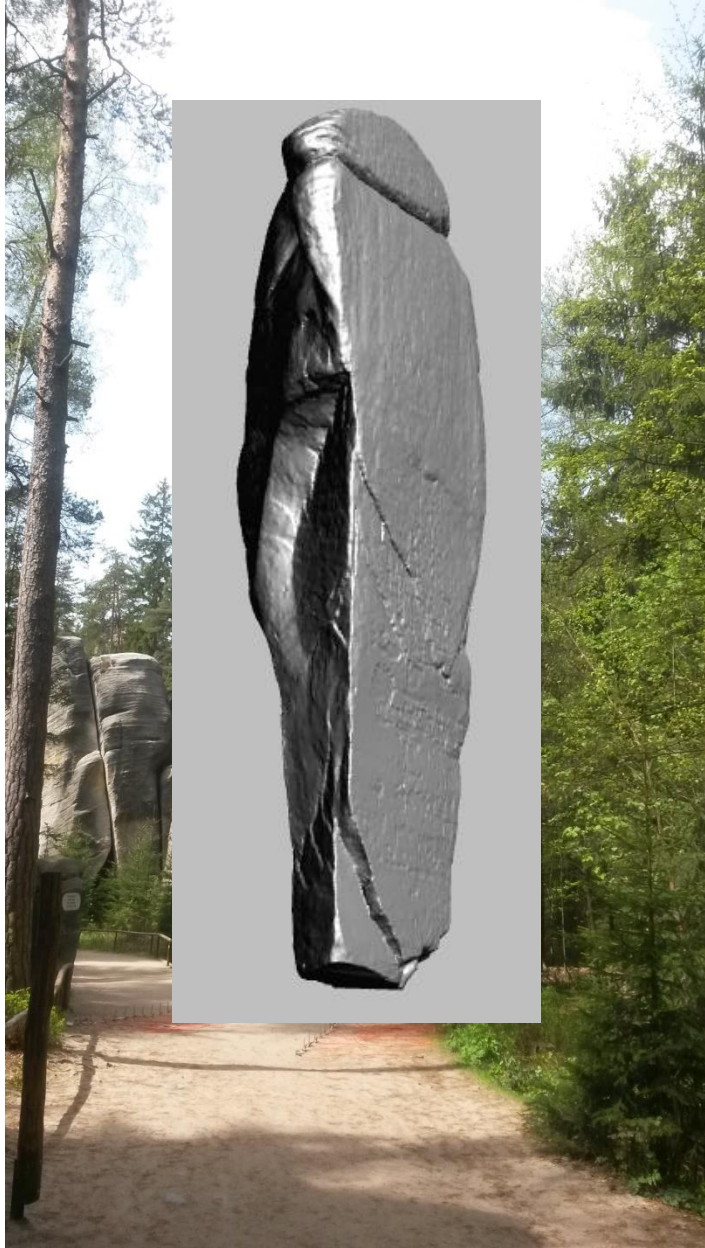


GeoTec GS®



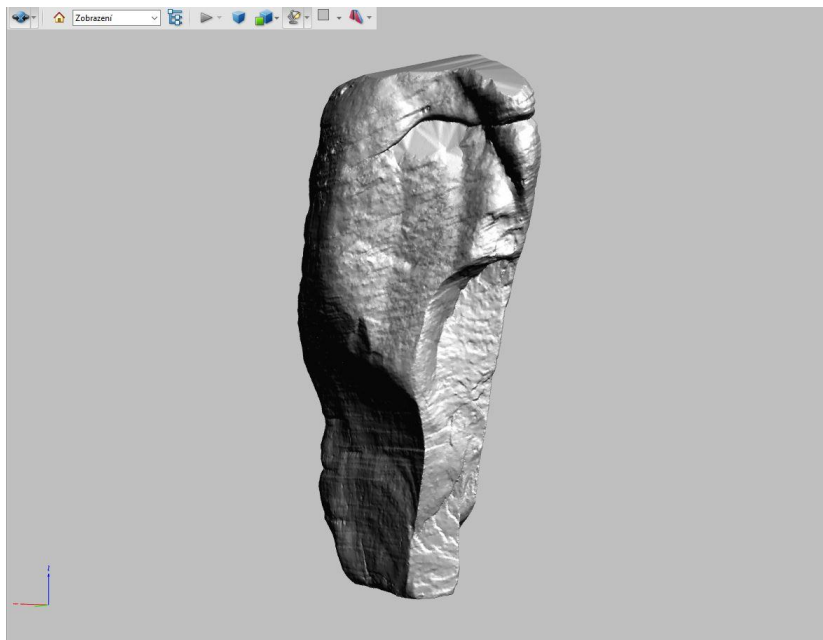
**Homole cukru
("Sugar cone")
lone-standing rock
tower**

- overhanging walls
- height: 23 m
- calculated volume: 864.5m³
- Adršpach rocky town
- Cretaceous Teplice sandstone formation
- „CHKO Broumovsko“ protected area



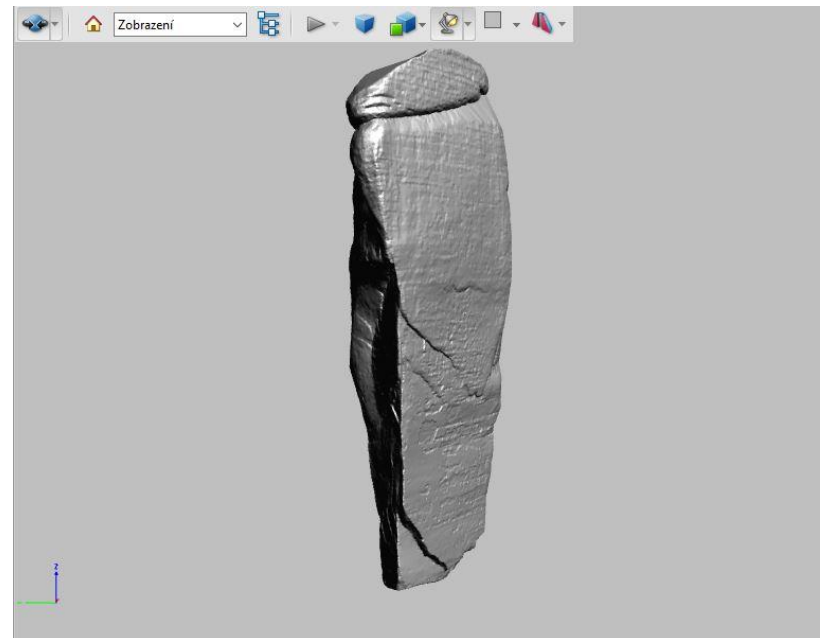
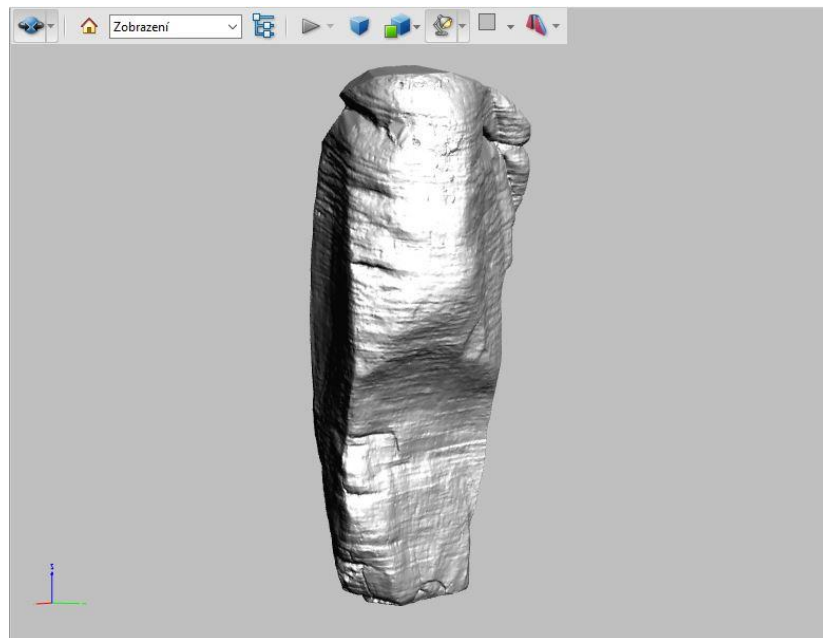
Homole cukru ("Sugar cone") lone-standing rock tower

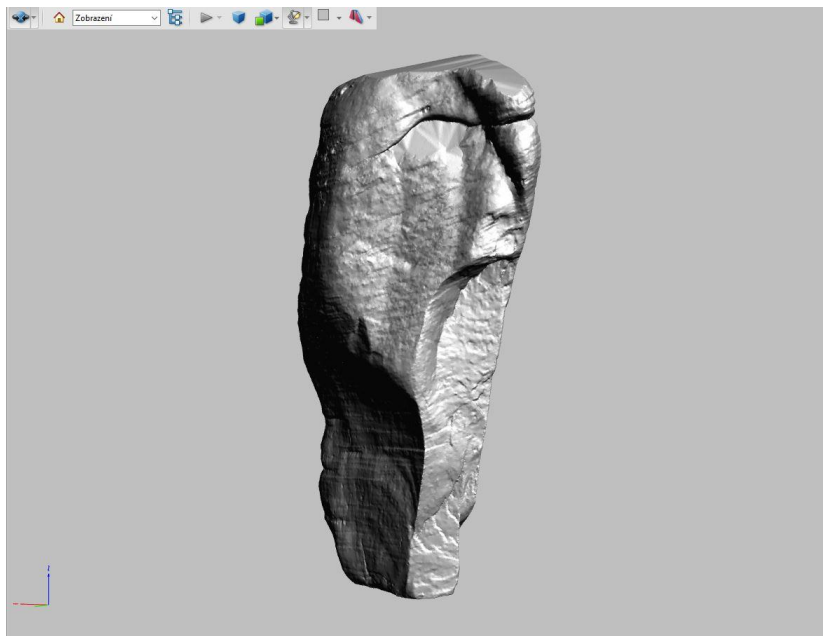
- overhanging walls
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- calculated volume: 864.5m³
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- Cretaceous Teplice sandstone formation
- „CHKO Broumovsko“ protected area



EVALUATION of the ROCK TOWER STABILITY

Stability computation on
the 3-D ground based
LiDAR DEM



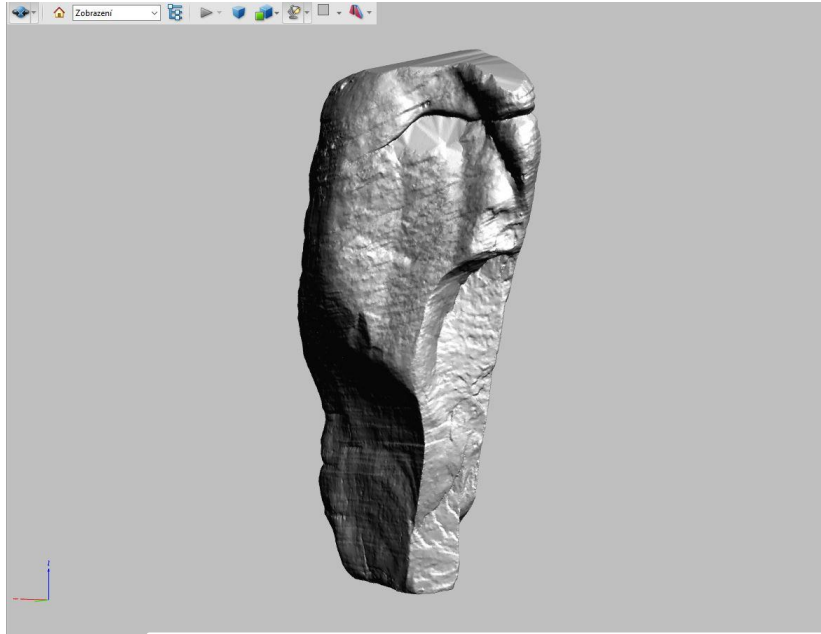


EVALUATION of the ROCK TOWER STABILITY

Stability computation on
the 3-D ground based
LiDAR DEM

...the above-ground part of the rock only !!!



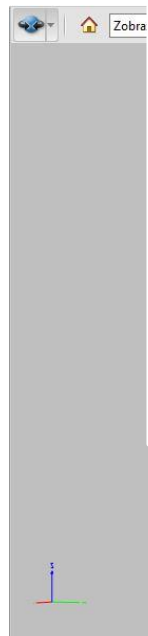


EVALUATION of the ROCK TOWER STABILITY

Stability computation on
the 3-D ground based
LiDAR DEM

...the above-ground part of the rock only !!!

Underground information on the tower root
and bedrock needed!
(in a non-destructive way)





Geophysical survey

ERT

**(2-D measurement /
3-D inversion)**
ARES resistivity system





Geophysical survey

GPR

**3-D georadar
(100 and 250 MHz)
Malá RAMAC system X3M**





Geophysical survey

SSR

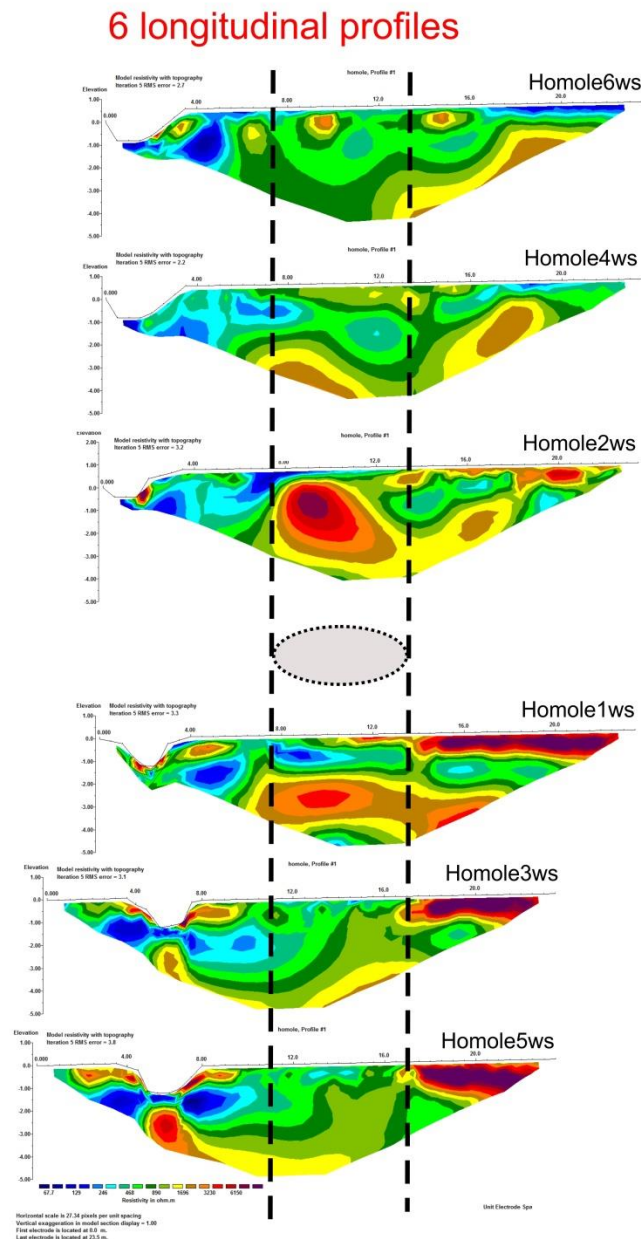
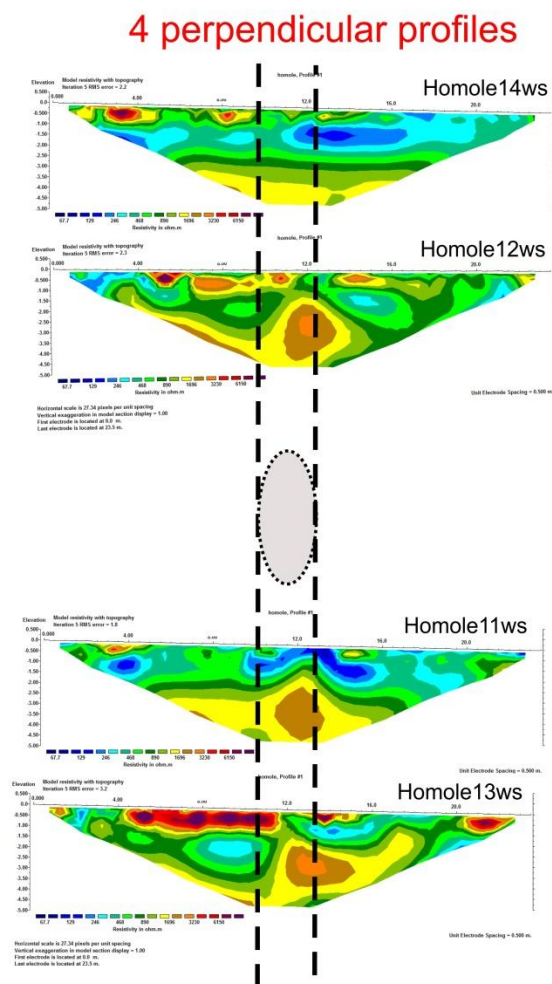
Shallow seismic refraction



**GEODE
seismograph**

RESULTS

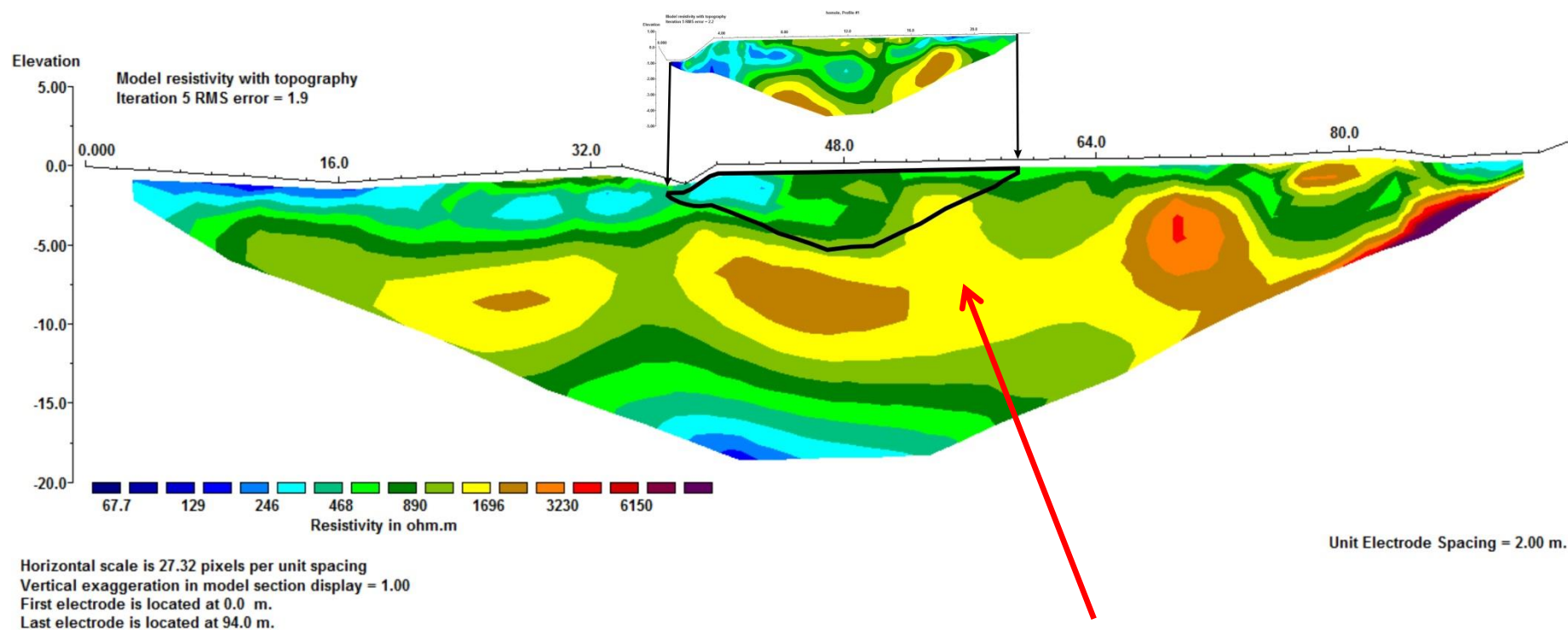
2-D ERT



RESULTS

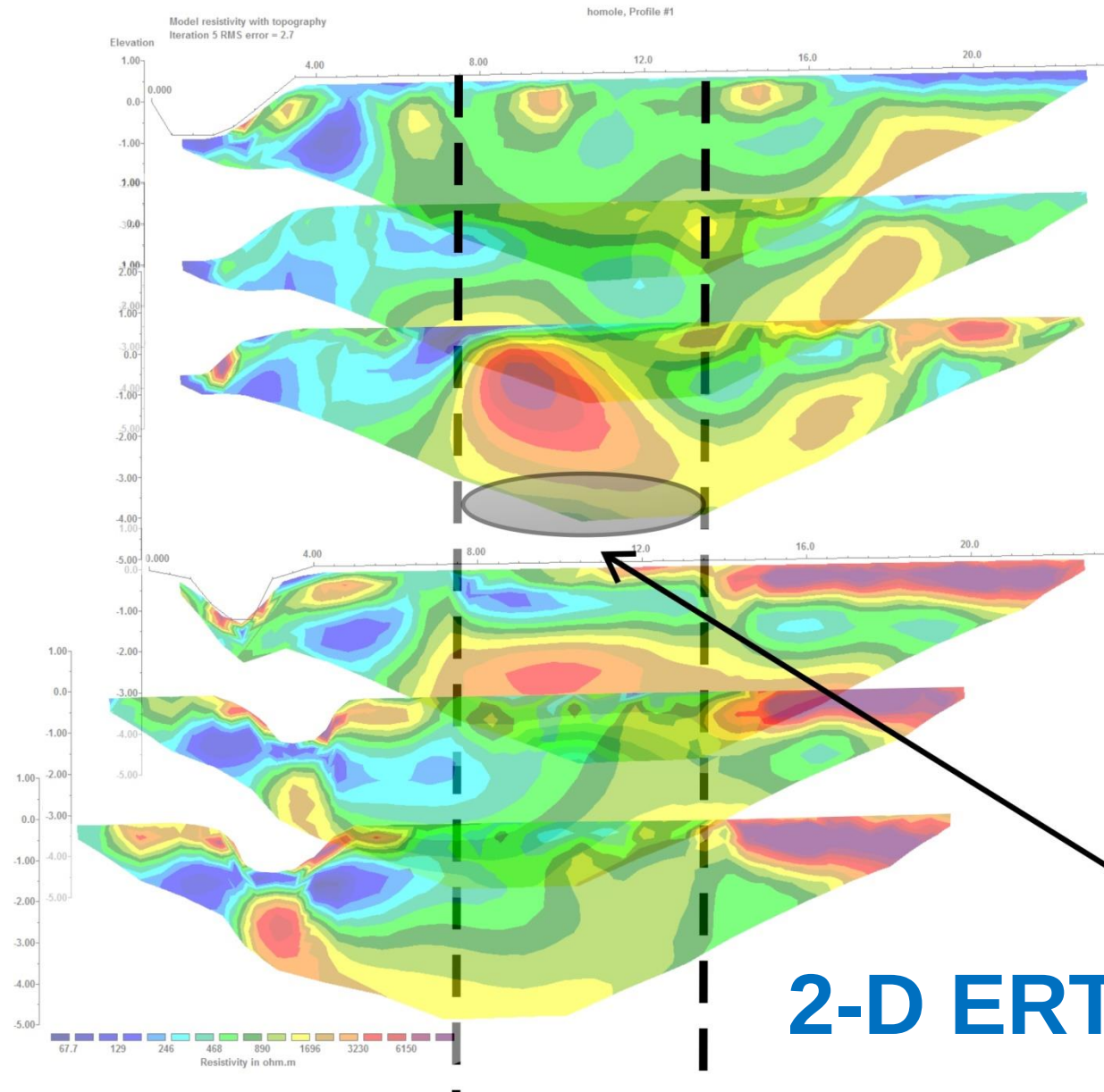
2-D ERT

extended ERT measurement

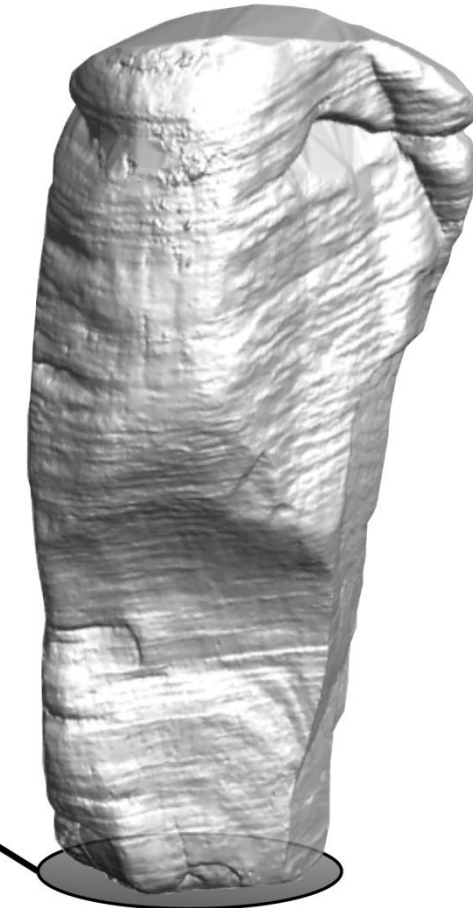


... solid bedrock existence confirmed!

RESULTS

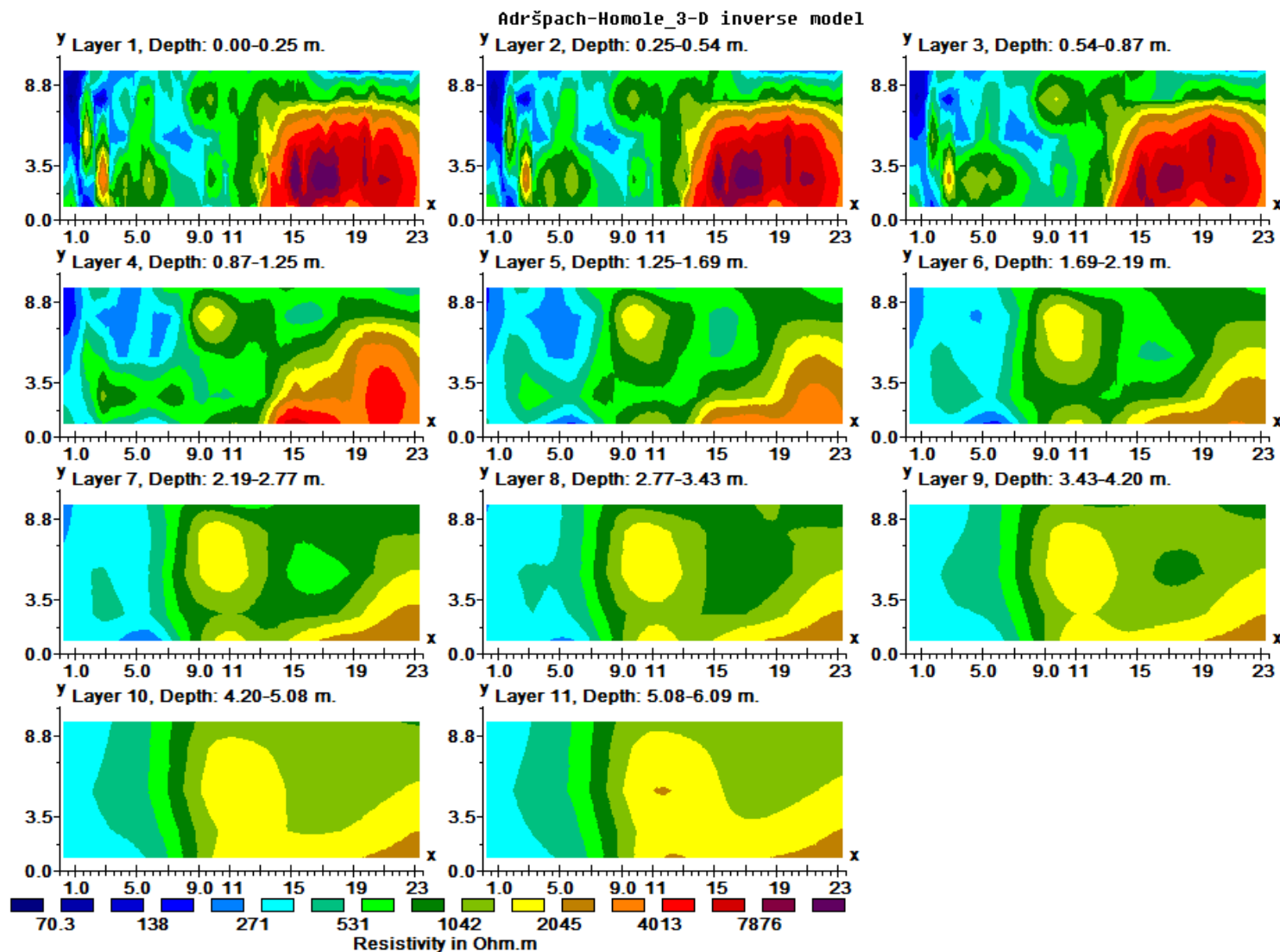


2-D ERT



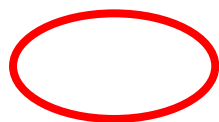
RESULTS

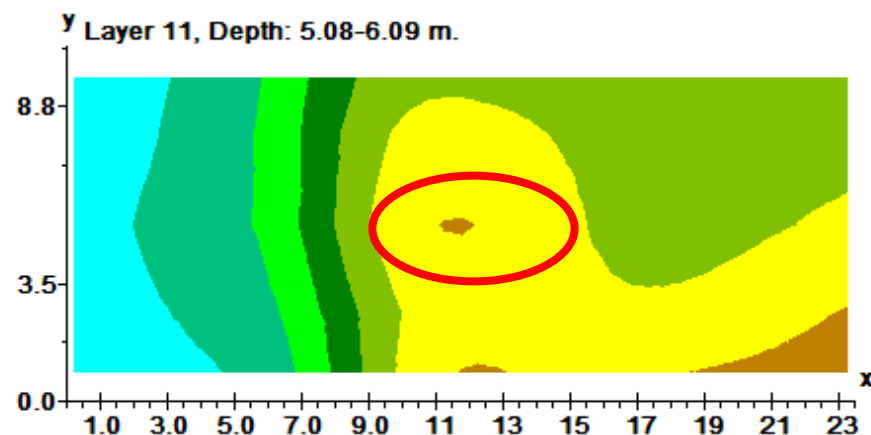
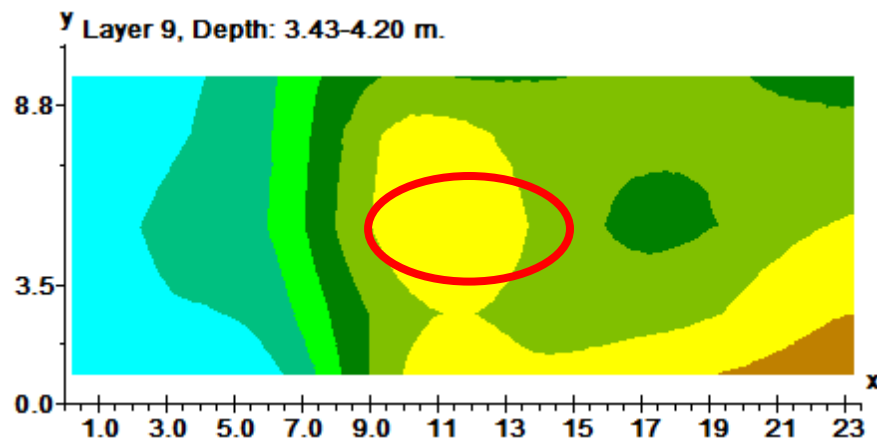
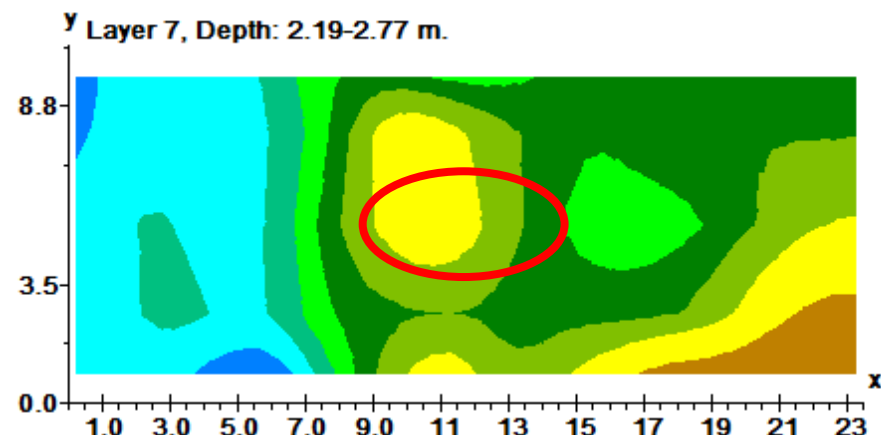
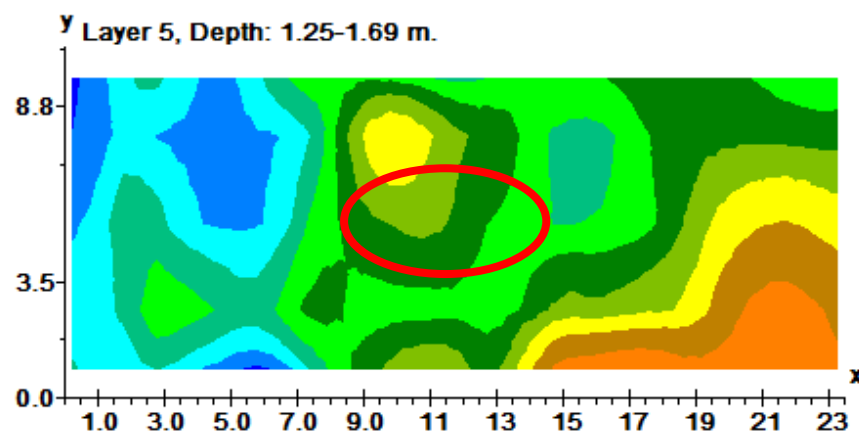
3-D ERT



RESULTS

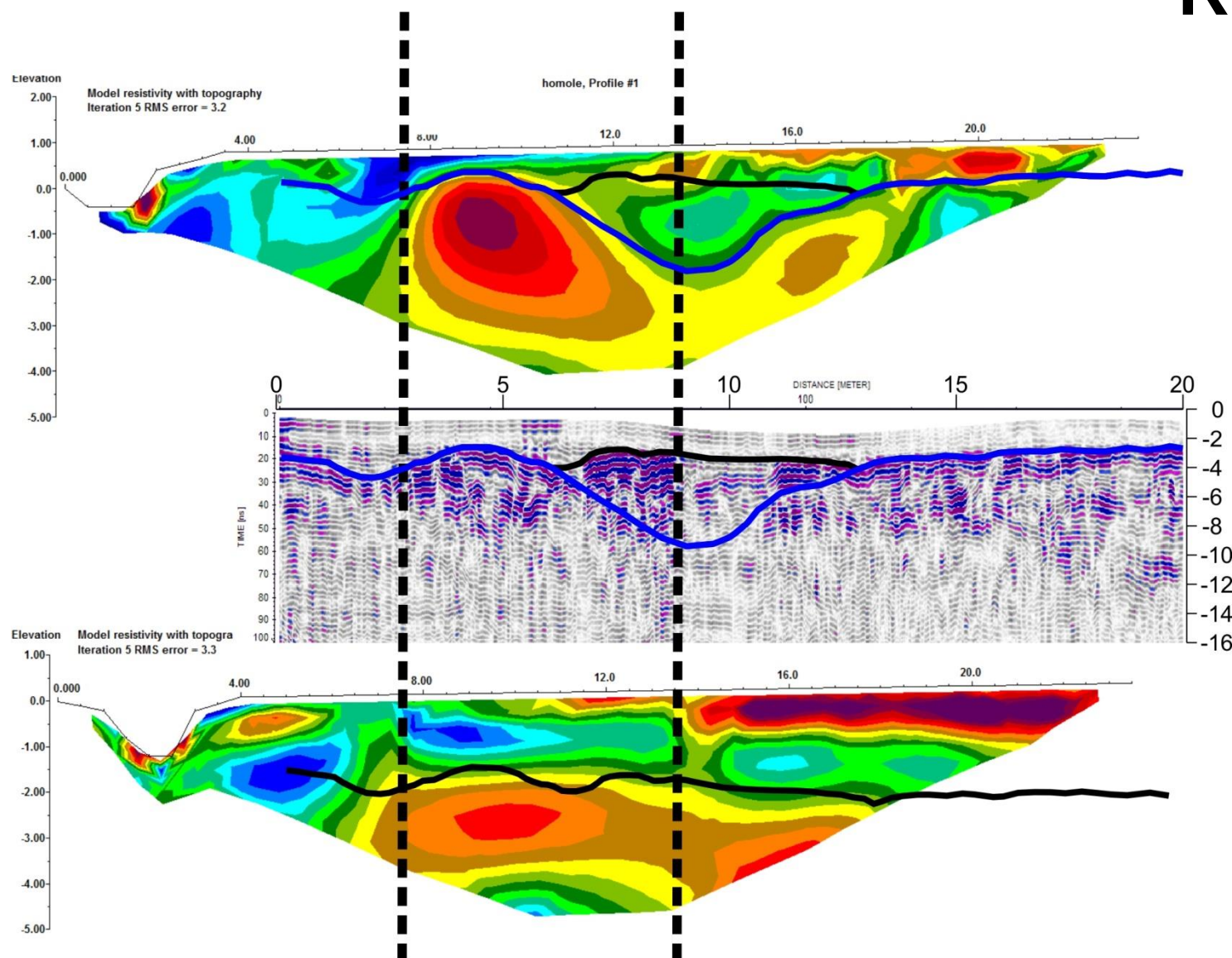
3-D ERT

 the rock tower root position



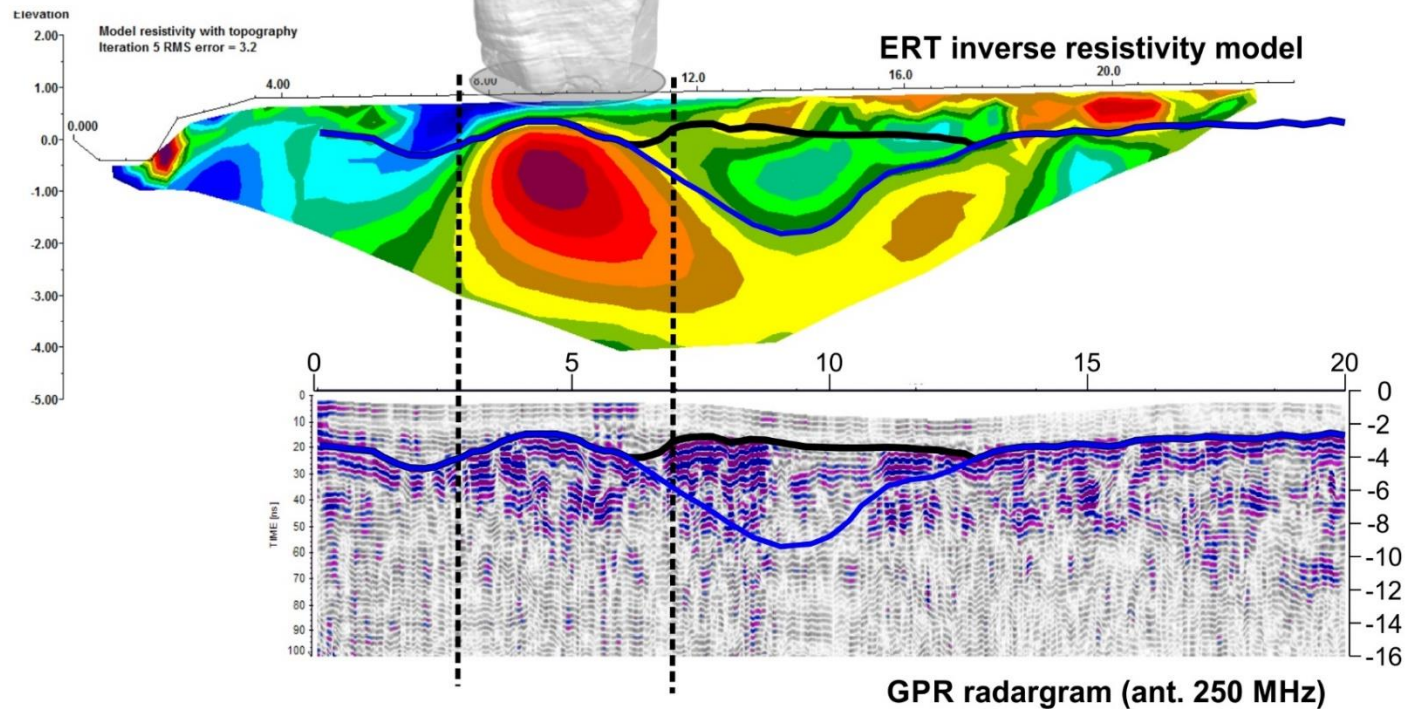
RESULTS

ERT VS GPR





Homole cukru
("Sugar Cone")
lone-standing
rock tower

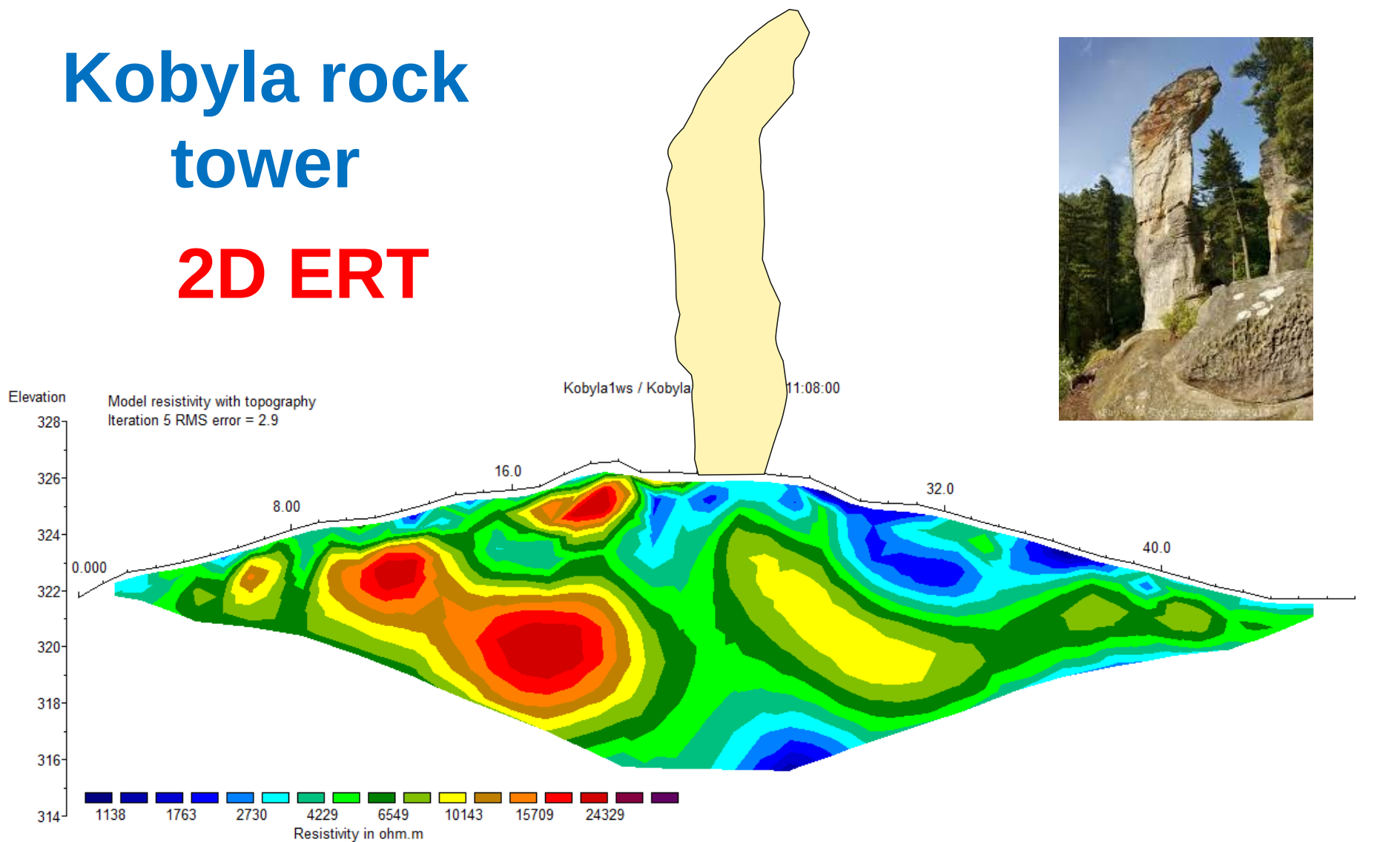


RESULTS

ERT
VS
GPR

Kobyla rock tower

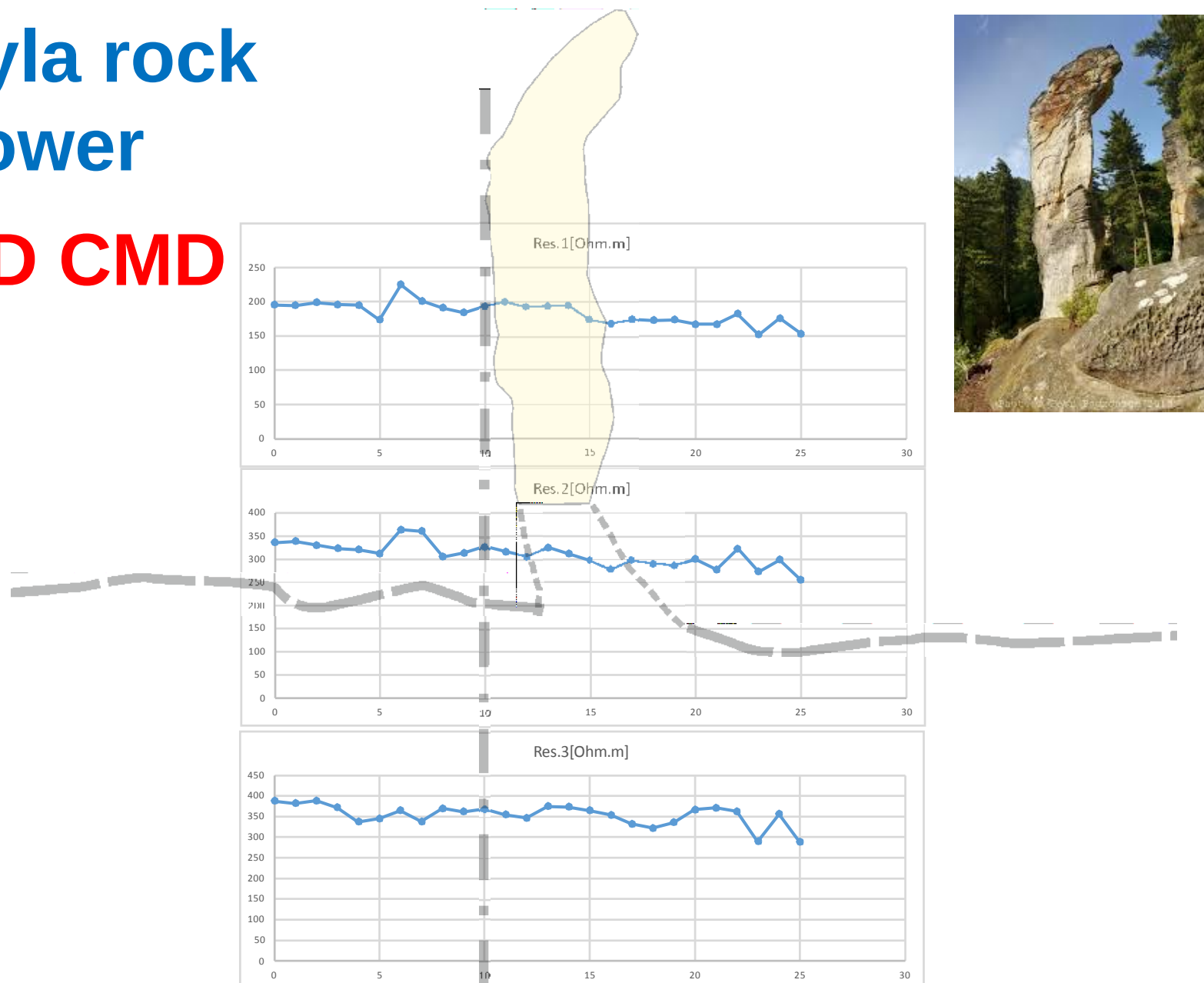
2D ERT



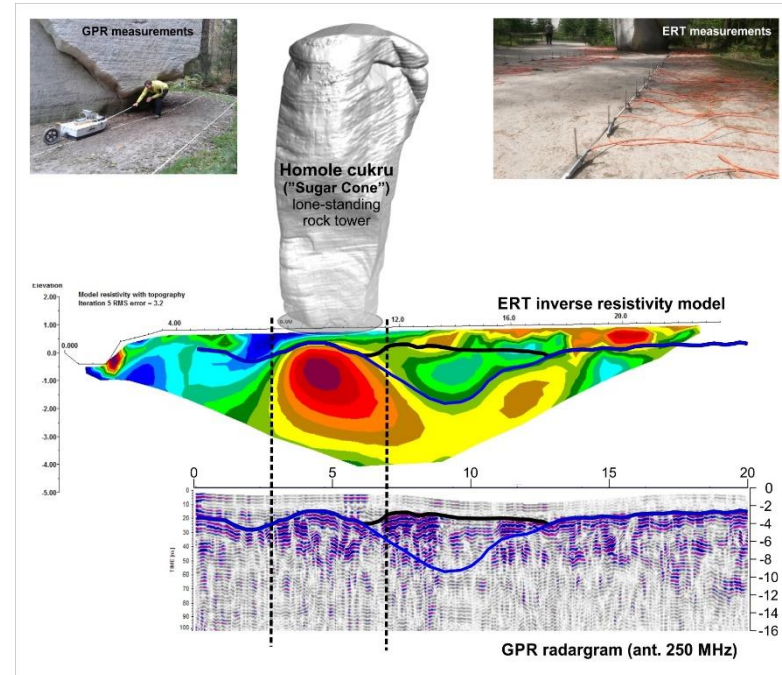
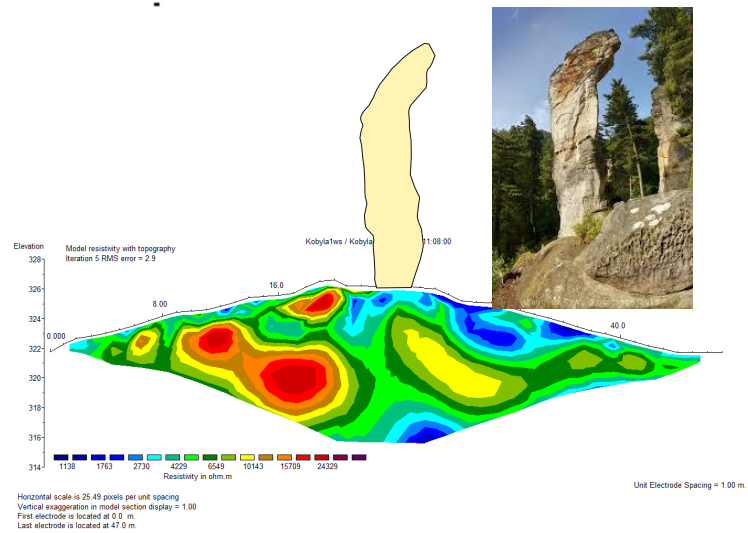
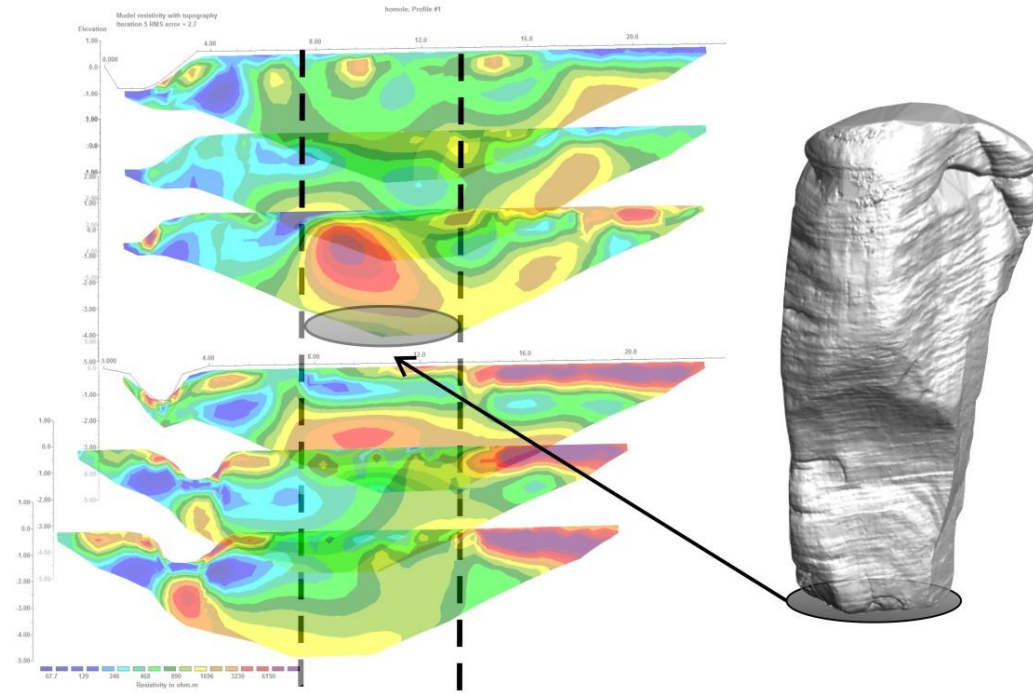
Horizontal scale is 25.49 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 47.0 m.

Kobyla rock tower

2D CMD

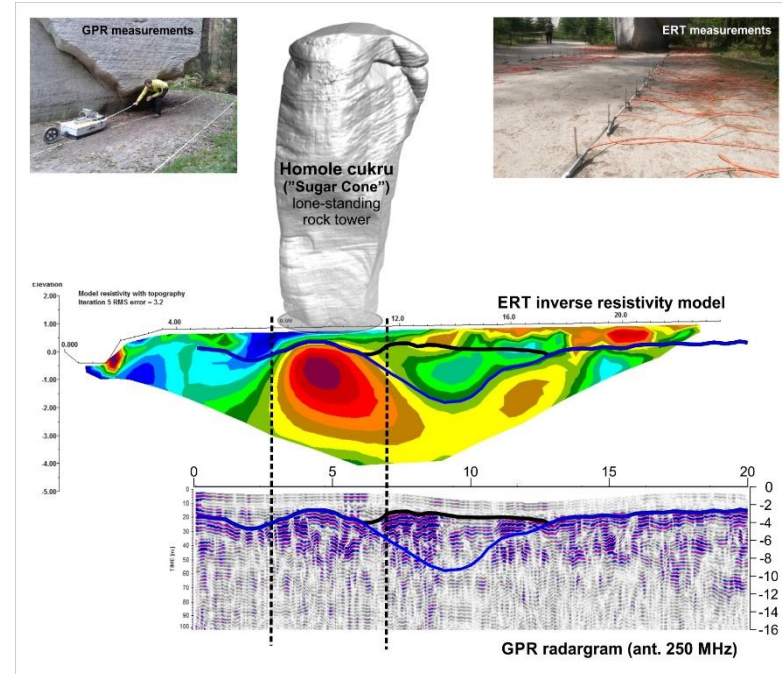
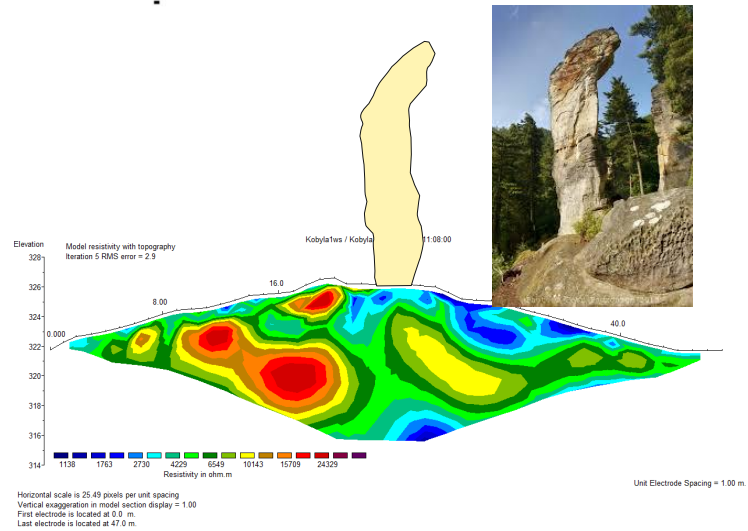
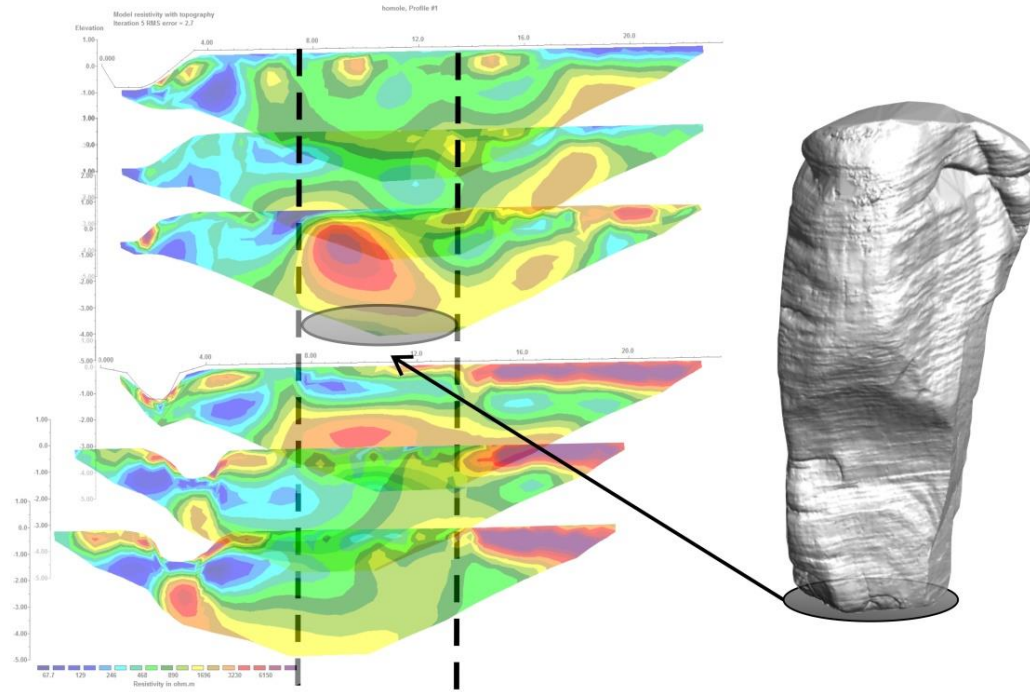


Geophysical survey



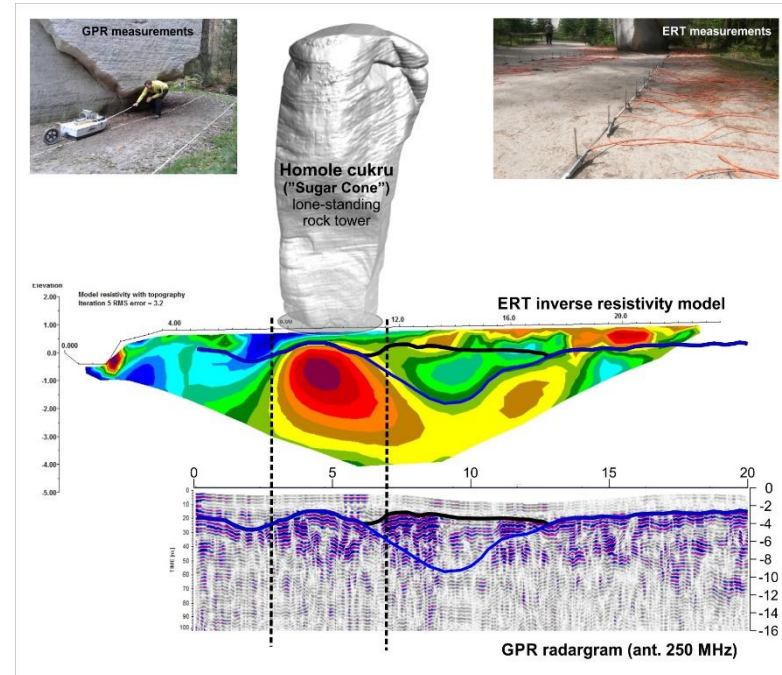
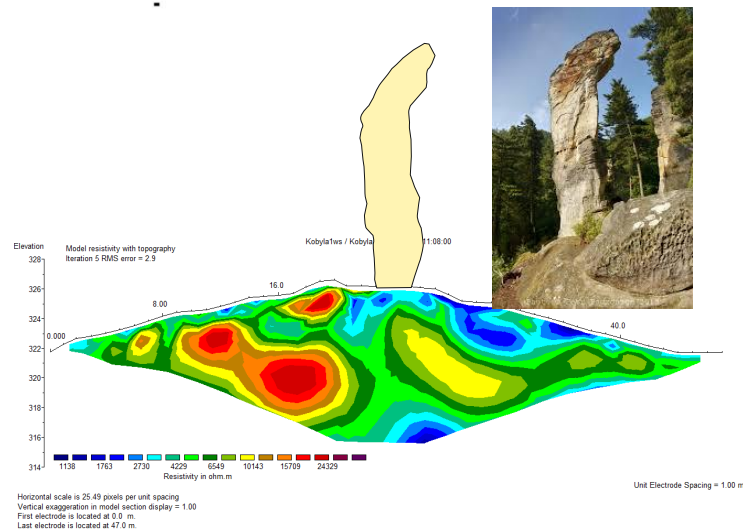
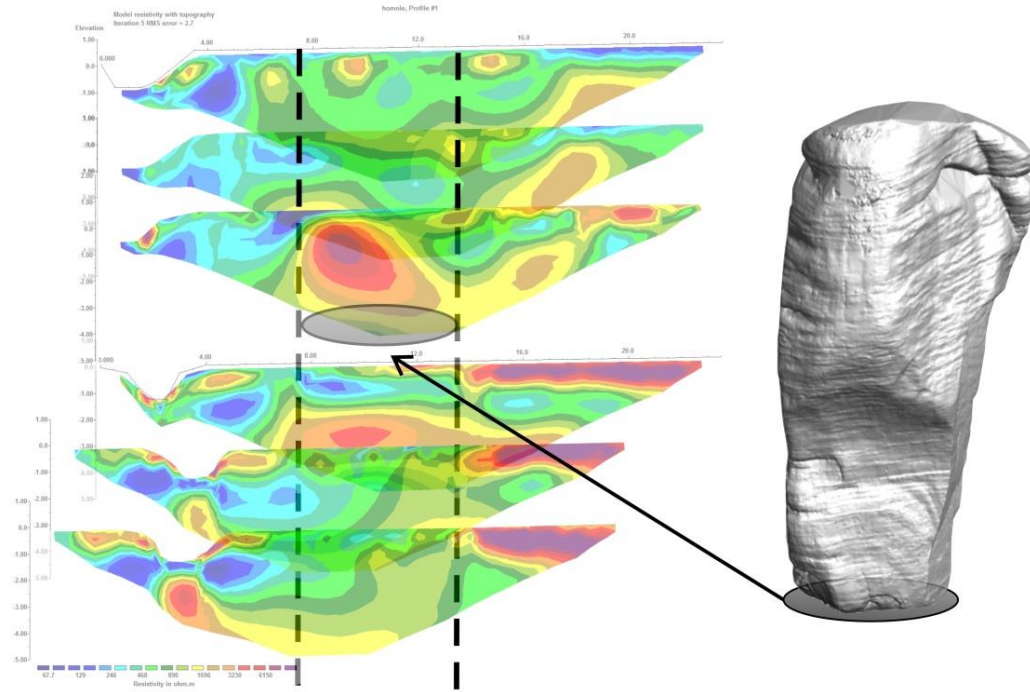
Geophysical survey

A new challenge
arised!



Geophysical survey

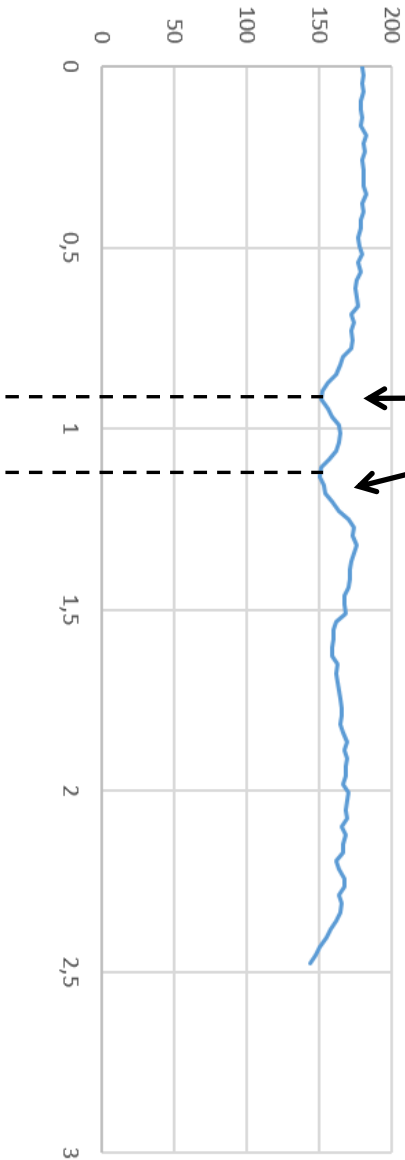
How to measure
the rock tower
itself?!



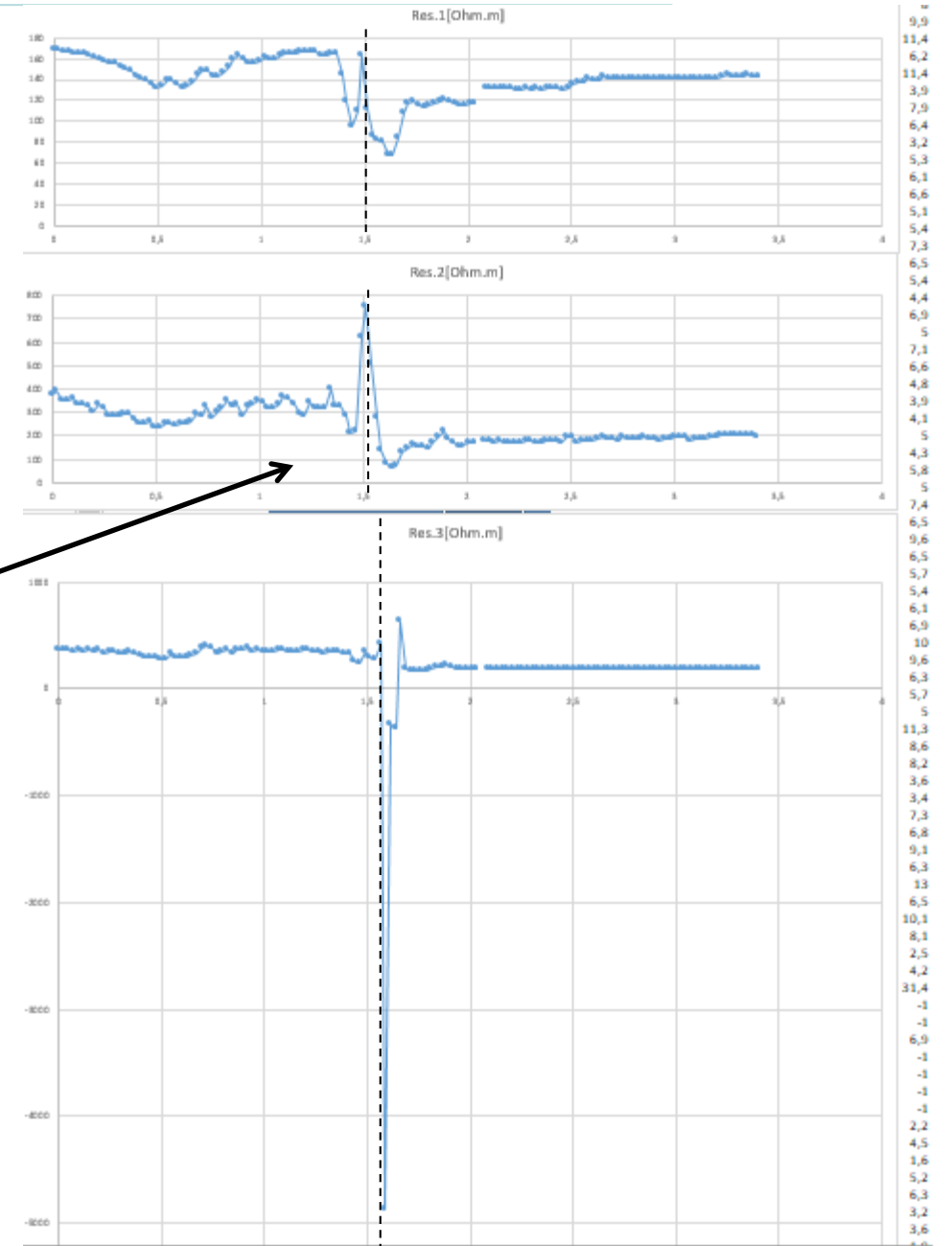
2D CMD measurements

Horizontal
fissures

Res.1[Ohm.m]



„Sharp“
reaction on a
subvertical
fissure
(at all three
measurement
depths)

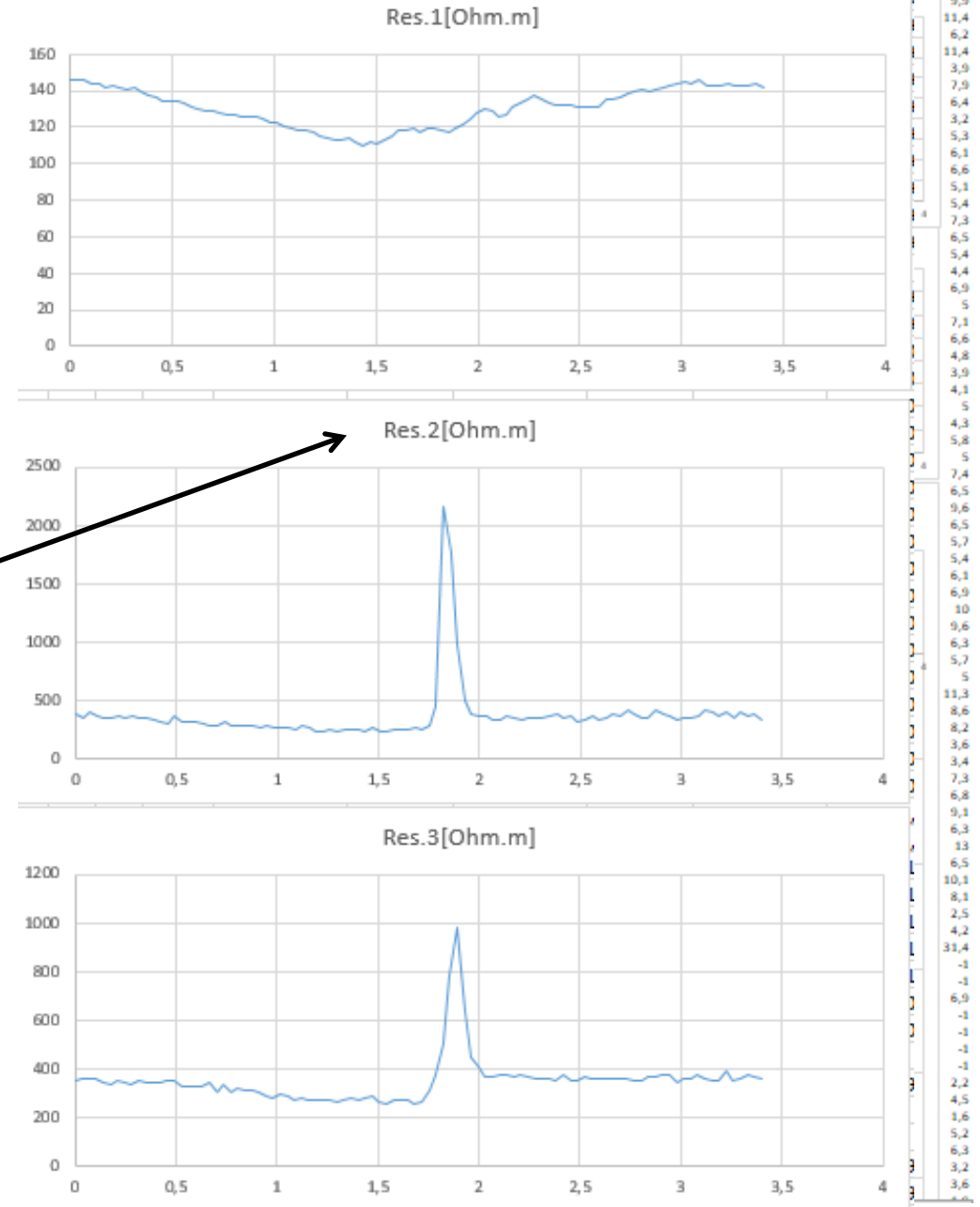


2D CMD measurements

Horizontal
fissures

Res.1[Ohm.m]

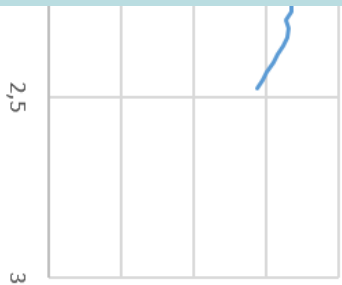
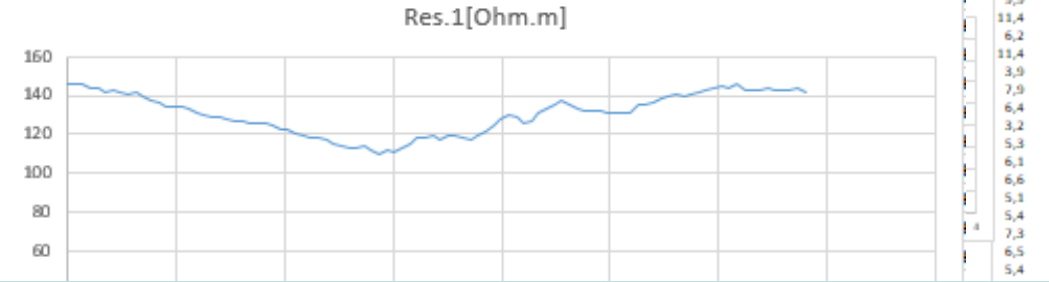
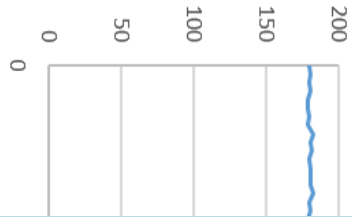
„Sharp“
reaction on a
subvertical
fissure
(at all three
measurement
depths)



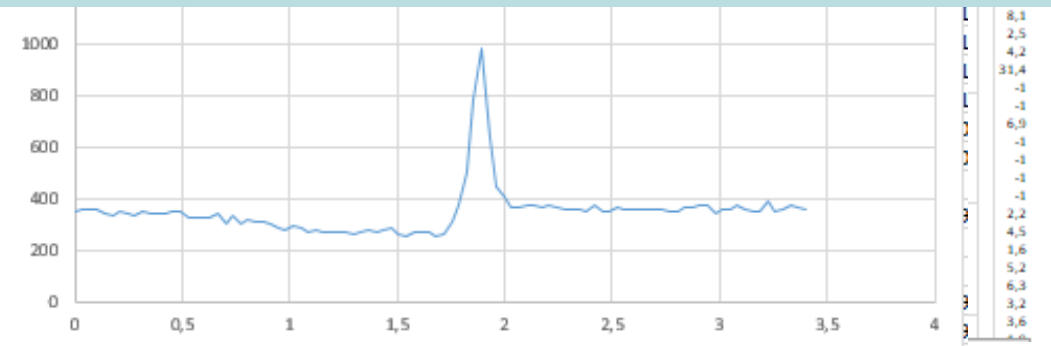
2D CMD measurements

„Feet-on-ground“ measurement

Applicable only for „from-ground“ measurements or testing the method



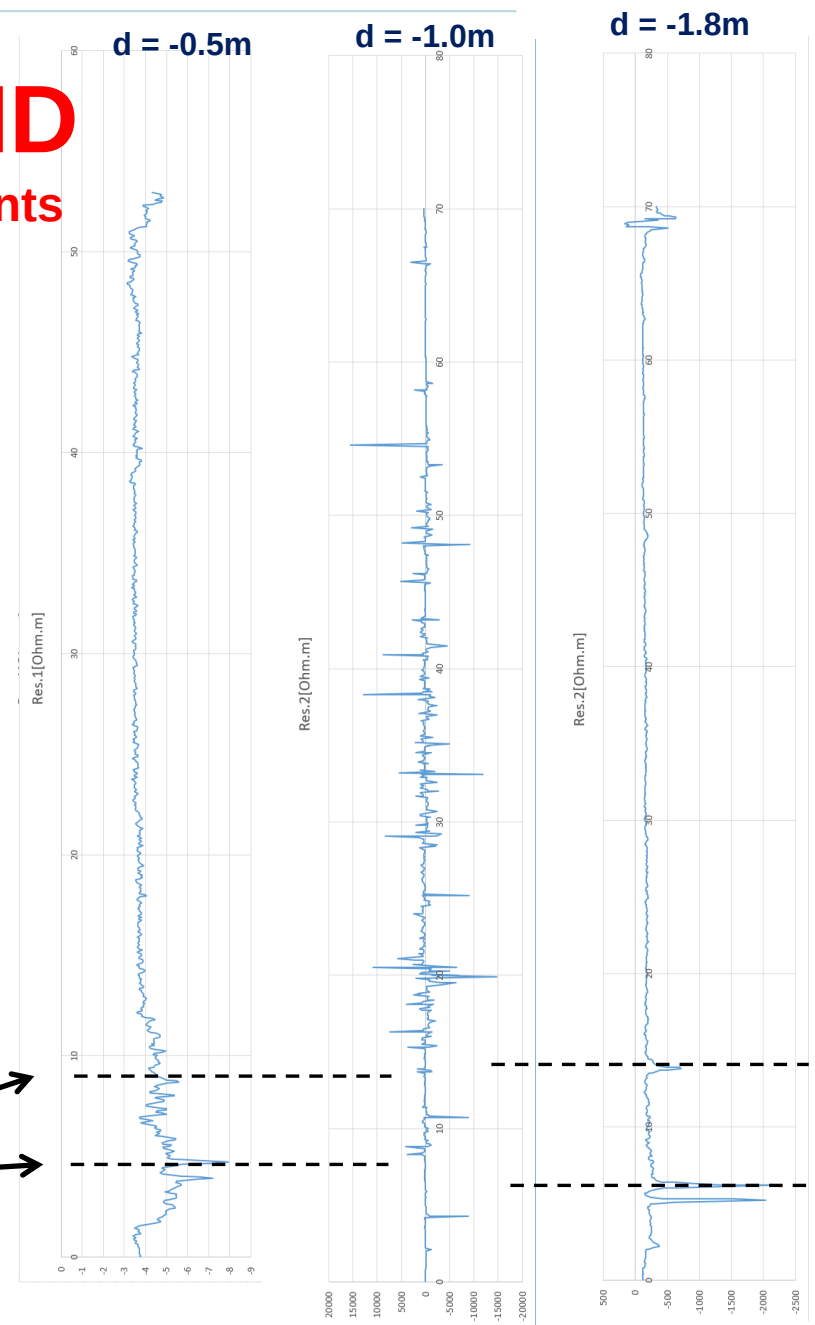
(at all three
measurement
depths)





2D CMD measurements

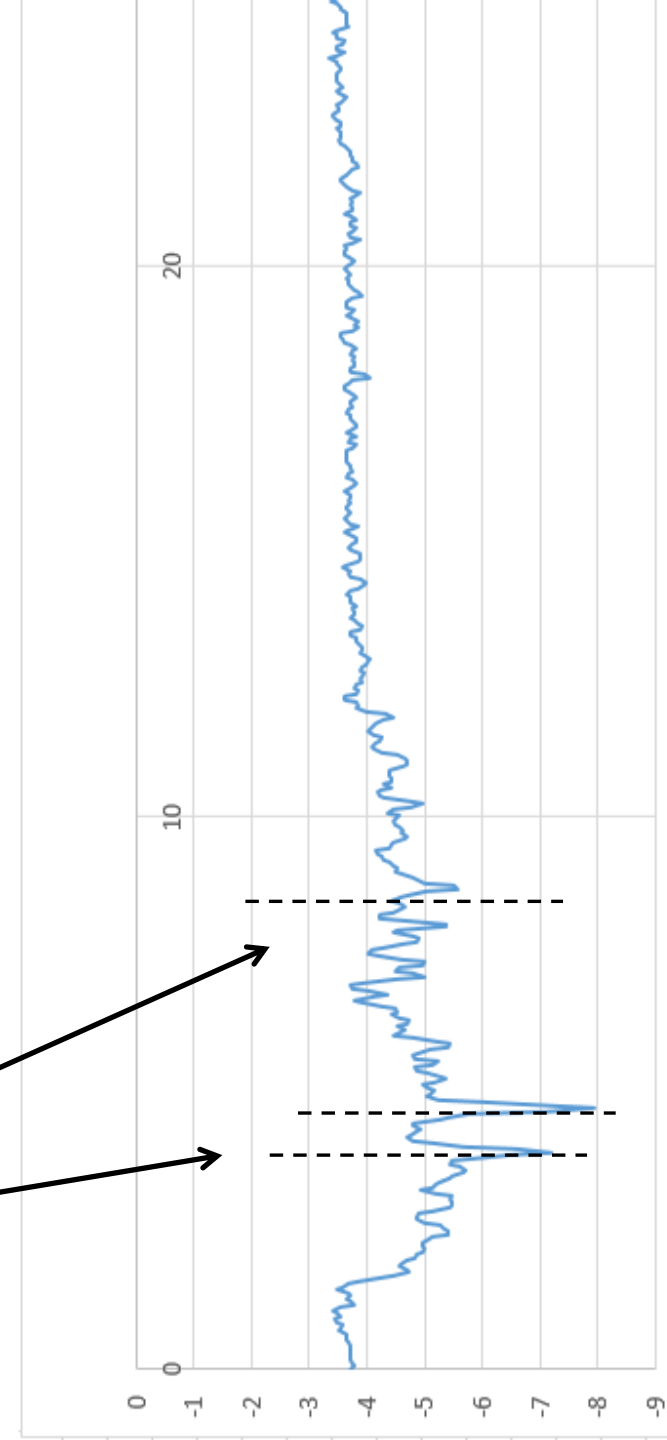
Horizontal
fissures

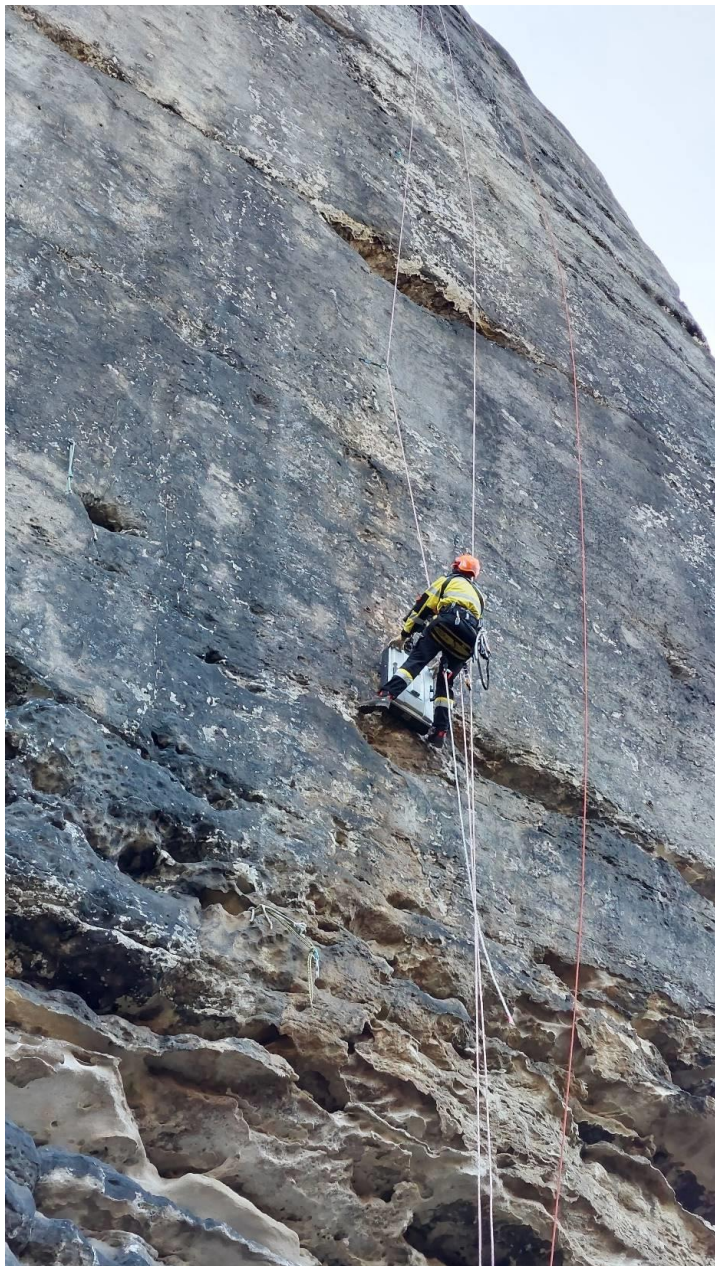




2D CMD measurements

Horizontal
fissures

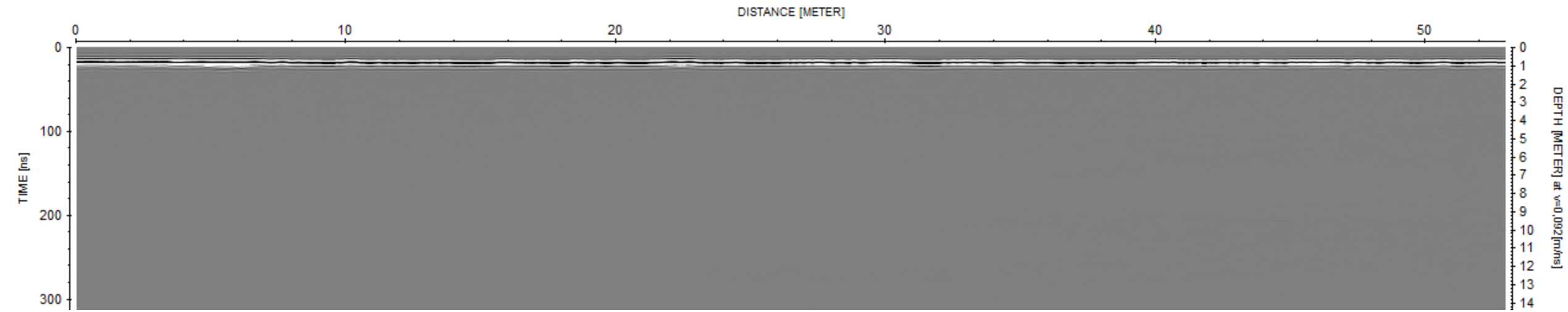




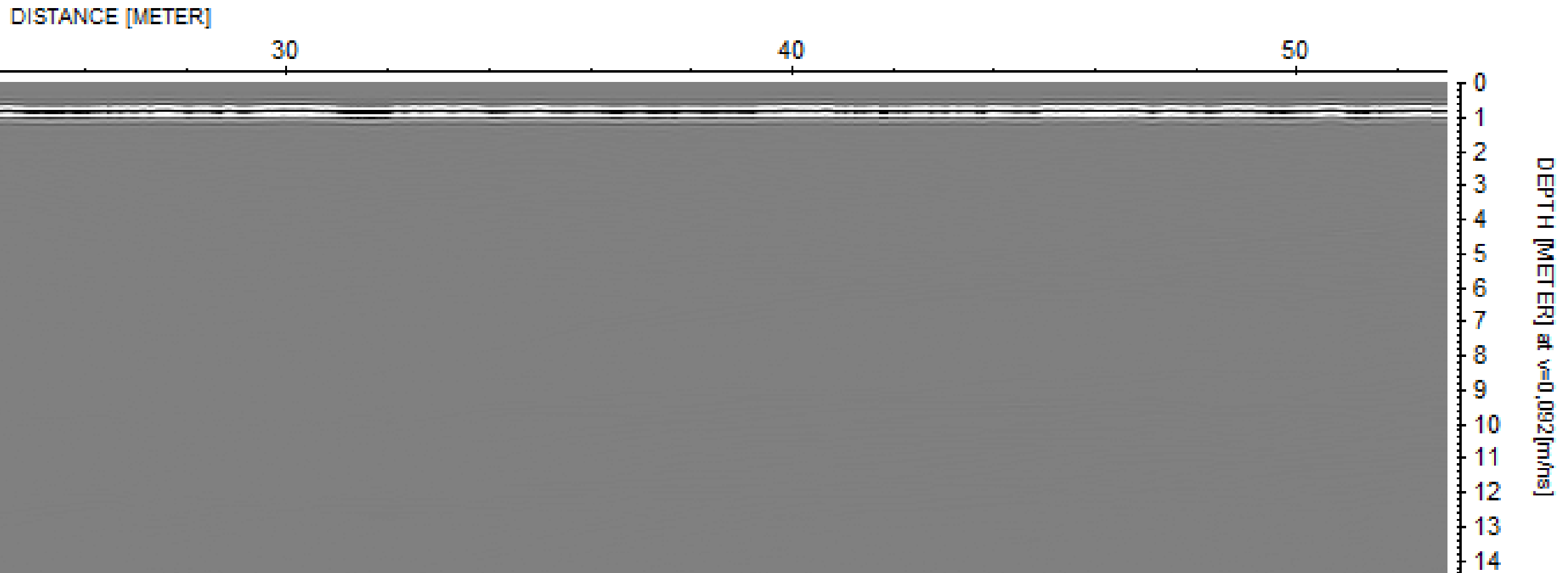
2D GPR measurements

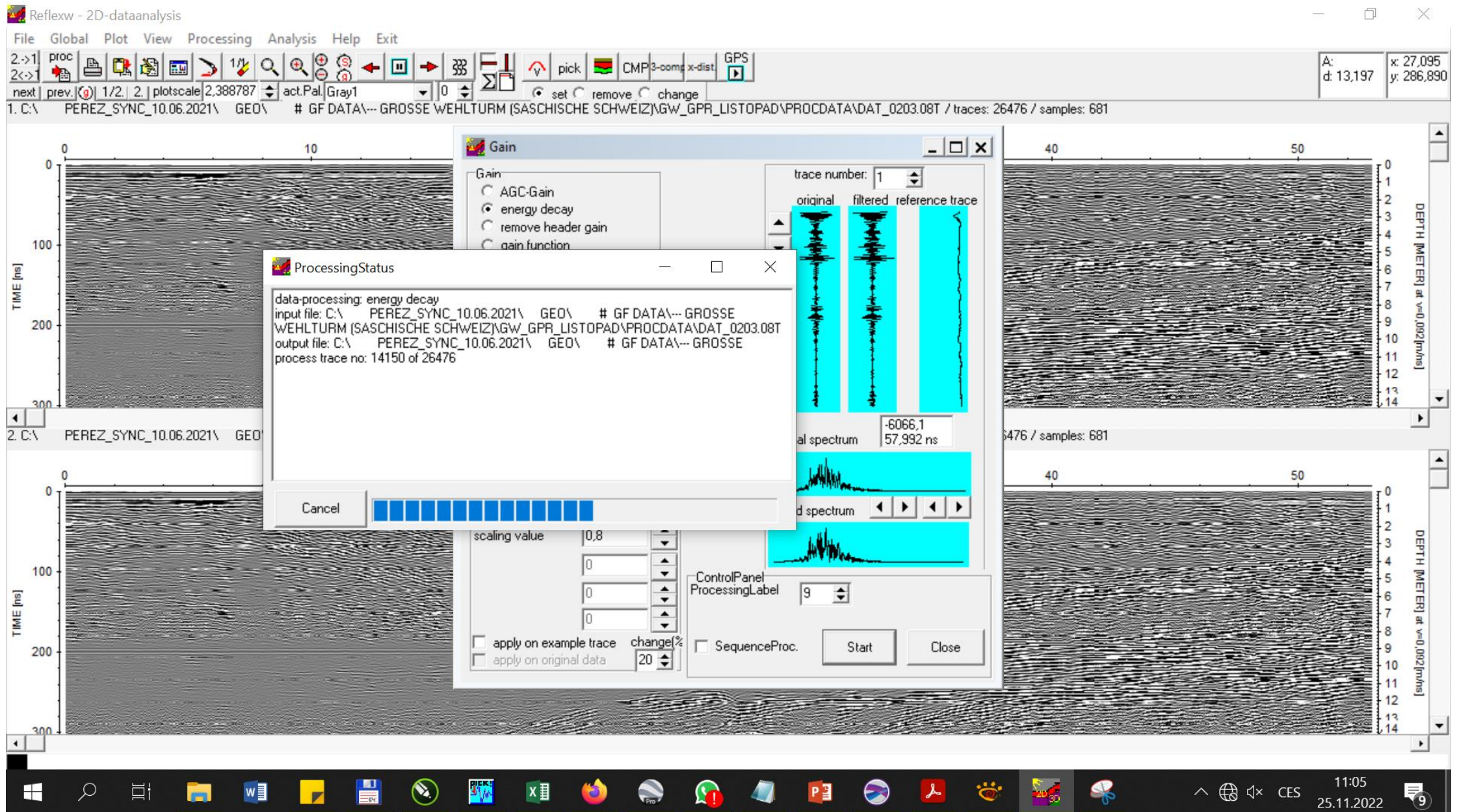


2D GPR measurements

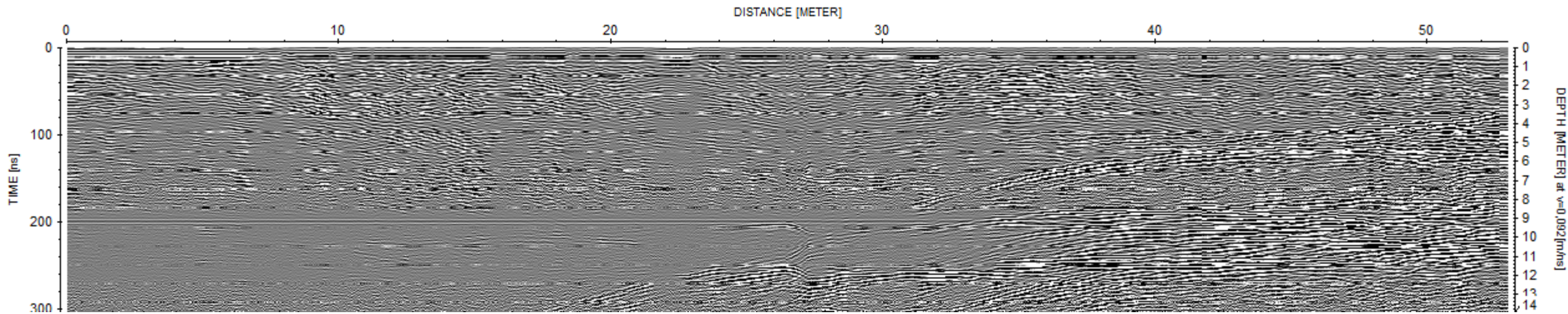


2D GPR measurements

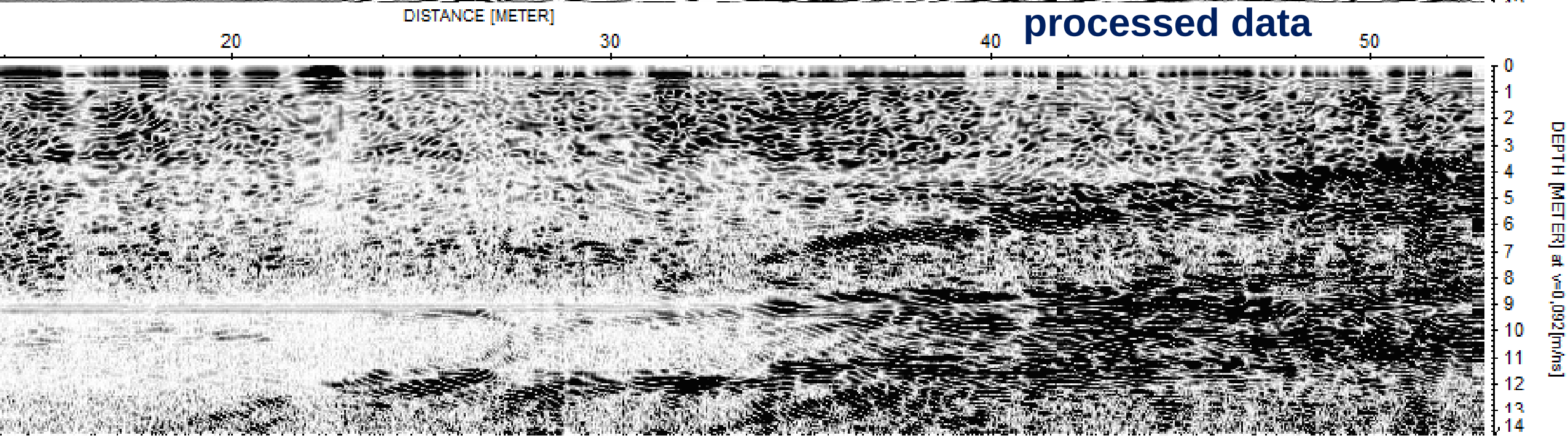
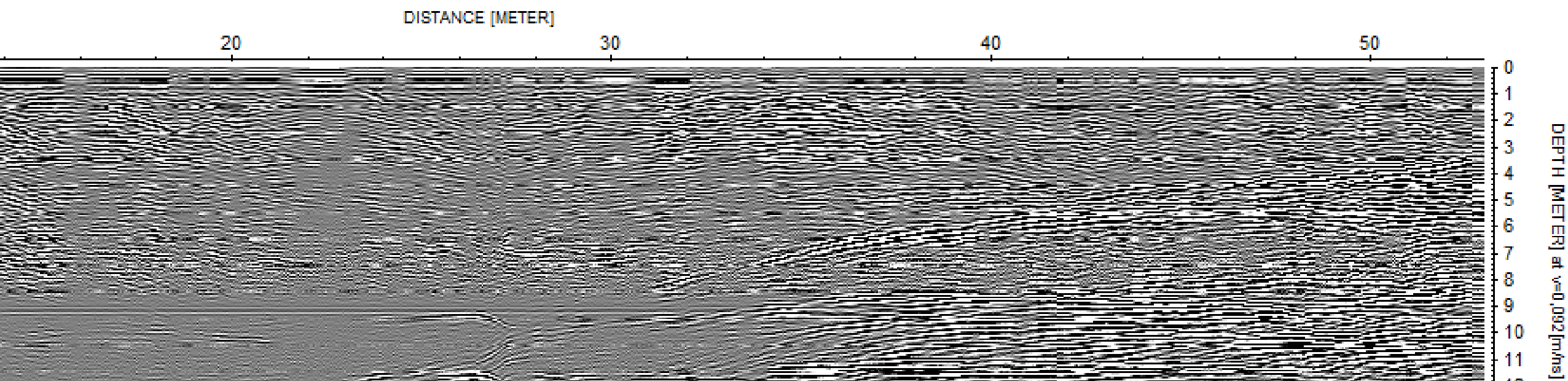


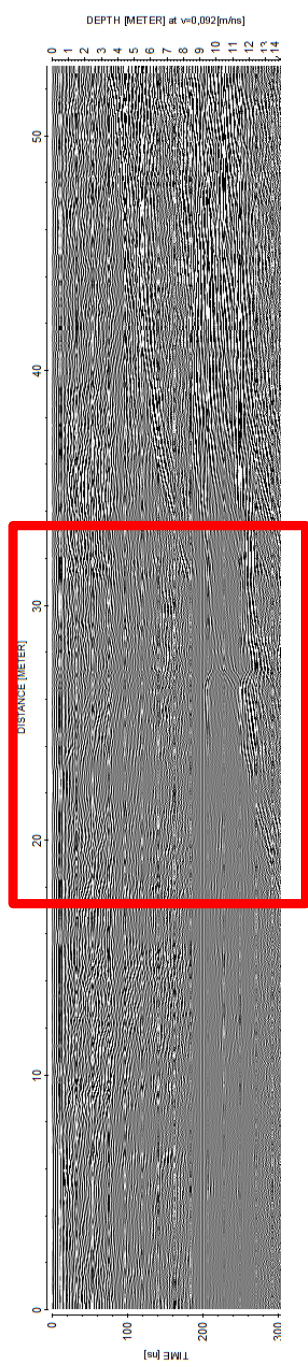


2D GPR measurements



processed data





DISTANCE [METER]

20

30

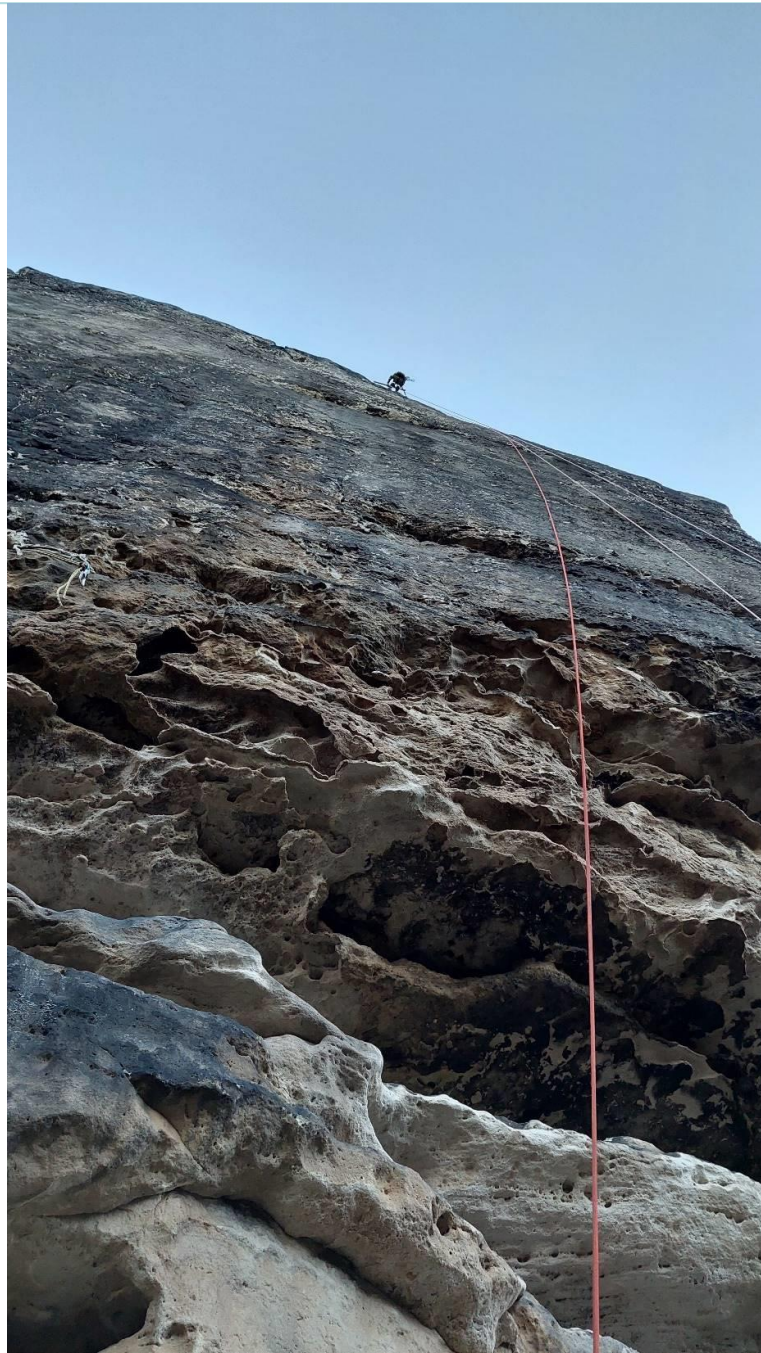
40

DISTANCE [METER]

20

30

40









Conclusions (proof of concept)

- Both method can bring valuable information on the rock properties
- Applicable with certain limitations

Future Prospects

- Development of the measurements methodology
(measurement geometry, parameters, adjustments)
- Interpretation of the measured data sets, connections to the water content