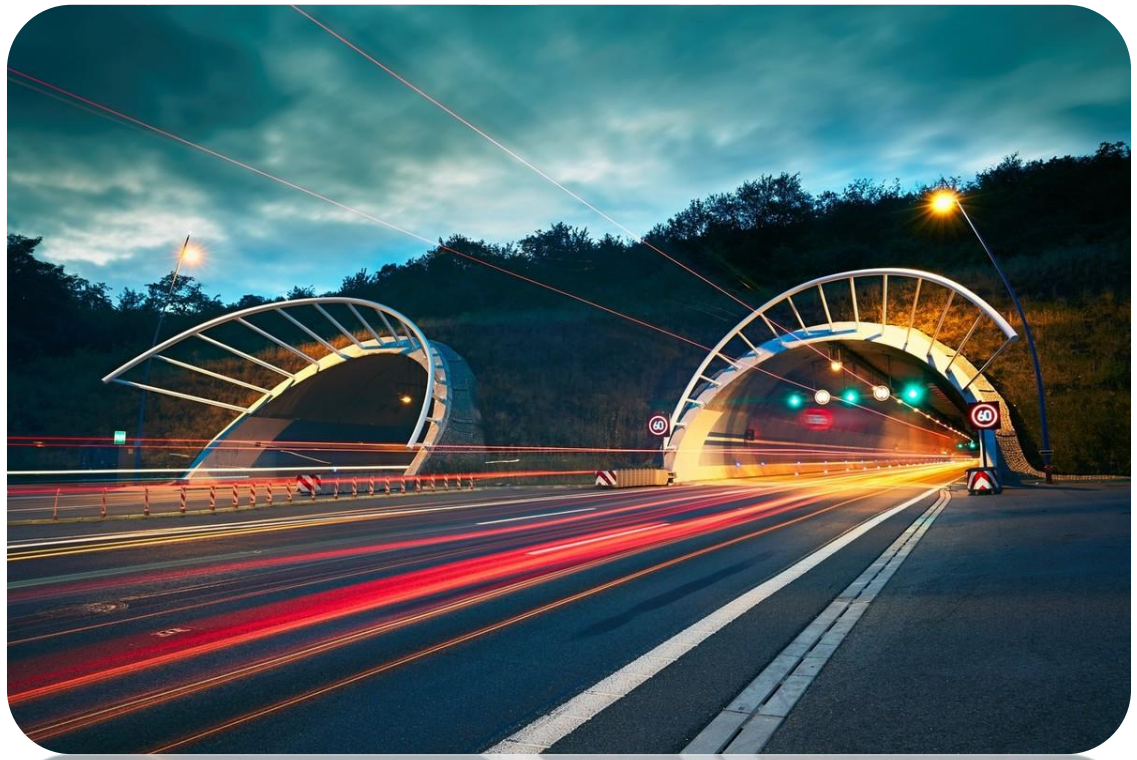
New Age Geophysical Survey Techniques for Subsurface Investigations



Presented by:

Dr. Sanjay Rana

Managing Director, PARSAN

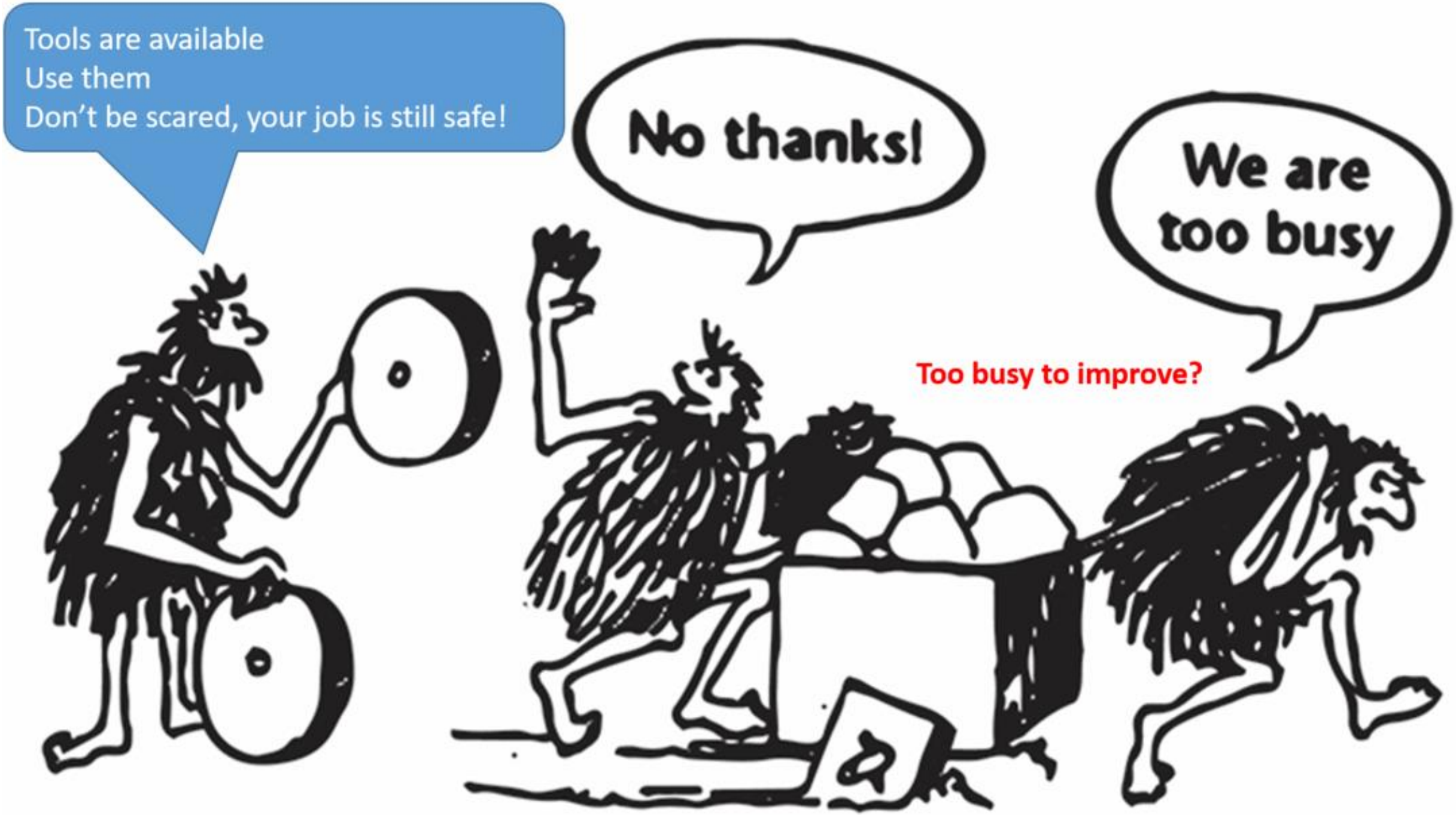
About PARSAN

- An ISO 9001:2015 certified geophysical company
- Promoters recognized as leaders in region for launching new technology. Responsible for launch of:
  - Ground Penetrating Radar Technology- 1996
  - Shear Wave Seismic Refraction- 1997
  - High Resolution Seismic Tomography- 1998
  - Passive Seismic Tomography for Oil Exploration- 2008
  - Innovative use of geophysical methods for high resolution non-destructive testing of dams- 1998
- Highly experienced and trained staff.
- Offices in Delhi, Kolkata, Bhopal, Bahrain & Saudi Arabia
- Work experience in India, Nepal, Bhutan, Saudi Arabia, Bahrain, Kuwait, Oman, Afghanistan, Singapore, Greece, Iran, Algeria, Georgia…….

About Speaker (Dr. Sanjay Rana)

- Professional Geophysicist, with **32 years** of work experience. Chairman AF Academy & Managing Director, PARSAN, An engineering geophysics company
- **Gold Medalist- 1990**, University of Roorkee (Now IIT-Roorkee)
- Pioneered use of Near Surface Geophysics (Private Sector) in India in **1995.**
- Completed geophysical investigations of **>2000** projects.
- Member of various working committees for development of Code of Practices and Standards, **including IRC, TAI, IndSTT**.
- Principal author of
  - Guidelines on Geophysical Investigation of Dams
  - Guidelines for Geophysical Investigation of Tunnels (TAI)
  - Guideline for Geophysical Investigations for Bridges (IRC)
  - Indian Code for Subsurface Utility Mapping.

The Engineer’s first problem in any design situation is to discover what the problem really is


Tools are available
Use them
Don’t be scared, your job is still safe!
No thanks!
We are too busy
Too busy to improve?

What is Investigation?

A methodology of acquiring advance knowledge of the site condition so that a techno-commercially viable project layout can be developed.

Survey & Investigations Issues

1. Adequacy of Investigation of Underground Projects under question? *(How Much?)*
2. Optimum time to be allowed for Investigations? *(Rushing into Construction)*
3. Technological Improvements required to brought in? *(Tender conditions/ standards)*
4. Cost to be allowed for Investigations? *(3-5%)*


Quality of Investigations
Quantity of Investigations
Time allowed for Investigations
Less Uncertainties
Less Cost & Claims

Geological Surprises?

1. Expertise & engineering solutions available for dealing with any (almost) ground condition
2. The problem is ‘meeting the unexpected’ and ‘uncertainty’ of ground conditions

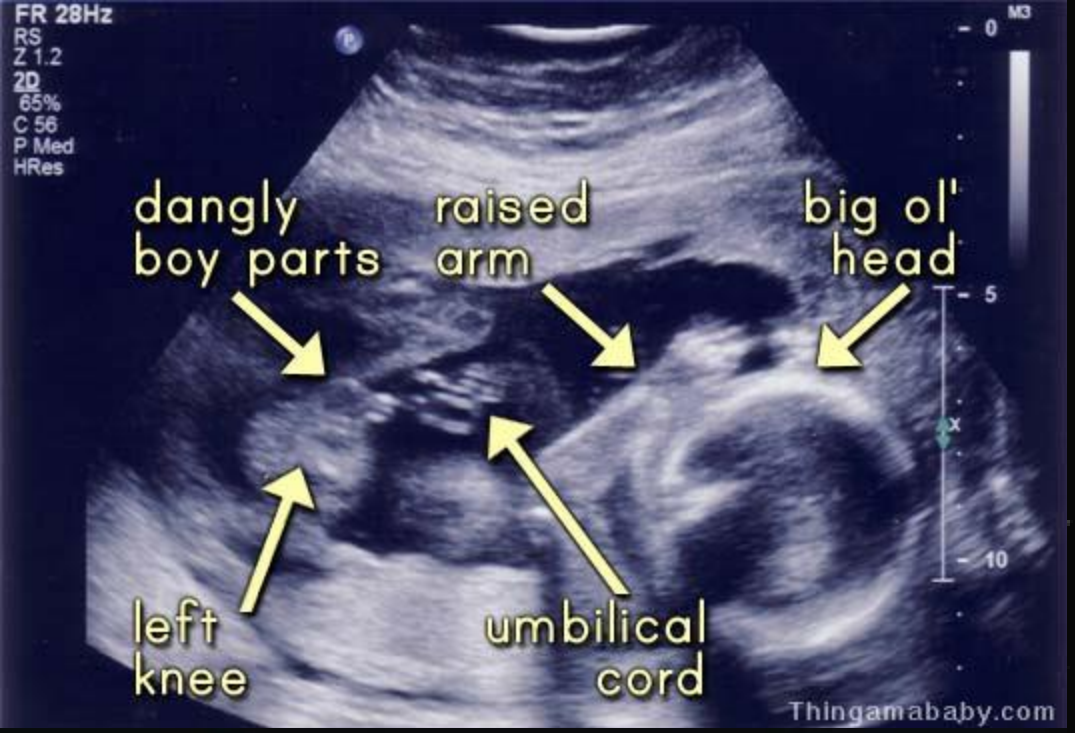
Challenges of Underground

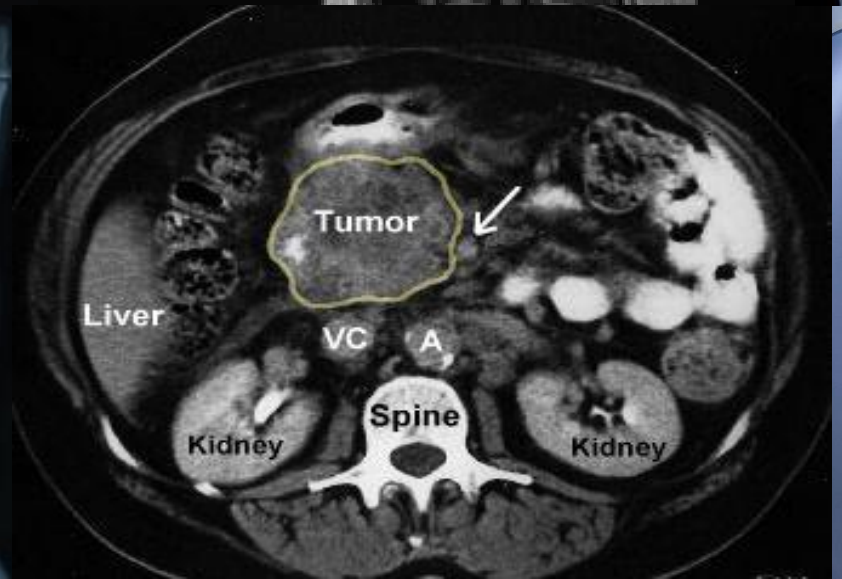
Even comprehensive exploration programs recover a relatively minuscule drill core volume that is less than 0.0005 percent of the future excavated volume of the tunnel

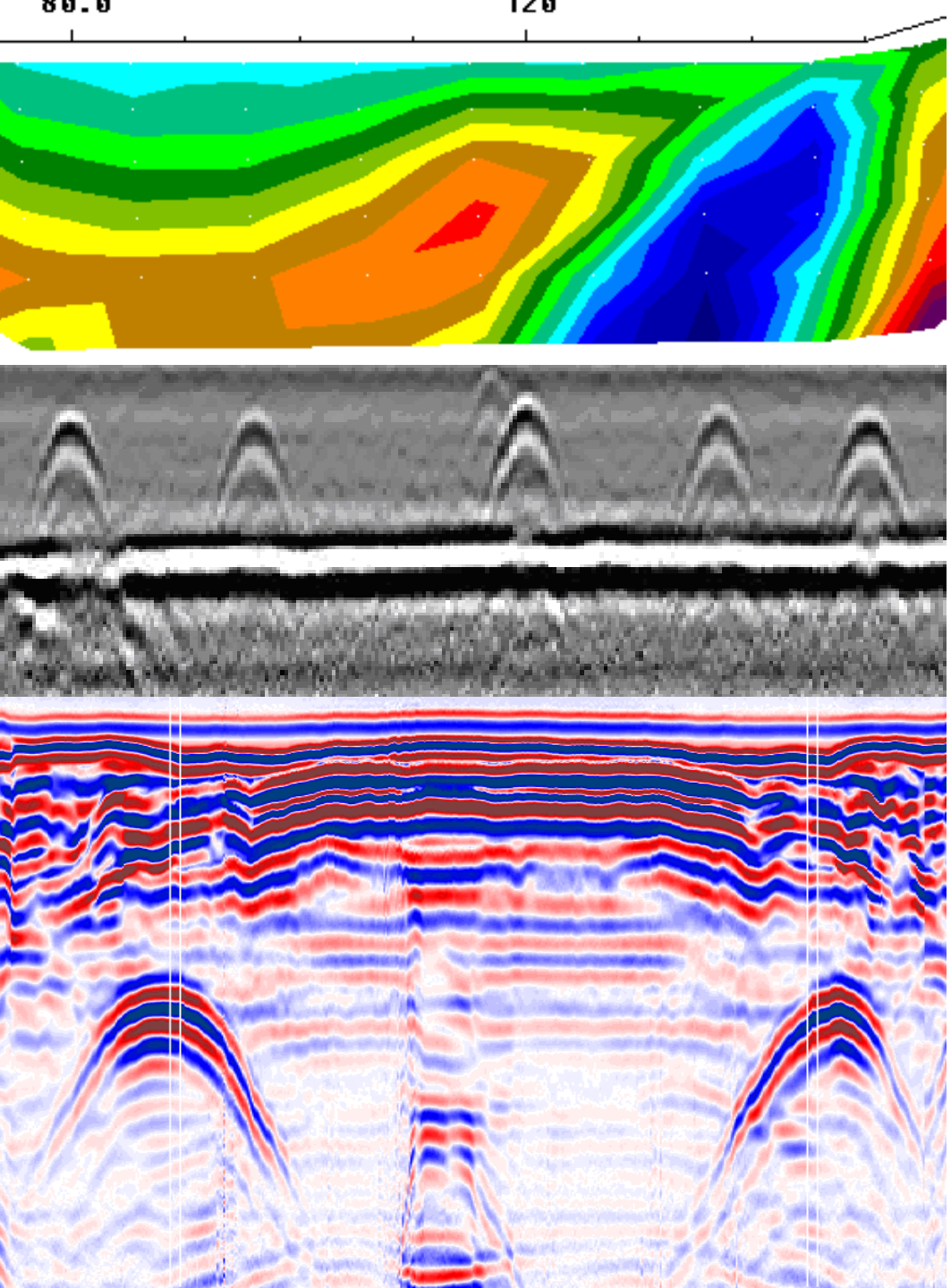
A Smart Decision Maker???

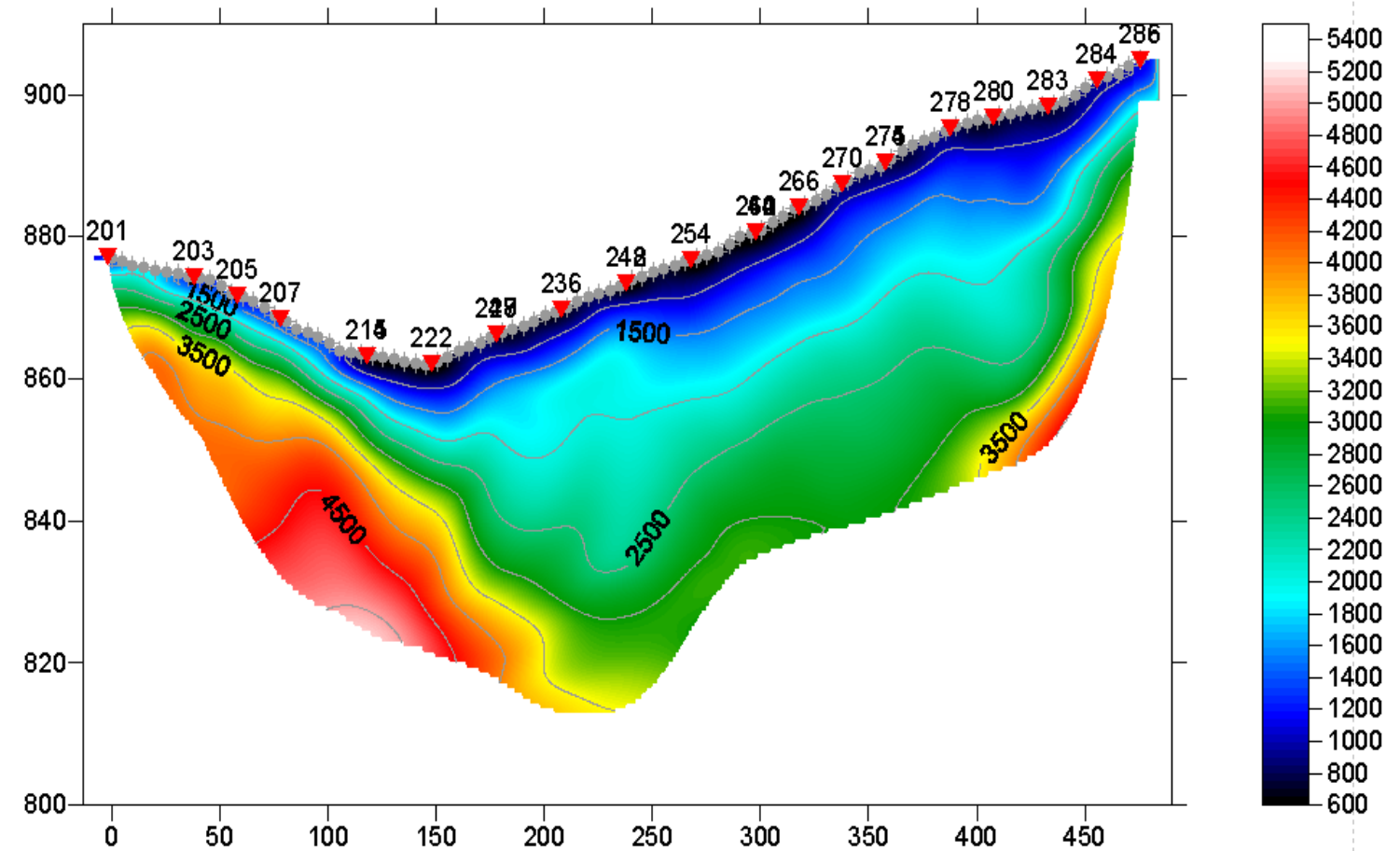
Investigations, How & How Much?

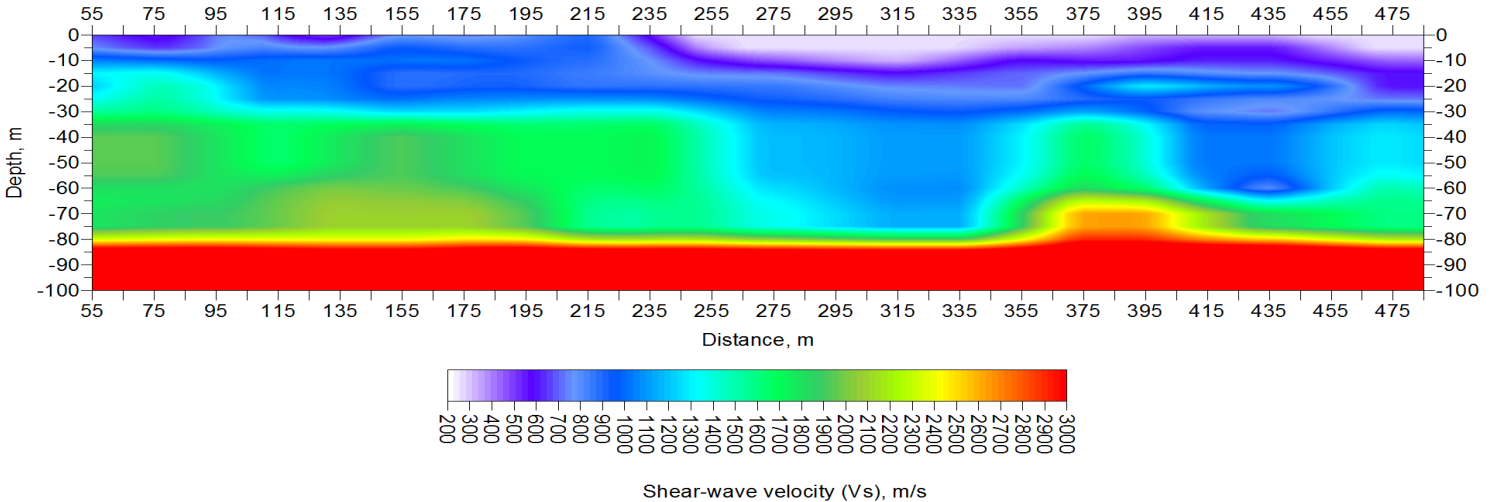
Geophysical Investigations……


FR 28Hz
RS
Z 1.2
2D
65%
C 56
P Med
HRes
M3
0
5
10
dangly boy parts
raised arm
big ol' head
left knee
umbilical cord
Thingamababy.com

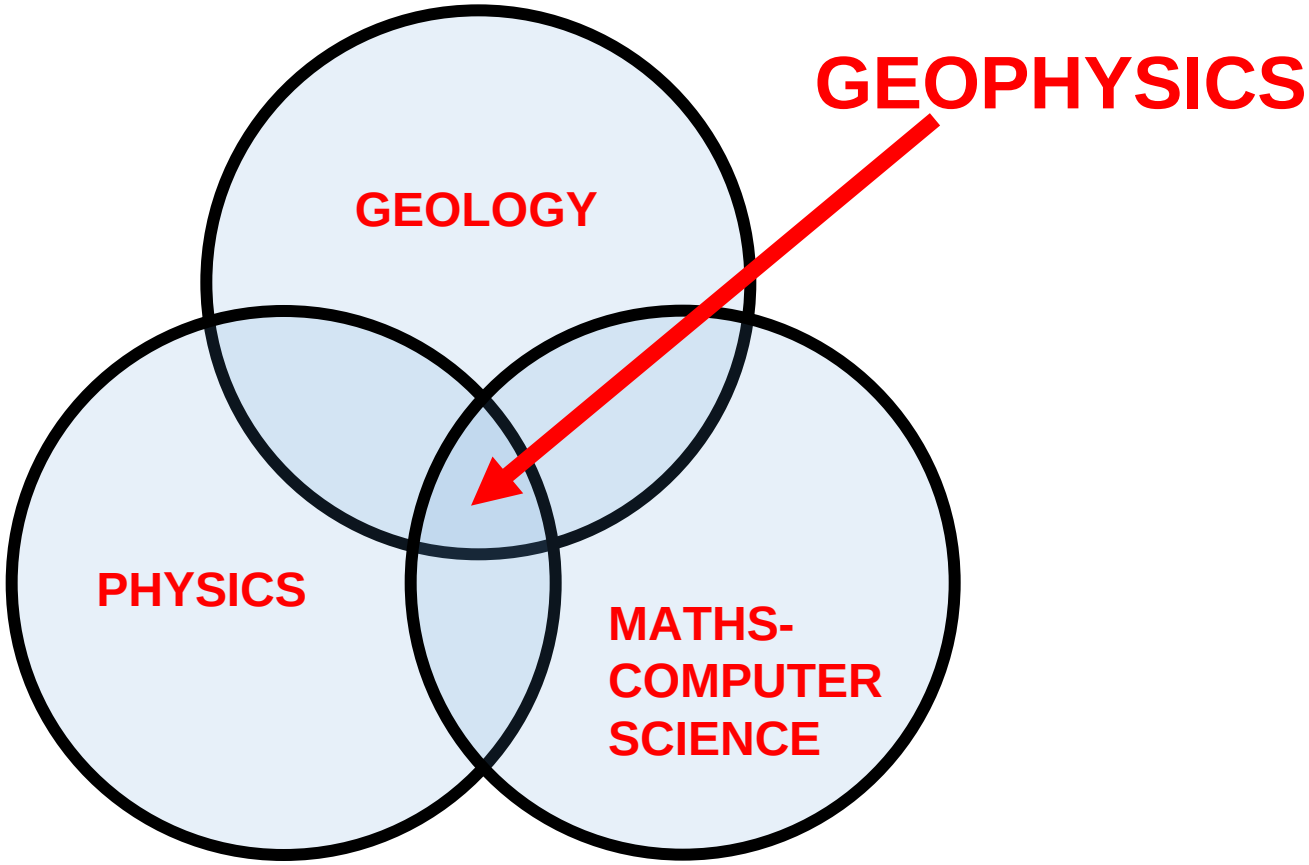

Tumor
Liver
VC
A
Spine
Kidney
Kidney




201
203
205
207
215
222
236
248
254
266
270
275
278
280
283
284
286
1500
2500
3500
4500
900
880
860
840
820
800
0
50
100
150
200
250
300
350
400
450
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600

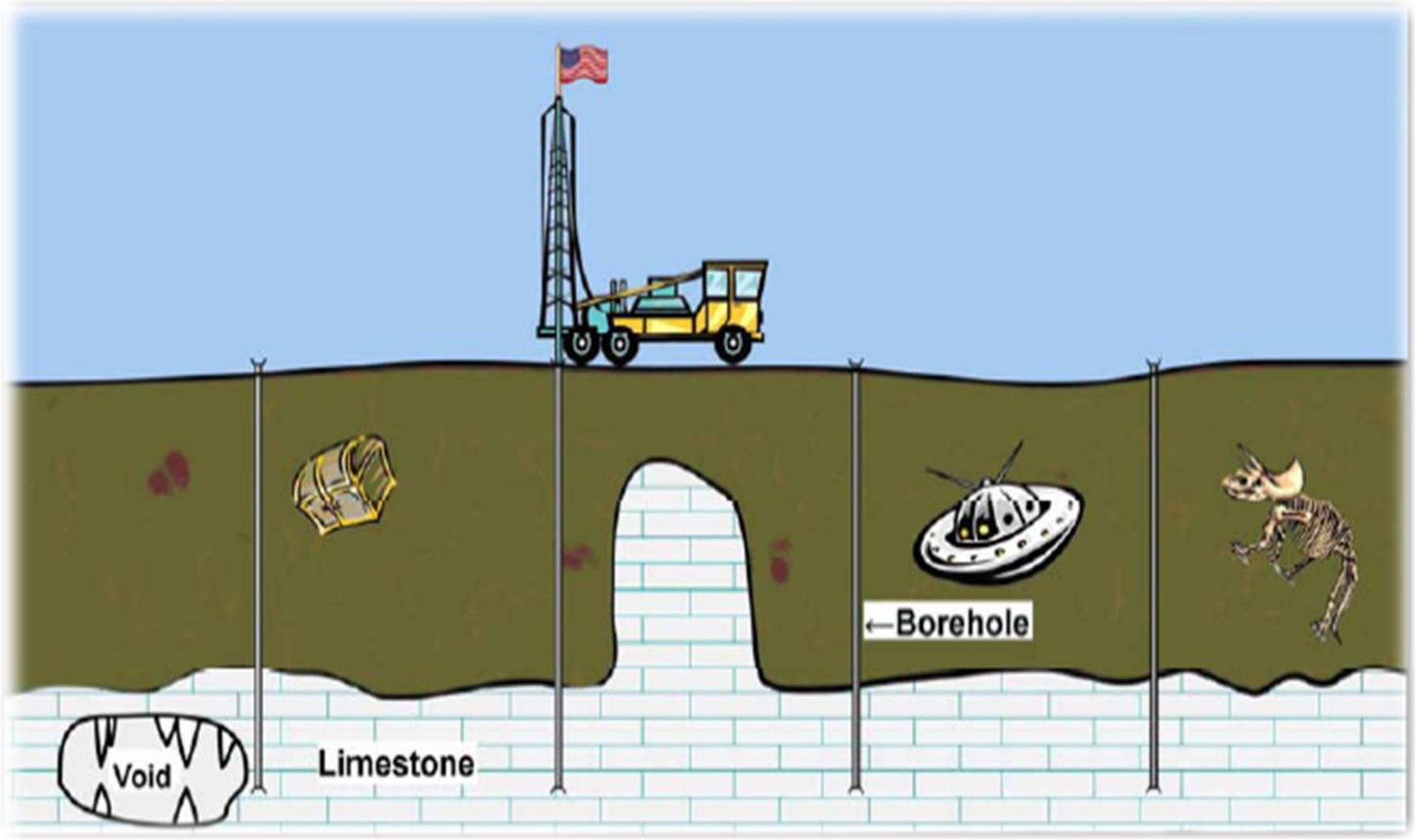

Depth, m
Distance, m
Shear-wave velocity (Vs), m/s

Geophysics as a Science



Why Use Geophysics…….

- Low Cost
- Rapid Coverage
- Continuous information
- Optimization of dill holes
- Minimization of ‘Surprises’
- Early stage application…Better planning, smooth execution.



Seven-step framework of Geophysics

Setup: Establish the geoscience objectives, consider conventional practice, and identify how geophysics might contribute.

Contrasts: Characterize materials that can be expected and establish the likely physical property contrasts.

Survey Design: Determine a suitable geophysical survey, and design an effective and efficient field survey. Identify possible sources of error, noise and mis-interpretation.

Data Collection: Carry out the field survey, taking all necessary actions to ensure complete, high quality, and cost effective data sets.

Processing: Plot the data, and apply appropriate processing and analysis.

Interpretation: Interpret results in terms of physical property distribution, and then in terms of the original geoscience objectives.

Synthesis: Combine interpretations with prior knowledge about the problem, and with other relevant information. Decide if your results are adequate for the particular problem. Decide further investigations, if needed.

Choice of method- An Important Step

- The user has considerable scope for choice. However, some factors to be considered are:

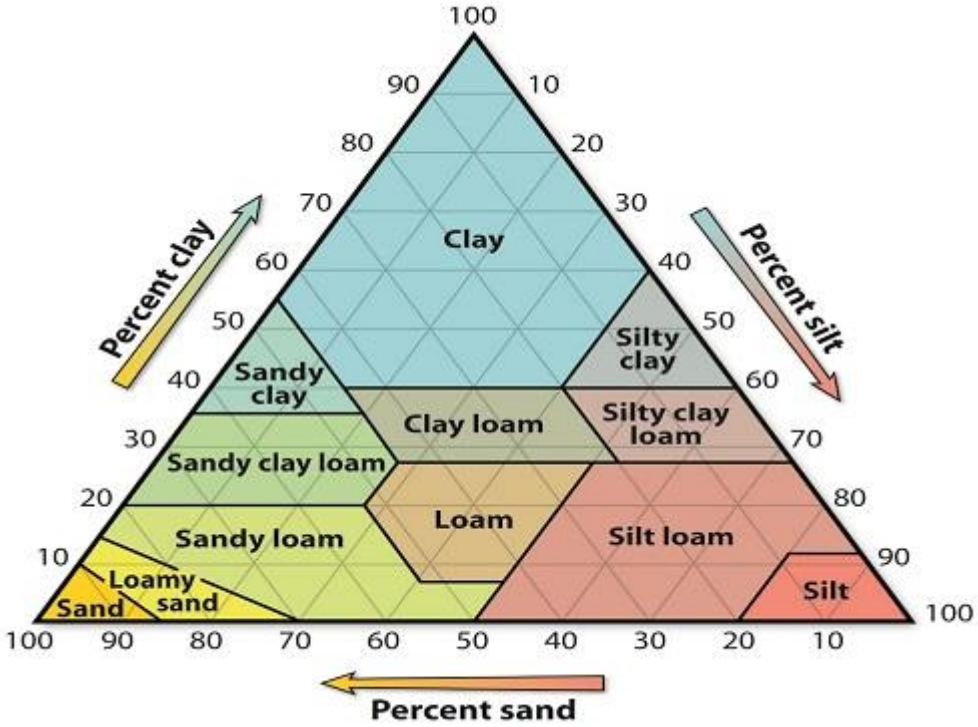
  - What type and shape of feature is being imaged?
  - What physical properties will show the best contrast?
  - Are there any strong but irrelevant contrasts that will mask the results?
  - To what depth must the survey penetrate?
  - What spatial resolution is needed?
  - What are the time or cost constraints?
  - Are there any special restrictions eg. on access or damage?

Advantages & Limitations

- Advantages of geophysics
  - Rapid and cheap survey tool
  - Easily integrated with other forms of ground survey
  - Non-destructive (archaeology, Dams, urban areas generally)
  - Modern processing methods give a visual image of the subsurface
- Limitations of geophysics
  - Can be ambiguous without controls
  - Poor discrimination in some cases
  - Can suffer from noise or artefacts

Different Methods for Different Property

- Some methods that are commonly used are:
  - **Seismic methods** = Elastic wave velocity
  - **Ground Penetrating Radar (GPR)** = EM pulse velocity
  - **DC resistivity methods** = Electrical DC resistance
  - **EM conductivity methods** = Electrical AC conductivity
  - **Magnetic methods** = Magnetic field strength
  - **Gravity methods** = Gravity field strength
- The value of the surface measurement is determined by the contrast in the relevant property (hence material type) and by the three dimensional structure.



Geophysics- Huge ROI...

- Detailed investigation of site…Saving huge costs towards changed plans, project delays when surprises crop up….
- No drilling, No digging…Vast information at fraction of cost of traditional methods.
- Early-stage application…Better planning, smooth execution.

Tunnel Projects Site Investigations

Necessary Investigation Steps...

- Study available geological maps
- Study satellite images
- Geological Mapping
- **Geophysical Investigations**
- Drilling (with geophysical logging)
- Hydrogeological studies
- Seismicity Study
- ……..

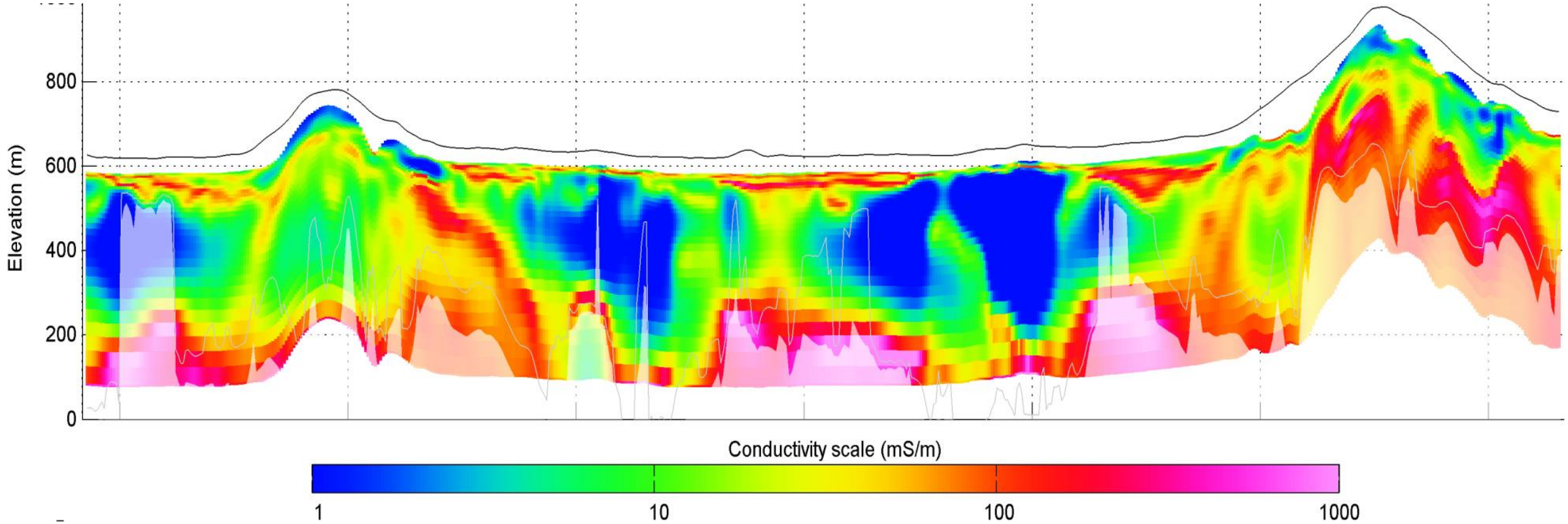
Geophysical Investigation for Tunnel Projects...

Different types of geophysical studies can be performed for new projects (at planning stage), for various components like tunnel route, portals etc.

- Investigations to choose best and least problematic tunnel alignment
- To indicate the mechanical properties of the rocks and the depth of the weathering zone.
- To detect faults/ fractures/ shear zones/ weak zones
- To conduct slope stability studies
- To determine shear wave velocities for seismic hazard studies
- Investigation of the water level or extended water bearing strata
- Investigation of contaminated areas
- Other obstacles like utilities, foundations, cavities etc., for urban tunneling projects

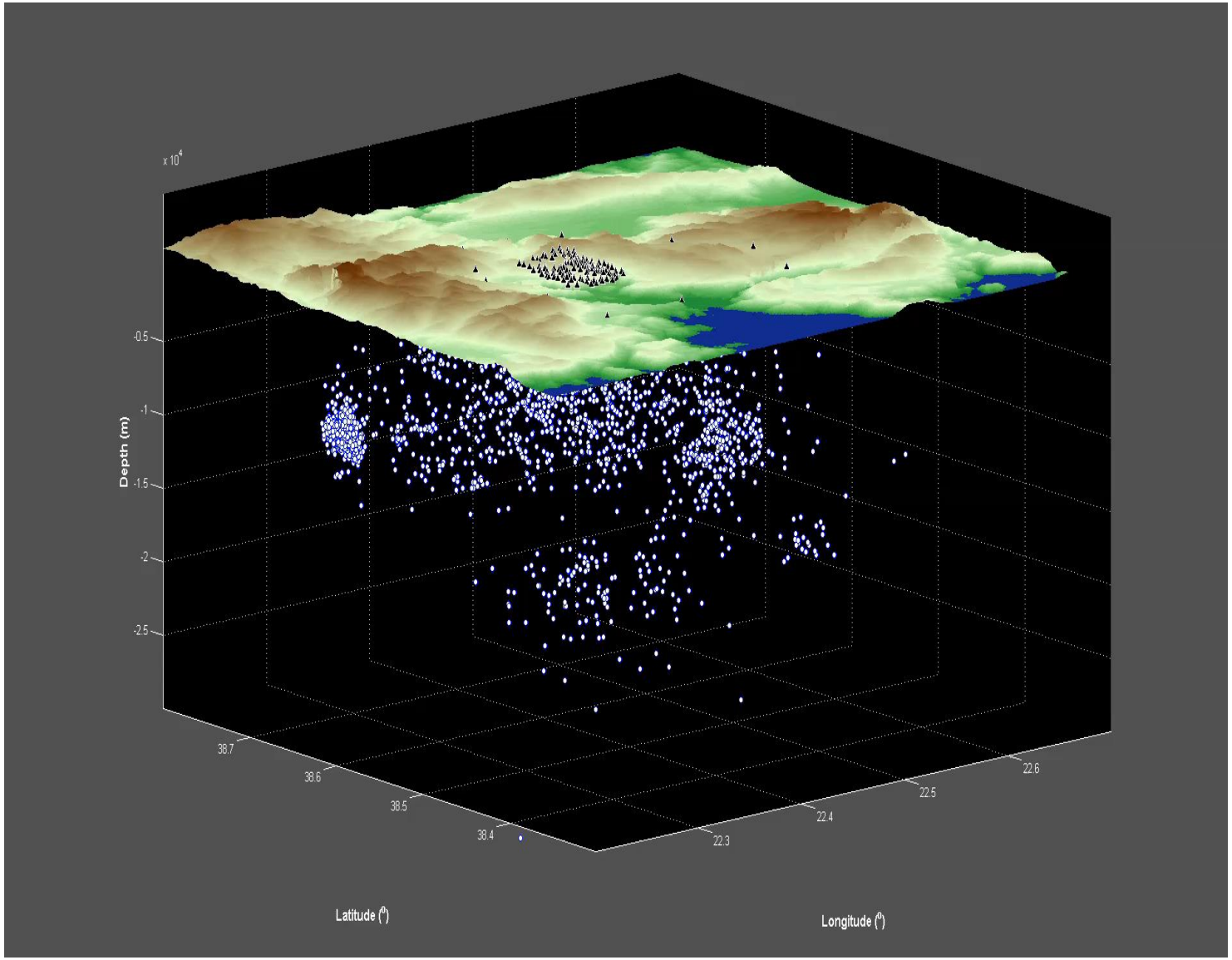
Heliborne TDEM…….

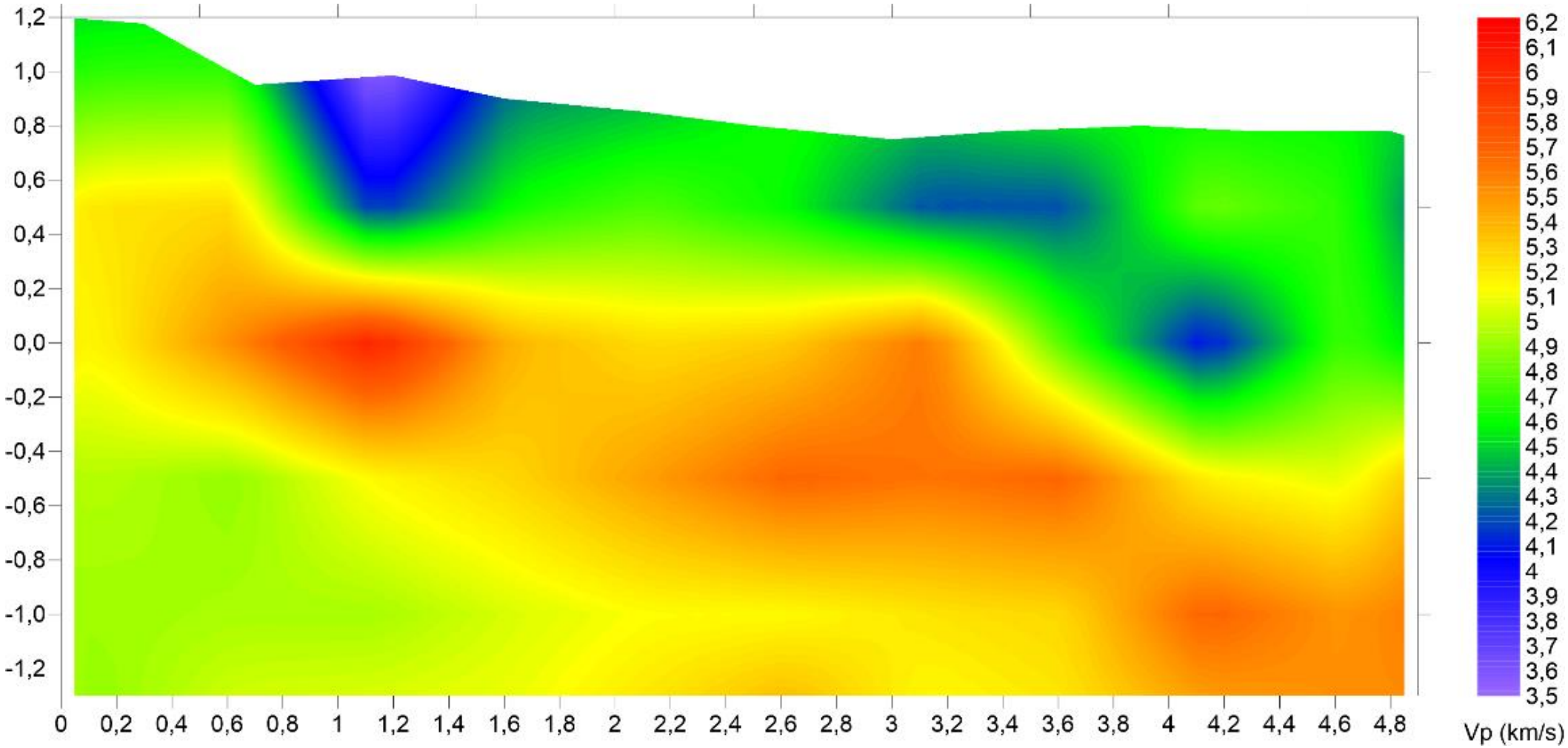

SKYTEM


Elevation (m)
800
600
400
200
0
Conductivity scale (mS/m)
1
10
100
1000

Passive Seismic Tomography…….

- **Local Earthquake Tomography** and **Reflected-wave Passive Seismic Interferometry** using earthquake sources. Also possible to use ambient noise, traffic noise.

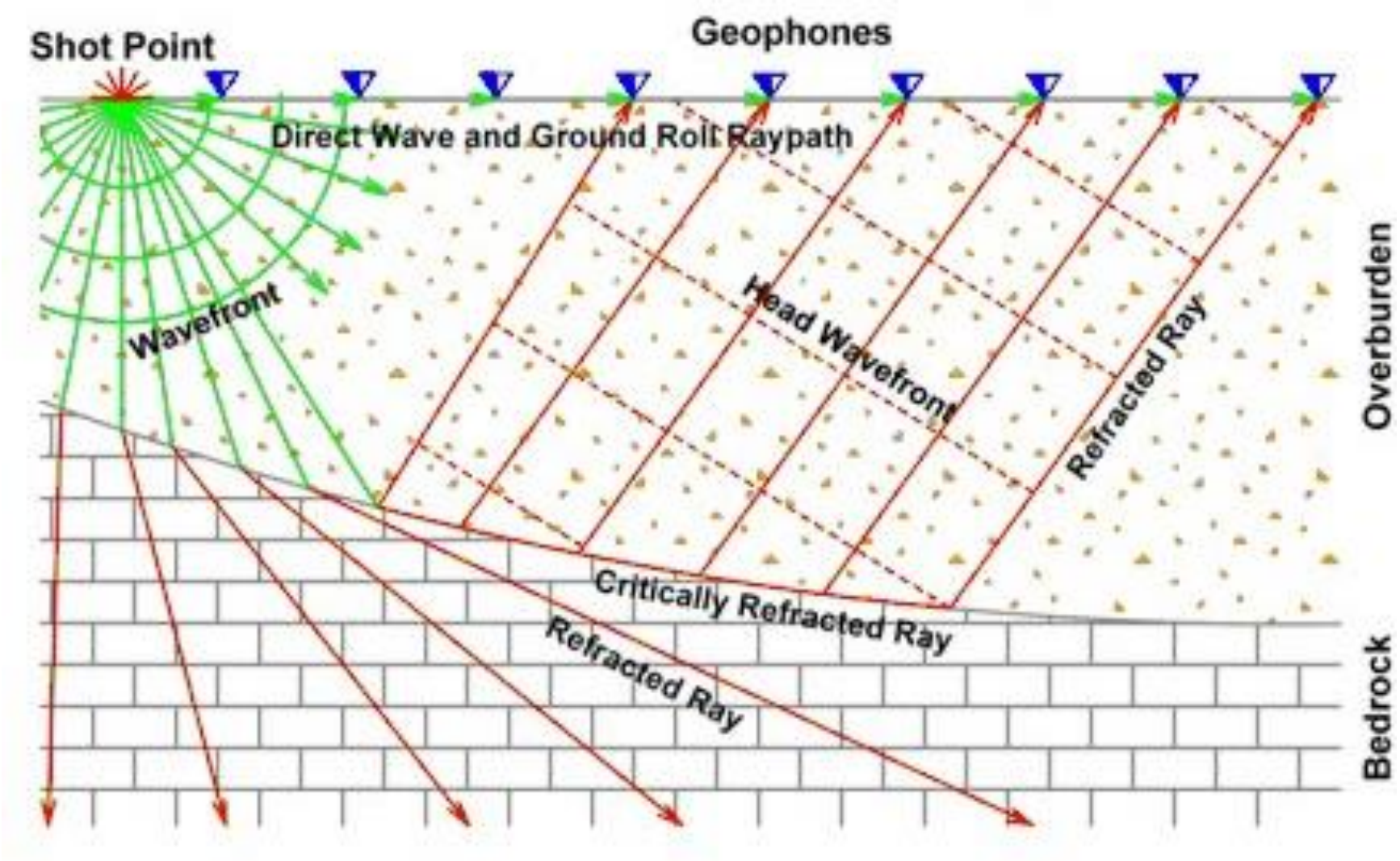


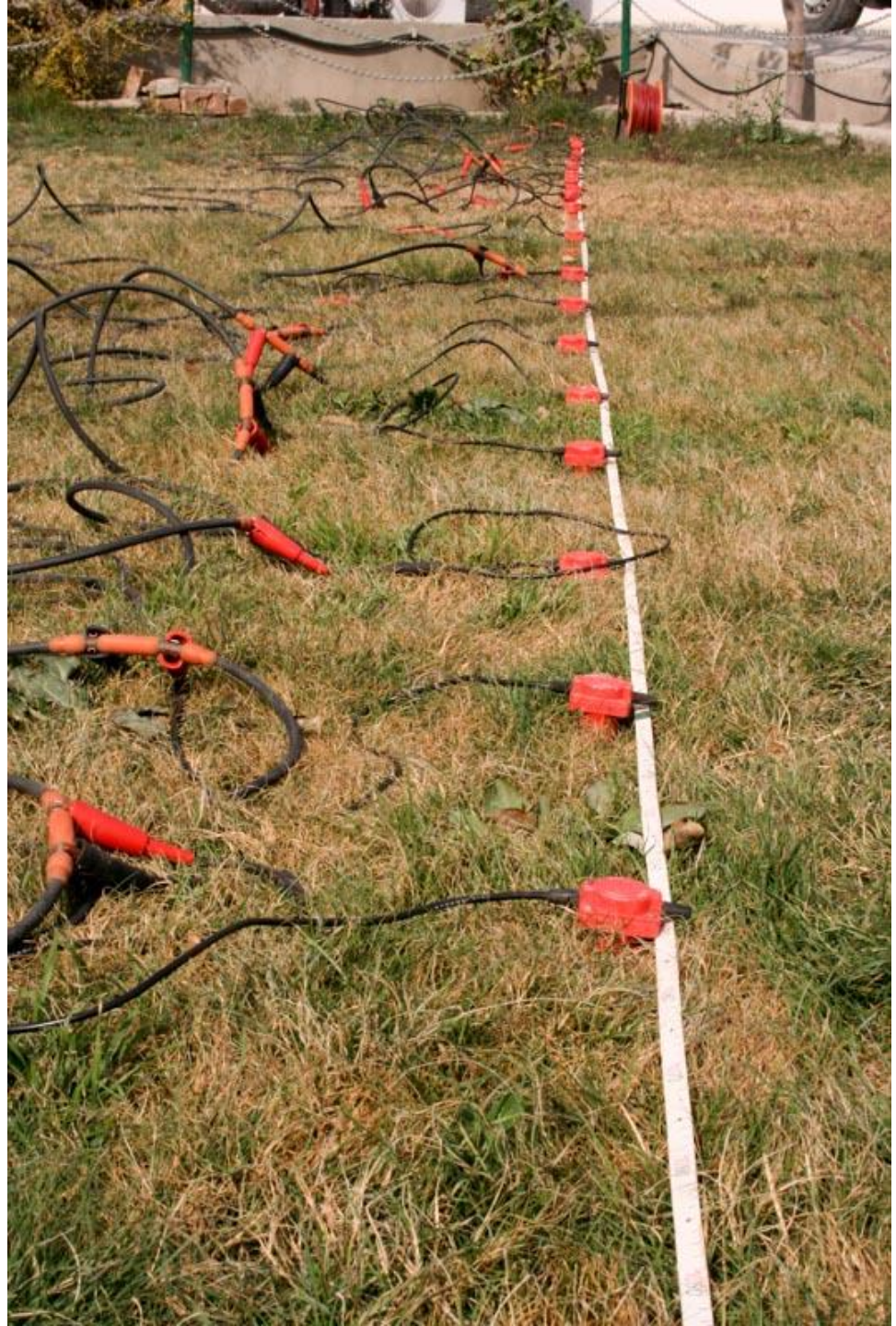


Depth Investigated > 2km

Seismic Refraction Tomography.....

Seismic Refraction- Basic Principle…

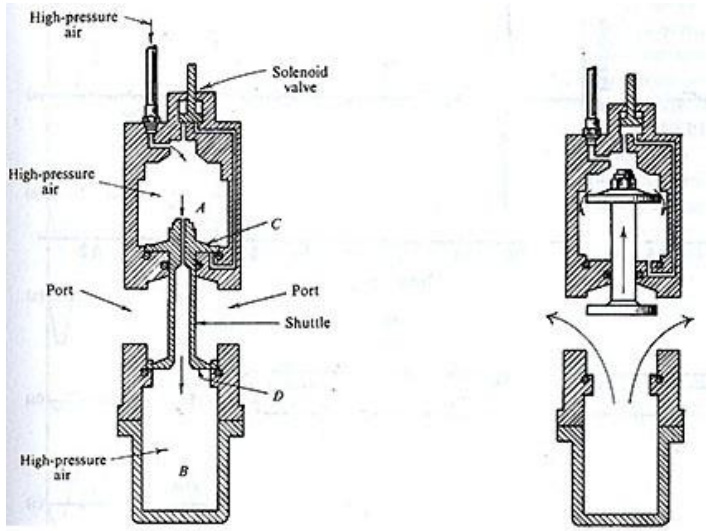




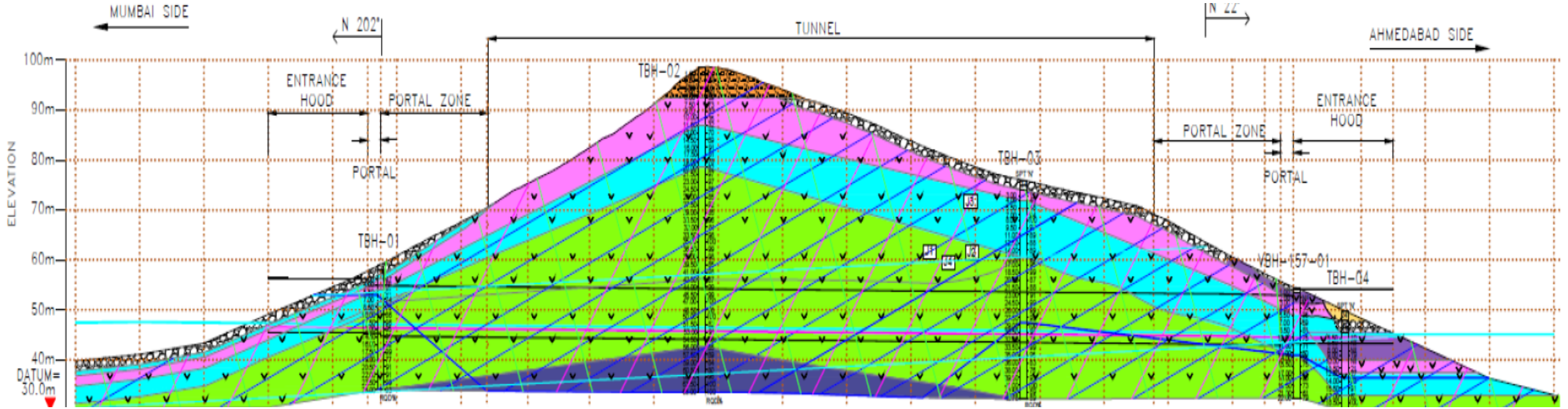
Seismic Refraction- Field Work…

- Geophone Planting
    - Through Spikes
    - Through Metal Base
- Connecting geophones with multicore cable
- Cable connection to seismograph
- Trigger
- Checks (channels, Noise etc.)
- Recording of data

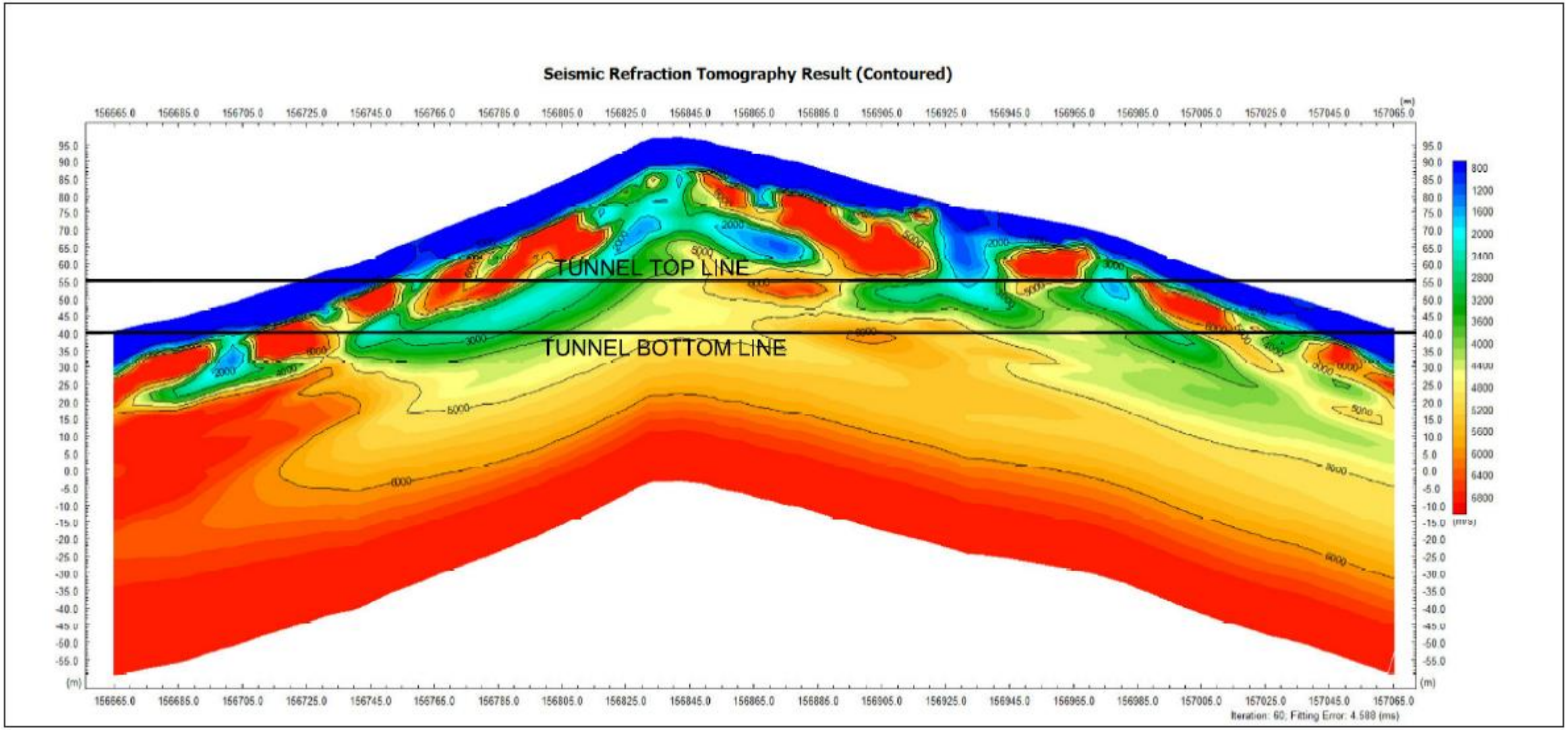
Seismic Refraction- Field Work in Water…



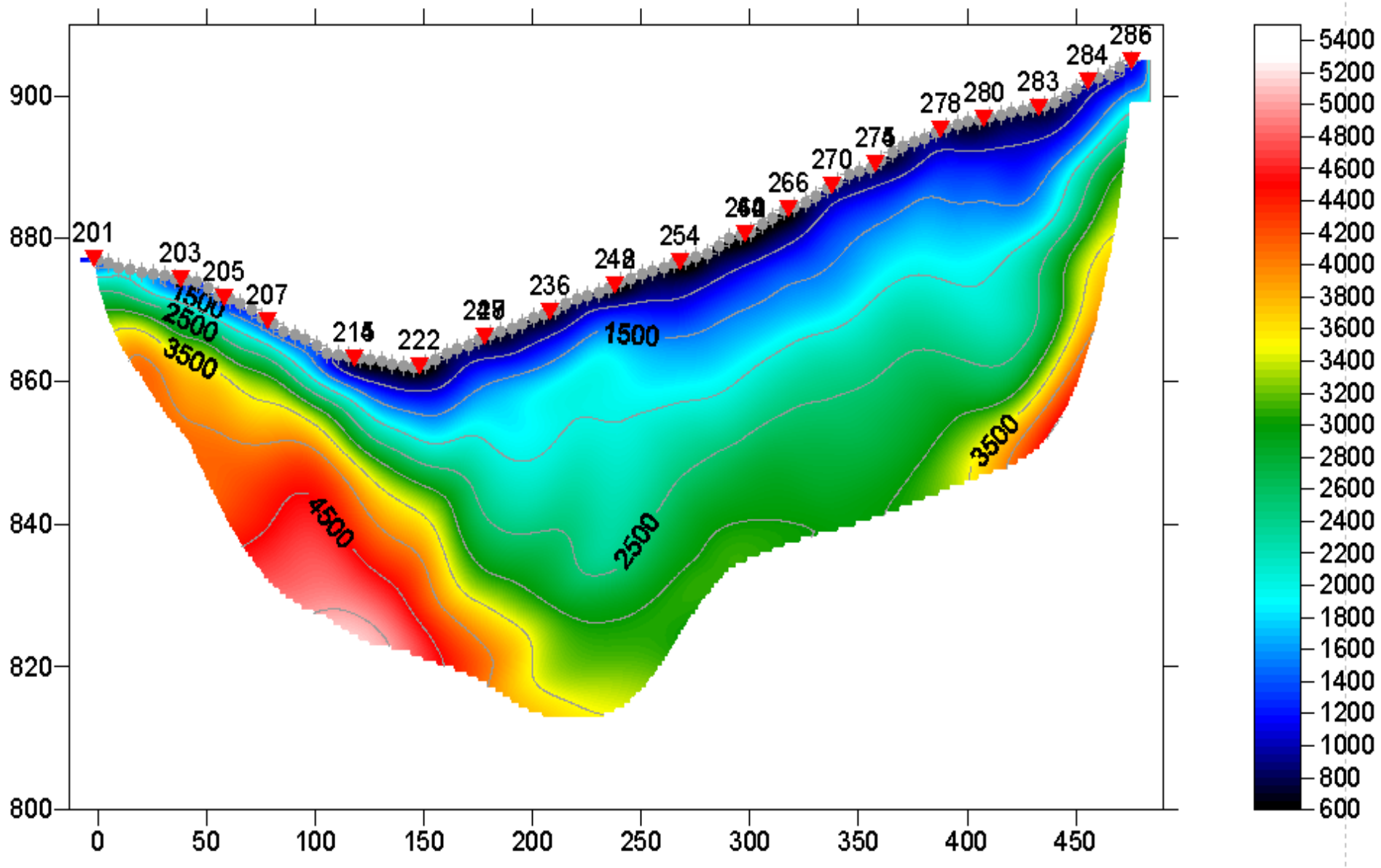
Geological Model based on Boreholes…….



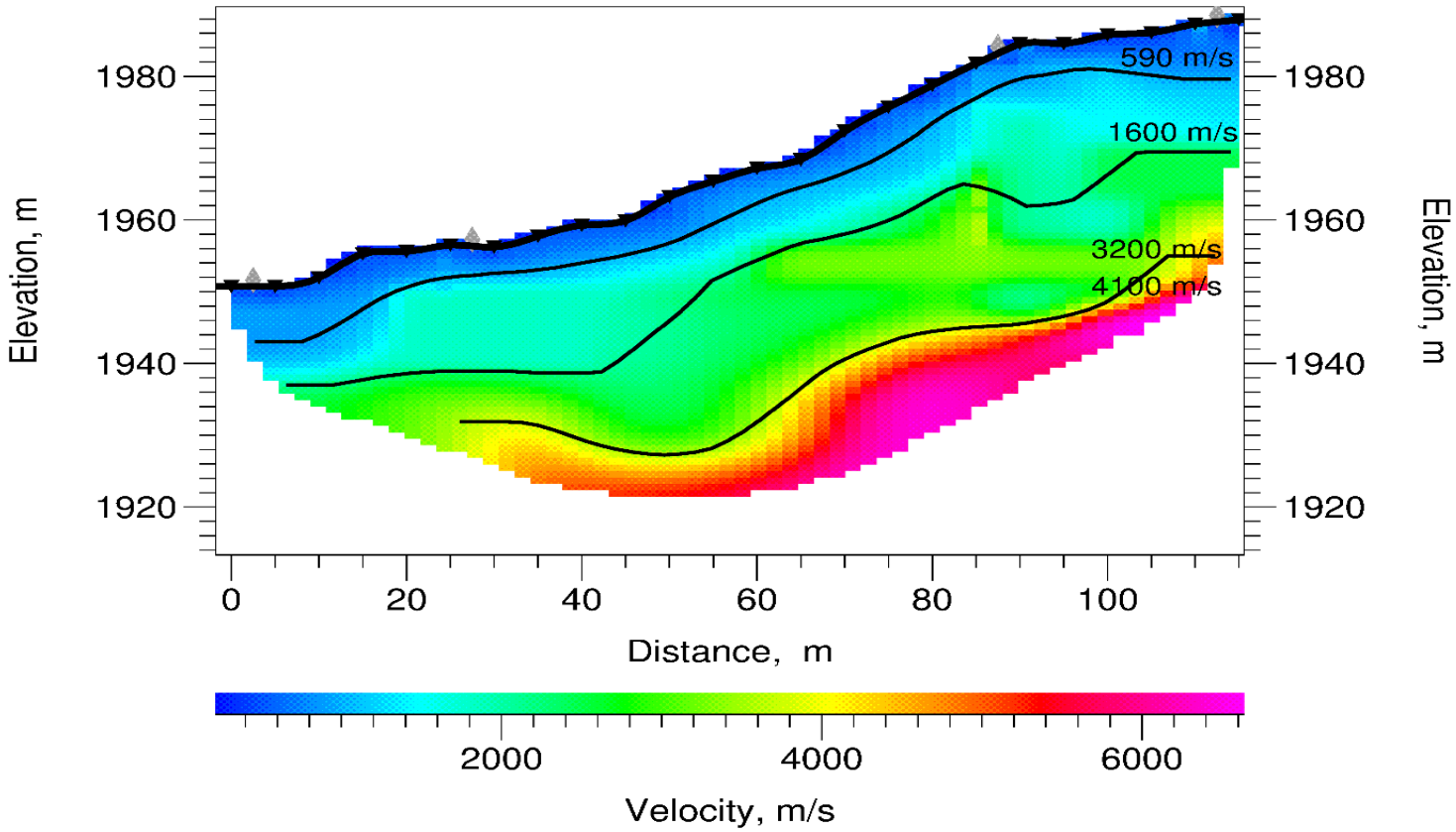
Seismic Refraction Tomography Results…….

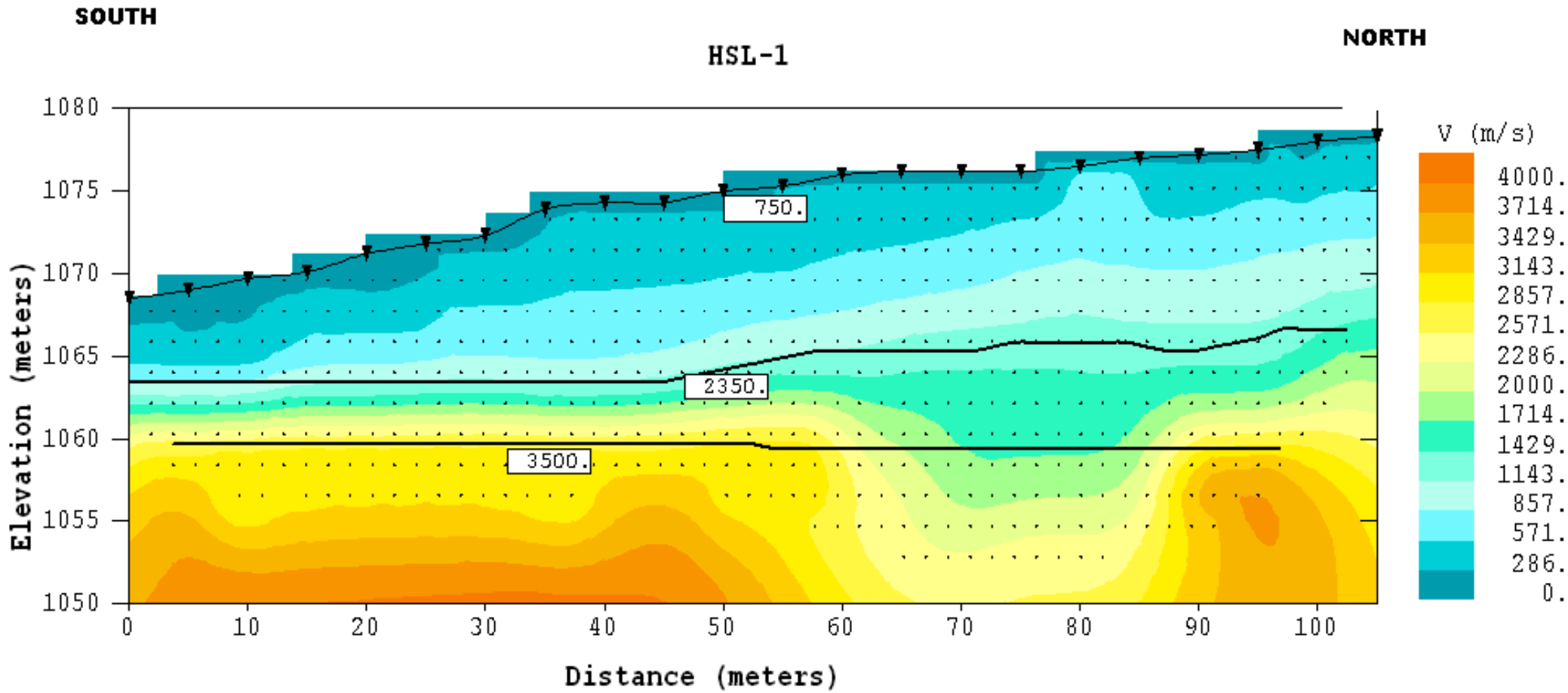


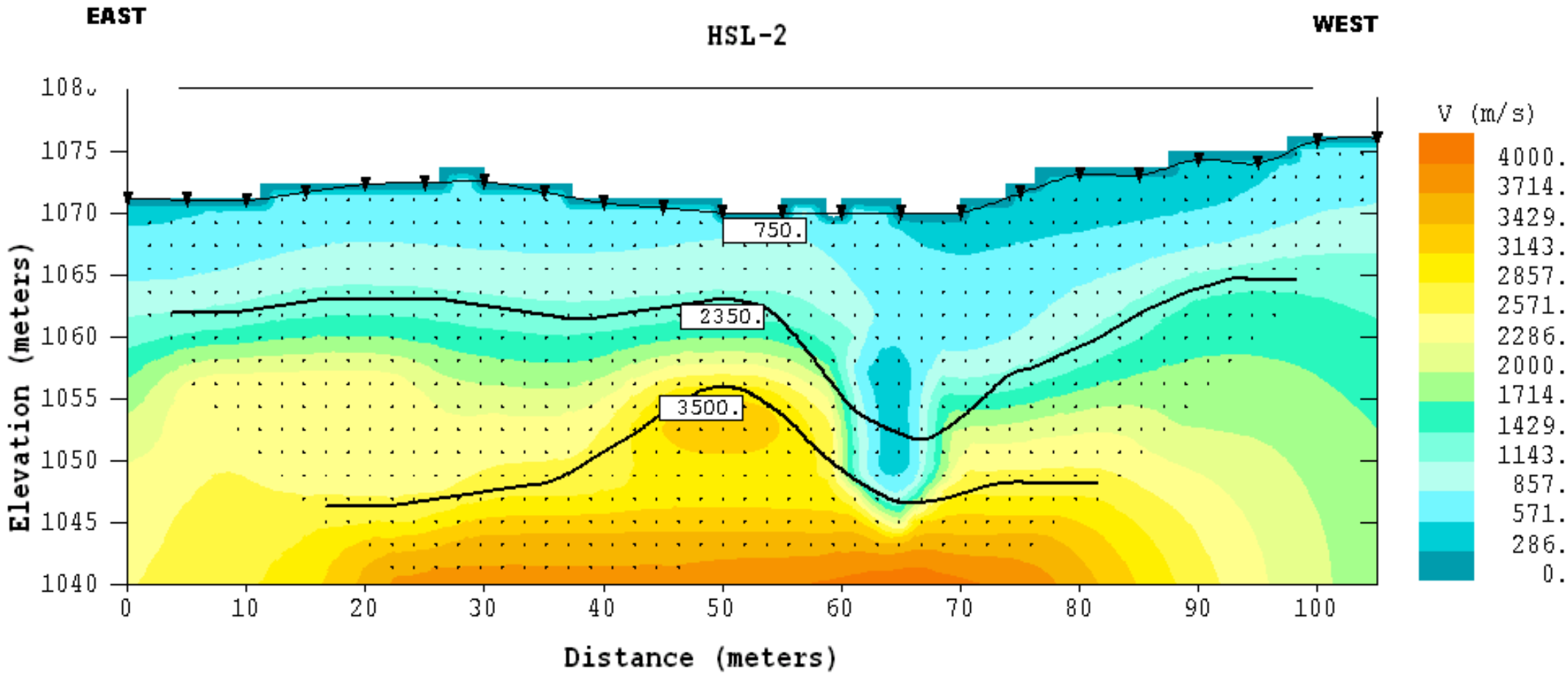
Seismic Refraction Tomography Results…….

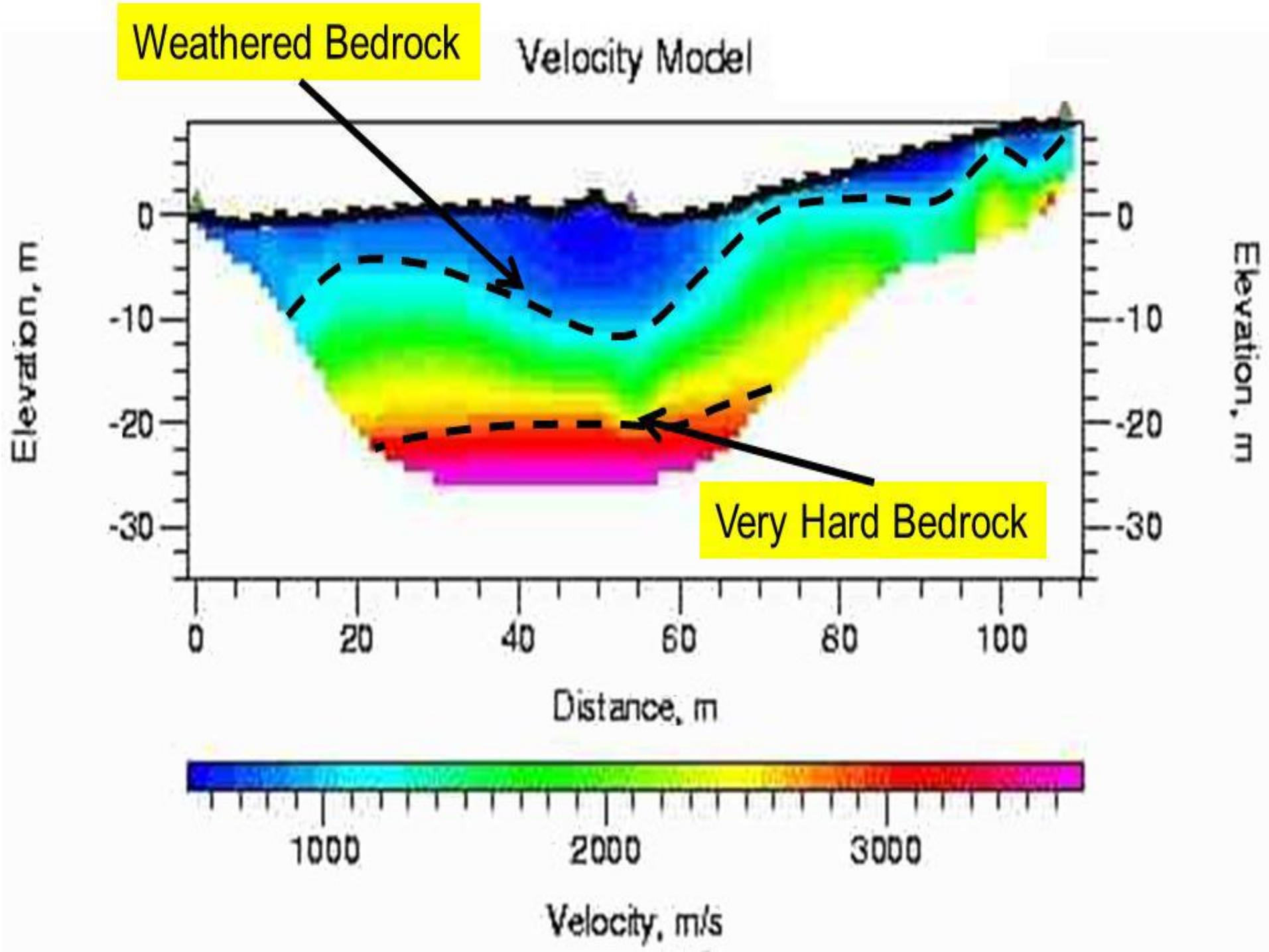


Velocity Model…….




SOUTH
NORTH
HSL-1
1080
1075
1070
1065
1060
1055
1050
Elevation (meters)
750.
2350.
3500.
0
10
20
30
40
50
60
70
80
90
100
Distance (meters)
V (m/s)
4000.
3714.
3429.
3143.
2857.
2571.
2286.
2000.
1714.
1429.
1143.
857.
571.
286.
0.


EAST
HSL-2
WEST
1080
1075
1070
1065
1060
1055
1050
1045
1040
Elevation (meters)
750.
2350.
3500.
0
10
20
30
40
50
60
70
80
90
100
Distance (meters)
V (m/s)
4000.
3714.
3429.
3143.
2857.
2571.
2286.
2000.
1714.
1429.
1143.
857.
571.
286.
0.


Weathered Bedrock
Velocity Model
Very Hard Bedrock
Elevation, m
0
-10
-20
-30
0
20
40
60
80
100
Distance, m
1000
2000
3000
Velocity, m/s

Seismic Refraction- Applications

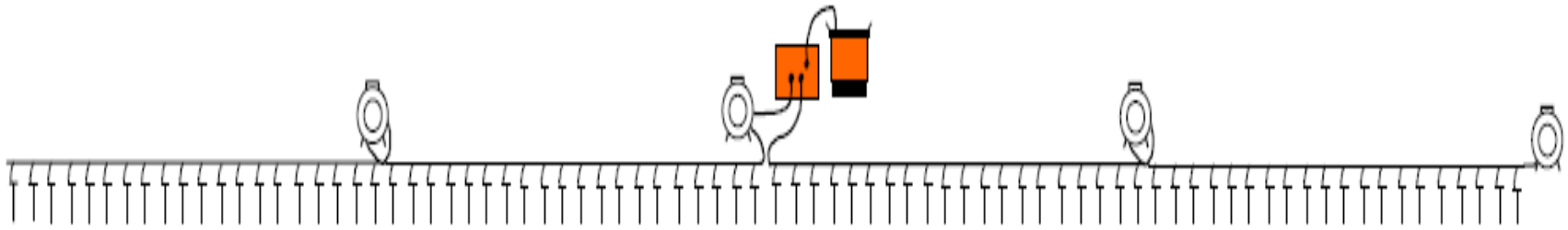
- Bedrock profile, rock quality and depth.
- Thickness of overburden
- Fractures and weak zones
- Slope stability studies

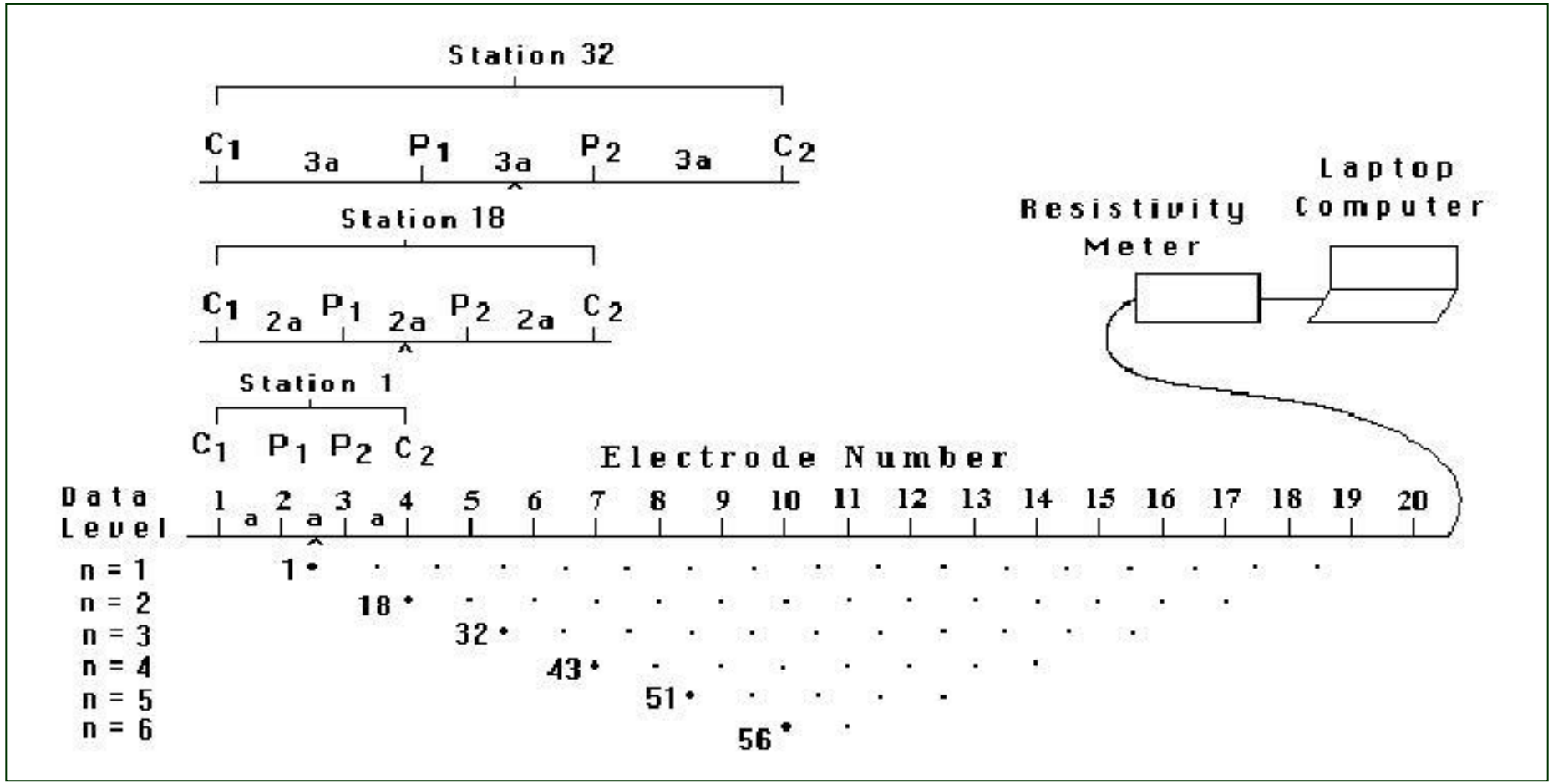
Seismic Refraction- Applications Areas

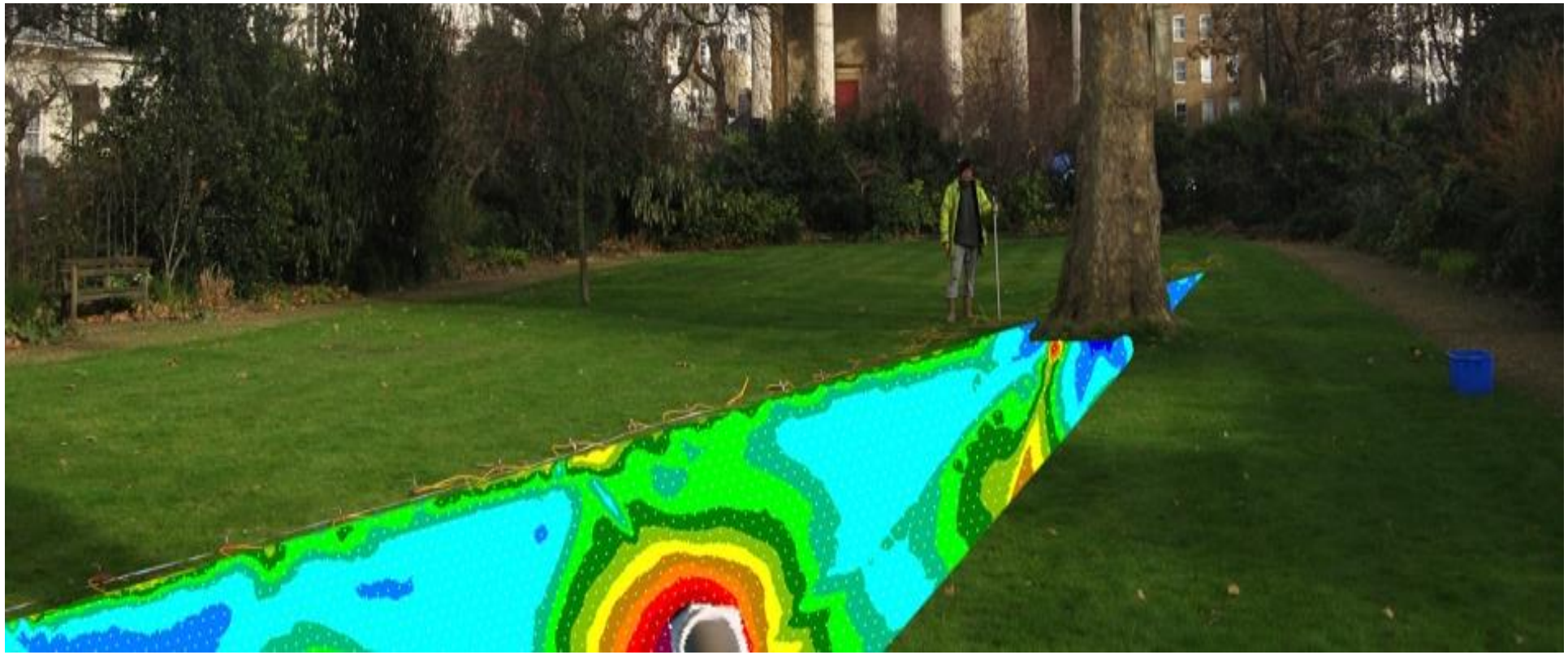
- Tunnel Portals.
- Tunnel Alignment
- Underground Caverns
- Complimentary tool to any geotechnical investigation

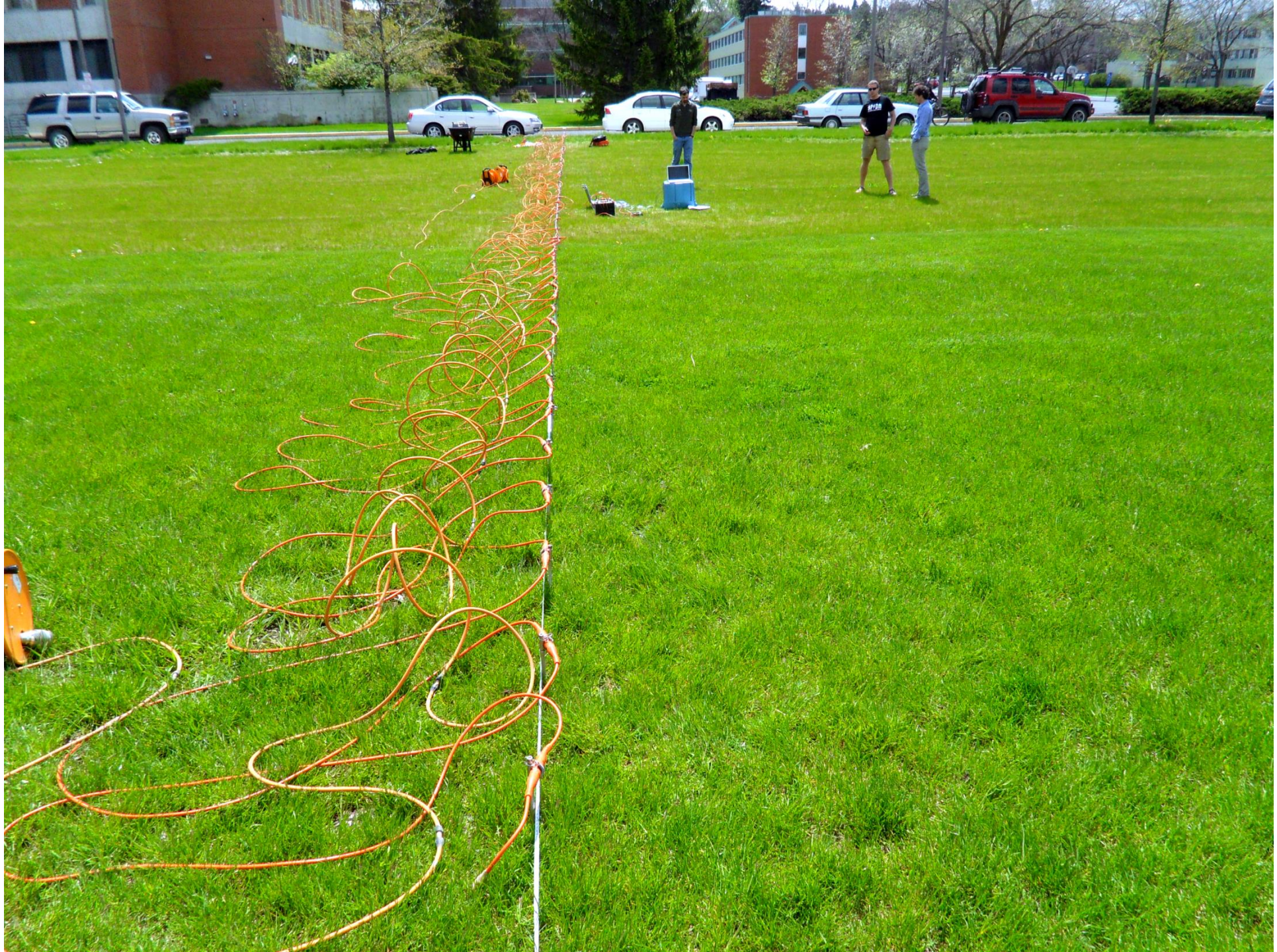
Electrical Resistivity Imaging/ Tomography…….

Electrical Resistivity Imaging…



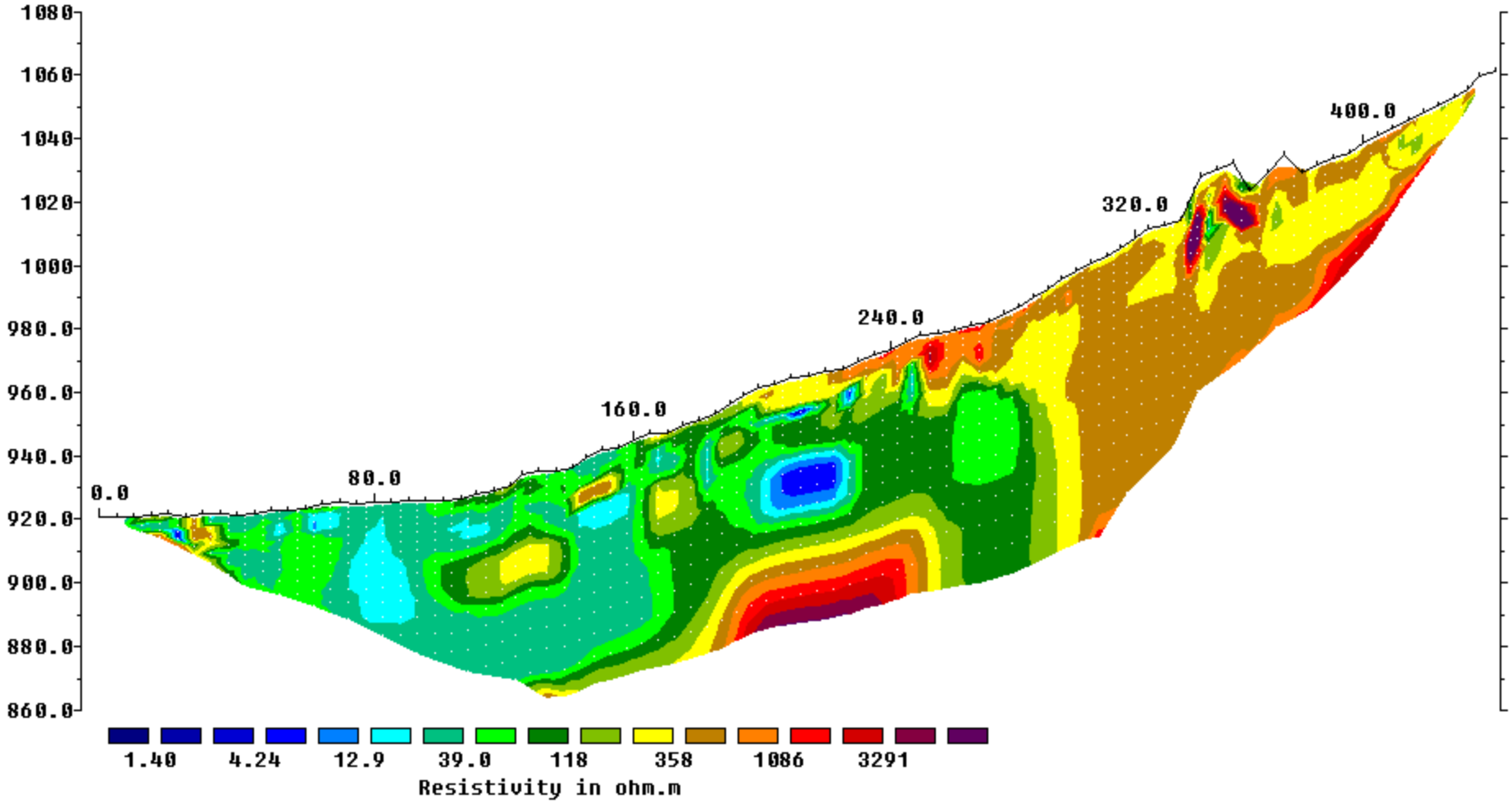




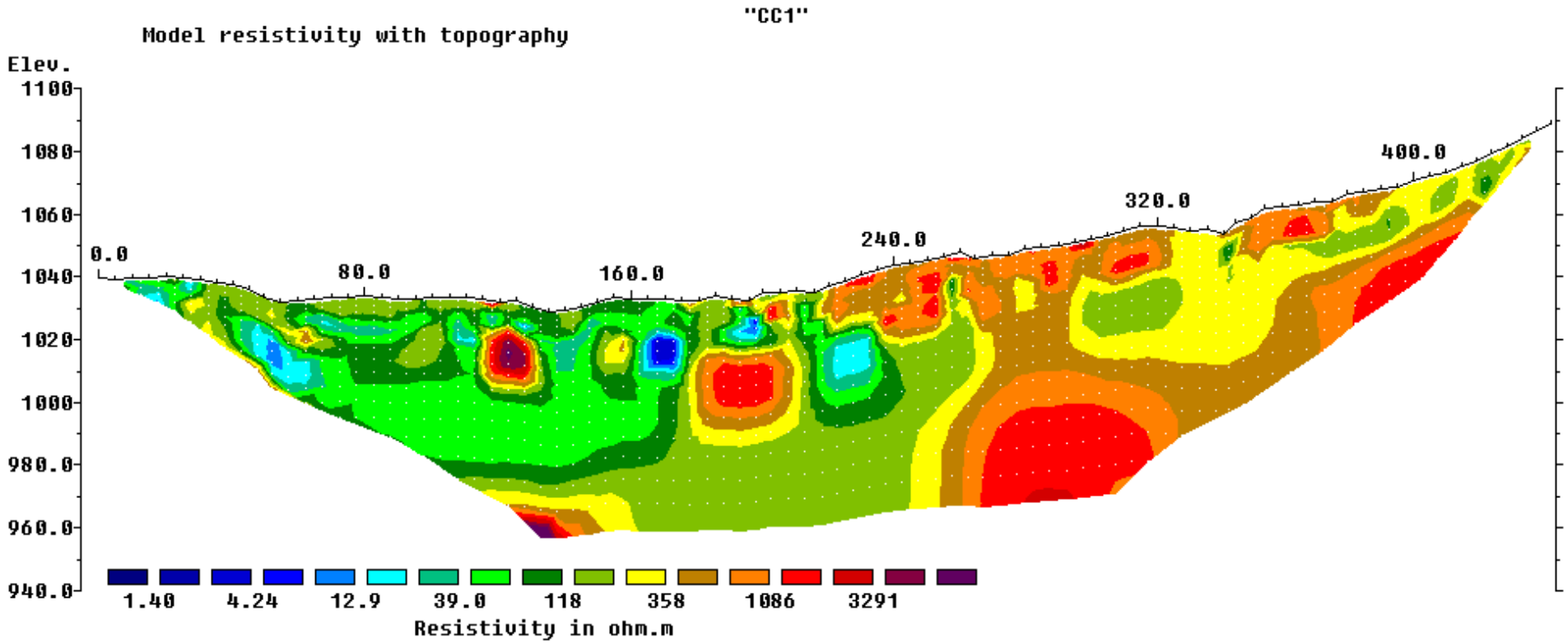


"AA1"

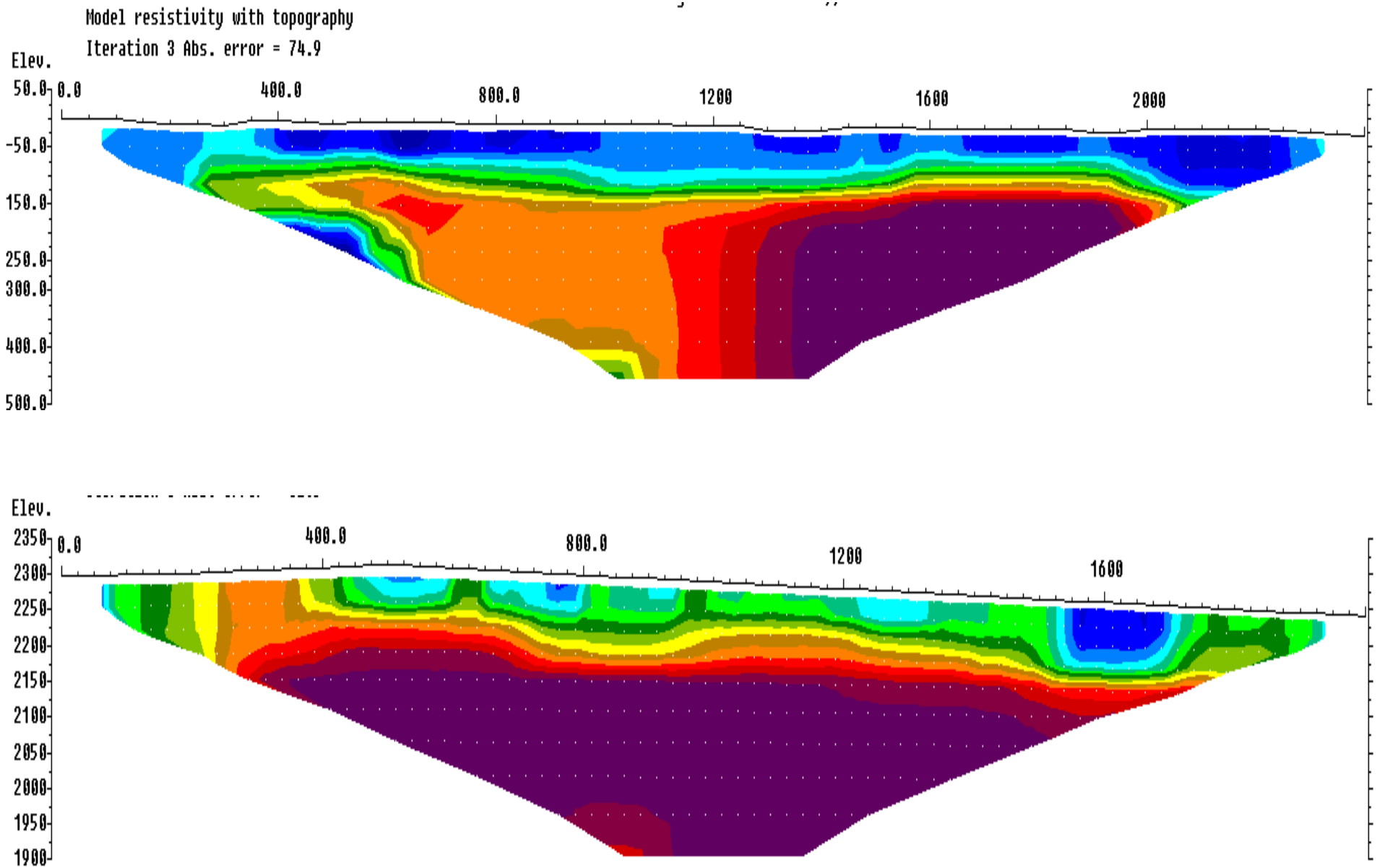
Model resistivity with topography

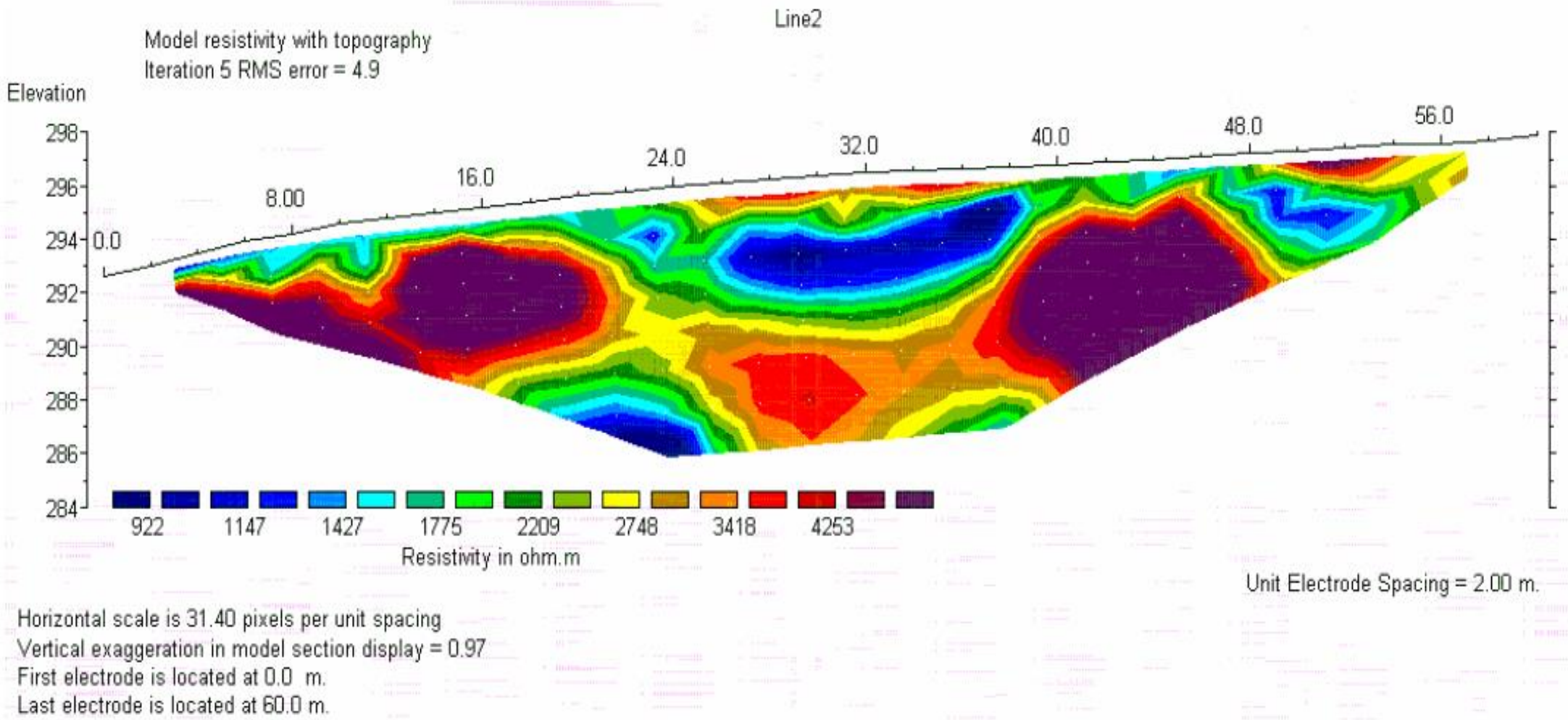


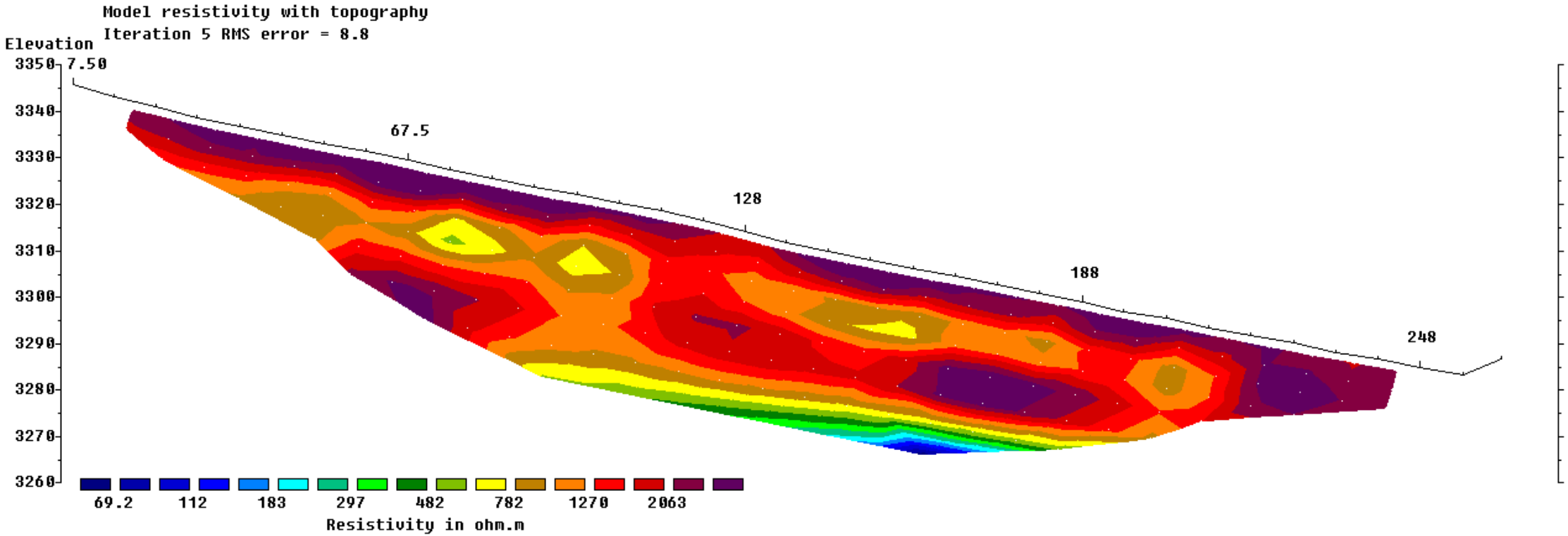
Horizontal scale is 10.58 pixels per unit spacing
Vertical exaggeration in model section display = 0.91
First electrode is located at 0.0 m.
Last electrode is located at 445.0 m.



Horizontal scale is 10.47 pixels per unit spacing
Vertical exaggeration in model section display = 0.92
First electrode is located at 0.0 m.
Last electrode is located at 445.0 m.

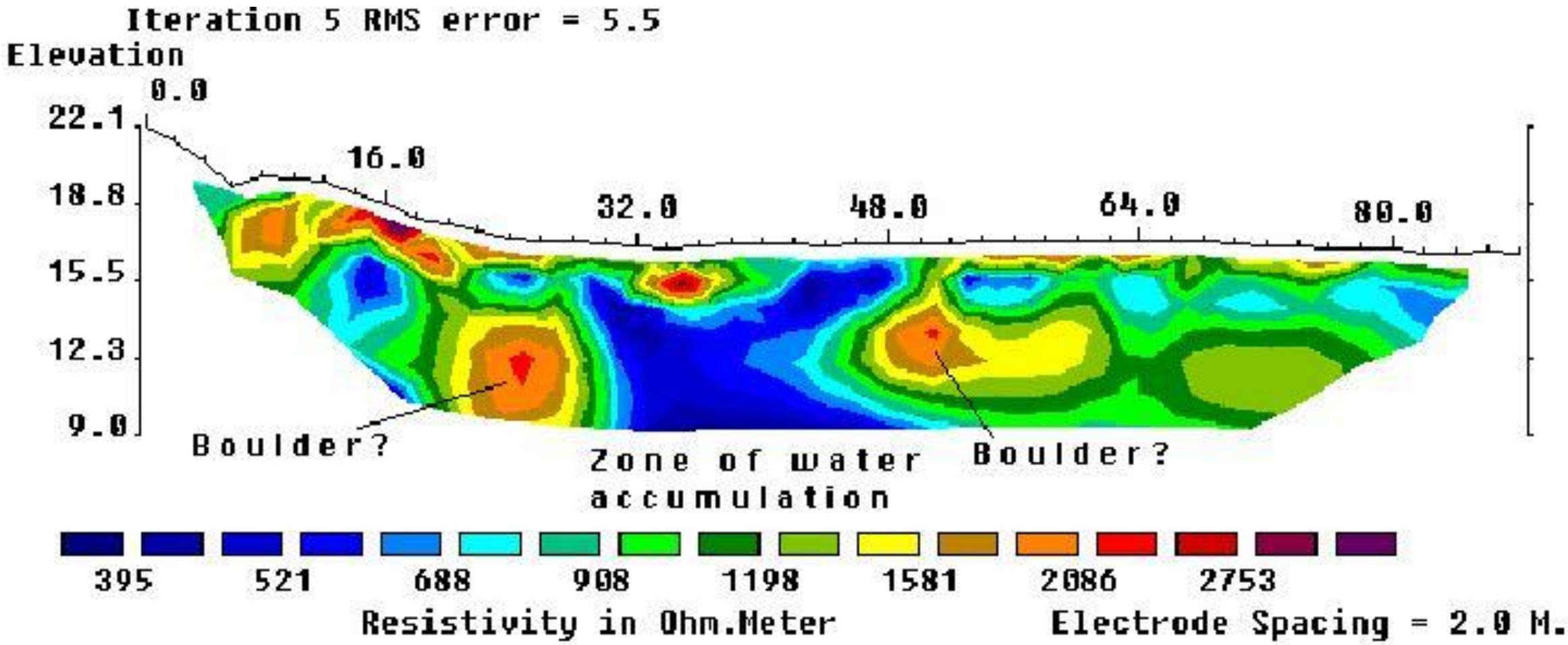

Model resistivity with topography
Iteration 3 Abs. error = 74.9
Elev.
50.0
-50.0
150.0
250.0
300.0
400.0
500.0
0.0
400.0
800.0
1200
1600
2000
Elev.
2350
2300
2250
2200
2150
2100
2050
2000
1950
1900
0.0
400.0
800.0
1200
1600


Line2
Model resistivity with topography
Iteration 5 RMS error = 4.9
Elevation
298
296
294
292
290
288
286
284
0.0
8.00
16.0
24.0
32.0
40.0
48.0
56.0
922
1147
1427
1775
2209
2748
3418
4253
Resistivity in ohm.m
Unit Electrode Spacing = 2.00 m.
Horizontal scale is 31.40 pixels per unit spacing
Vertical exaggeration in model section display = 0.97
First electrode is located at 0.0 m.
Last electrode is located at 60.0 m.



Unit Electrode Spacing = 7.50 m.

Horizontal scale is 35.26 pixels per unit spacing
Vertical exaggeration in model section display = 0.80
First electrode is located at 7.5 m.
Last electrode is located at 262.5 m.


Iteration 5 RMS error = 5.5
Elevation
0.0
22.1
16.0
18.8
32.0
48.0
64.0
80.0
15.5
12.3
9.0
Boulder?
Zone of water accumulation
Boulder?
395
521
688
908
1198
1581
2086
2753
Resistivity in Ohm.Meter
Electrode Spacing = 2.0 M.

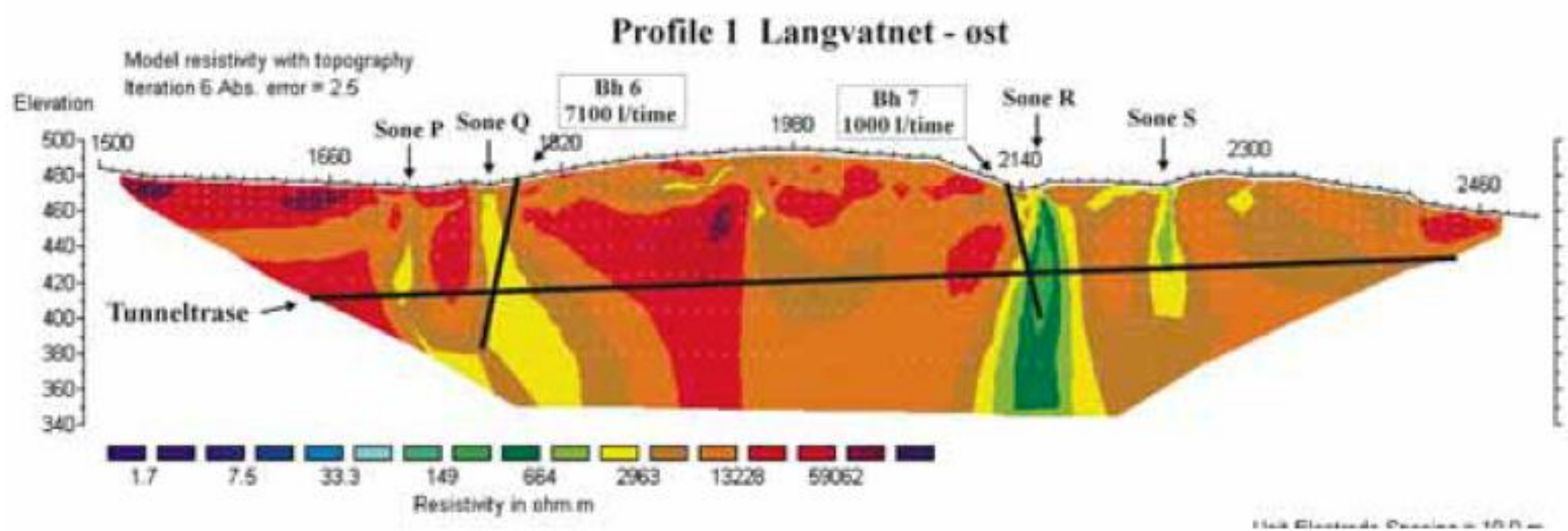
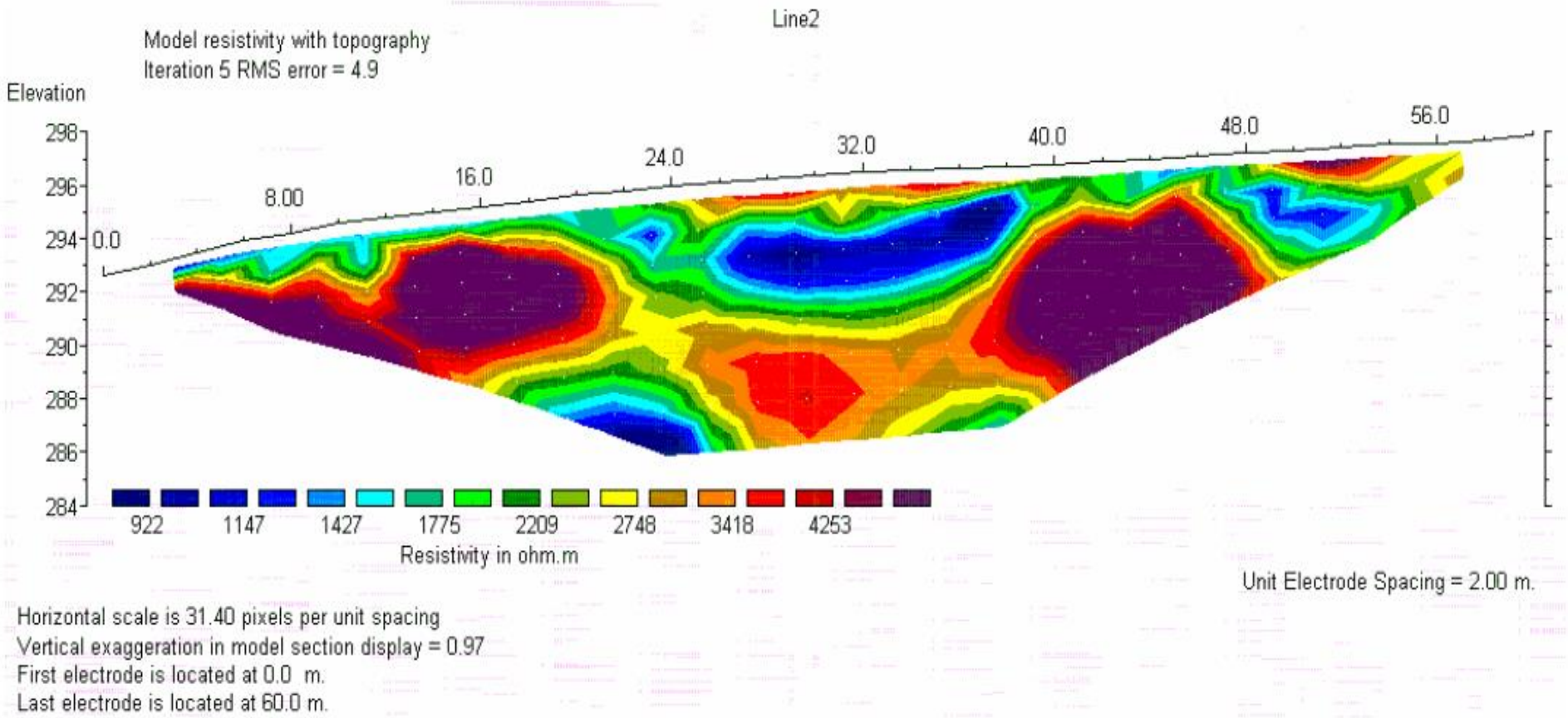
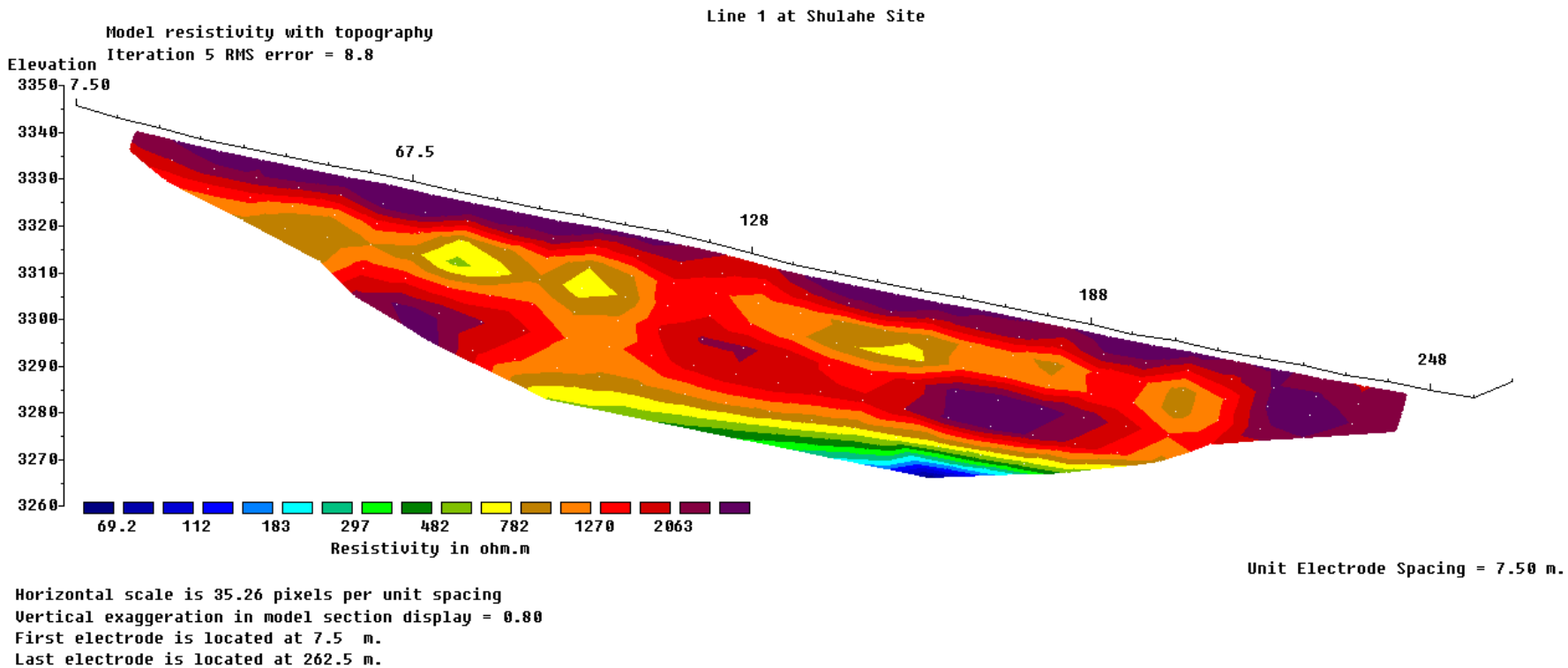


Figure 4 Resistivity profile from a section of the Lunner tunnel. Zones of low resistivity are further examined by borehole logging.

Example……

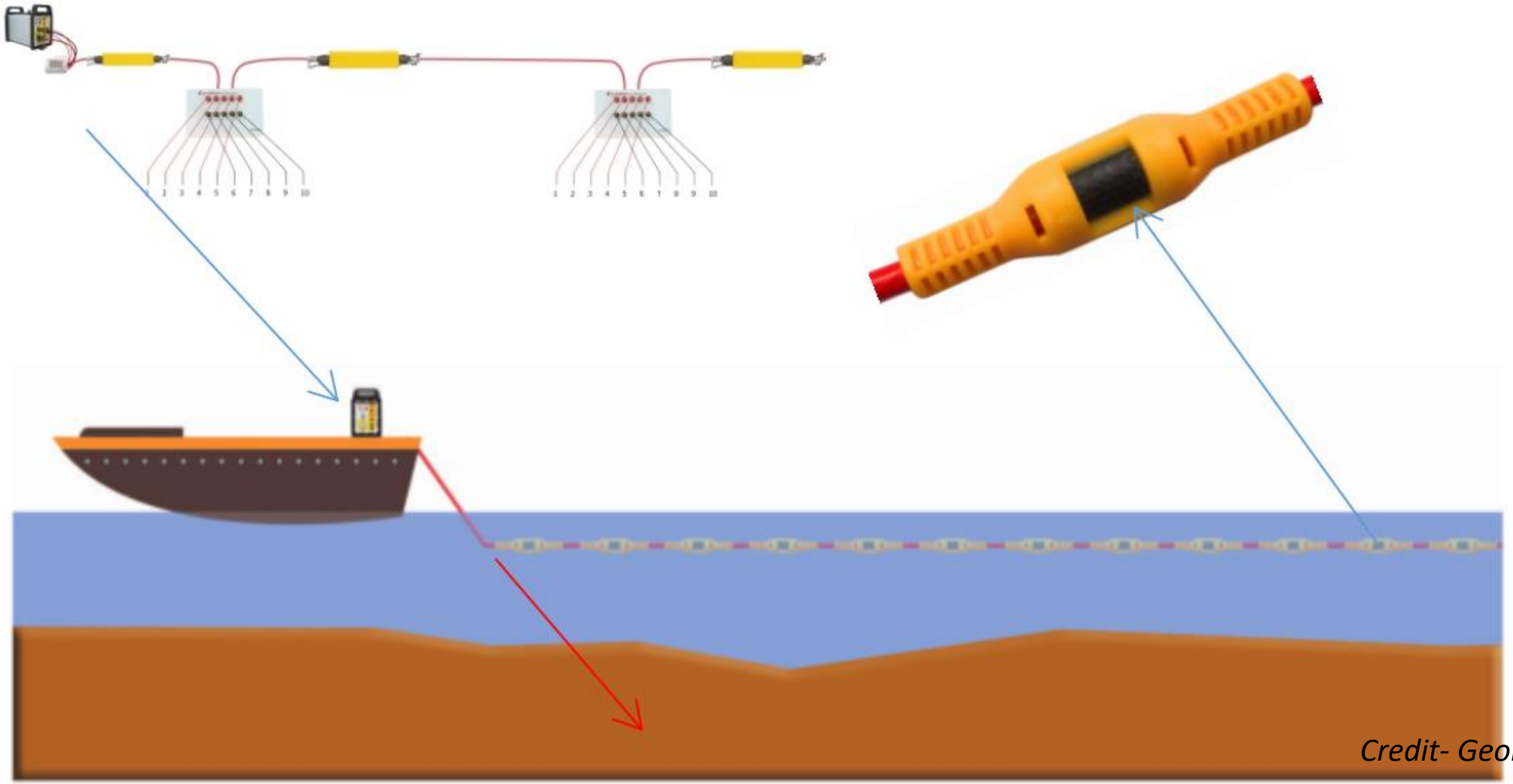

Line2
Model resistivity with topography
Iteration 5 RMS error = 4.9
Elevation
298
296
294
292
290
288
286
284
0.0
8.00
16.0
24.0
32.0
40.0
48.0
56.0
922
1147
1427
1775
2209
2748
3418
4253
Resistivity in ohm.m
Unit Electrode Spacing = 2.00 m.
Horizontal scale is 31.40 pixels per unit spacing
Vertical exaggeration in model section display = 0.97
First electrode is located at 0.0 m.
Last electrode is located at 60.0 m.

Example……


Line 1 at Shulahe Site
Model resistivity with topography
Iteration 5 RMS error = 8.8
Elevation
3350
3340
3330
3320
3310
3300
3290
3280
3270
3260
7.50
67.5
128
188
248
69.2
112
183
297
482
782
1270
2063
Resistivity in ohm.m
Unit Electrode Spacing = 7.50 m.
Horizontal scale is 35.26 pixels per unit spacing
Vertical exaggeration in model section display = 0.80
First electrode is located at 7.5 m.
Last electrode is located at 262.5 m.

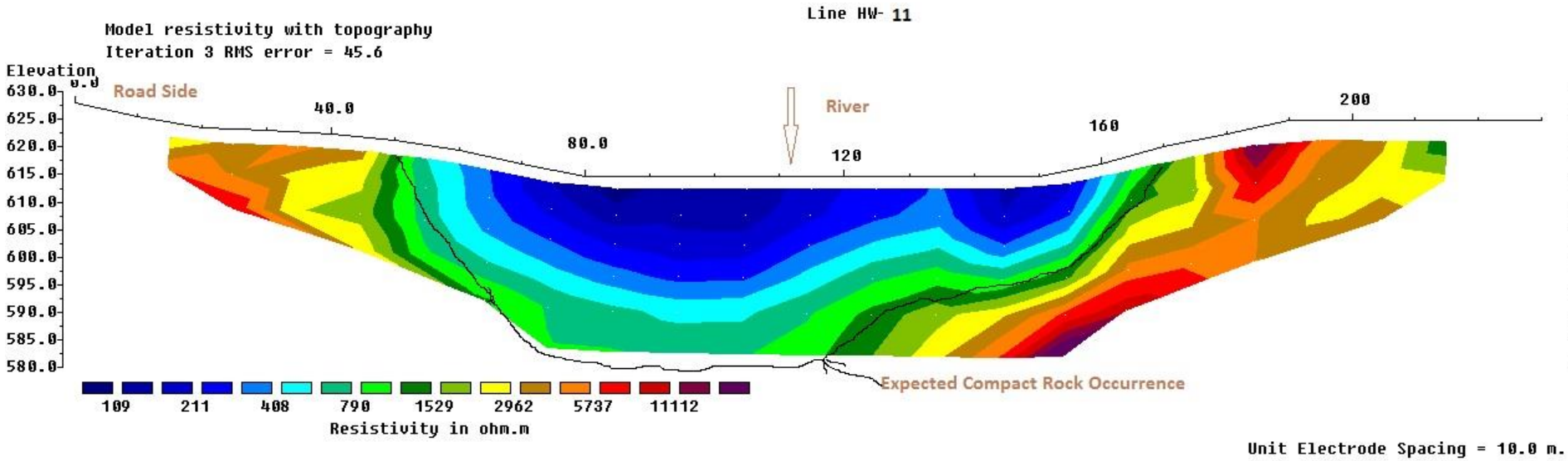
River Crossing……

Submersible ERT cables with Titanium alloy takeouts



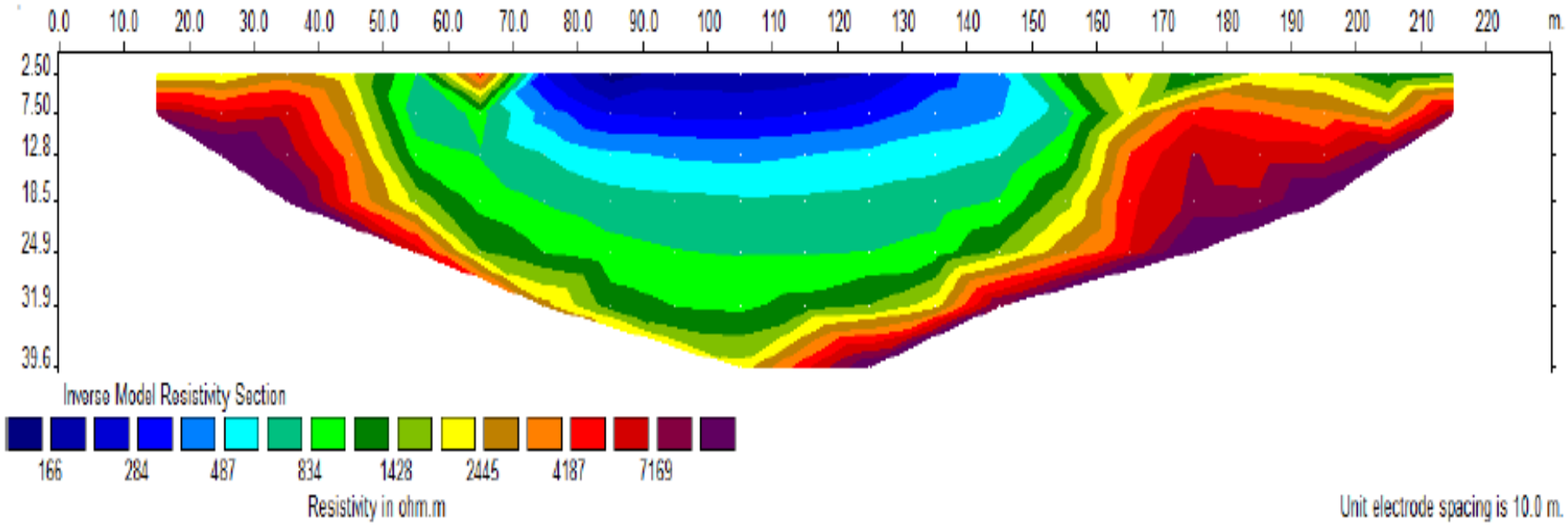
Credit- Geomative

River Crossing…….

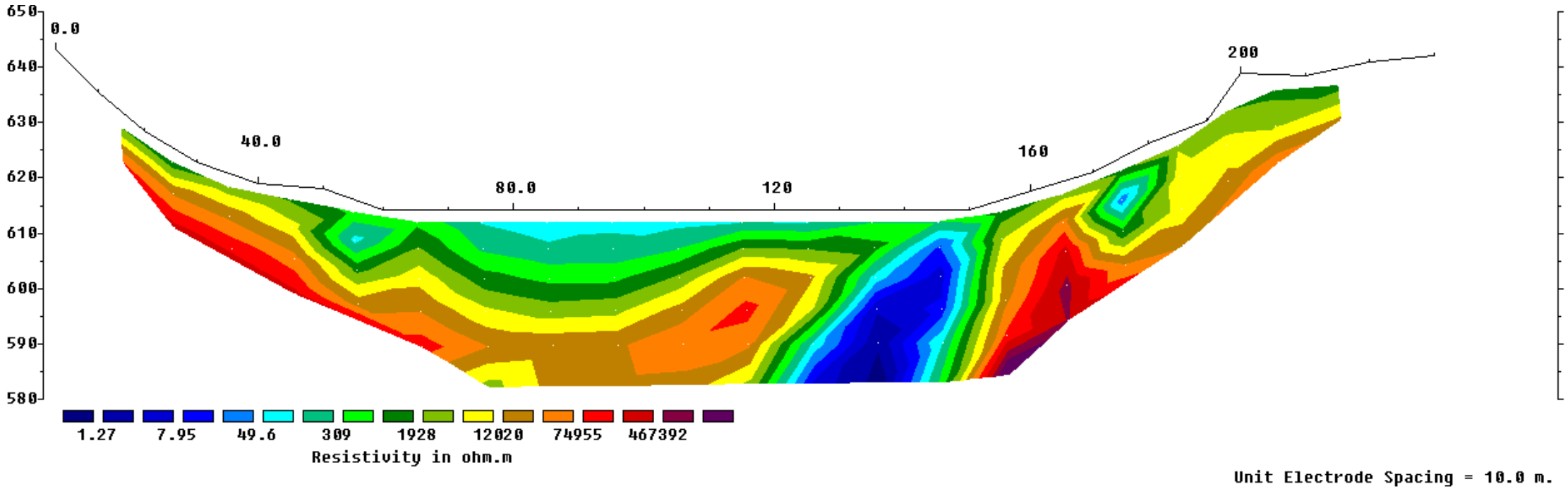


Horizontal scale is 52.13 pixels per unit spacing
Vertical exaggeration in model section display = 0.85
First electrode is located at 0.0 m.
Last electrode is located at 230.0 m.

River Crossing……

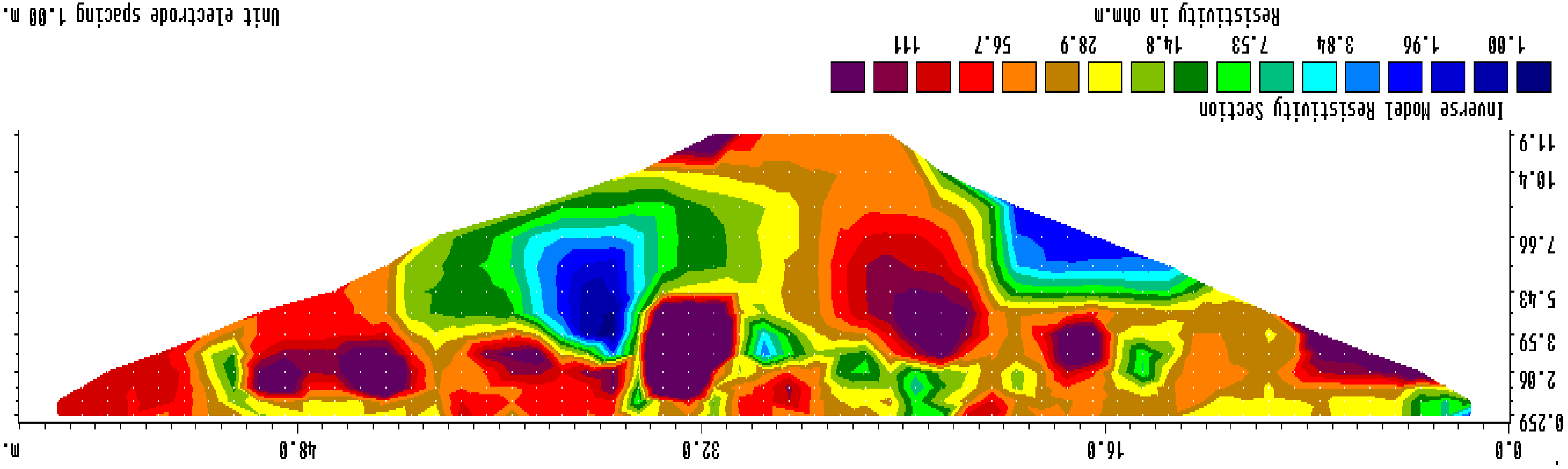


River Crossing (Dam Axis)- Shear Zone…….

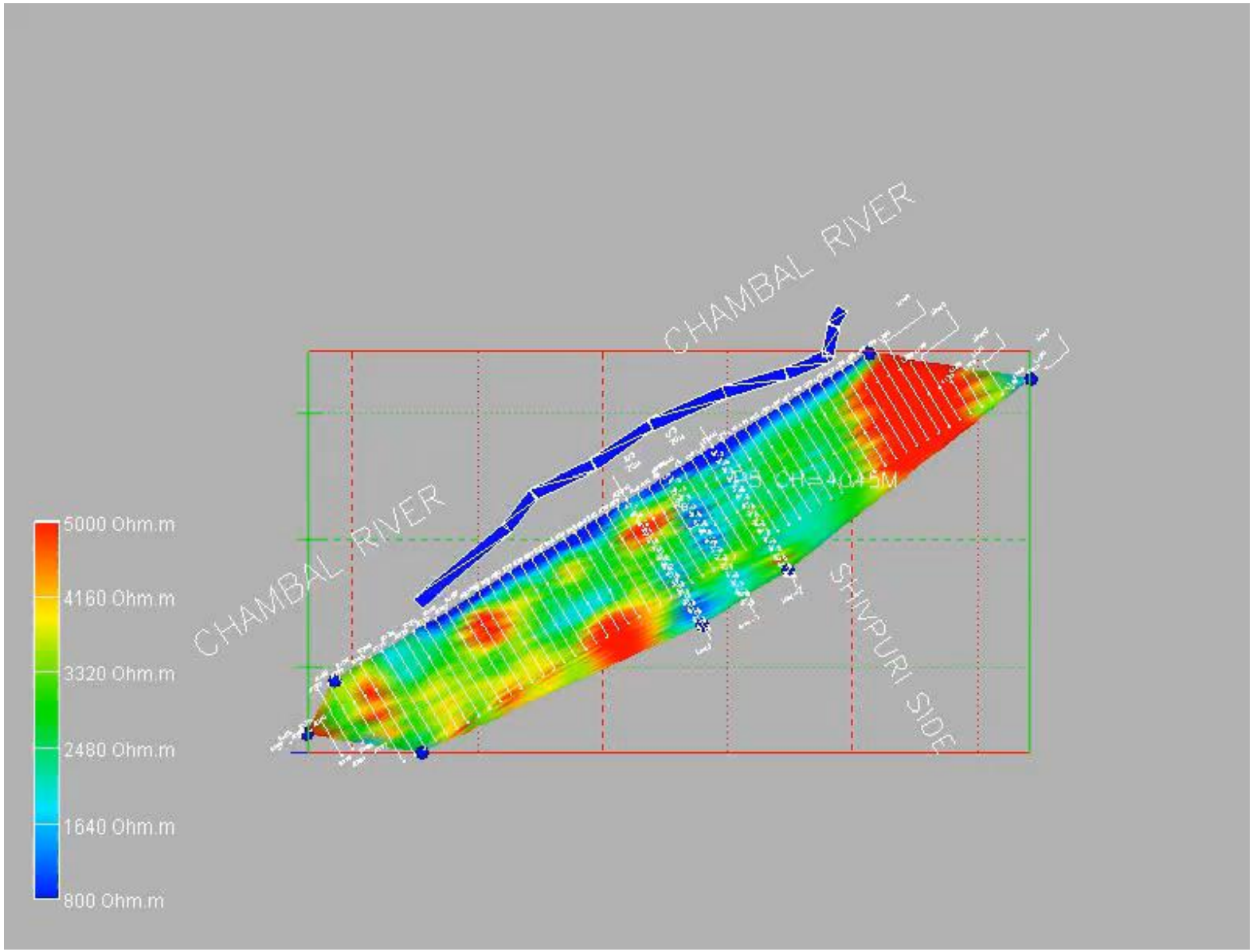


Electrical Resistivity- Existing Tunnels Seepage...

Electrical Resistivity Imaging Results...



Electrical Resistivity Imaging Results- 3D Volume...

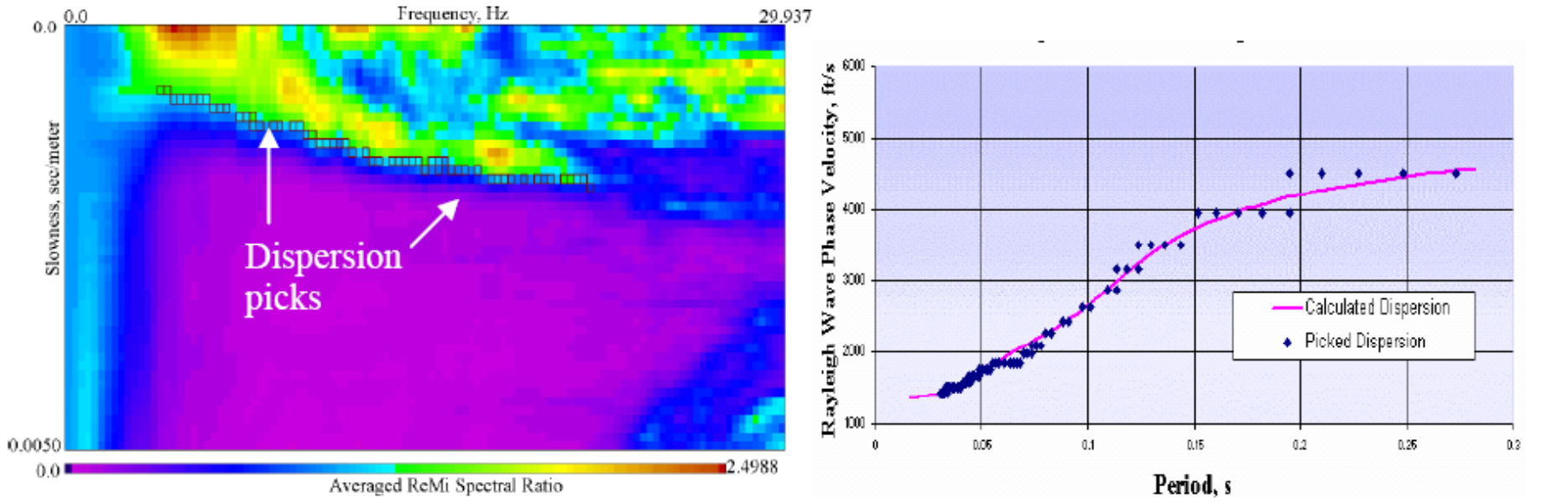


Electrical Resistivity Imaging- Applications Areas

- Tunnel Portals
- Tunnel alignment/ tunnel route
- Inspection of existing tunnels (seepage zones)
- Complimentary tool to any geotechnical investigation

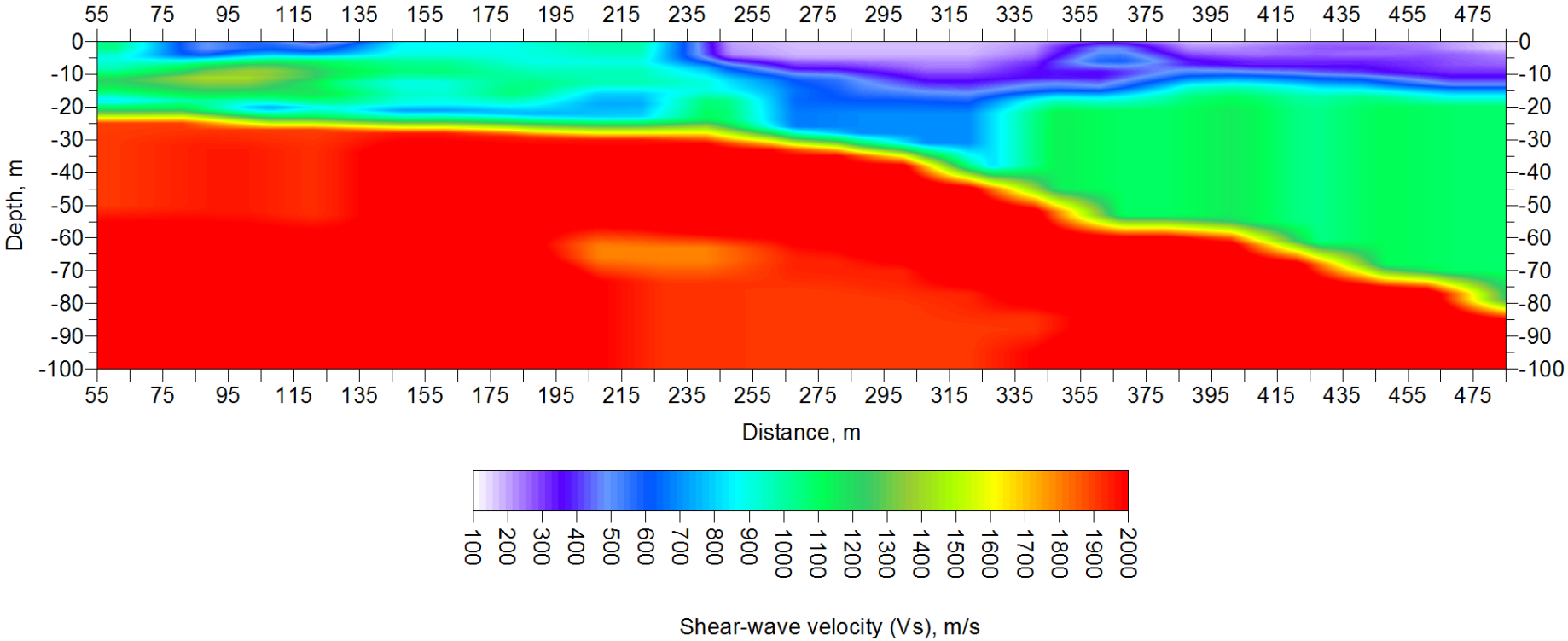
ReMi/ MASW

Basic Principle…

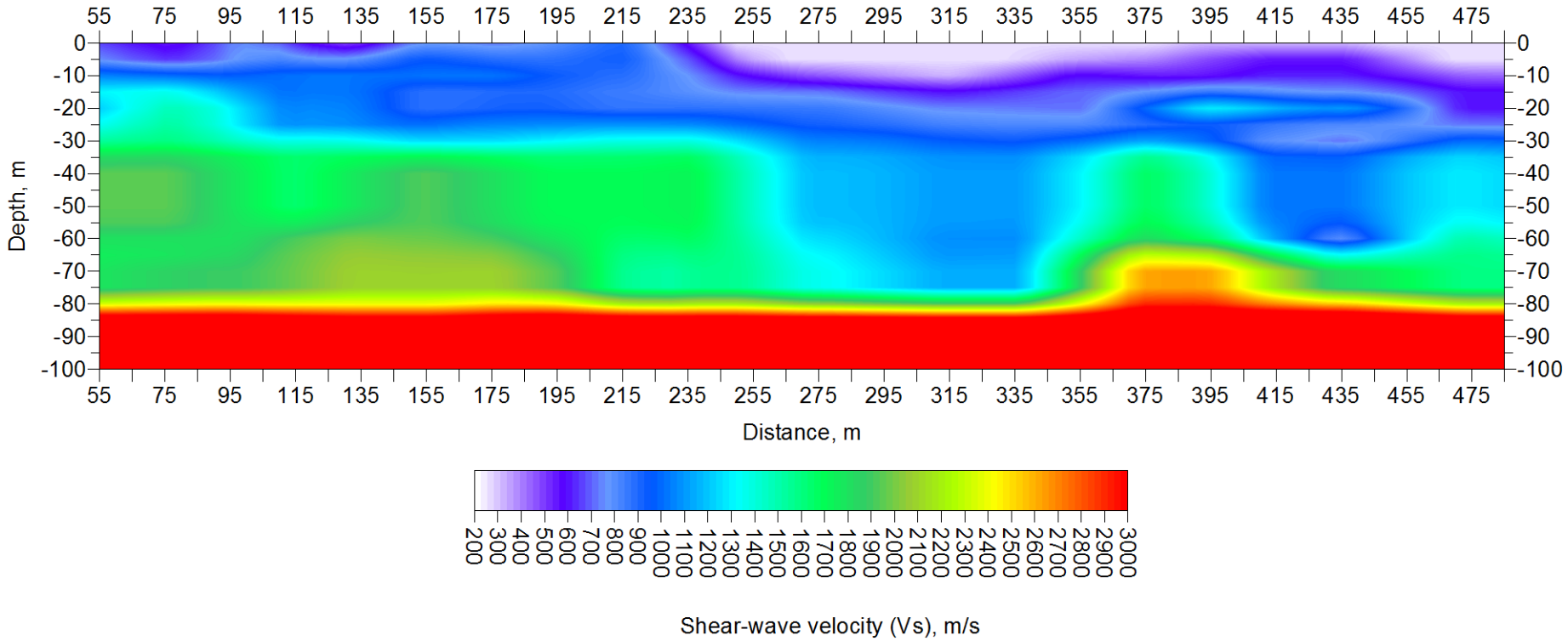


Shear-wave dispersion curve derived from ambient seismic noise, shown on the left, is picked and modeled (right panel)

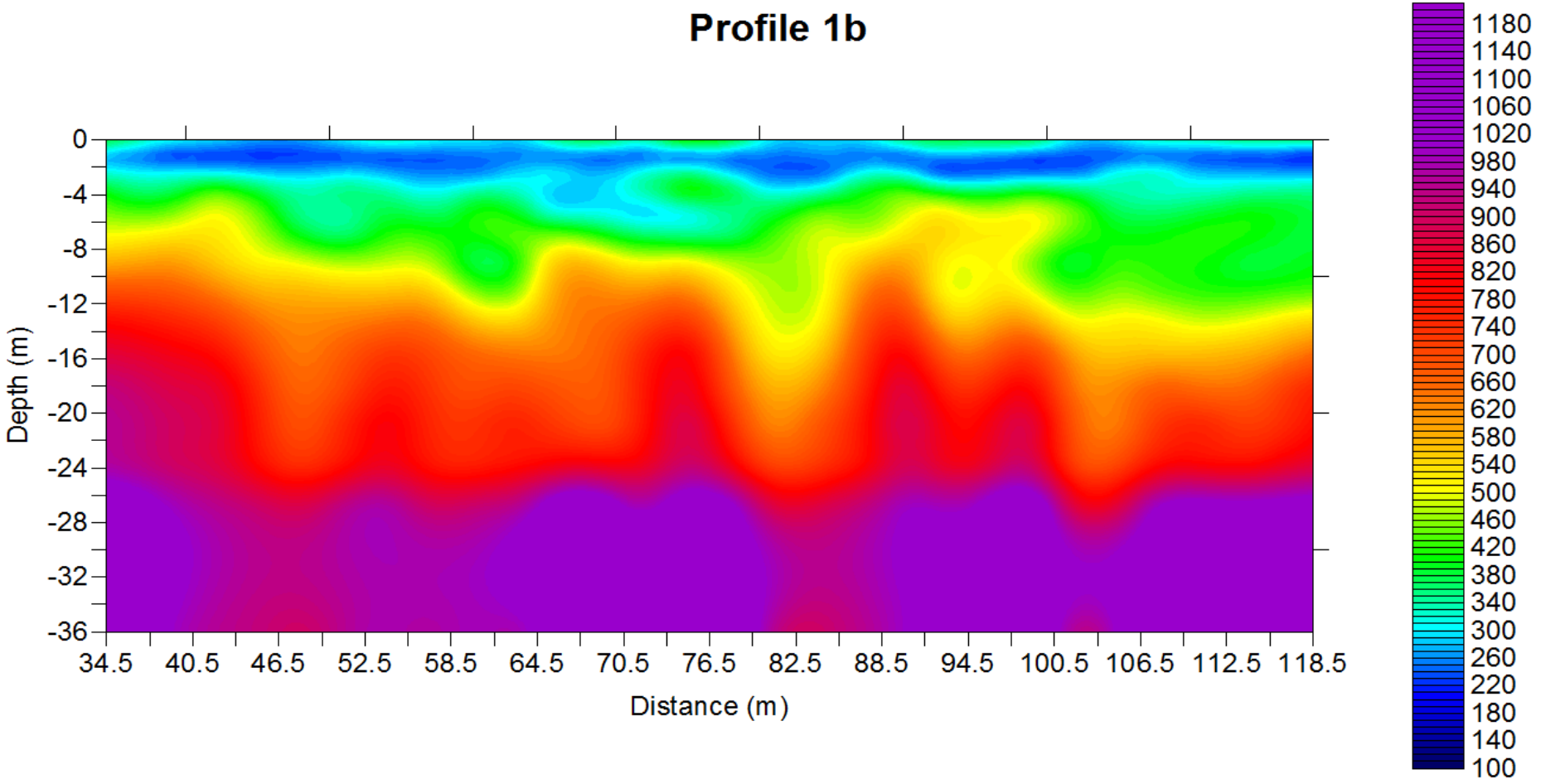
ReMi Results…



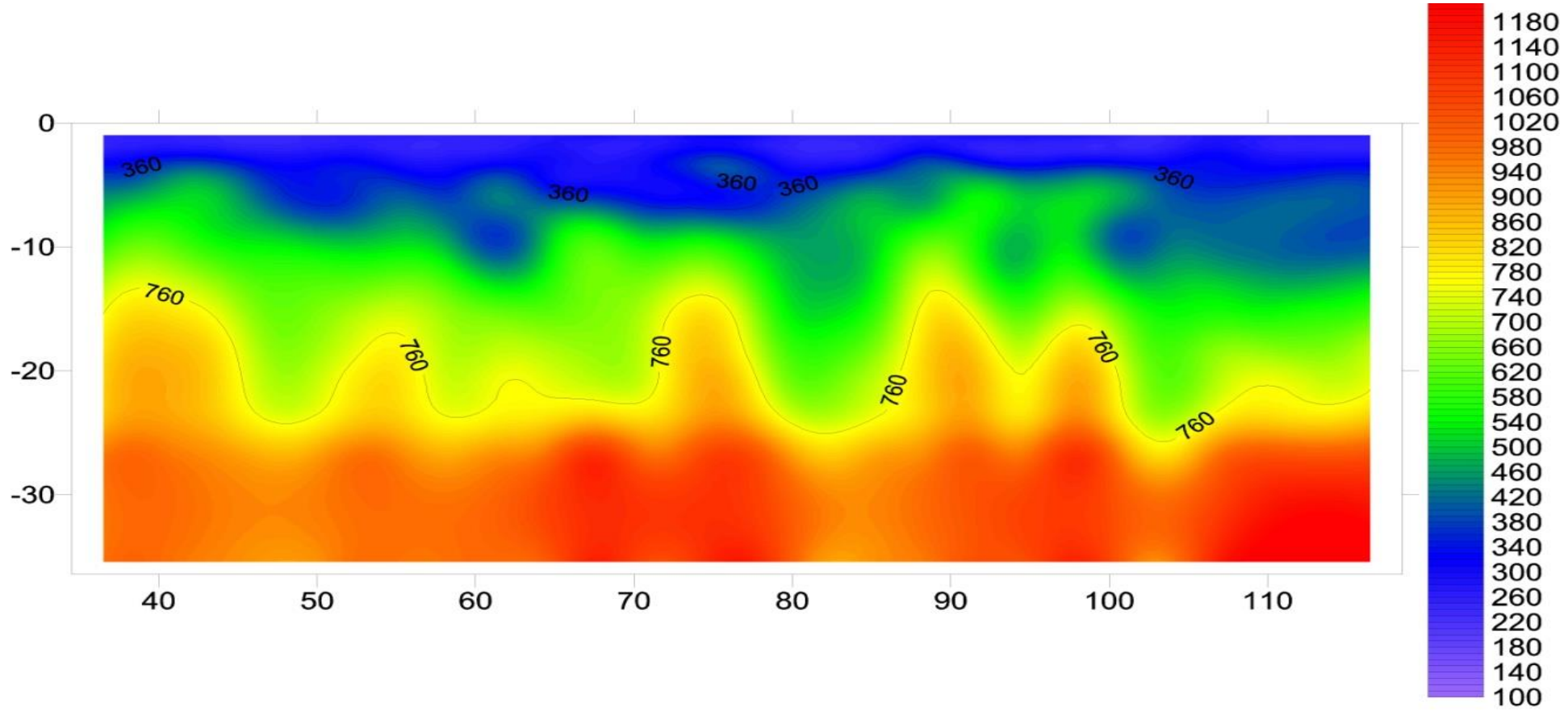
ReMi Results…



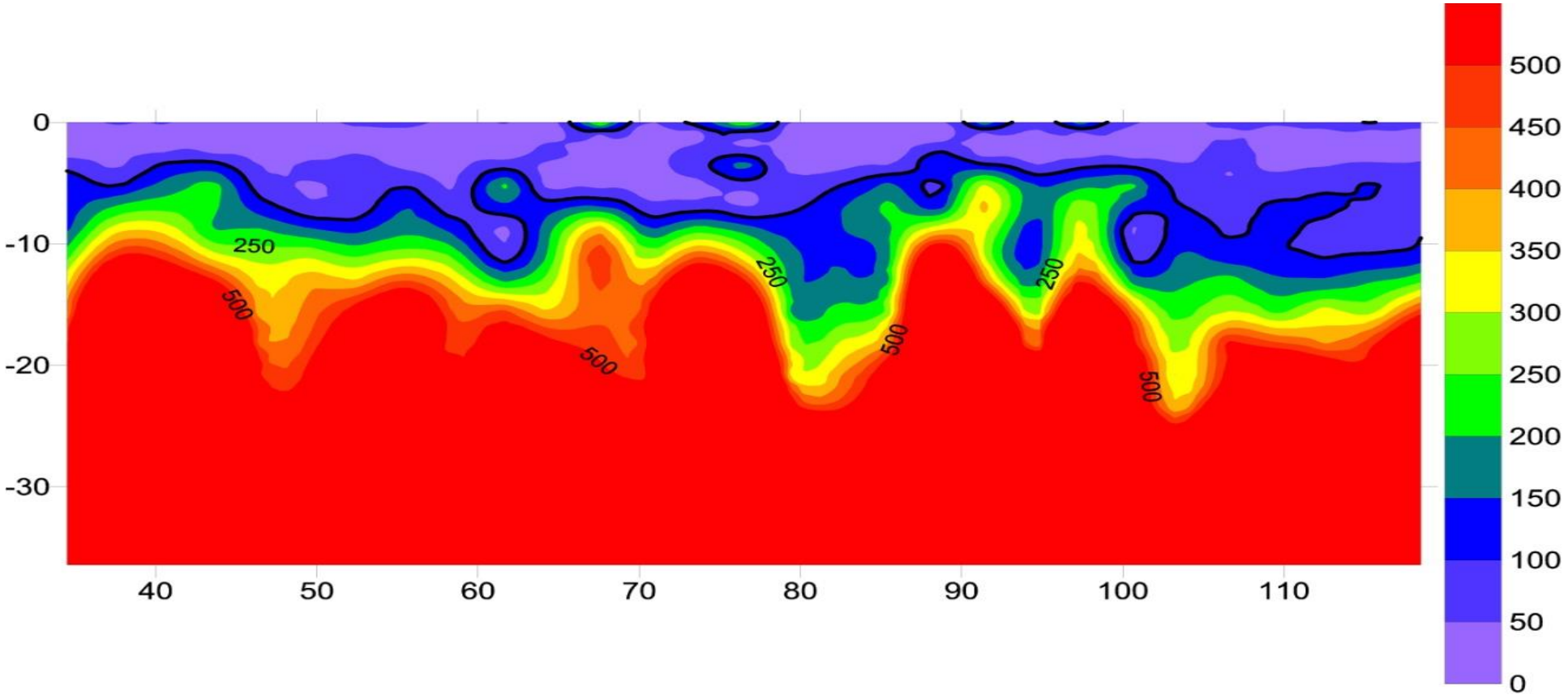
Shear Wave Velocity……

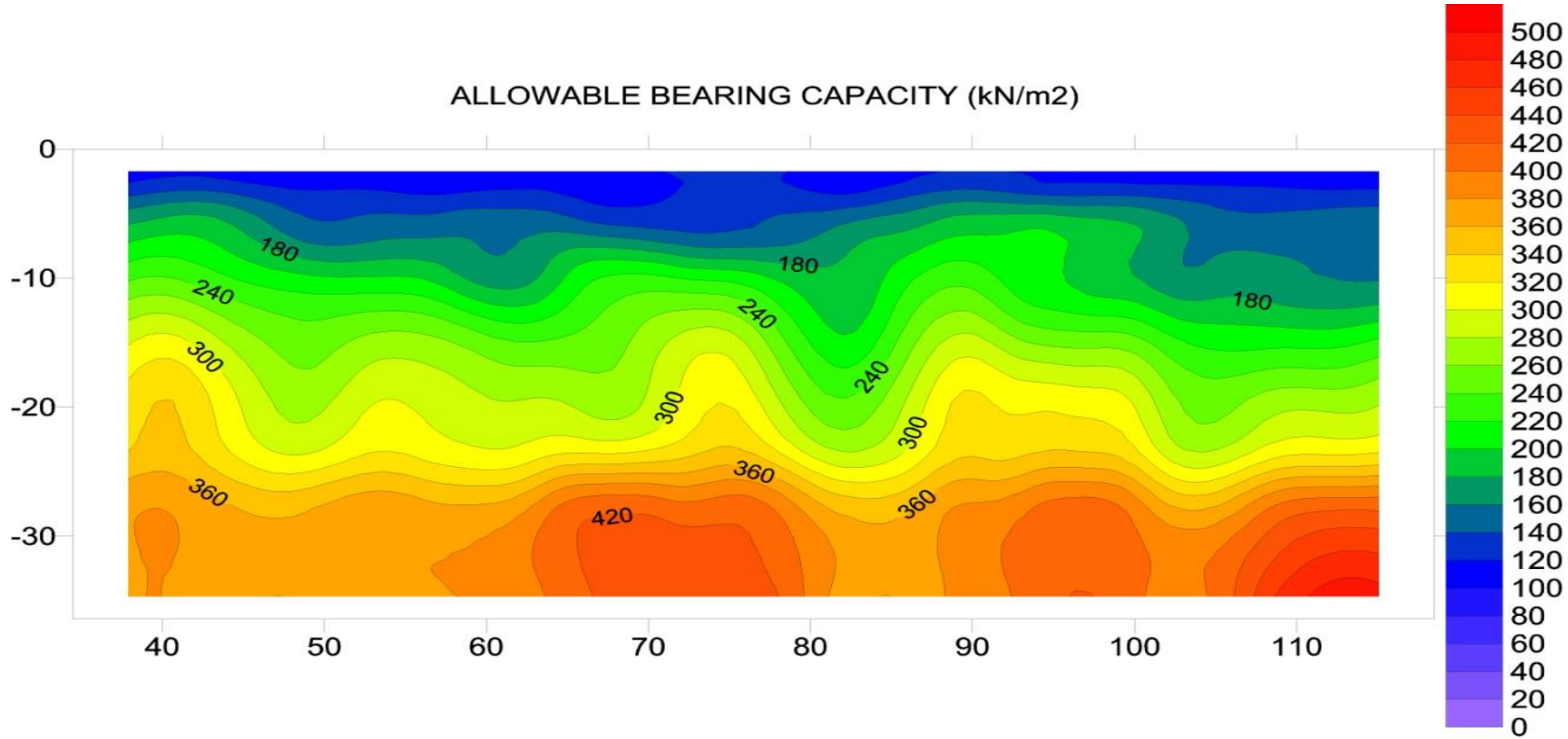


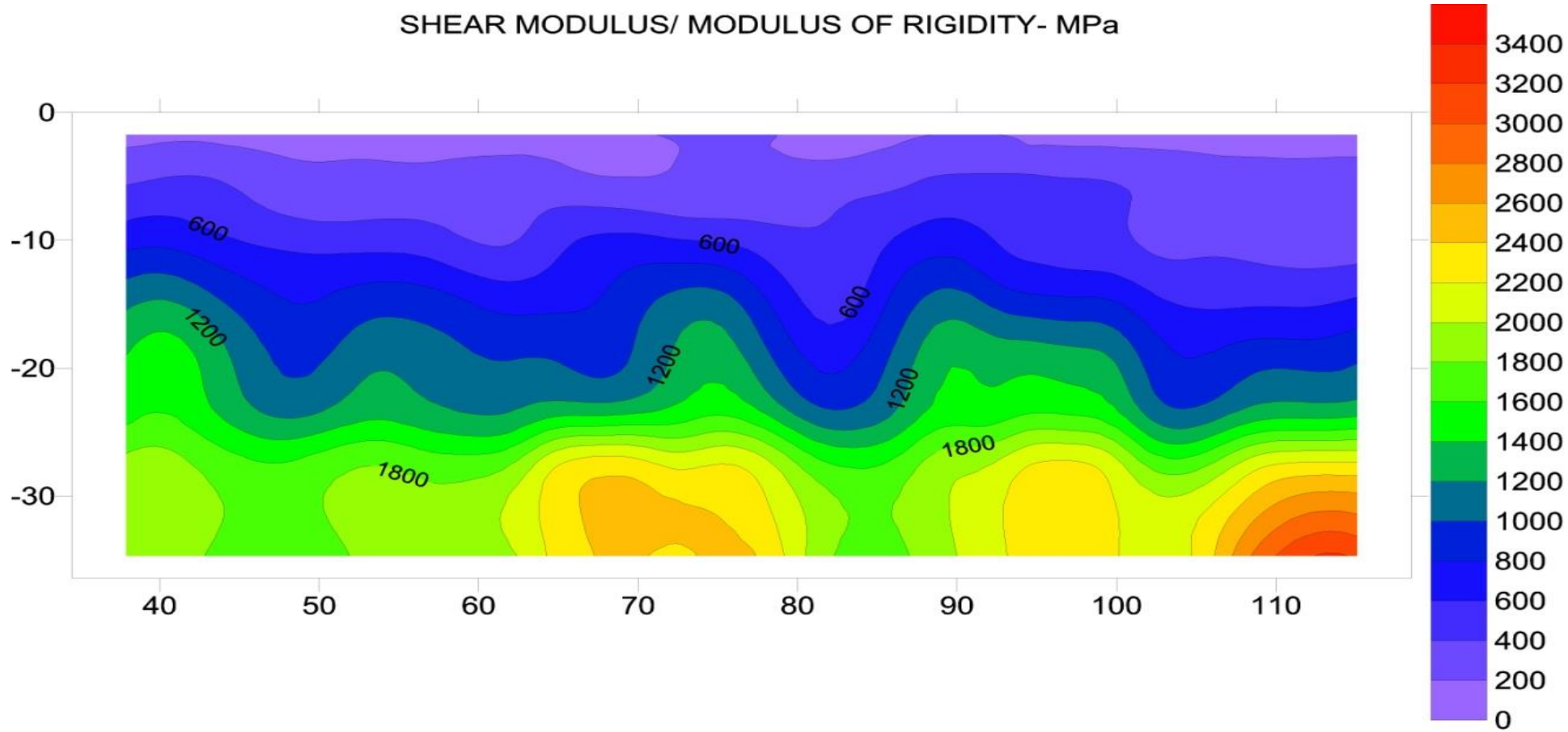
Site Classification……



N Value Distribution……




ALLOWABLE BEARING CAPACITY (kN/m2)
0
-10
-20
-30
40
50
60
70
80
90
100
110
180
240
300
360
420
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0


SHEAR MODULUS/ MODULUS OF RIGIDITY- MPa
0
-10
-20
-30
40
50
60
70
80
90
100
110
600
600
600
1200
1200
1200
1800
1800
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

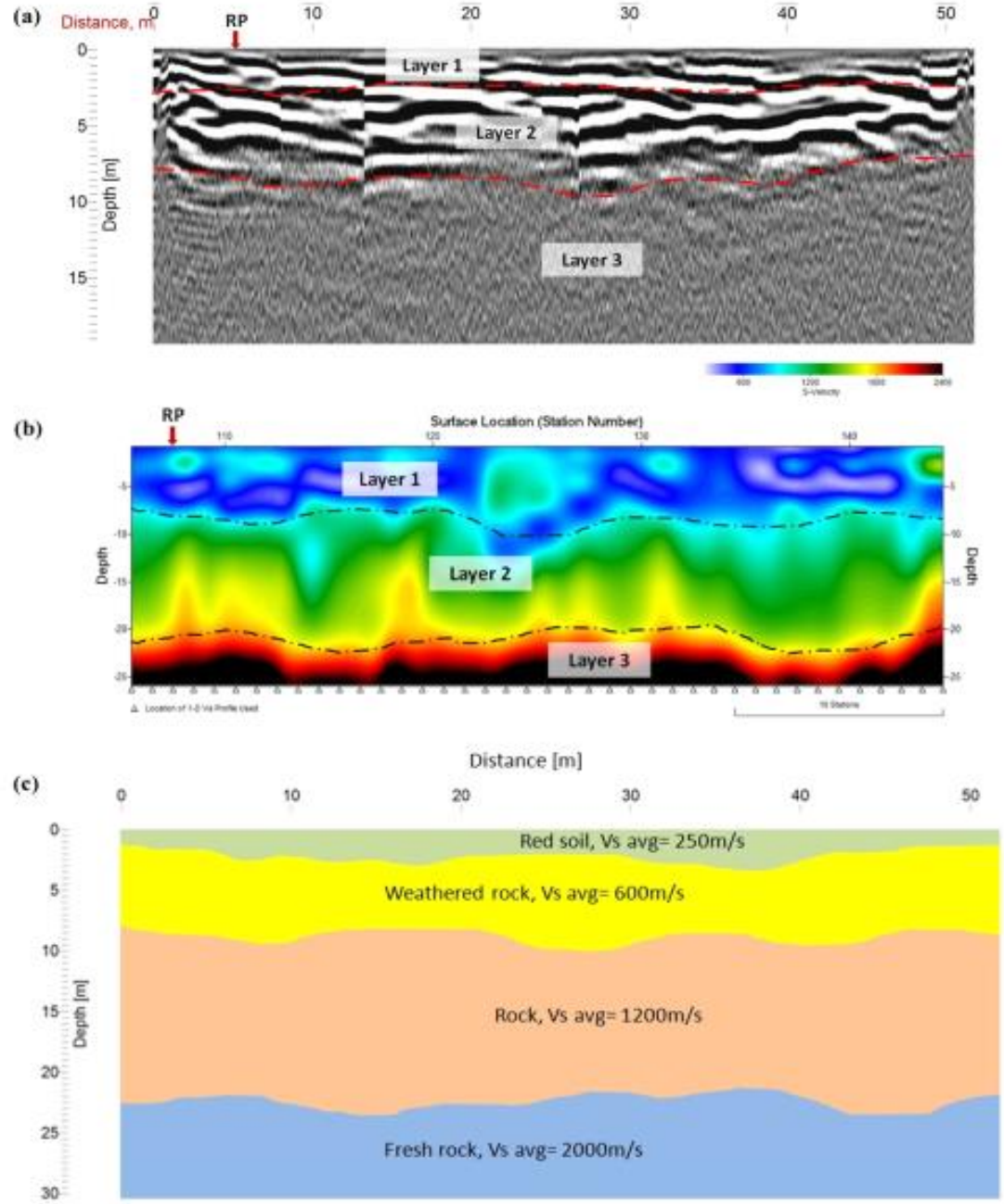
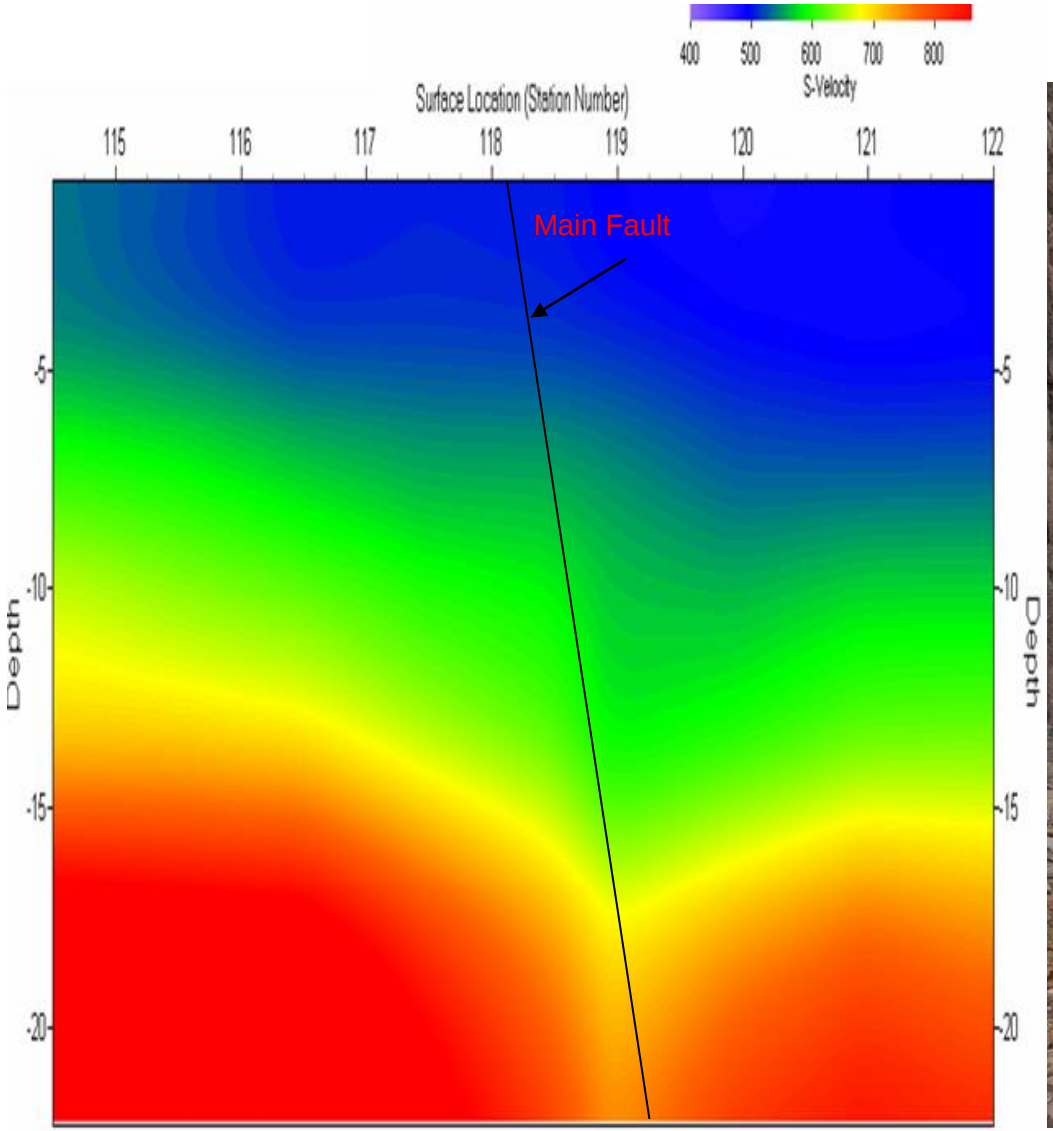
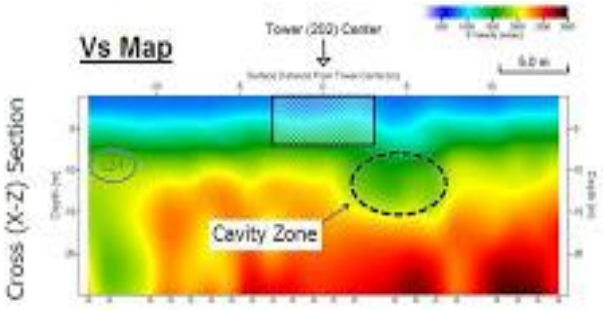


Figure 12. (a) GPR profile of line 2 after all corrections at the IISc site. (b) 2D MASW profile of line 2 at the IISc site. (c) Final subsurface profile of line 2 by comparing all the methods.

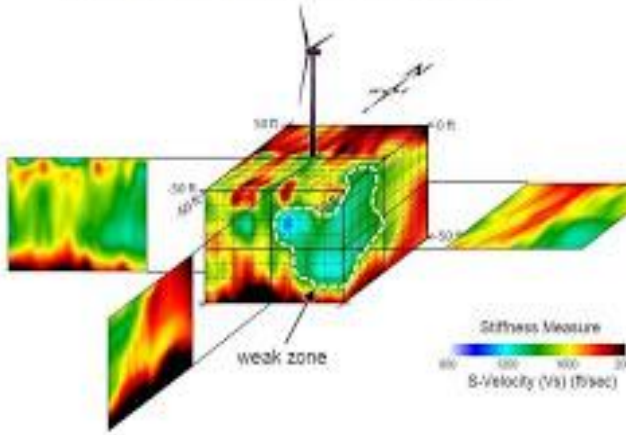
Detection of subsurface fault using MASW technique



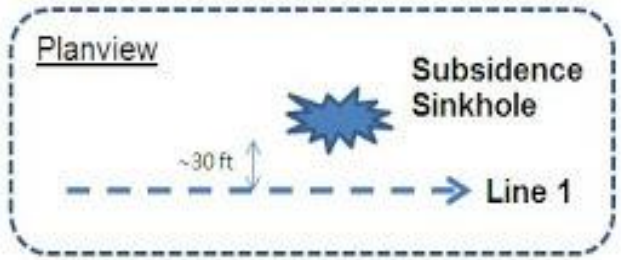
Cavity Detection (2-D)

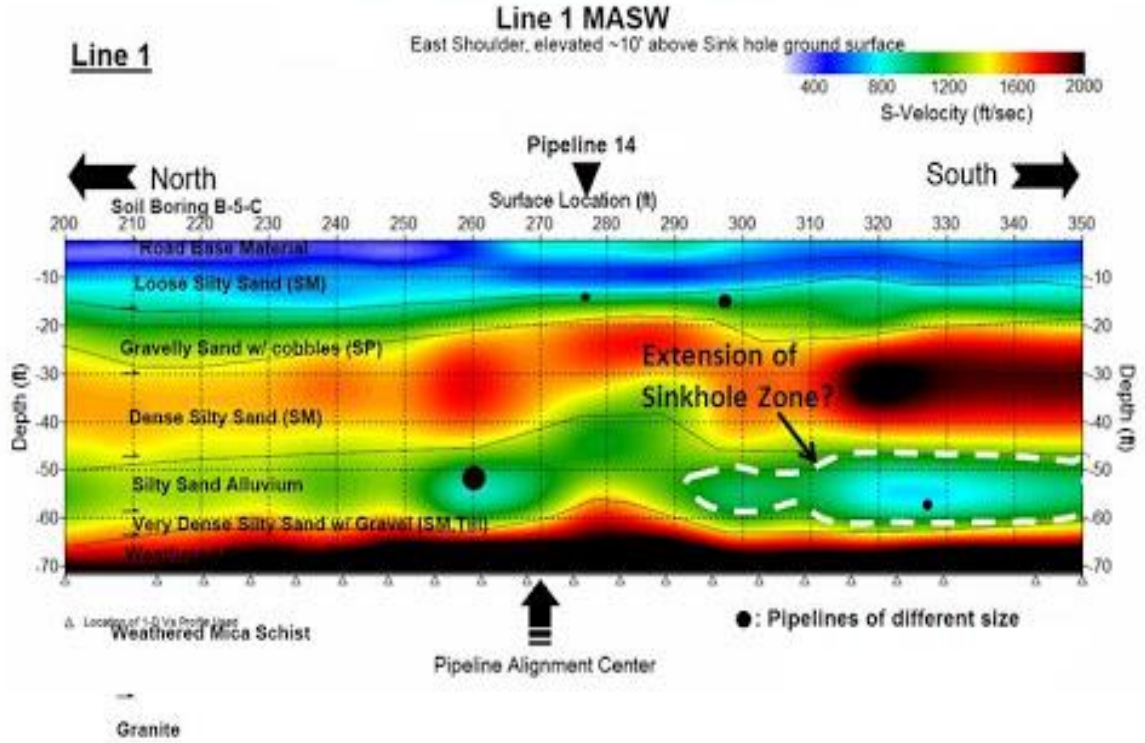


Weak Zone Detection (3-D)

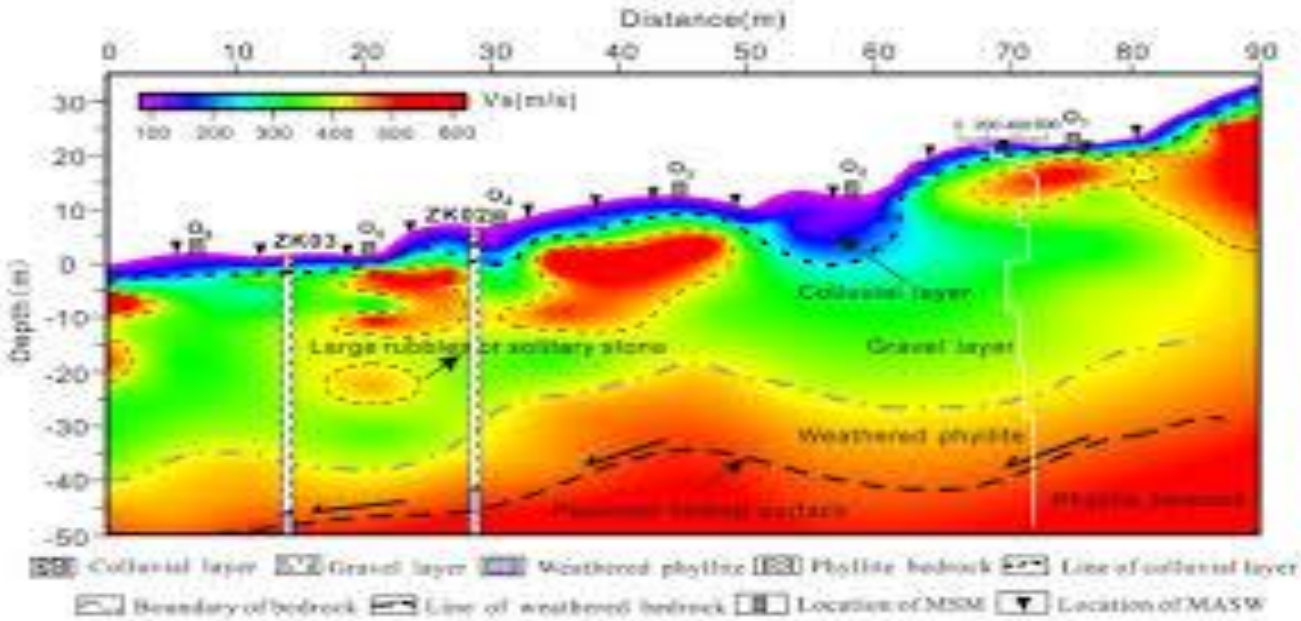


Sinkhole study





Landslide Study



A 2-D Vs map showing subsurface stiffness distribution matched to buried features of pipelines and borehole data. The survey was undertaken about 30 ft away from a surface subsidence sinkhole to map its possible subsurface extension.

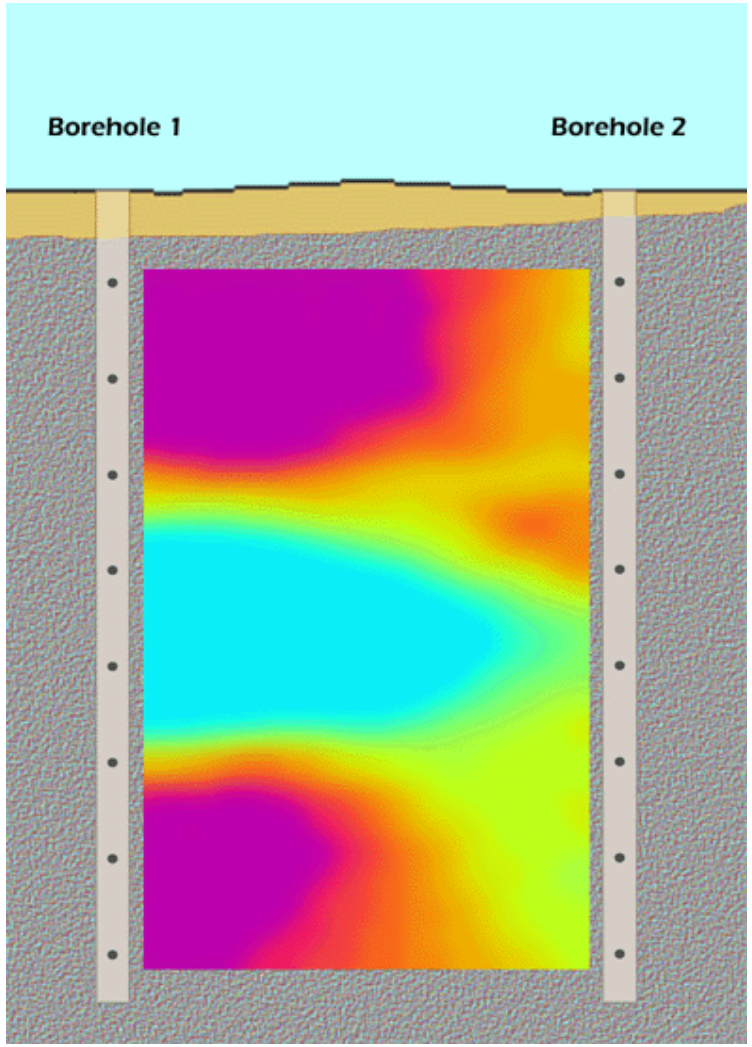
MASW- Applications Areas

- Tunnel Portals
- Detection of cavities/ voids
- Liquefaction analysis
- Earthquake site response
- Complimentary tool to any geotechnical investigation

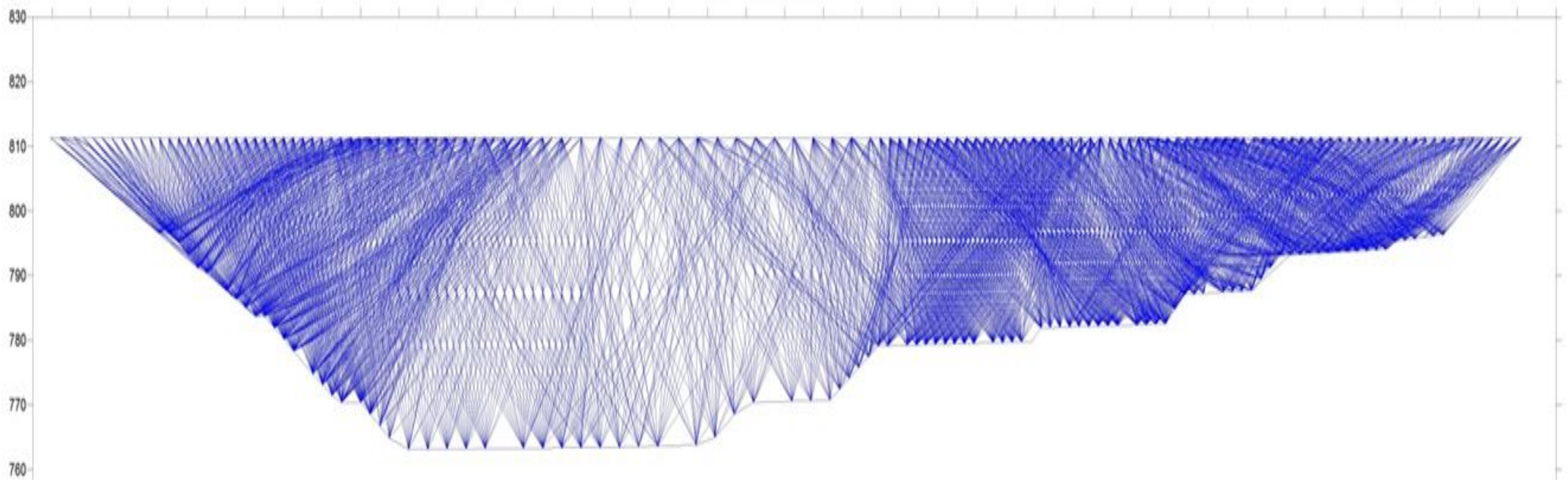
Seismic (Sonic) Tomography

Application of Seismic Tomography…

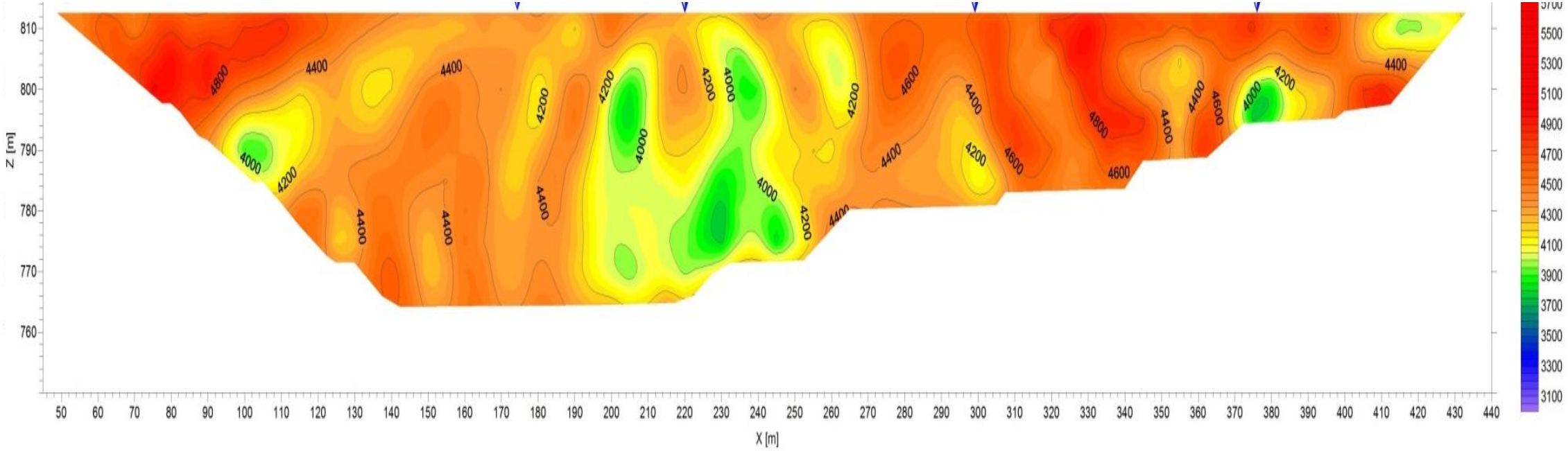
- Provides high resolution images of subsurface
- Provides P wave velocity- Directly linked to strength & Density
- Done between two boreholes/ faces
- Possible to pin-point weak zones
- Determines treatment success by pre and post treatment study



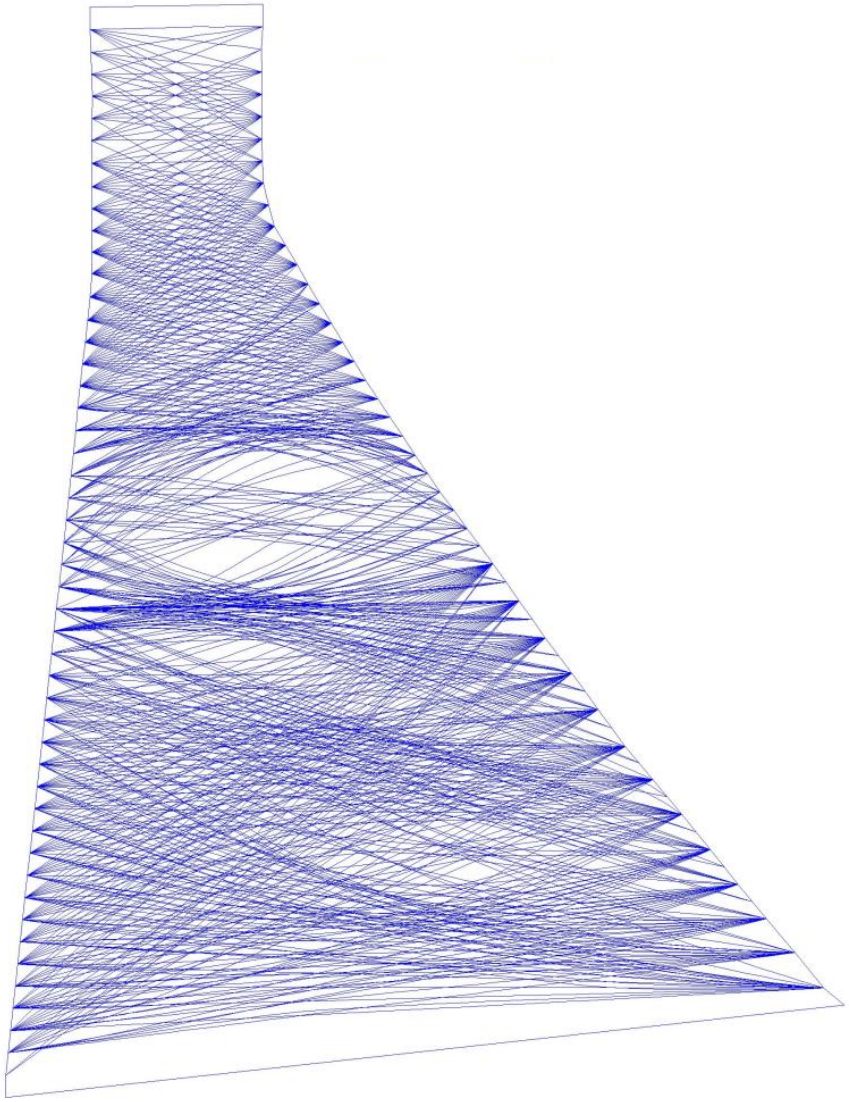
L-Section Tomography…Ray Path Coverage



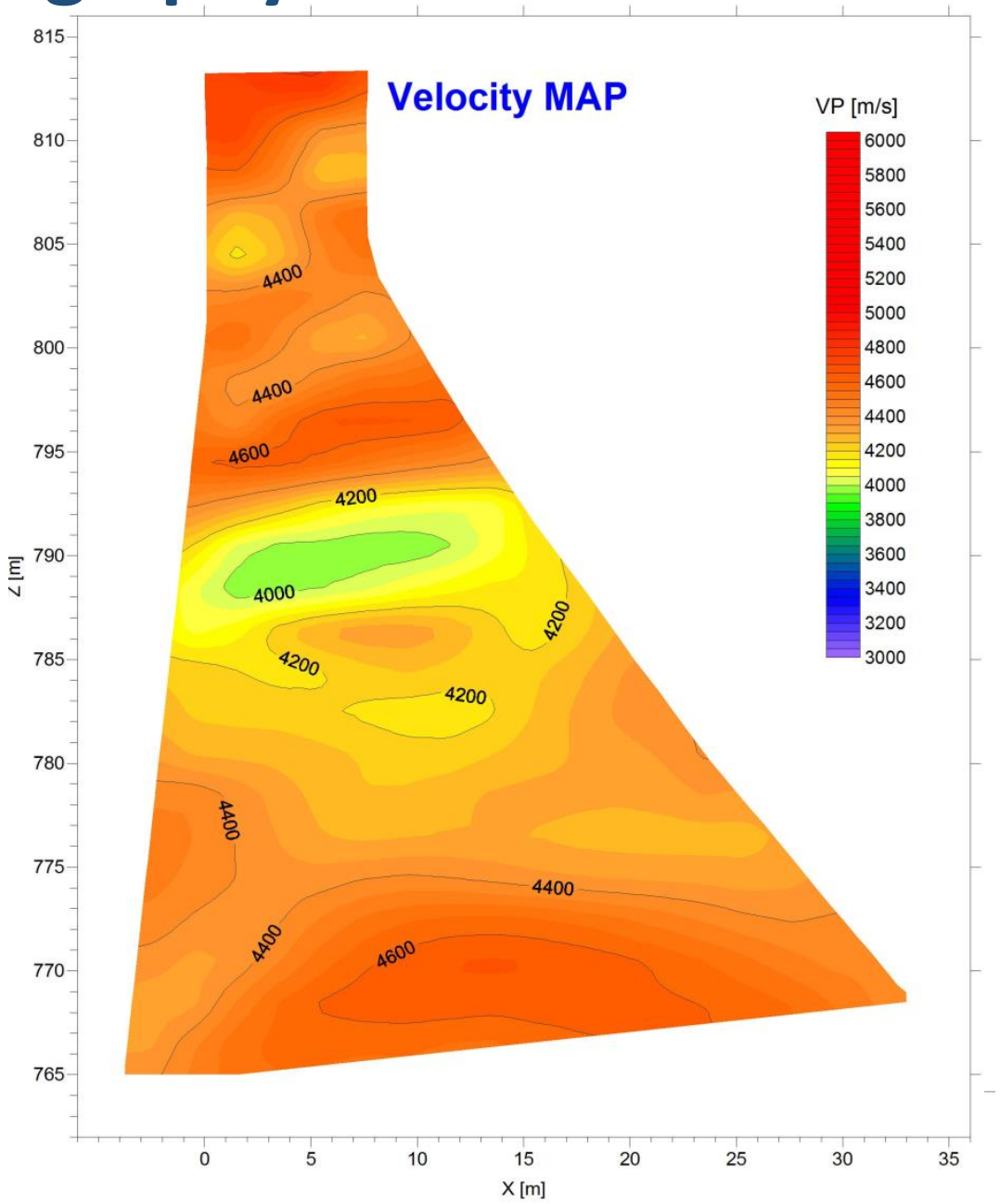
L-Section Tomography…Inversion & Velocity Model

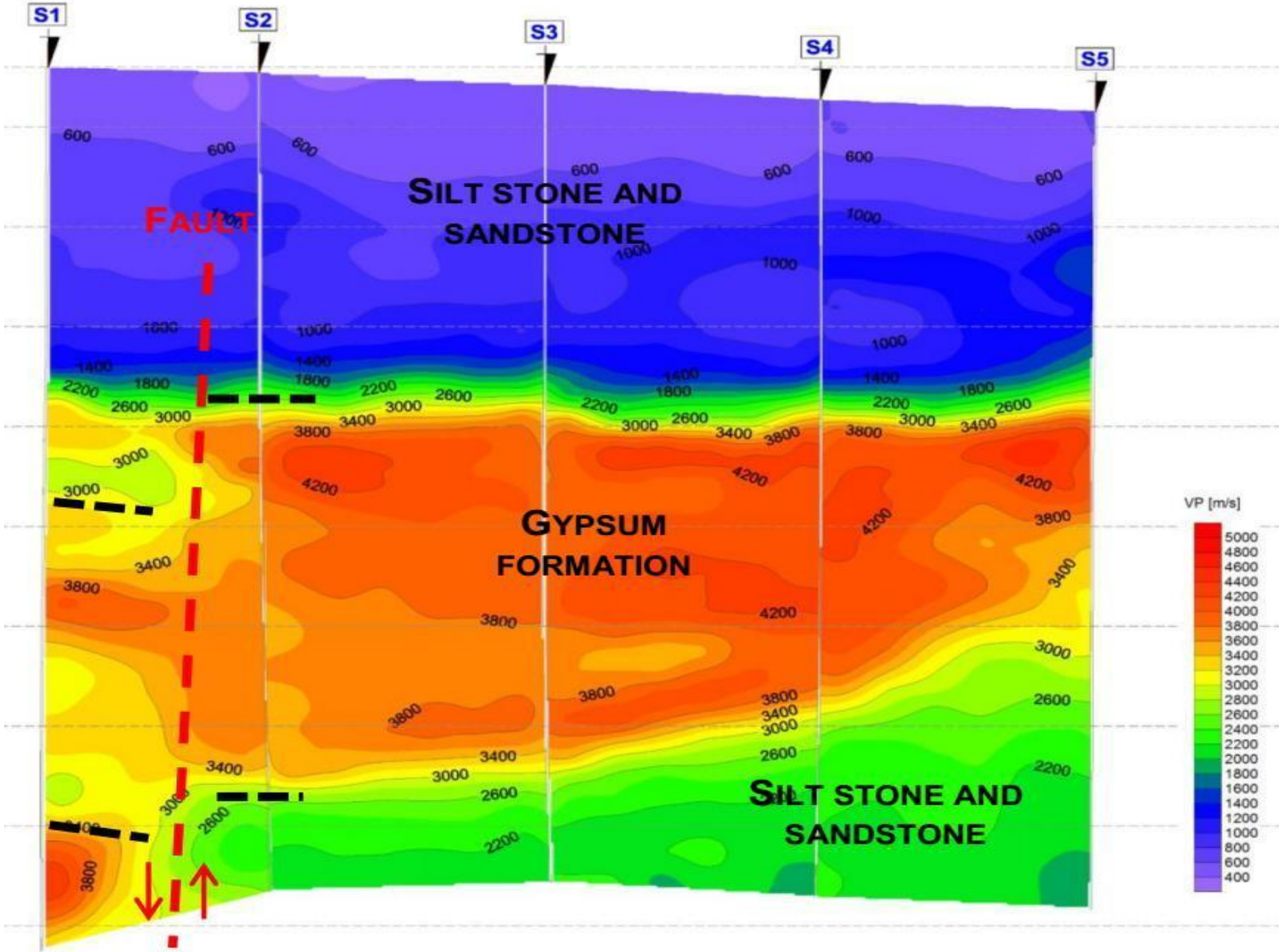


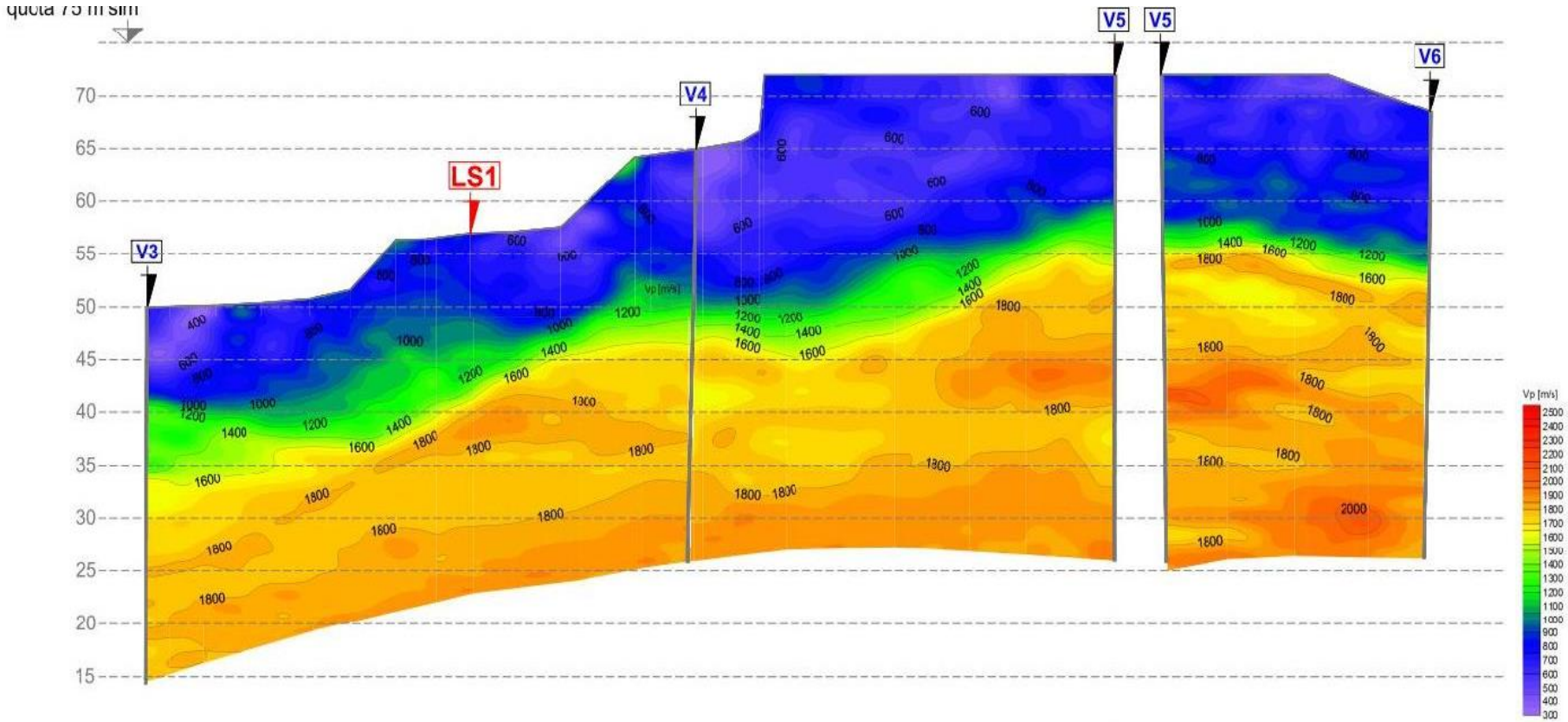
Cross Face Tomography… Ray Coverage

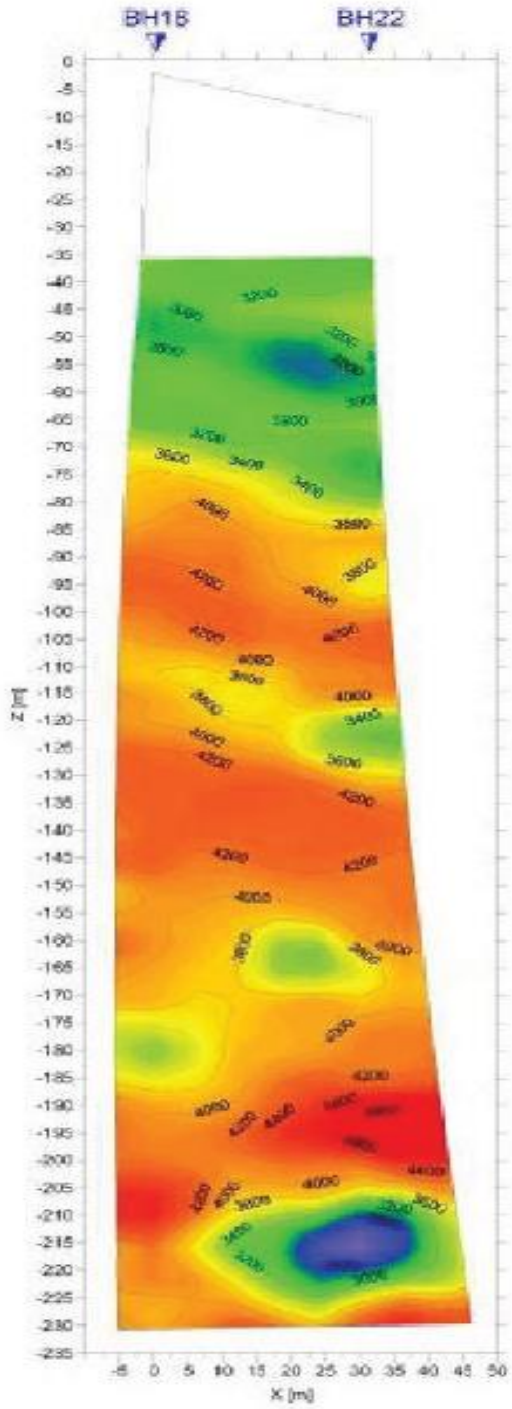


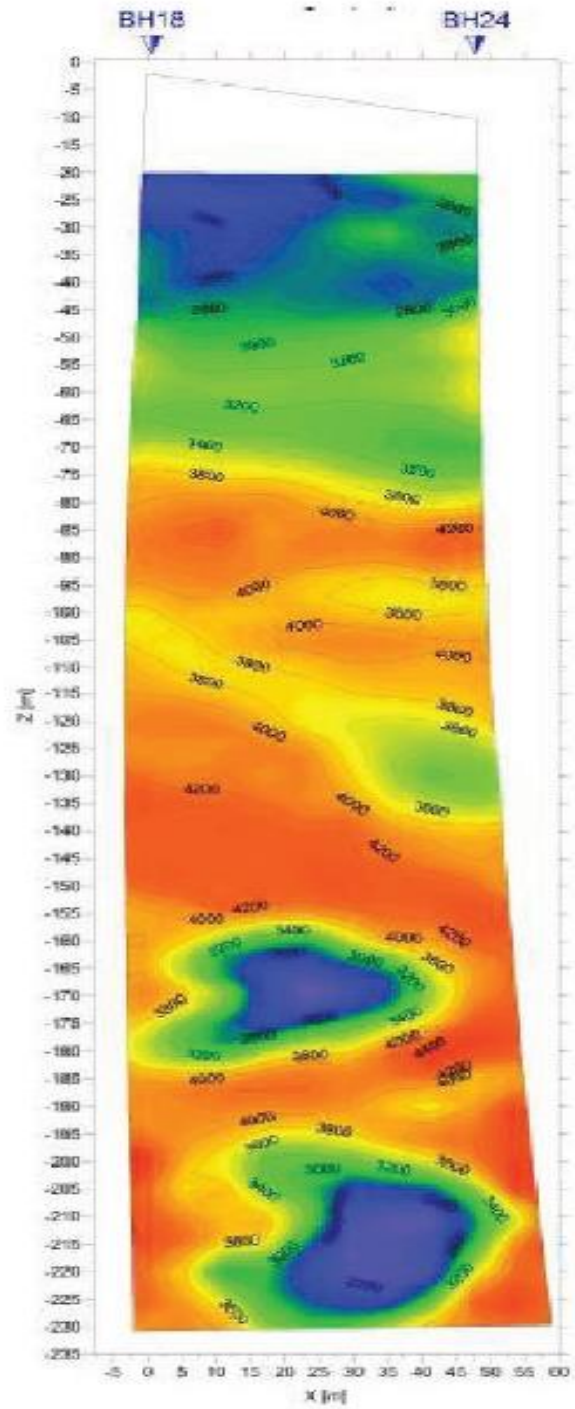
Cross Face Tomography… Inversion & Velocity Model

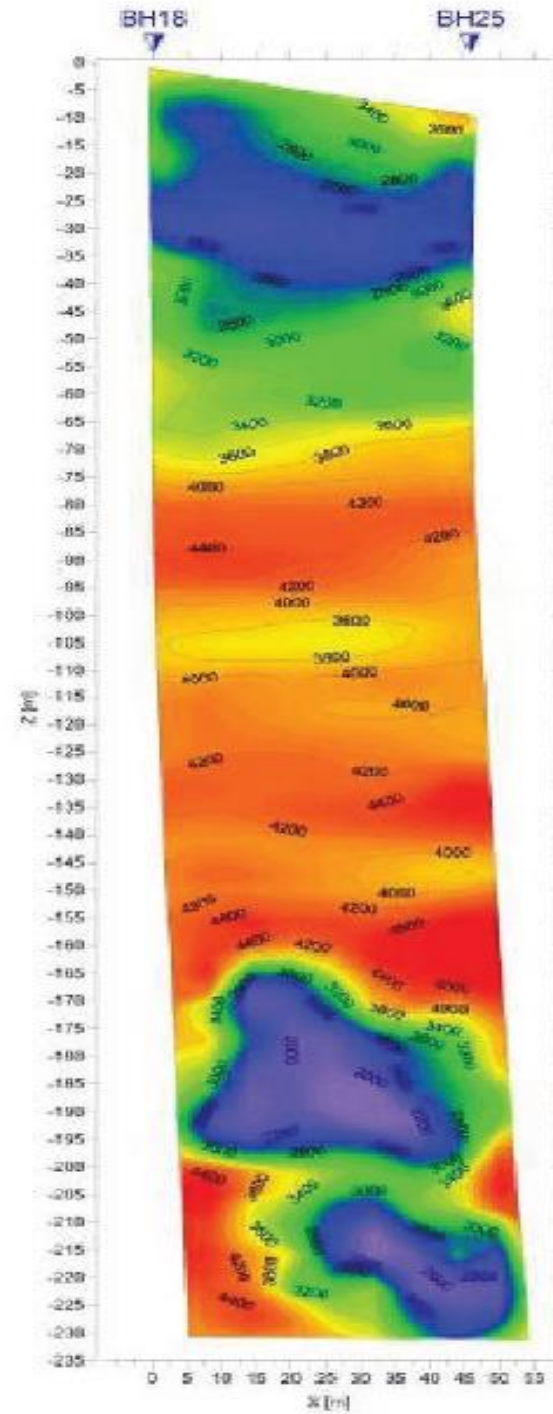


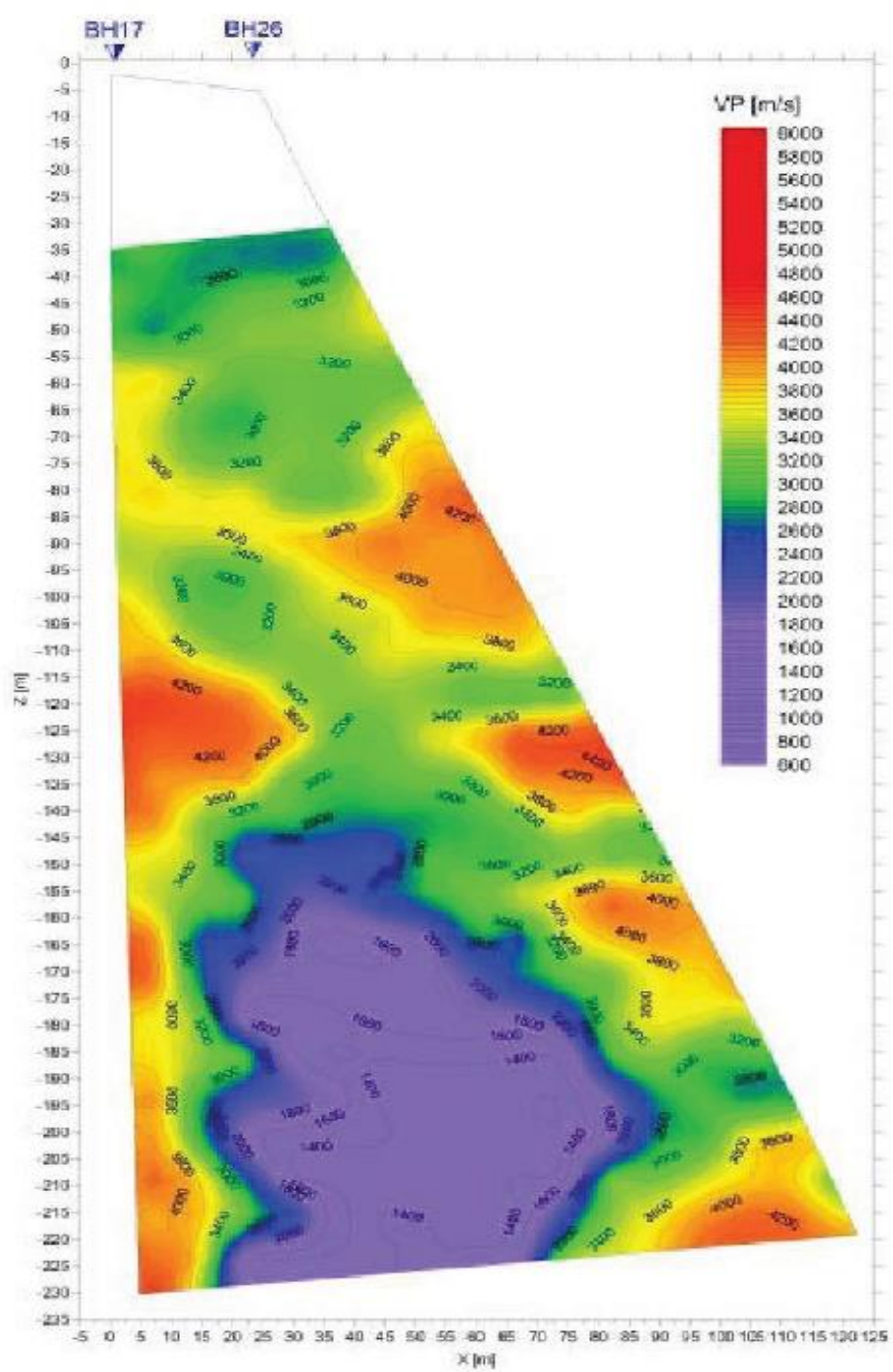

S1
S2
S3
S4
S5
FAULT
SILT STONE AND SANDSTONE
GYPSUM FORMATION
SILT STONE AND SANDSTONE
VP [m/s]
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400

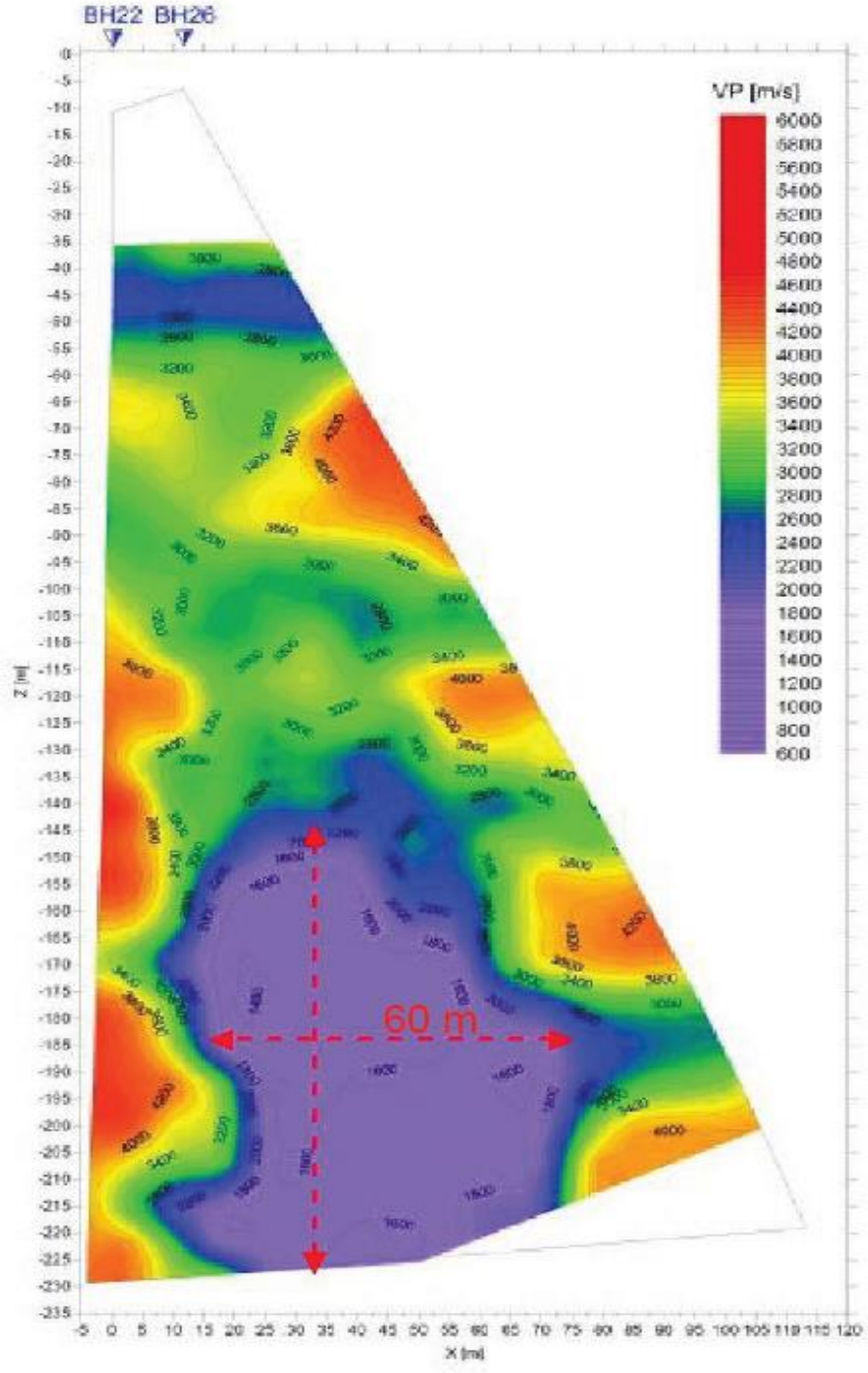

quota 75 m slm
V3
LS1
V4
V5
V5
V6
70
65
60
55
50
45
40
35
30
25
20
15
Vp [m/s]
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300


BH18
BH22
Z [m]
X [m]


BH18
BH24
Z [m]
X [m]

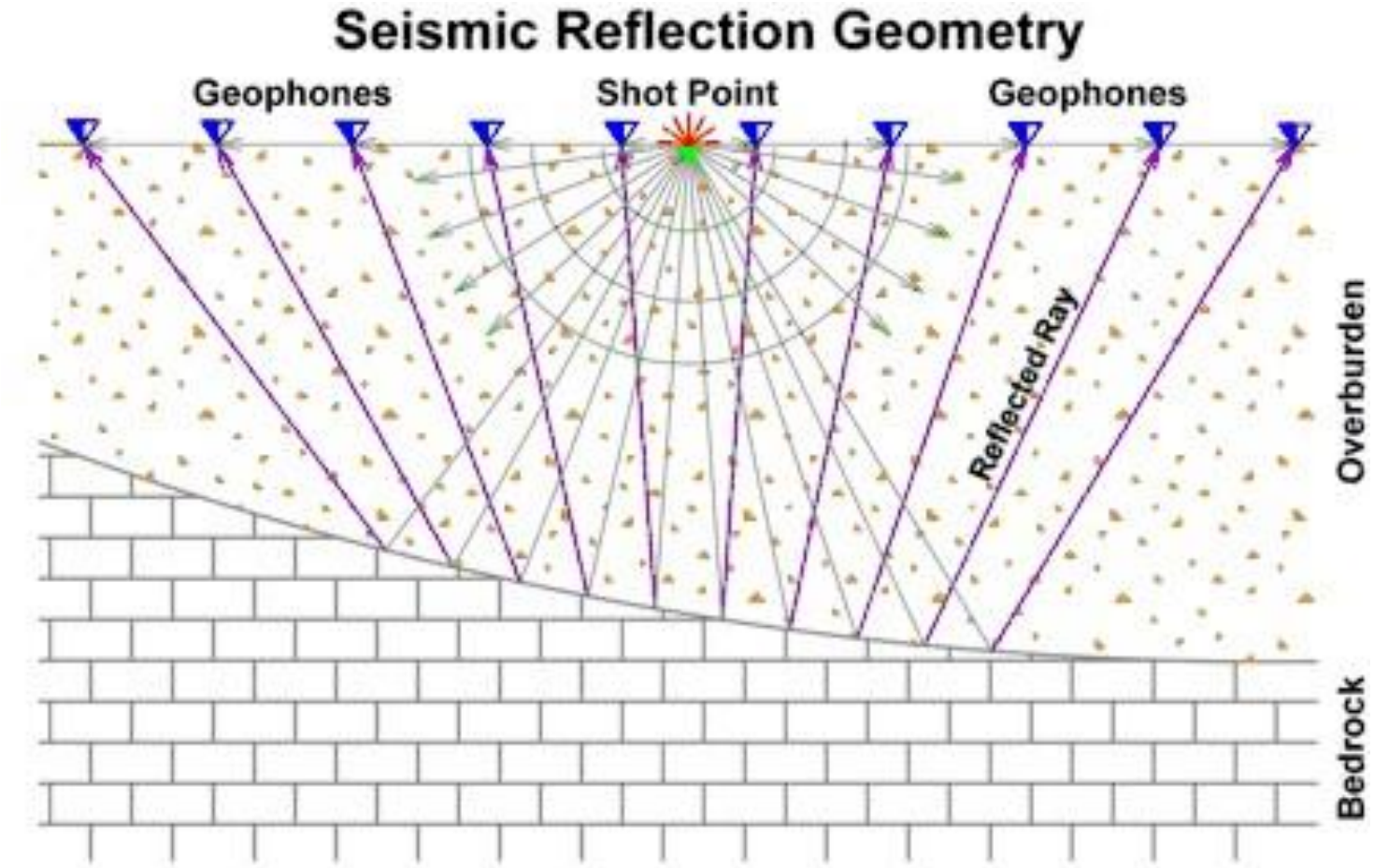

BH18
BH25
Z [m]
X [m]

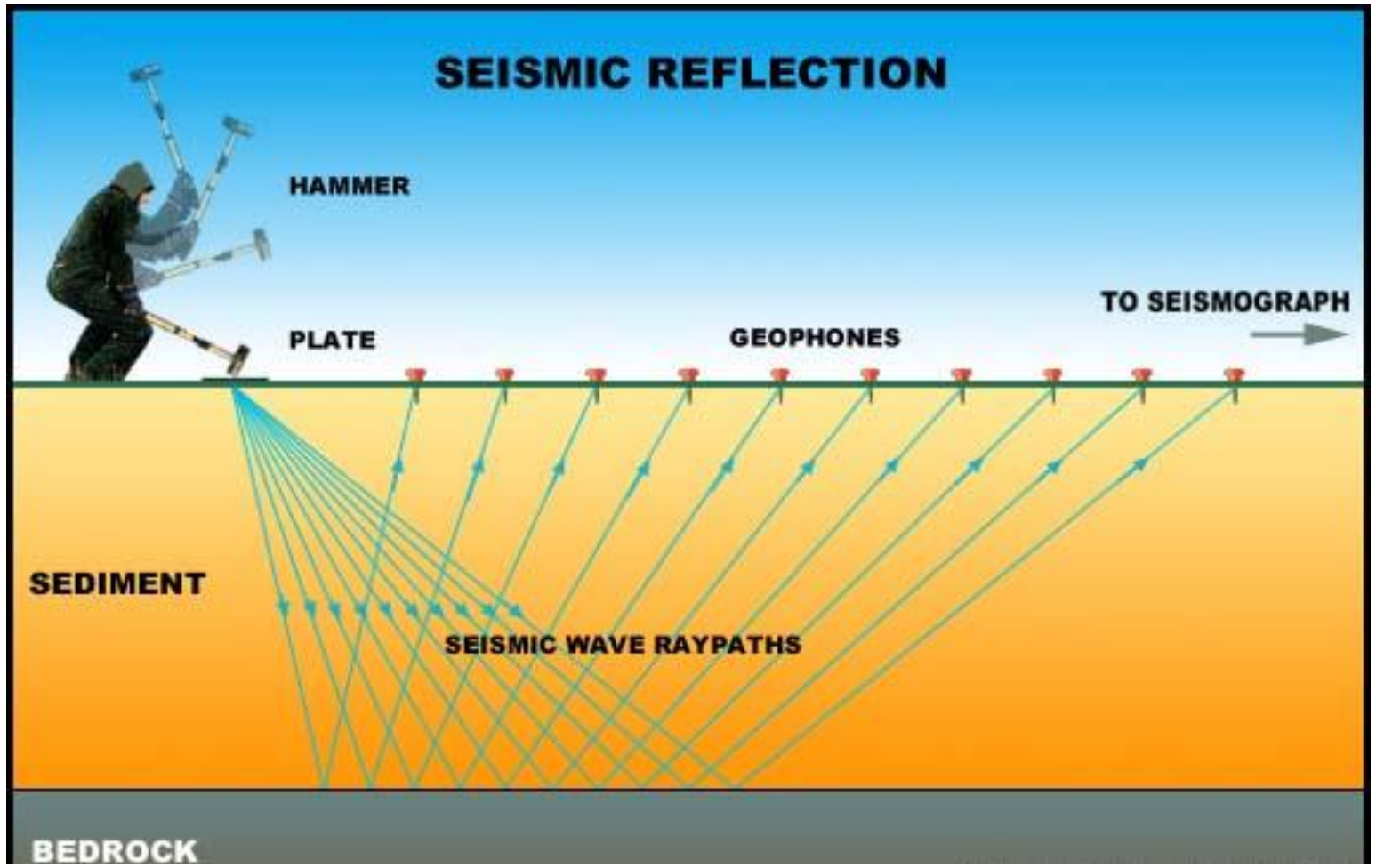

BH17
BH26
VP [m/s]
6000
5800
5600
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
Z [m]
X [m]

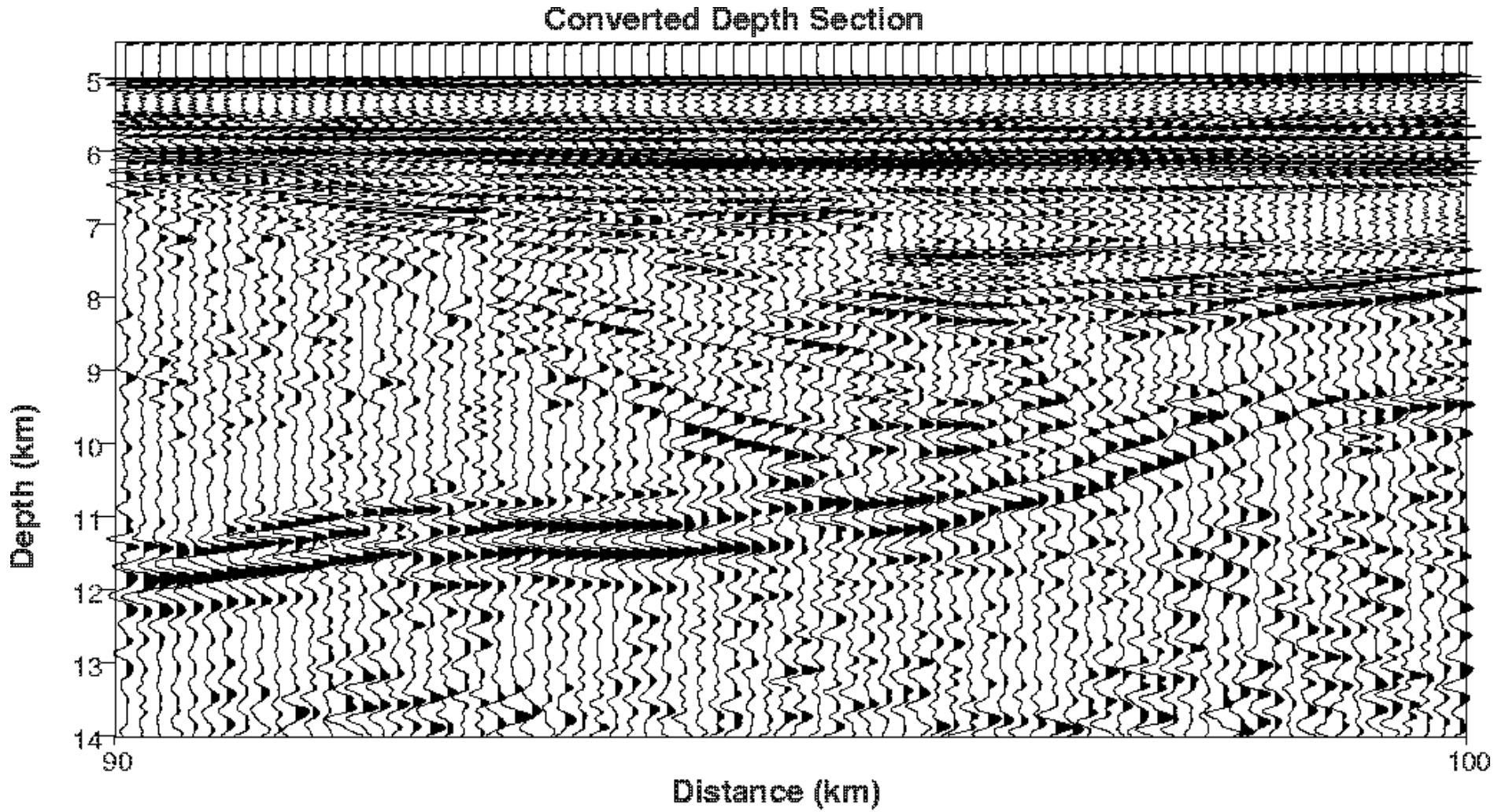

BH22
BH26
VP [m/s]
6000
5800
5600
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
60 m
Z [m]
X [m]

Seismic Reflection

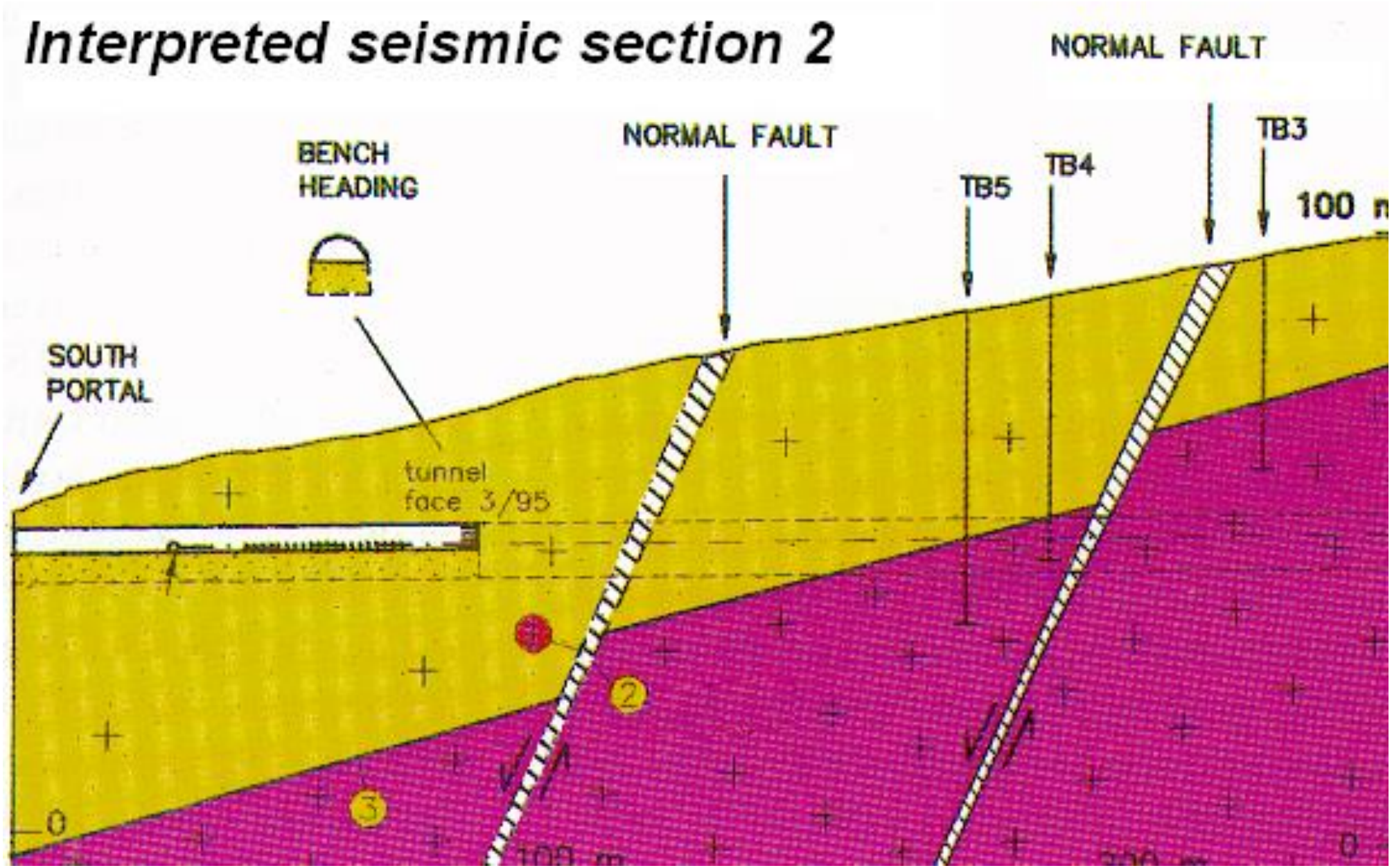
Basic Principle……

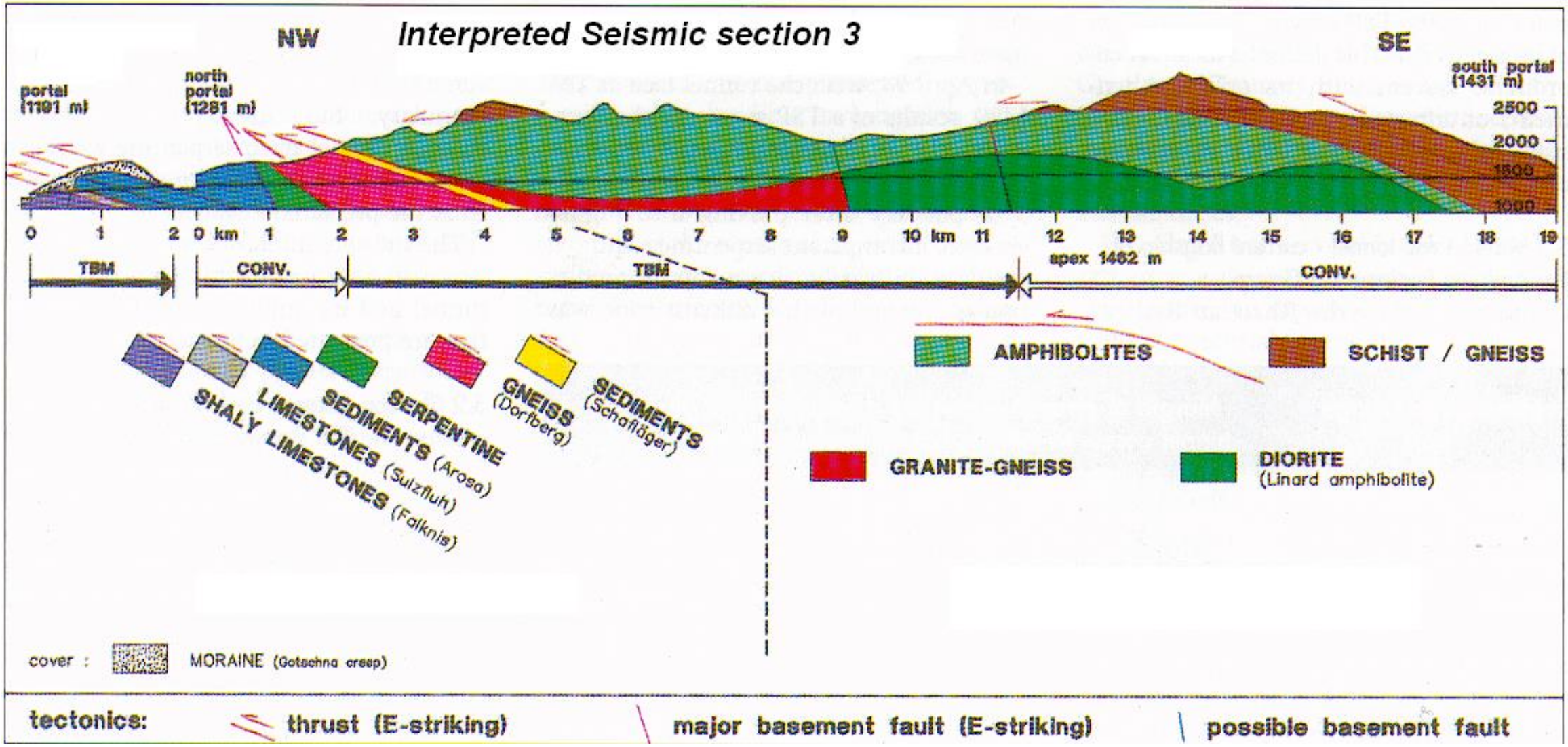



SEISMIC REFLECTION
HAMMER
PLATE
GEOPHONES
TO SEISMOGRAPH
SEDIMENT
SEISMIC WAVE RAYPATHS
BEDROCK

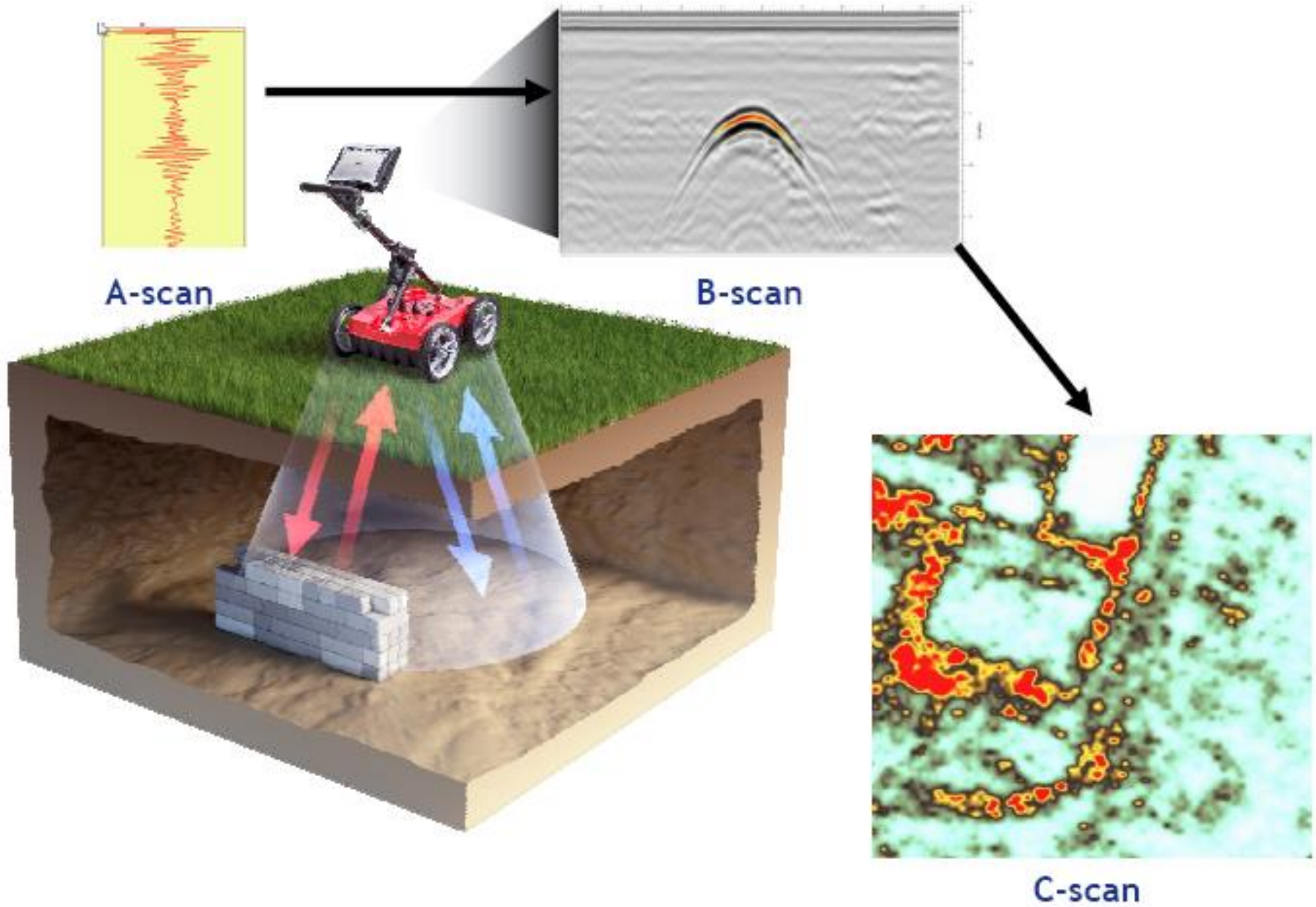

Converted Depth Section
Depth (km)
5
6
7
8
9
10
11
12
13
14
90
100
Distance (km)

Interpreted seismic section 2

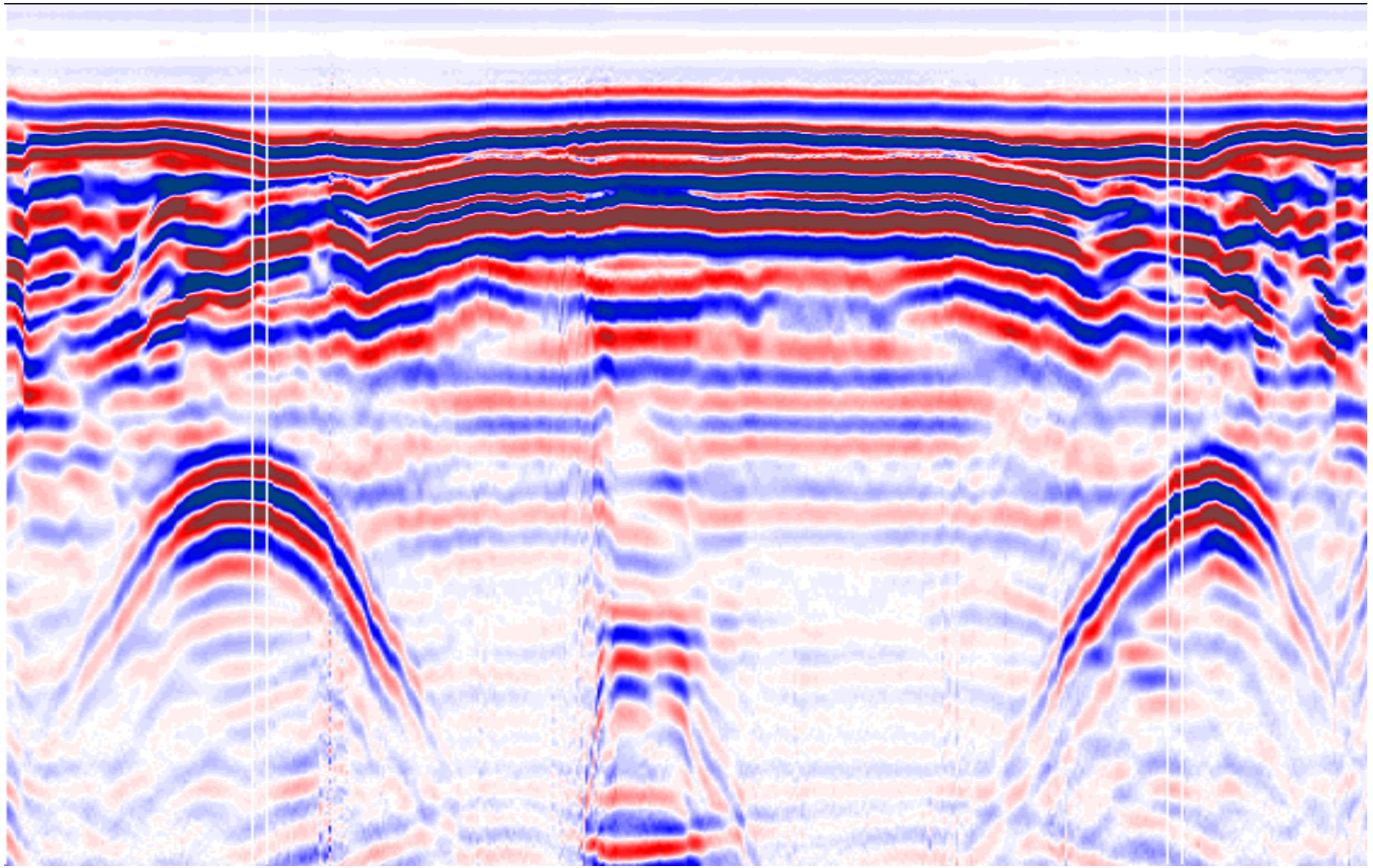



Interpreted Seismic section 3
NW
SE
portal (1191 m)
north portal (1281 m)
south portal (1431 m)
2500
2000
1500
1000
0 1 2 0 km 1 2 3 4 5 6 7 8 9 10 km 11 12 13 14 15 16 17 18 19
apex 1462 m
TBM
CONV.
TBM
CONV.
SHALY LIMESTONES (Falknis)
LIMESTONES (Sulzfluh)
SEDIMENTS (Arosa)
SERPENTINE
GNEISS (Dorfberg)
SEDIMENTS (Schafläger)
AMPHIBOLITES
SCHIST / GNEISS
GRANITE-GNEISS
DIORITE (Linard amphibolite)
cover :
MORAINE (Gotschna creep)
tectonics:
thrust (E-striking)
major basement fault (E-striking)
possible basement fault

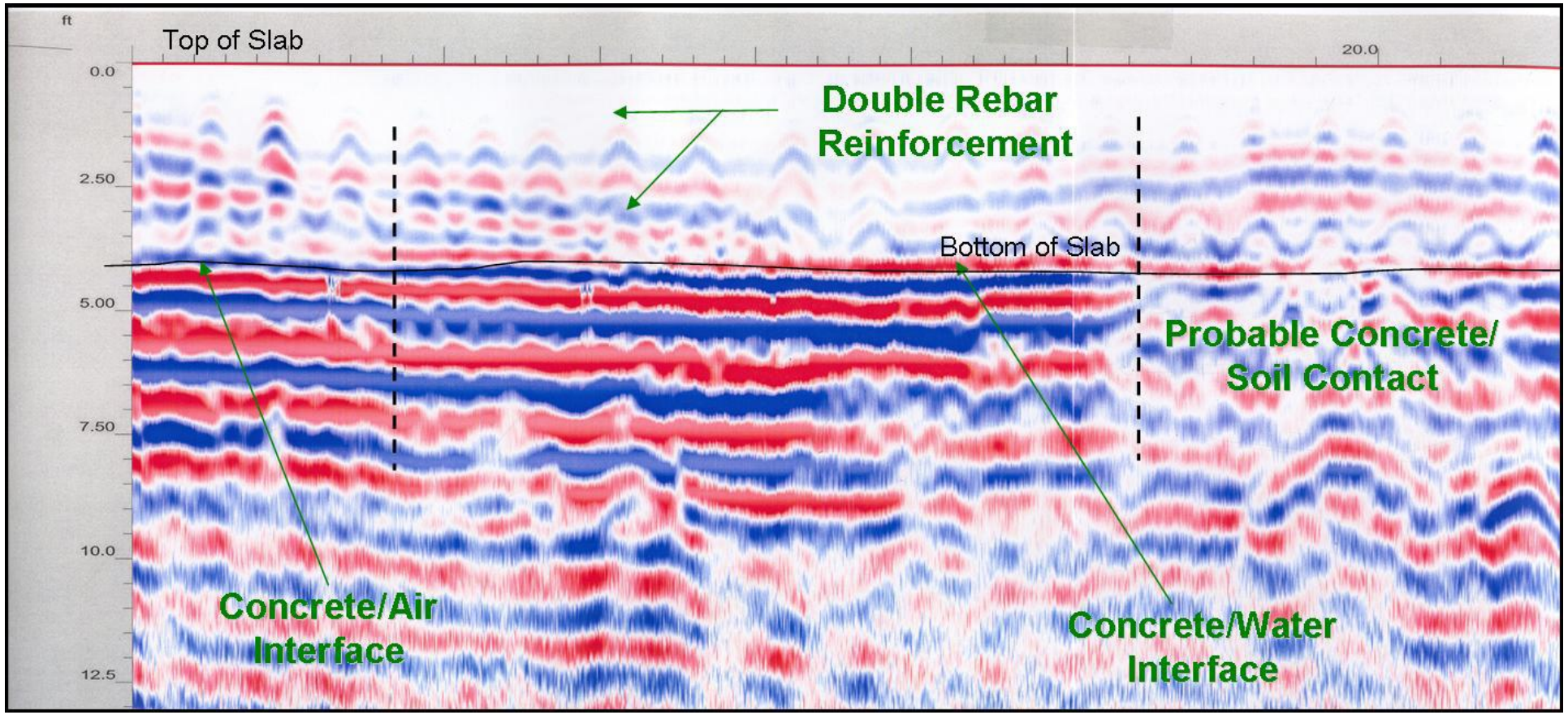
Ground Penetrating Radar


A-scan
B-scan
C-scan

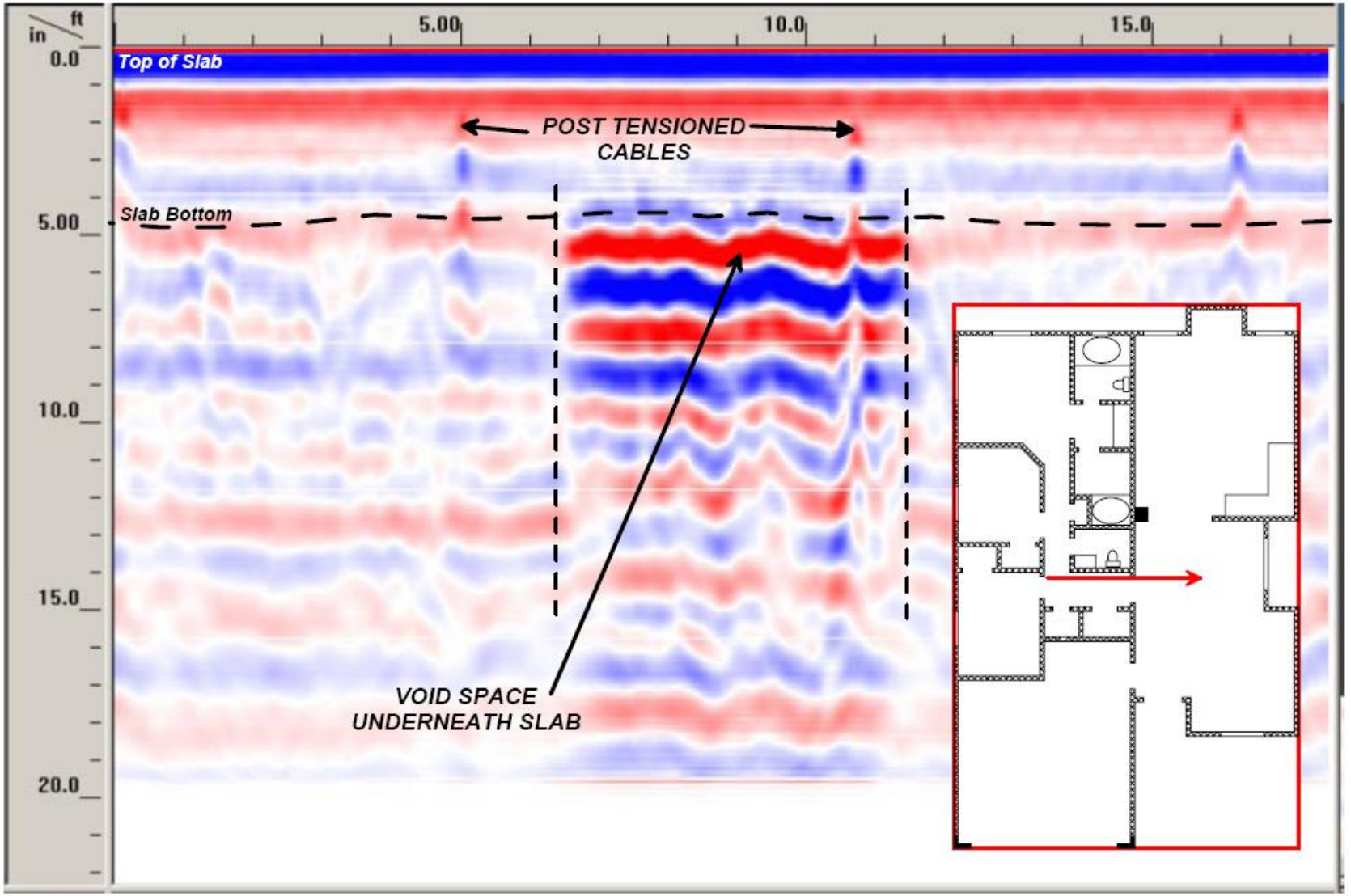
Field Example- Pipes……



Concrete Inspection……..



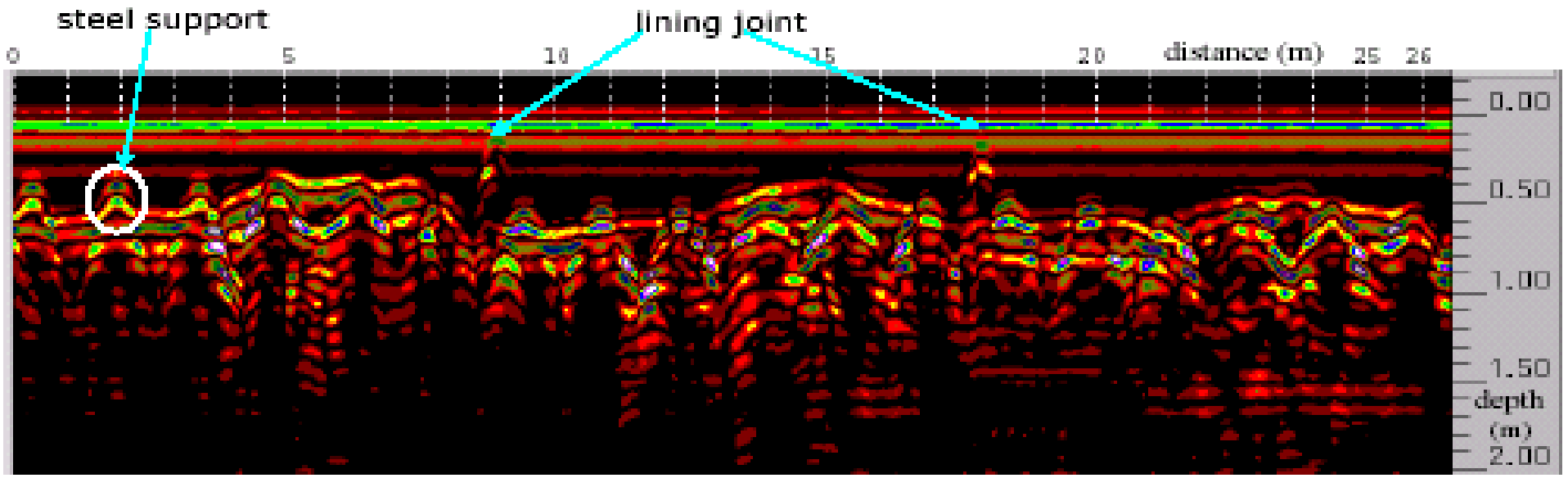
Concrete Inspection……..

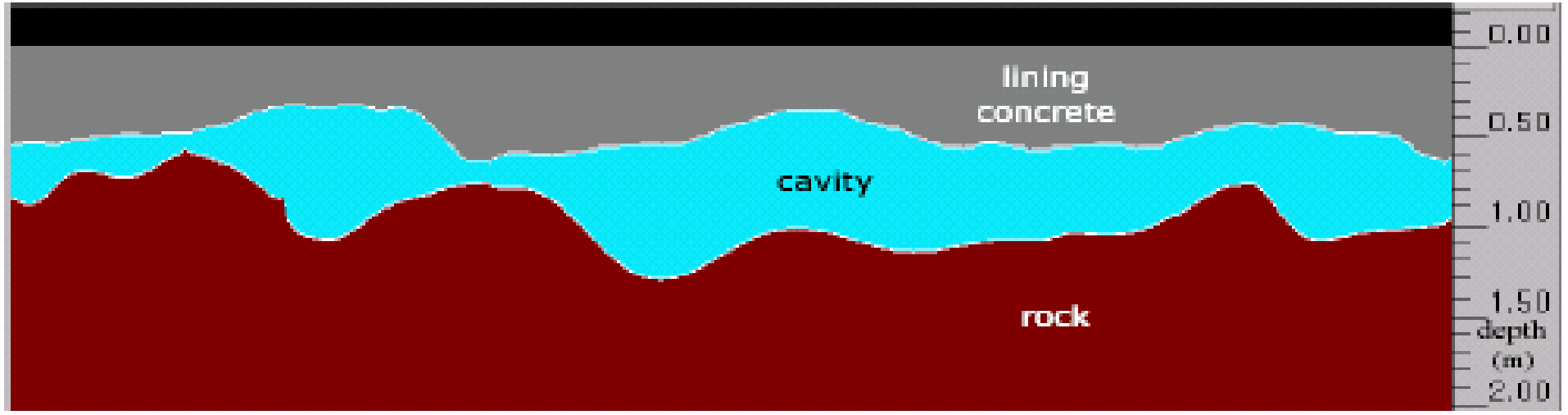


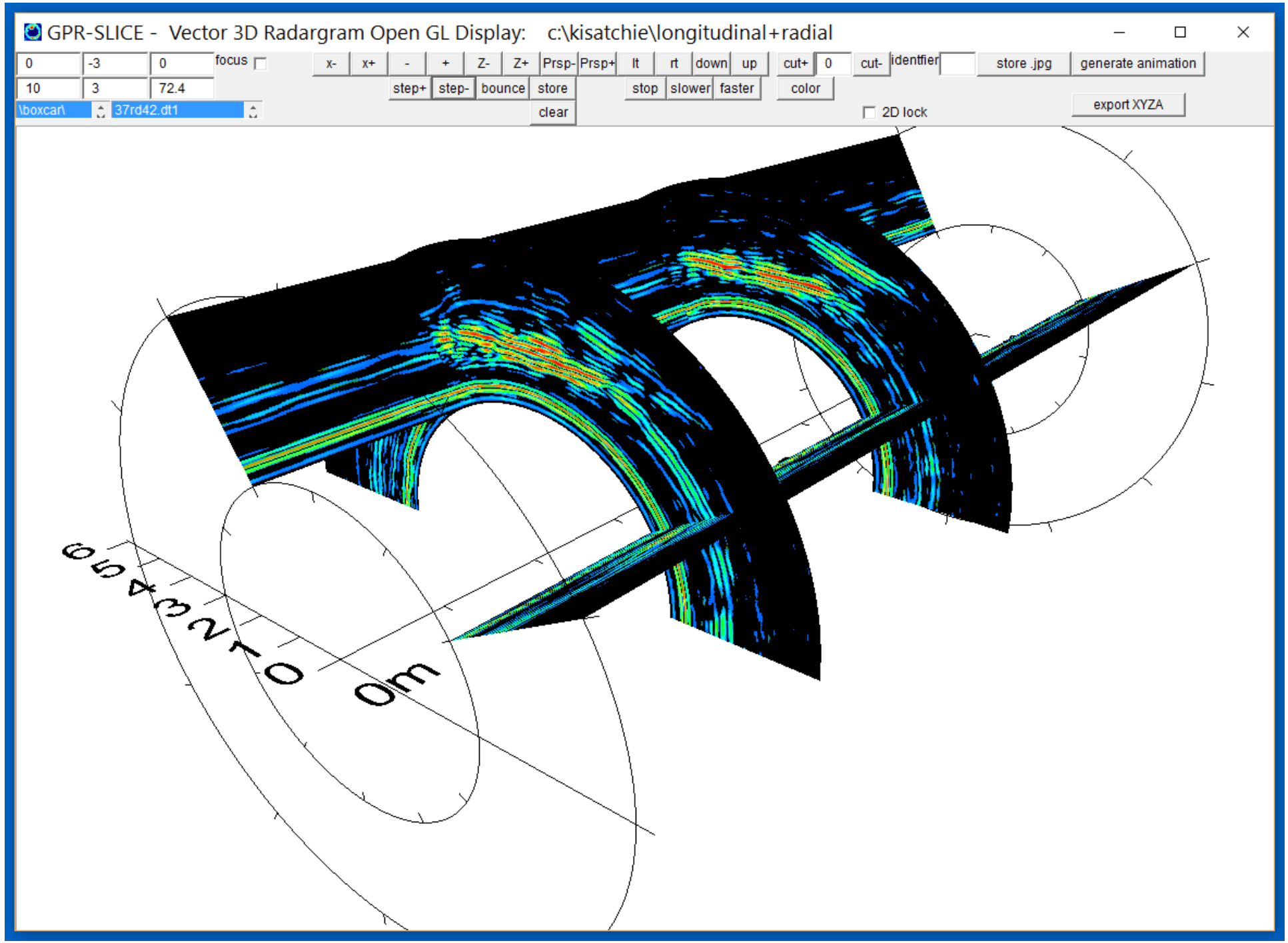
Tunnel Inspection

Tunnel Inspection

Tunnel Inspection





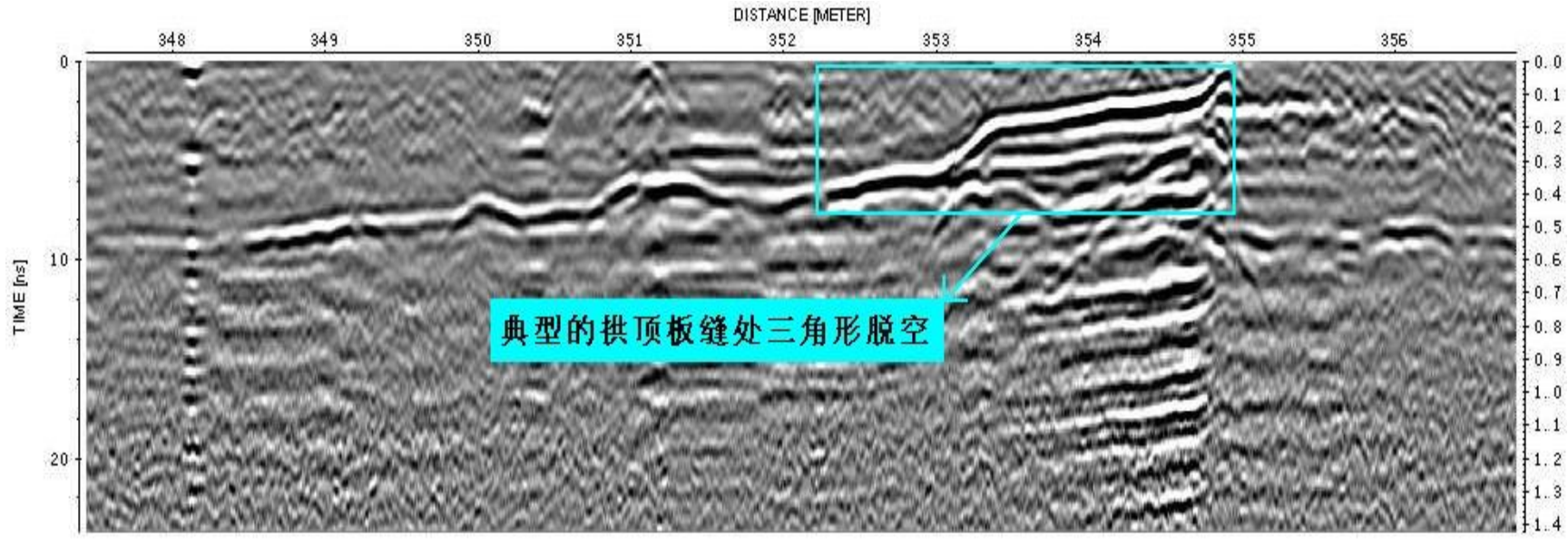

GPR-SLICE - Vector 3D Radargram Open GL Display: c:\kisatchie\longitudinal+radial
0
-3
0
focus
10
3
72.4
\boxcar\
37rd42.dt1
x-
x+
-
+
Z-
Z+
Prsp-
Prsp+
lt
rt
down
up
cut+
0
cut-
identfier
store .jpg
generate animation
step+
step-
bounce
store
clear
stop
slower
faster
color
2D lock
export XYZA
0m

Ground Penetrating Radar- Applications Areas

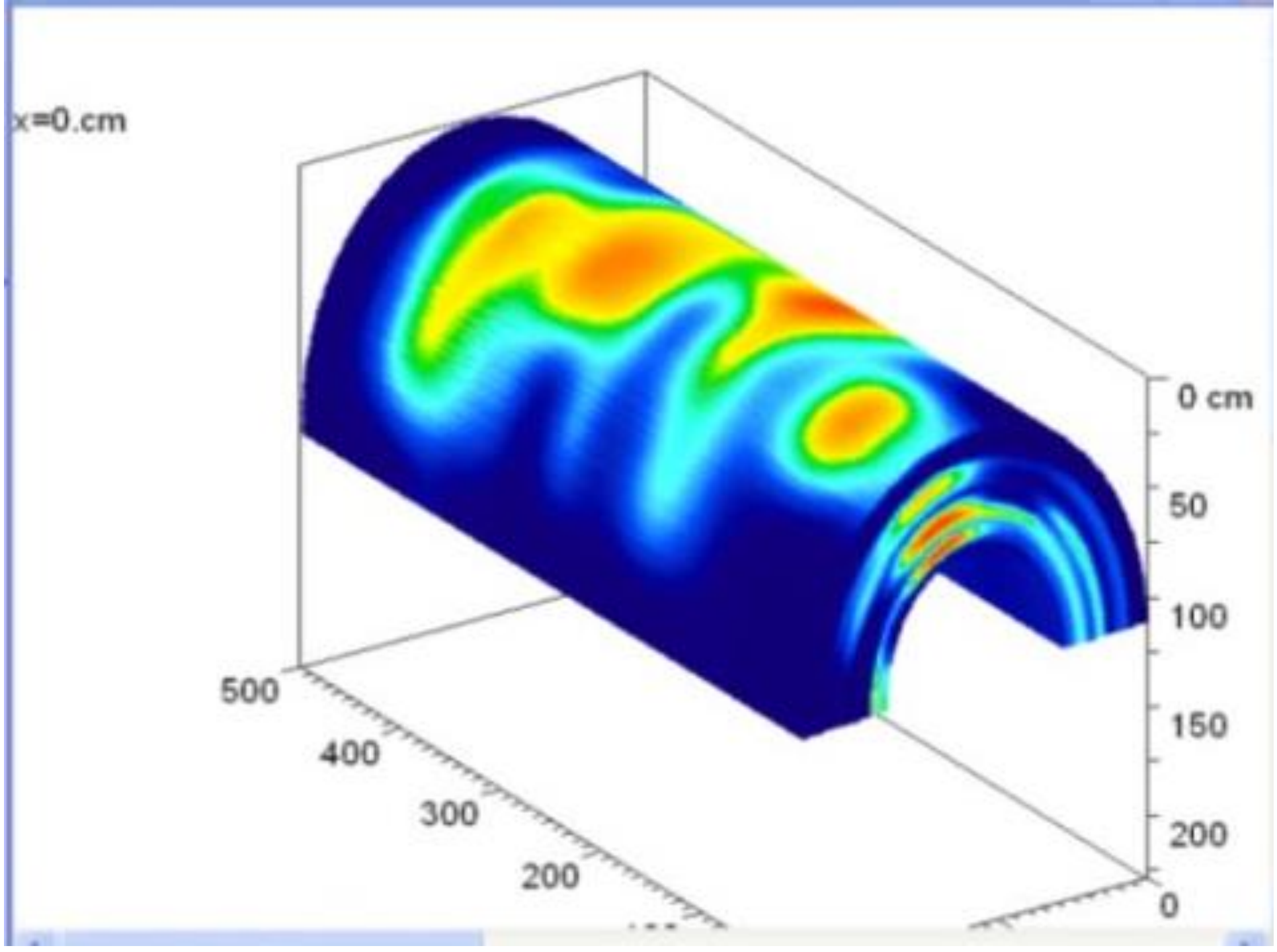
- Shallow geological investigations
- Utility mapping
- Concrete inspection at existing infrastructure
- QC of concrete structures
- Inspection of existing tunnels
- Complimentary tool to any geotechnical investigation

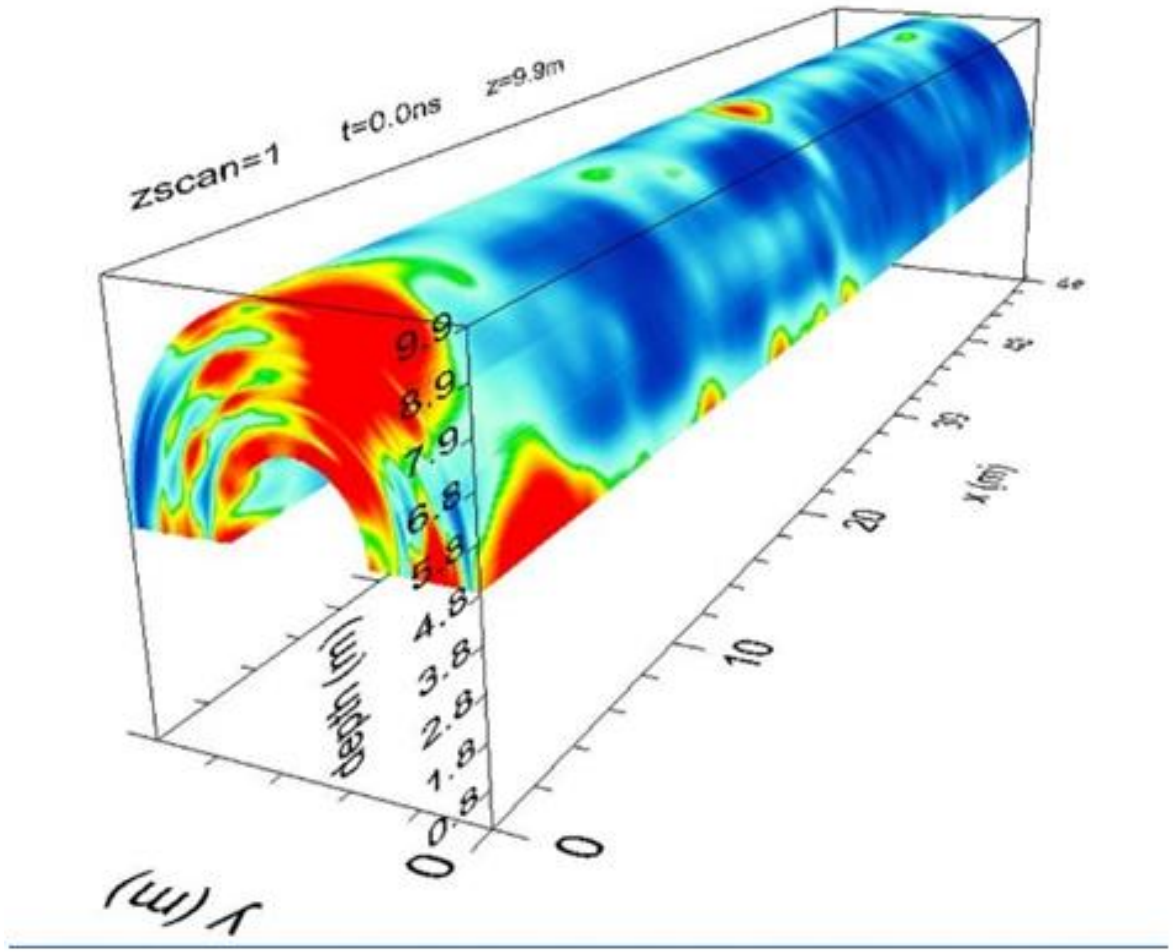
QC of Completed Tunnels

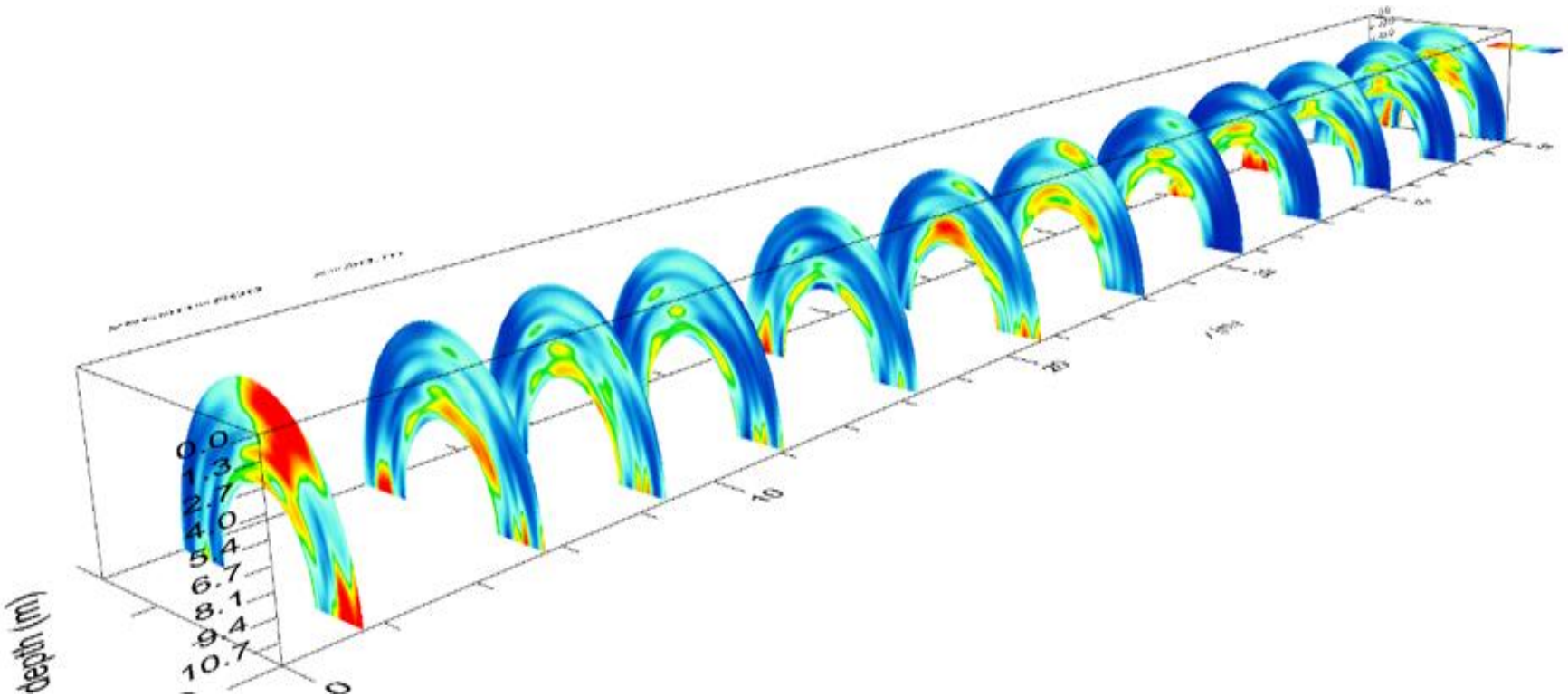
Tested in tunnels, ProEx+500MHz



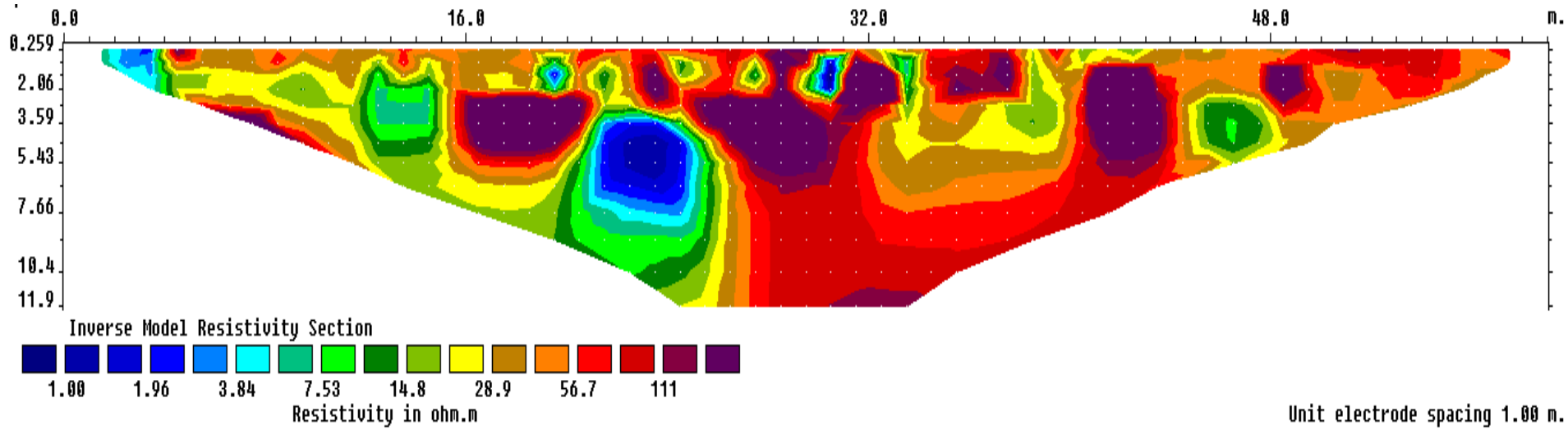
Cavity beneath slab profile

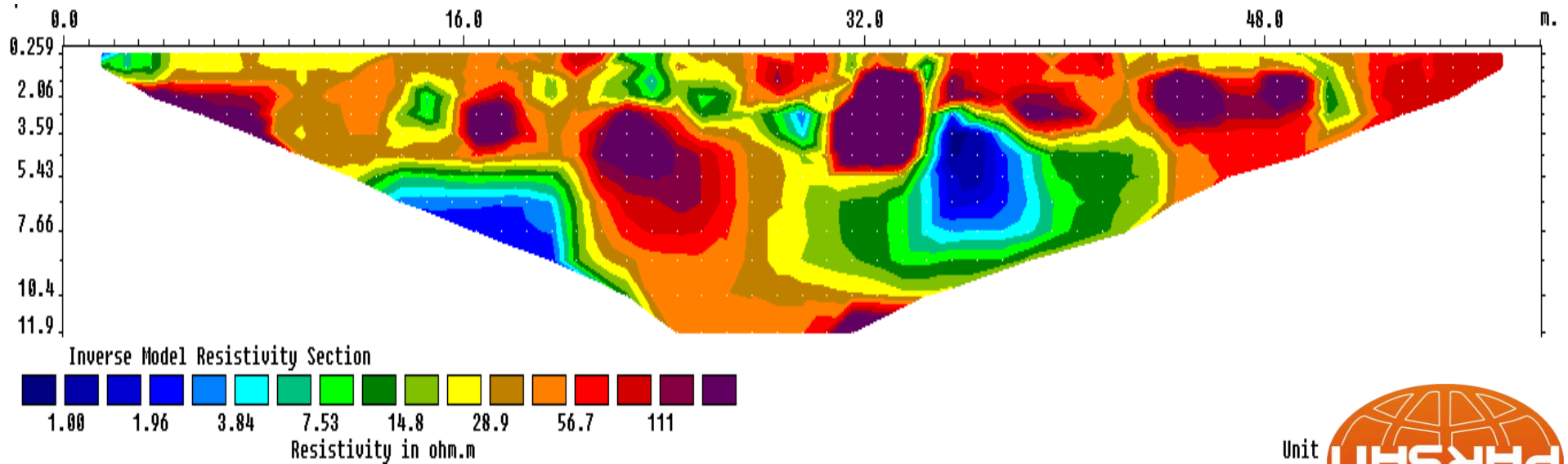

x=0.cm
0 cm
50
100
150
200
0
500
400
300
200

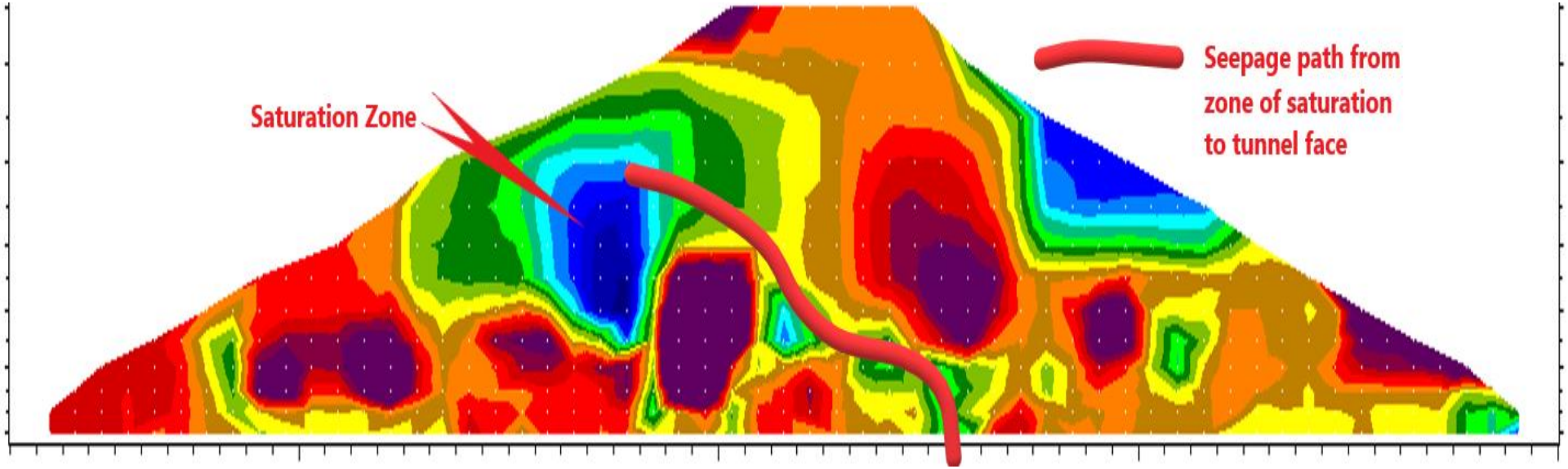

zscan=1
t=0.0ns
z=9.9m
9.9
8.9
7.9
6.8
5.8
4.8
3.8
2.8
1.8
0.8
Depth (m)
0
10
20
x (m)
y (m)


depth (m)
0.0
1.3
2.7
4.0
5.4
6.7
8.1
9.4
10.7
0
10
20


MANITOU


0.0
16.0
32.0
48.0
m.
0.259
2.06
3.59
5.43
7.66
10.4
11.9
Inverse Model Resistivity Section
1.00
1.96
3.84
7.53
14.8
28.9
56.7
111
Resistivity in ohm.m
Unit electrode spacing 1.00 m.


0.0
16.0
32.0
48.0
m.
0.259
2.06
3.59
5.43
7.66
10.4
11.9
Inverse Model Resistivity Section
1.00
1.96
3.84
7.53
14.8
28.9
56.7
111
Resistivity in ohm.m
Unit

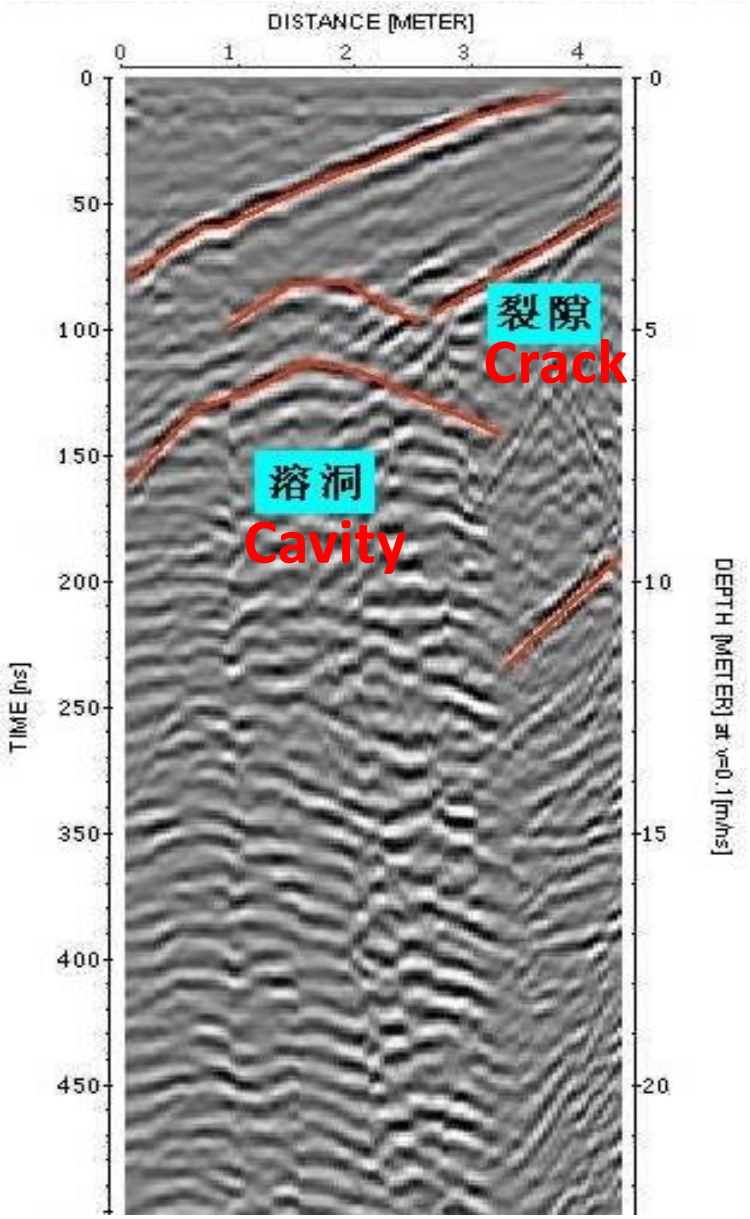

Saturation Zone
Seepage path from
zone of saturation
to tunnel face

Looking ahead of Tunneling

Tunnel foreahead using 100MHz shiended antenna

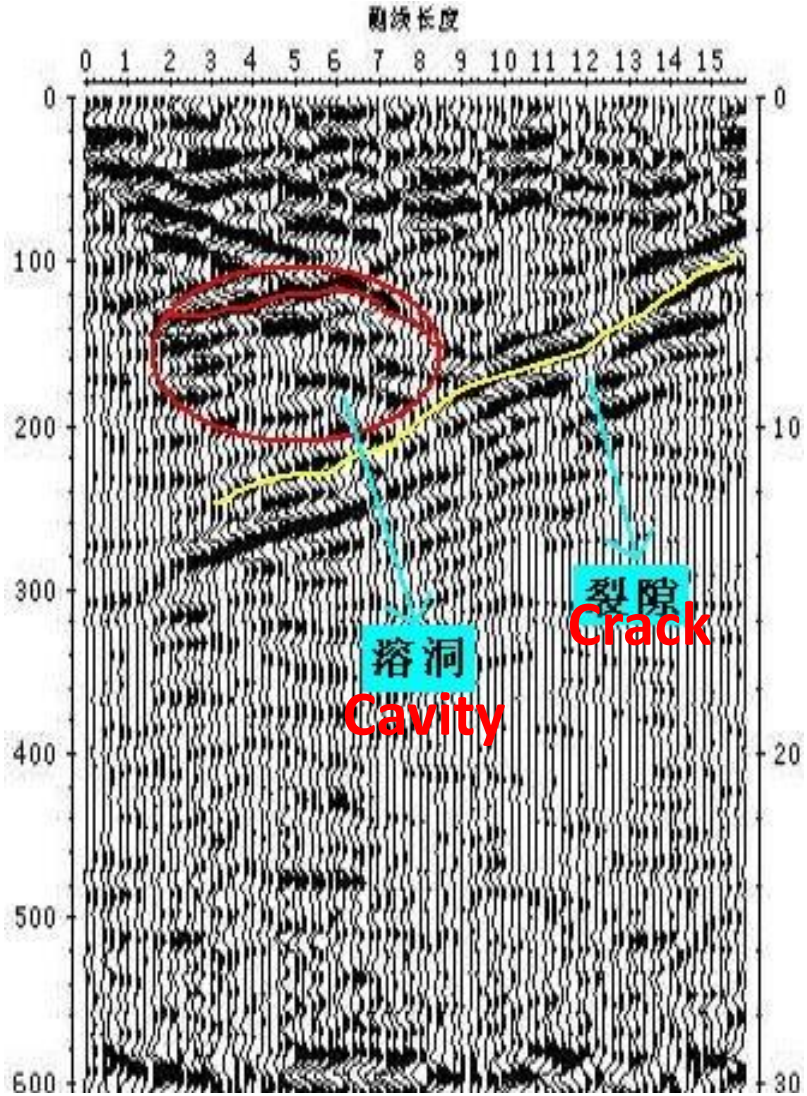
Now we can use GX80 or GX160

Tunnel forehead using 50MHz unshielded antenna

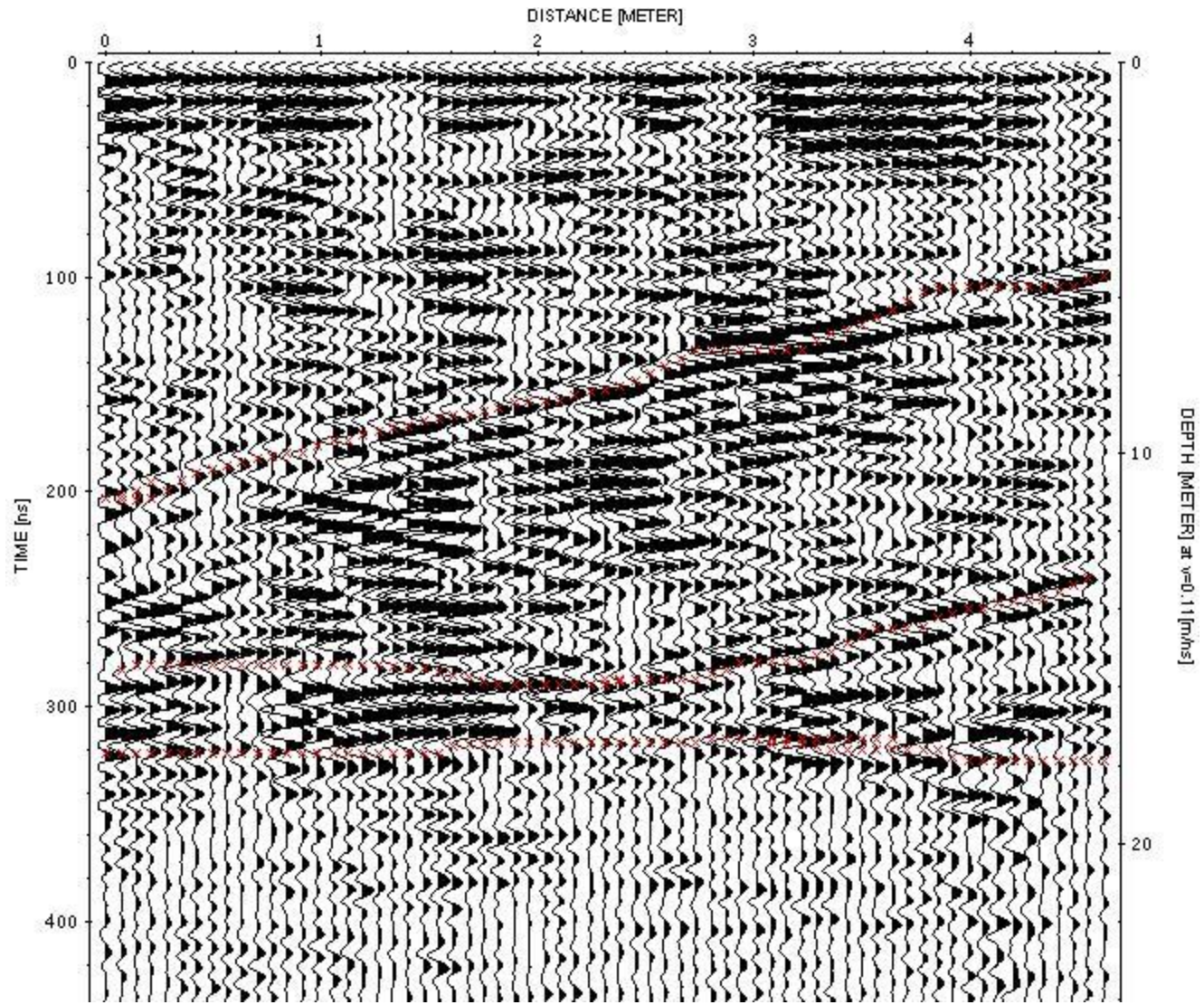


Tunnel foreahead

ProEx+100MHz shielded



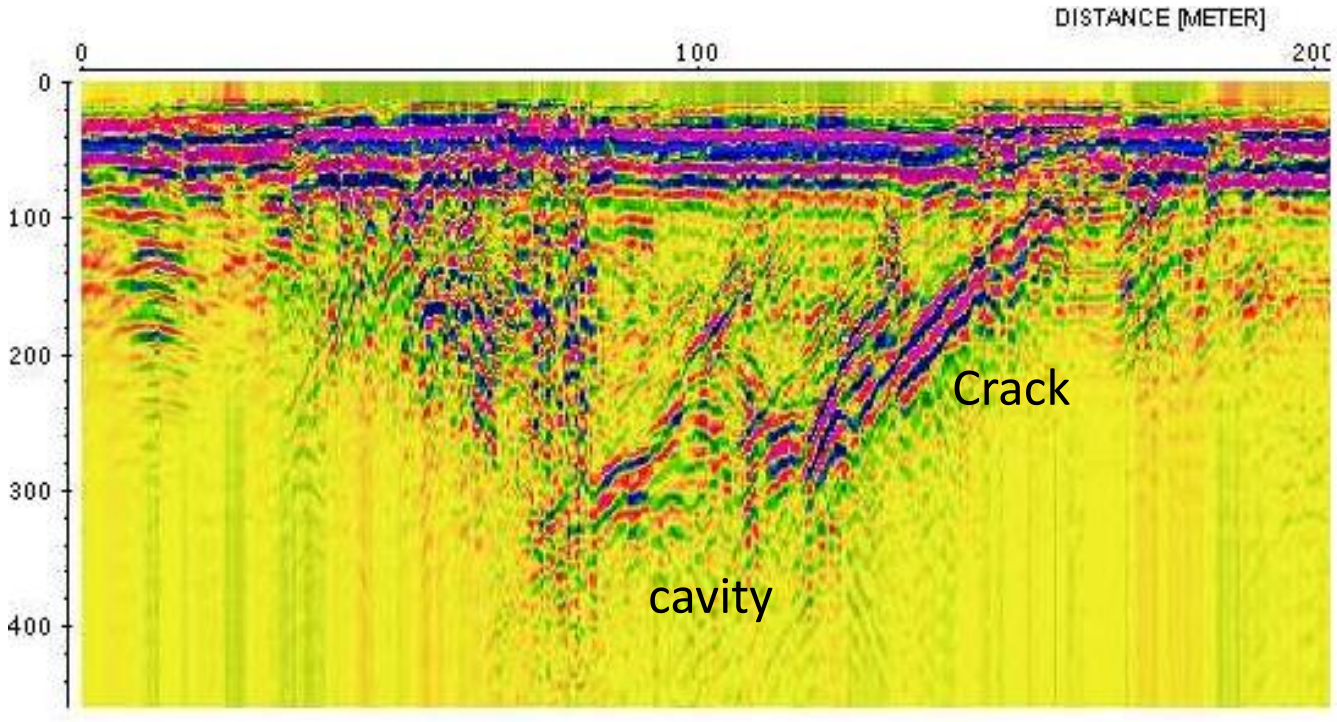
Tunnel foreahead
ProEx+50MHz unshielded



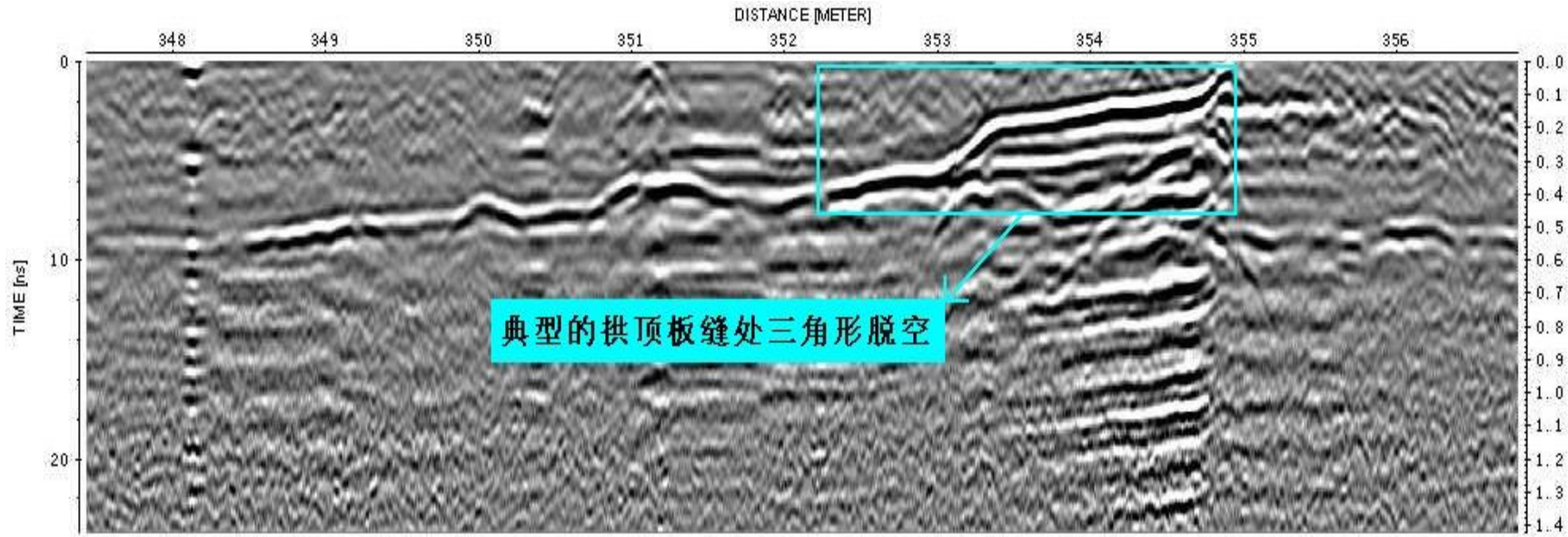
Tunnel forehead
Yichang-Wanzhou
Railway tunnel

Red area is cavity

Crack and cavity detection in tunnel

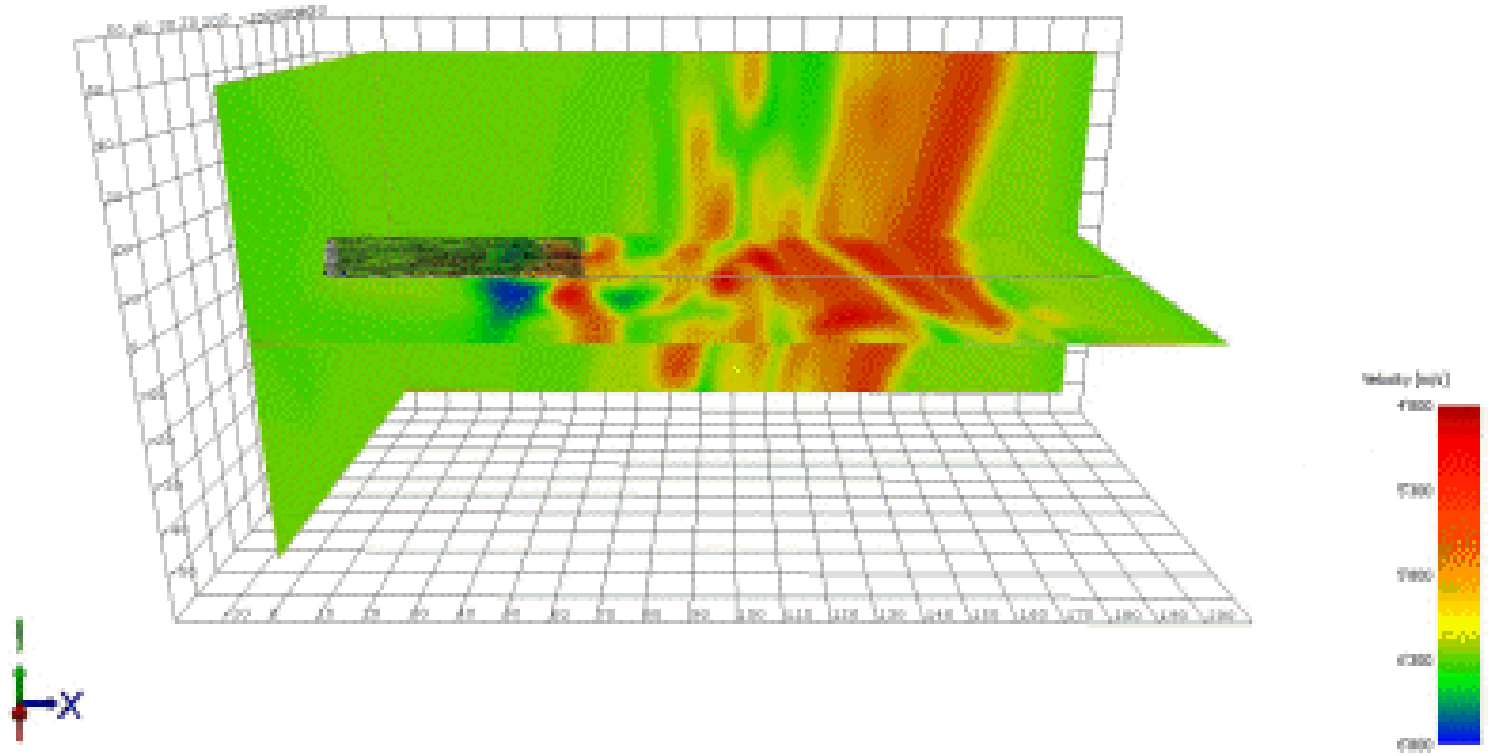


ProEx+50MHz unshielded antennas



Cavity beneath slab profile

Tunnel Seismic Prediction


Y
X

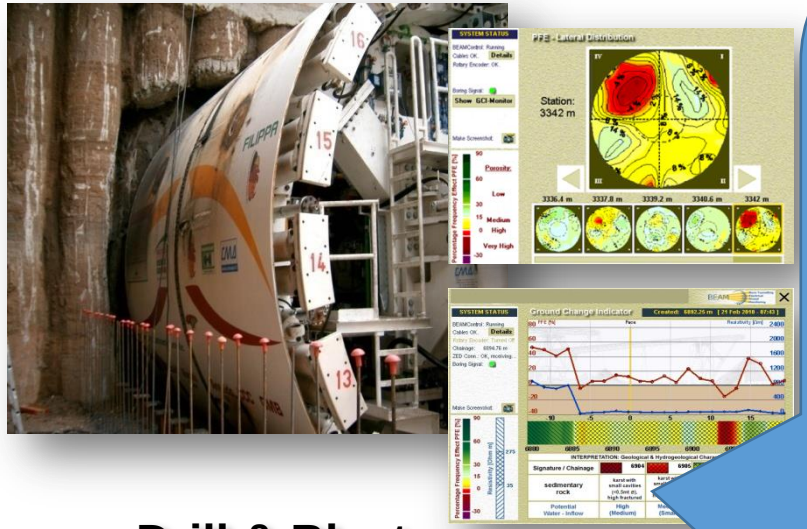
BEAM….

BEAM®
Bore-tunnelling Electrical Ahead Monitoring

Real-time Ground Prediction While TBM Boring

BEAM
Bore-tunnelling Electrical Ahead Monitoring

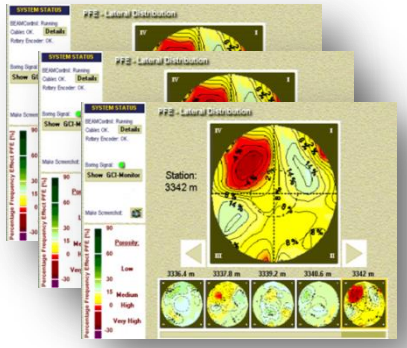
TBM



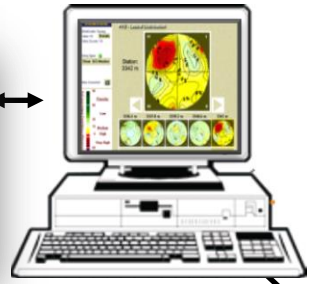
Drill & Blast

Most efficient and cost effective is the use for TBM ahead prediction because of the **automatic, continuous and non-invasive data acquisition, processing, evaluation, interpretation and documentation in real time without hindrance or stopping of TBM operation**.

System

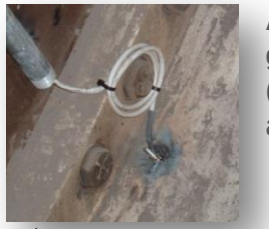


visualisation of geological classification and hydro-geological characterisation in real-time



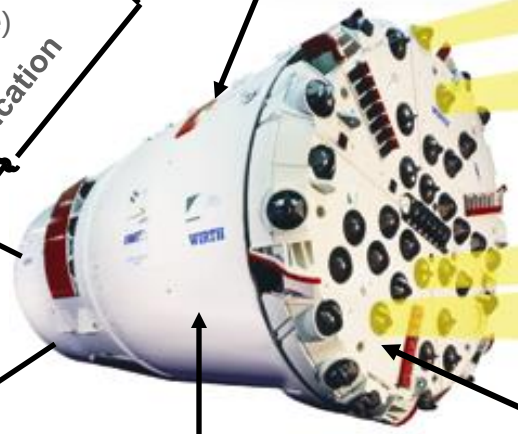
remote access
(e.g. office)

communication

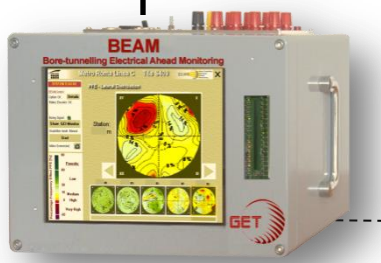


A1 (+)
guard electrode
(e.g. shield, cutter head, armed lining)

current beam



B (-)
return electrode
(e.g. steel rod, anchor etc. inside or outside the tunnel)

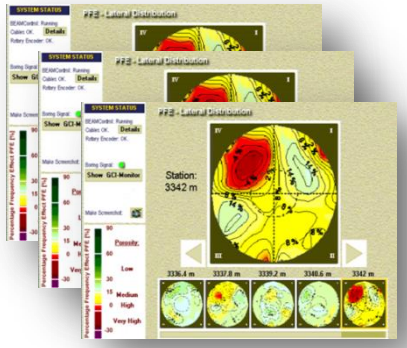


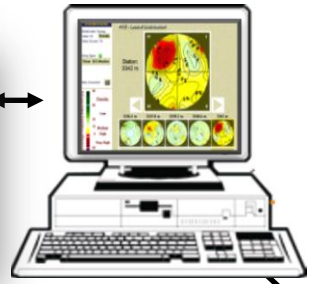
Automation:
guidance system

BEAM unit (placed in operator cabin)

A0 (+) measuring electrode
(e.g. cutter head, excavation tools)

System



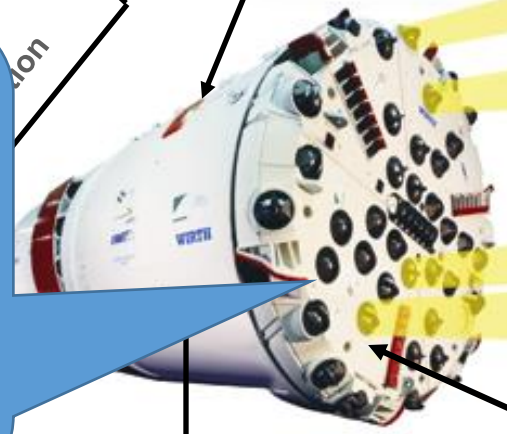


remote access

A1 (+)
guard electrode
(e.g. shield, cutter head, armed lining)

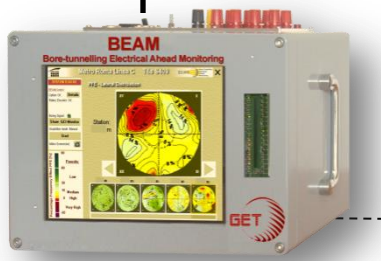
current beam

The focused-electrical system comprises the measuring electrode A0 which uses for the Integral mode the rotating and forward moving cutter head which therefore is well coupled to the face (1D forefield exploration).



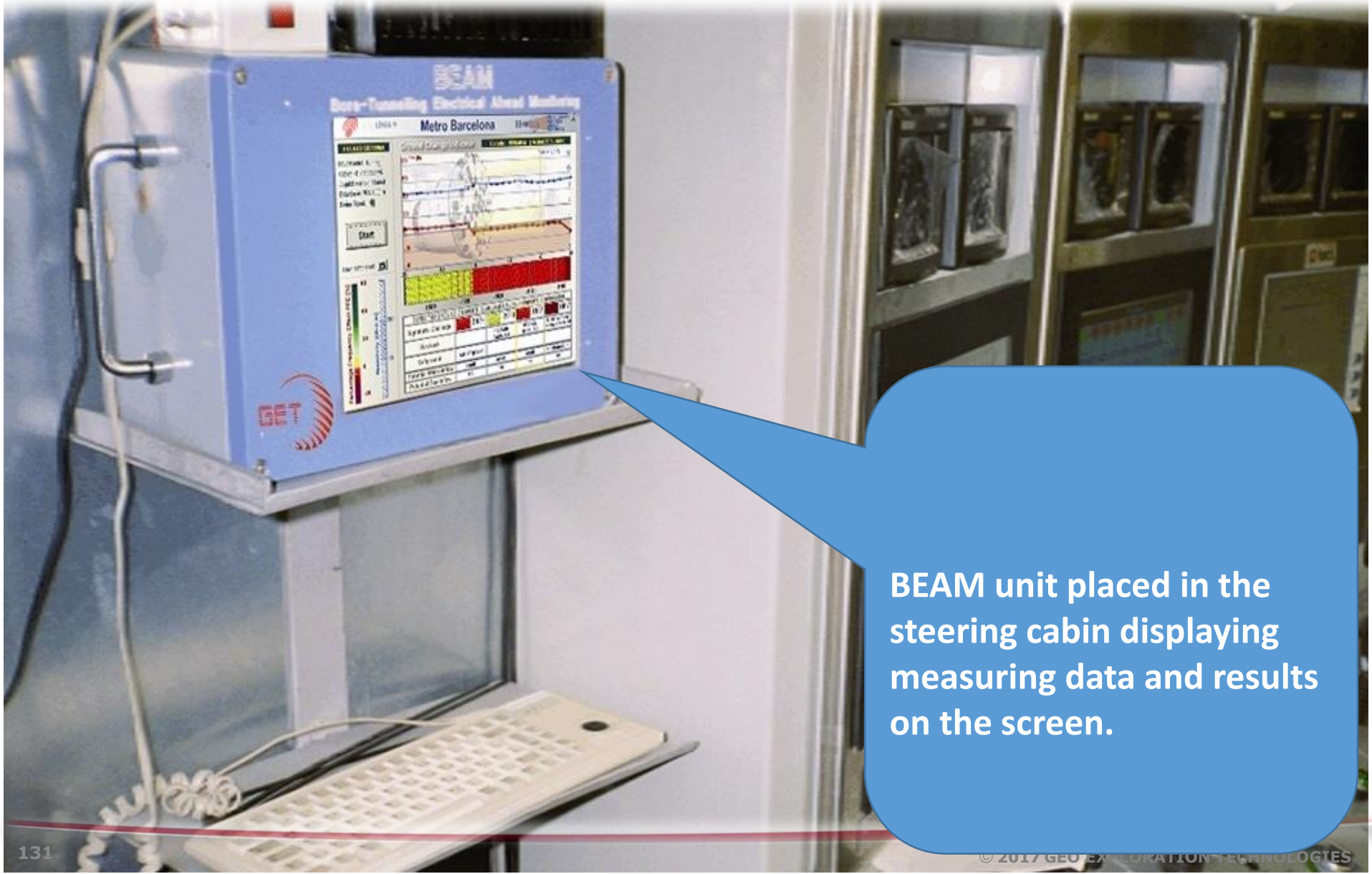
inside or outside the tunnel)

A0 (+) measuring electrode
(e.g. cutter head, excavation tools)



Automation:
guidance system

BEAM unit (placed in operator cabin)



BEAM unit placed in the steering cabin displaying measuring data and results on the screen.

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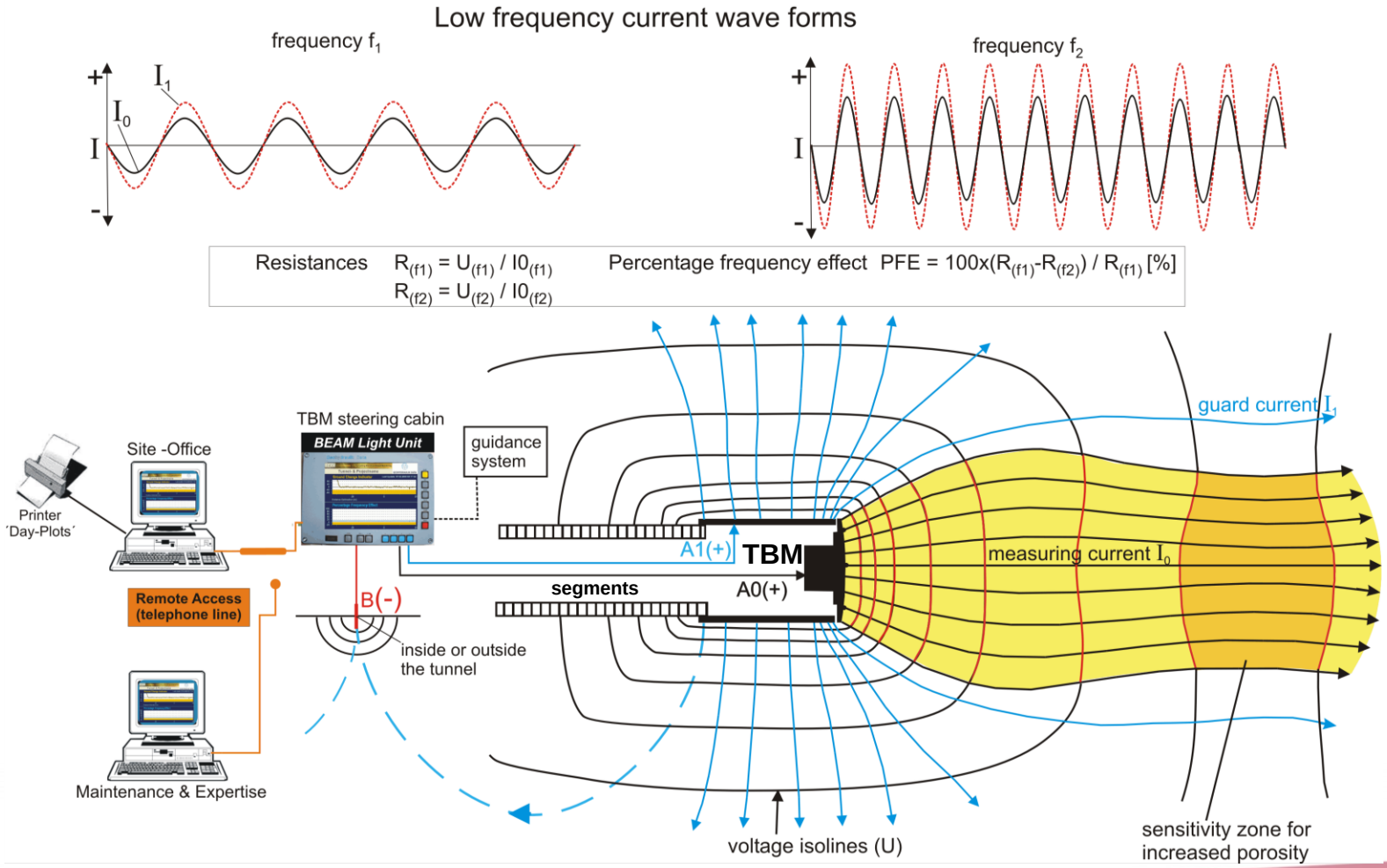
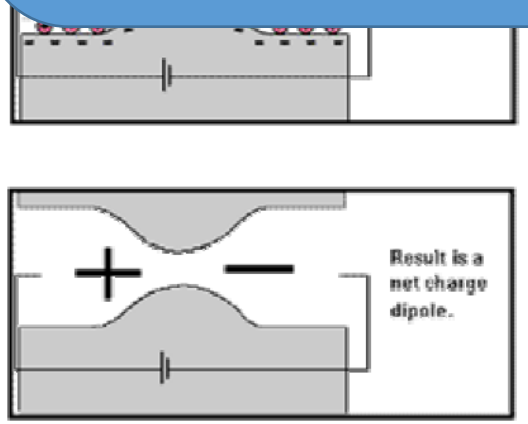
Focused Induced Polarization (IP): Electrical Field and Current Lines

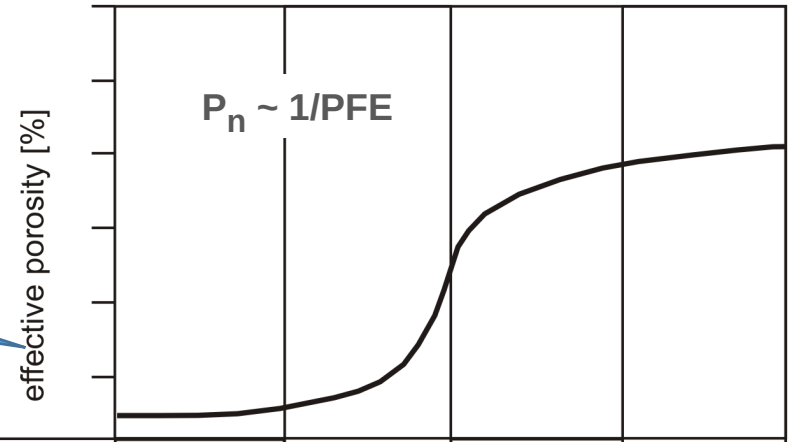


Origin of Induced Polarization Effects (PFE)

Hence, the PFE parameter is reciprocally related to the effective porosity, which provide a geological relevant property in hard rock and soft ground.



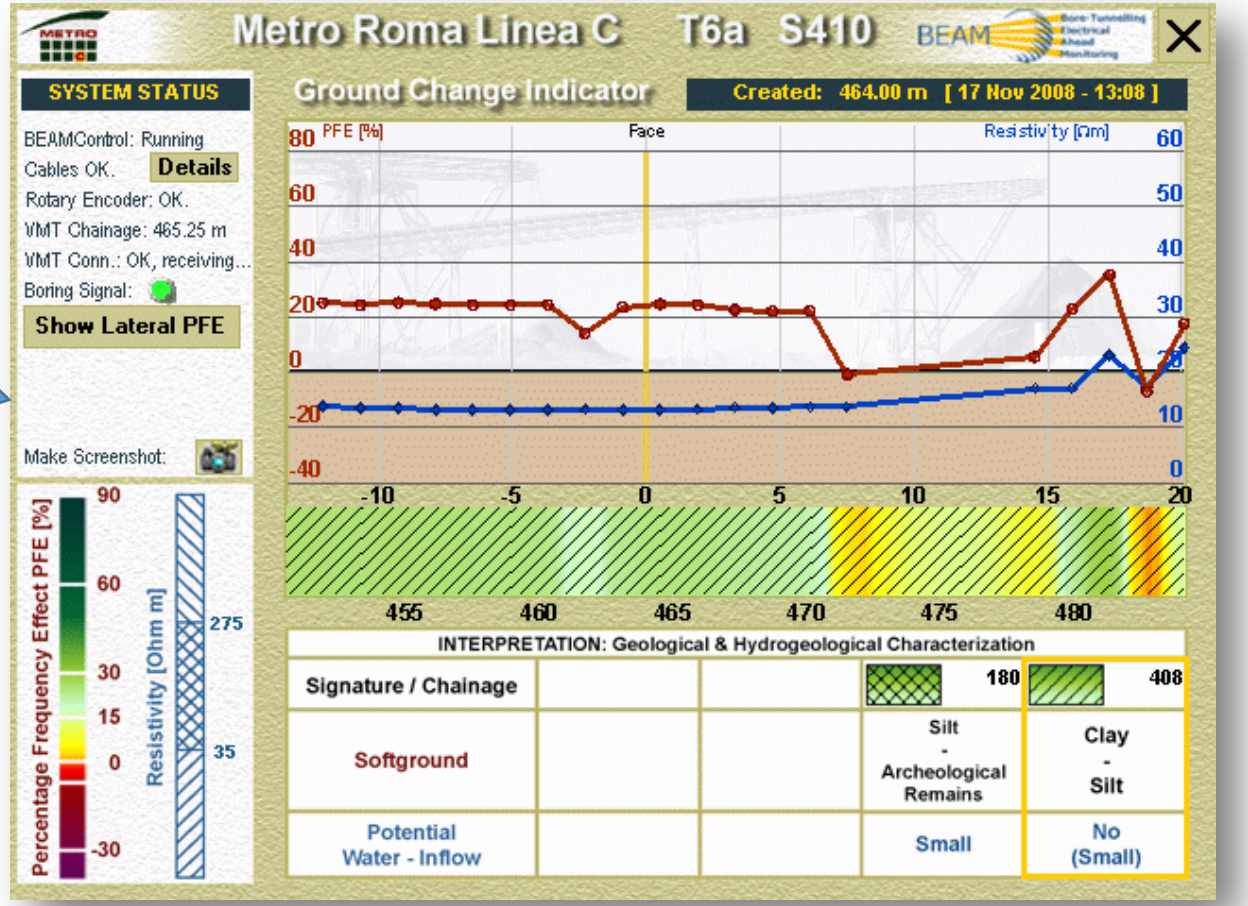
Membrane polarization reciprocal to porosity



Soft Ground	clay	silt	sand fs ms gs	gravel
Hard Rock	compact rock mass		fractured	faulted/ karstified
PFE [%]	>15		0-15	<0

Visualisation BEAM INTEGRAL (Animation)

This is a fast motion animation of a BEAM prediction during TBM drive of Rome Metro Line C. Different ground changes have been detected and characterized by various geoelectrical classes.



System: BEAM-SCAN inclusive INTEGRAL
TBM type/supplier: 4 EPB-TBMs Herrenknecht, each about 6.7 m boring diameter
Geology: gravel/sand, clay/silt and pyroclastics
Exploration targets: water-and air-filled cavities, archaeological remains

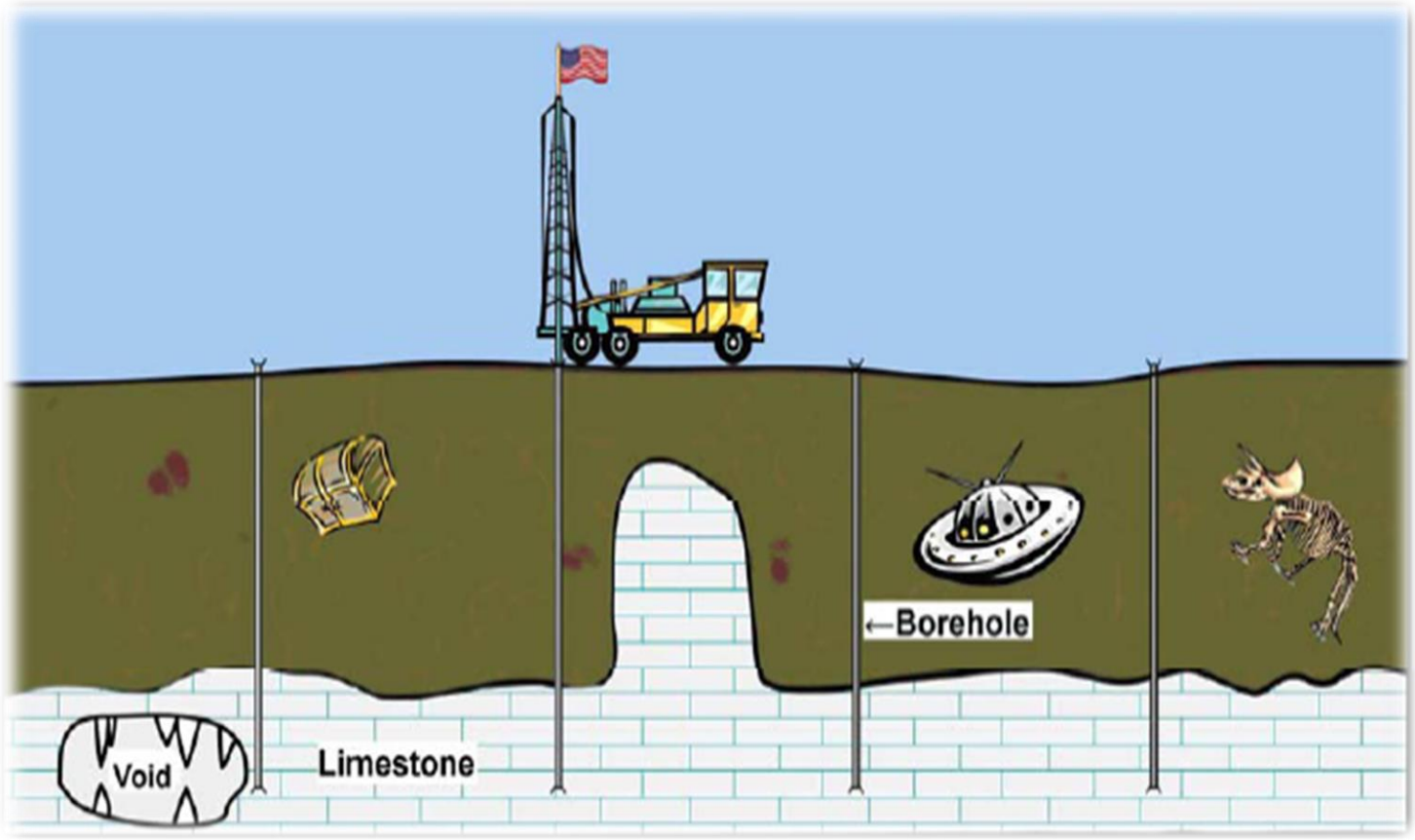
Publishing of BEAM results with kindly permission by METRO C

Limitations & Reasons for Failures?

- Wrong tool selection
- Method lacking desired resolution
- Geology ignored
- Calibration ignored
- Only single tool used
- Wrong initial model

Conclusion: Why Use Geophysics…….

- Low Cost
- Rapid Coverage
- Continuous information
- Optimization of dill holes
- Minimization of ‘Surprises’
- Early stage application…Better planning, smooth execution.



Thanks for your attention

Dr. Sanjay Rana
sanjay@parsan.biz
+91-9811168288