Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Ingenieur und Umwelt
Geophysik

Dr. Laurent Marescot
Dr. Jan van der Kruk

Who is Jan…

- Studied Electrical Engineering (Delft, Holland)
  - Internship at the Geological survey of Holland:
    first 3D shallow seismic survey with new system: SUMMIT
  - Master thesis (1995) project: an apparent resistivity method was developed employing magnetic dipoles.

- Several field surveys during a 3 monthly period at the Geological survey of Holland (TNO).

- Ph.D. (2001) Project "3D imaging of ground penetrating radar data"
  Section of Applied Geophysics, Delft University, Holland

- Ober-assistant (2001-) at the Applied and Environmental Geophysics group ETH Zurich

  "the development and improvement of numerical modeling, imaging and inversion of multi-offset, multi-component GPR & Seismic data"

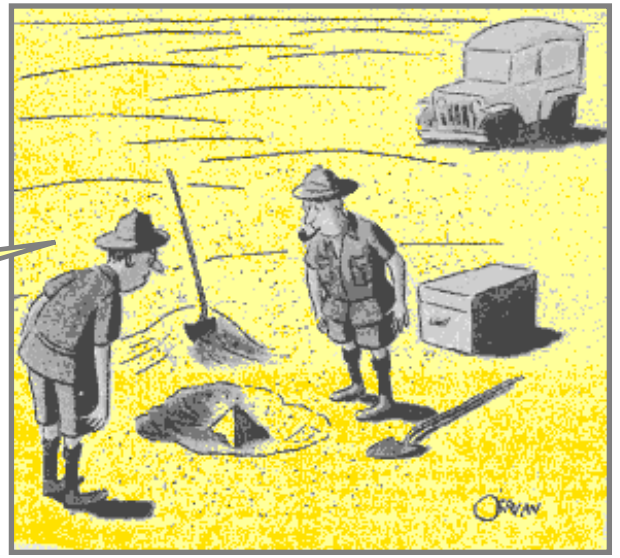
Who is Laurent…

- Studied geology and geophysics (University of Lausanne)
  - Diploma in Geophysics (1998): Resistivity methods for imaging Quaternary paleo-valleys (region Freiburg)
  - Diploma in Geology (2000): Tectonic modelling, geological mapping, mineralogy and paleontology in the Swiss molassic Basin (region Bern)
- PhD Thesis, 2004, (Uni. of Nantes, France, and Uni. Lausanne)
  - Forward and inverse resistivity modelling on complex three dimensional structures using the finite element method
- Several research periods in numerical modelling at the LCPC, Paris (2001-2004)
- Lecturer and assistant, University of Lausanne (2004-2005)
- Postdoc, AUG group, ETHZ since August 2005

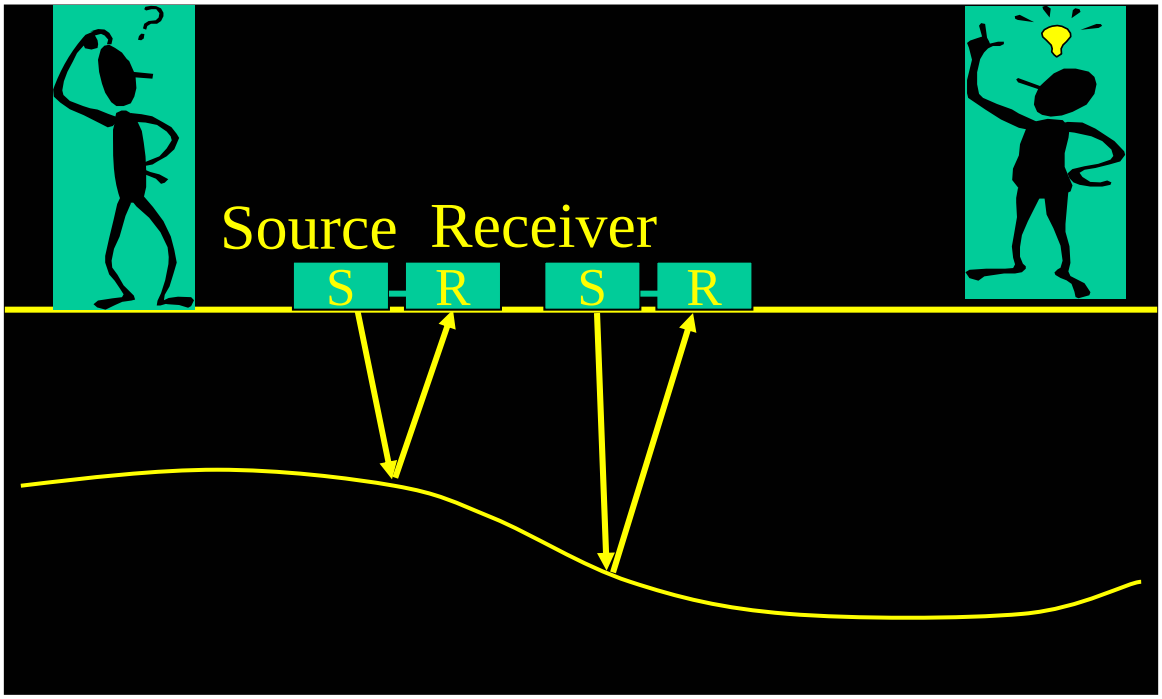
Geophysics?

- Apply the principles of physics to the study of the Earth
- Investigation of the interior of the Earth involves taking measurements at or near the Earth´s surface that are influenced by the internal distribution of physical properties. The analysis of these measurements reveals information on

  the Earth´s interior



Geophysical measurements: tool to obtain an image of the subsurface



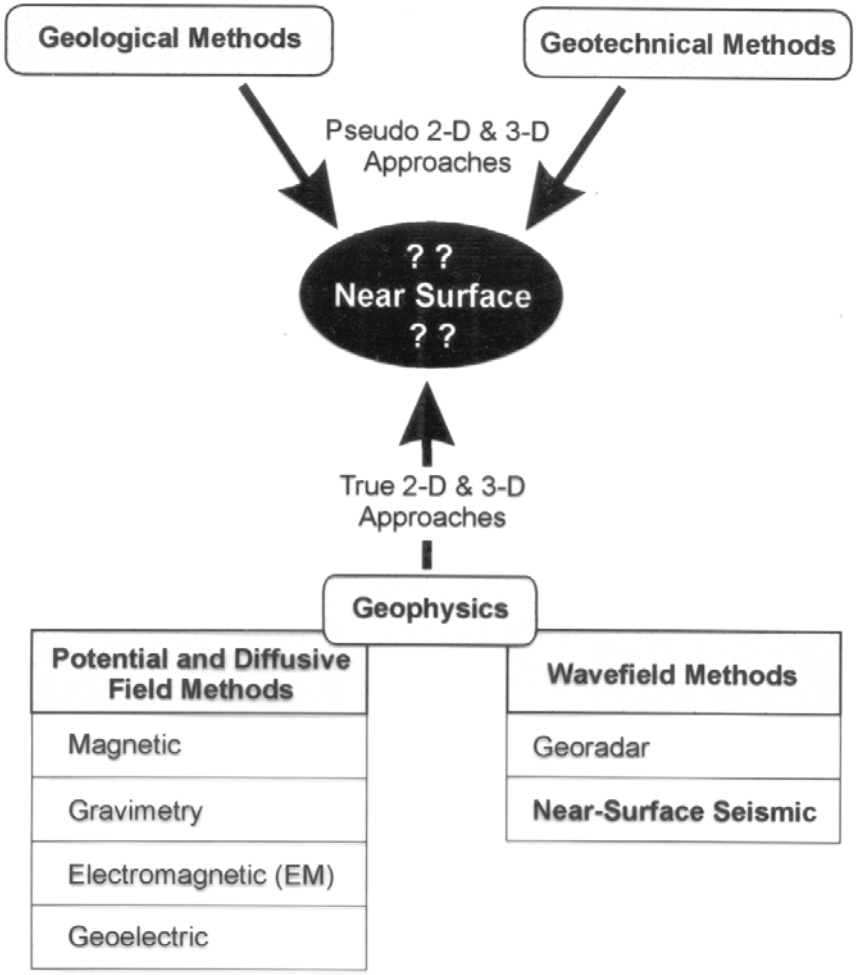
Measurement → Processing → Image

- Mapping of geological structure
- Detect objects

Aim of the course

- Complete overview on geophysical methods (potential, diffusive and wavefield methods)
- Understand the possibilities and limitations of geophysical techniques
- Understand the basis in qualitative and quantitative interpretation of geophysical data
- Give general basis for more advanced studies

Investigating the Near Surface



Often use a combination of geophysical methods to remove interpretation ambiguities

Geophysical methods

Potential methods: Laurent Marescot

- Gravimetry methods
- Magnetic methods
- Electrical methods

Diffusive methods Laurent Marescot

- Electromagnetic methods

Wavefield methods Jan van der Kruk

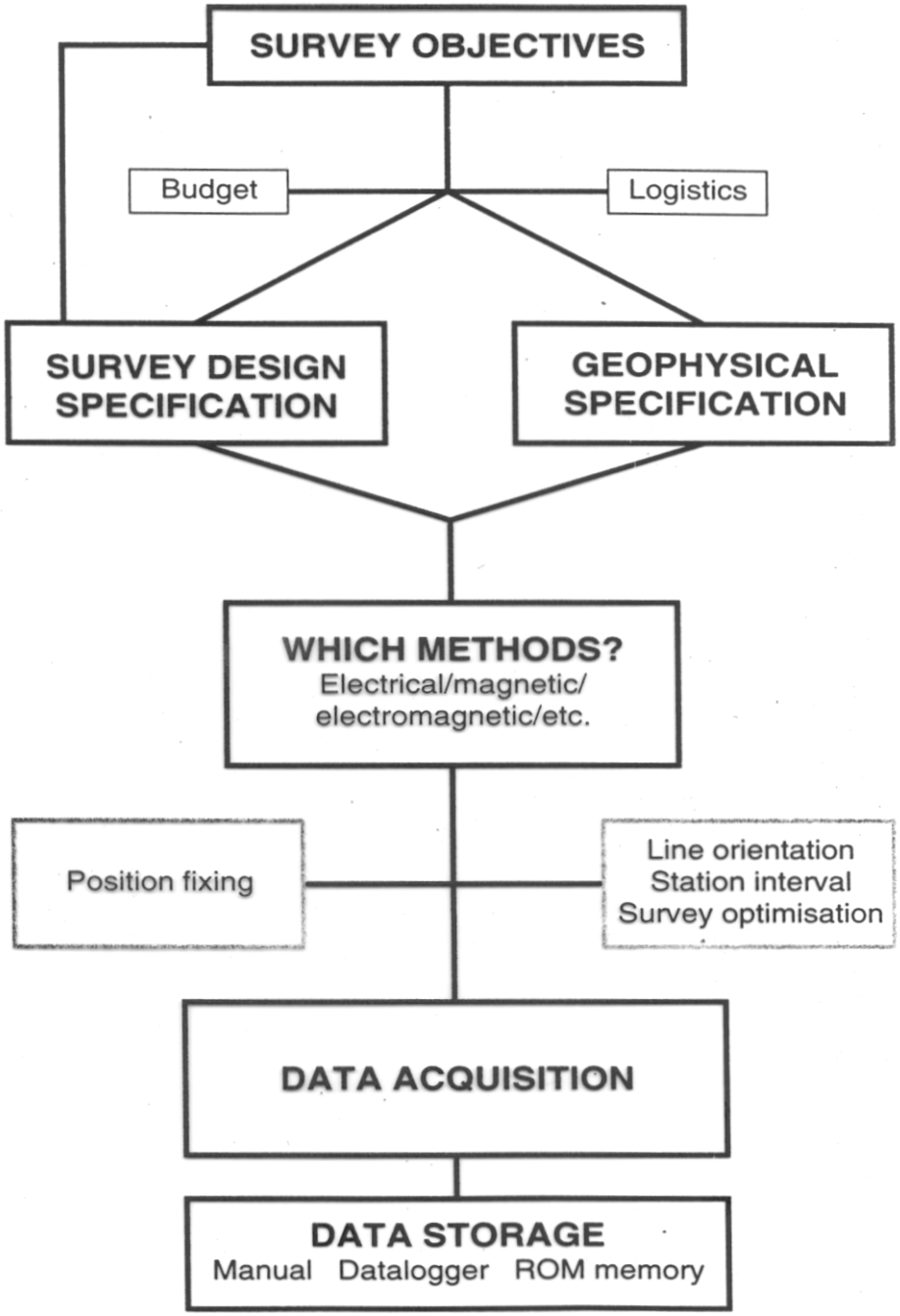
- Georadar
- Seismic methods

Structure of a lecture

Each topic will cover:

1. Physical properties of rocks/geology
2. Basic equations for the method
3. Survey strategies and interpretation
4. Summary of the method: case histories and examples
5. Conclusions

Exercises will strengthen the explanations


SURVEY OBJECTIVES
Budget
Logistics
SURVEY DESIGN SPECIFICATION
GEOPHYSICAL SPECIFICATION
WHICH METHODS?
Electrical/magnetic/
electromagnetic/etc.
Position fixing
Line orientation
Station interval
Survey optimisation
DATA ACQUISITION
DATA STORAGE
Manual Datalogger ROM memory

What is geophysics?

- Physics of the solid Earth
- Exploration of the structure and dynamic of the solid Earth using physical methods
- Non-expensive and non-invasive methods
- Geophysical information is less discrete than information from boreholes (and less expensive…). But does not dispense with the need for drilling! Geophysics can often optimize drilling requirements

What is geophysics?

Various scales...

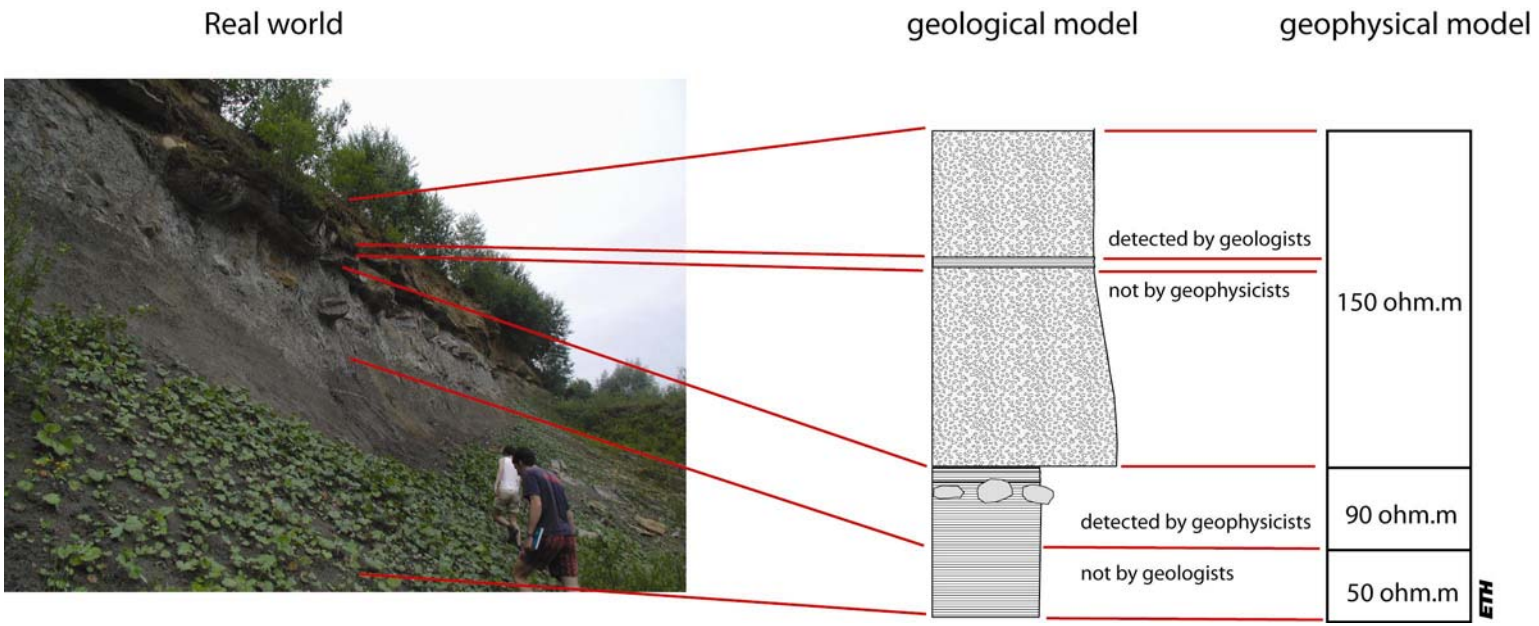
- Global geophysics 10^3 to 10^6 m
- Exploration geophysics 10^2 to 10^4 m
- Environmental and engineering geophysics $<10^2$ m

Various sources...

- Natural field sources (e.g. gravitational field) or artificially generated sources (e.g. seismic waves)
- Natural field source methods are more simple to carry out but give less resolved pictures than artifical source methods

Definition: model

A model is a simple and ideal view of a physical reality

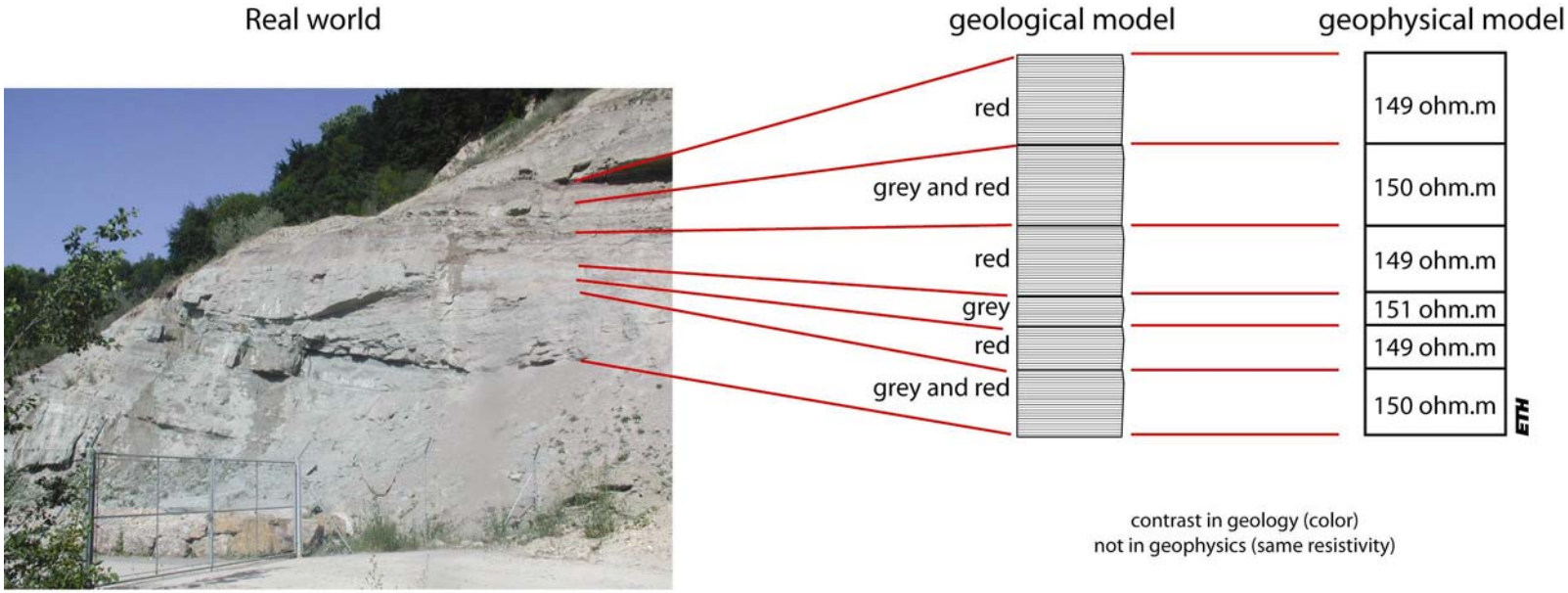


Operative physical properties

- Seismic: density and elastic moduli
- Gravity: density
- Magnetic: magnetic susceptibility and remanence
- Electrical resistivity: electrical conductivity
- Electrical induced polarization: electrical capacitance
- Self potential: electrical conductivity
- Electromagnetic: electrical conductivity and inductance
- Radar (GPR): dielectric constant

Definition: contrast

To characterize different material using geophysics, a contrast must exist (i.e. a difference in the physical properties)



Environmental/engineering geophysics

- Hydrogeology
- Exploration of waste sites and pollutant
- Exploration for bulk mineral deposits (sand and gravel)
- Ground stability, permafrost, glaciology
- Archaeology
- Cavity detection, cable location etc
- Subsurface geological imaging for civil engineering
- Bulk modulus and shear modulus for civil engineering
- Alternative energy sources

Environmental Geophysics

	Geology	*Hydrology*	*Waste sites*	*Slope stability*	*Archaeology*
Gravity methods	+	-	o	-	o
Magnetic m.	+	-	+	-	+
Geoelectrical m.	+	+	+	+	+
Electromagnetic m.	+	+	+	+	+
Georadar	+	+	o	+	+
Seismic m.	+	+	o	+	o

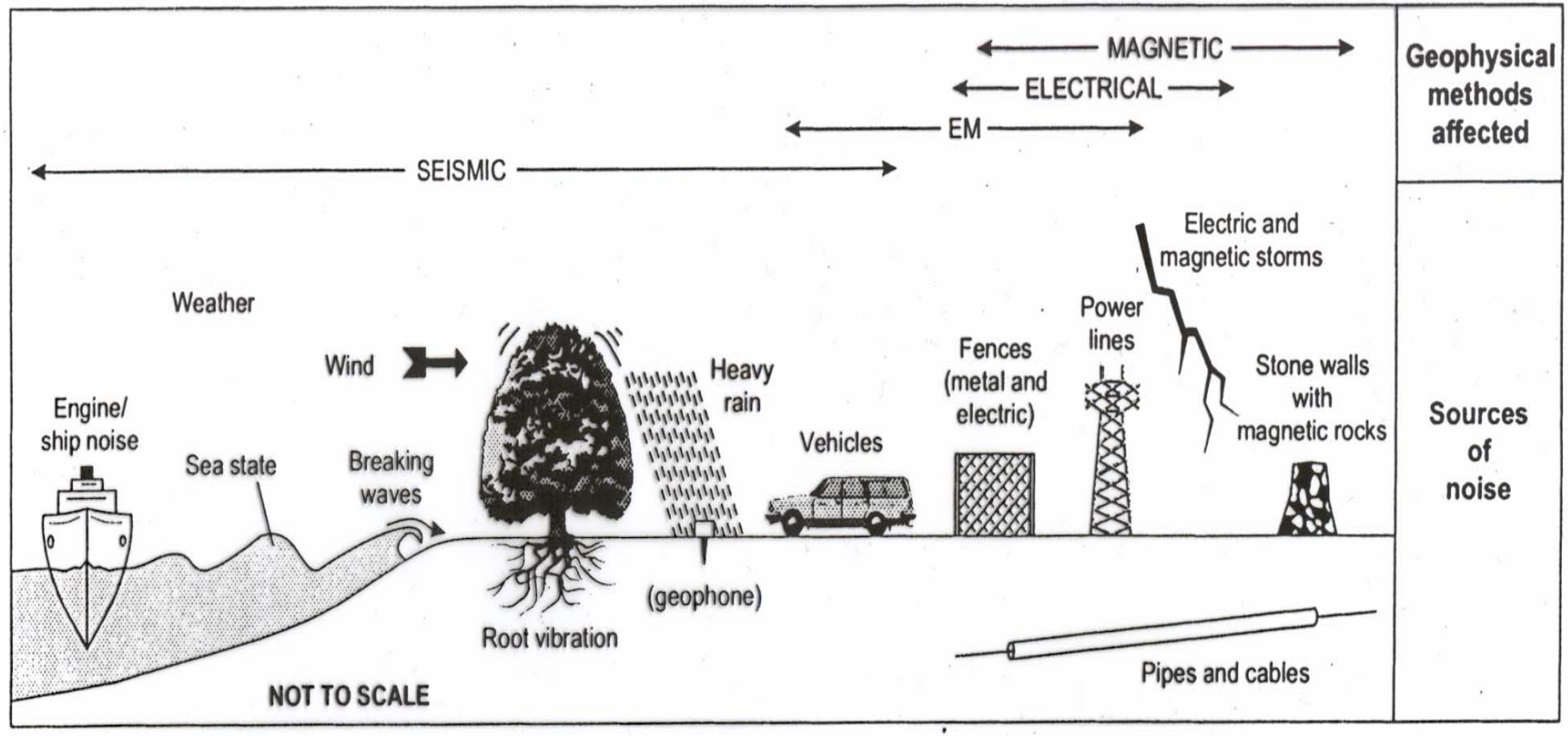
\+ appropriate method o partly appropriate method - inappropriate method

Engineering Geophysics

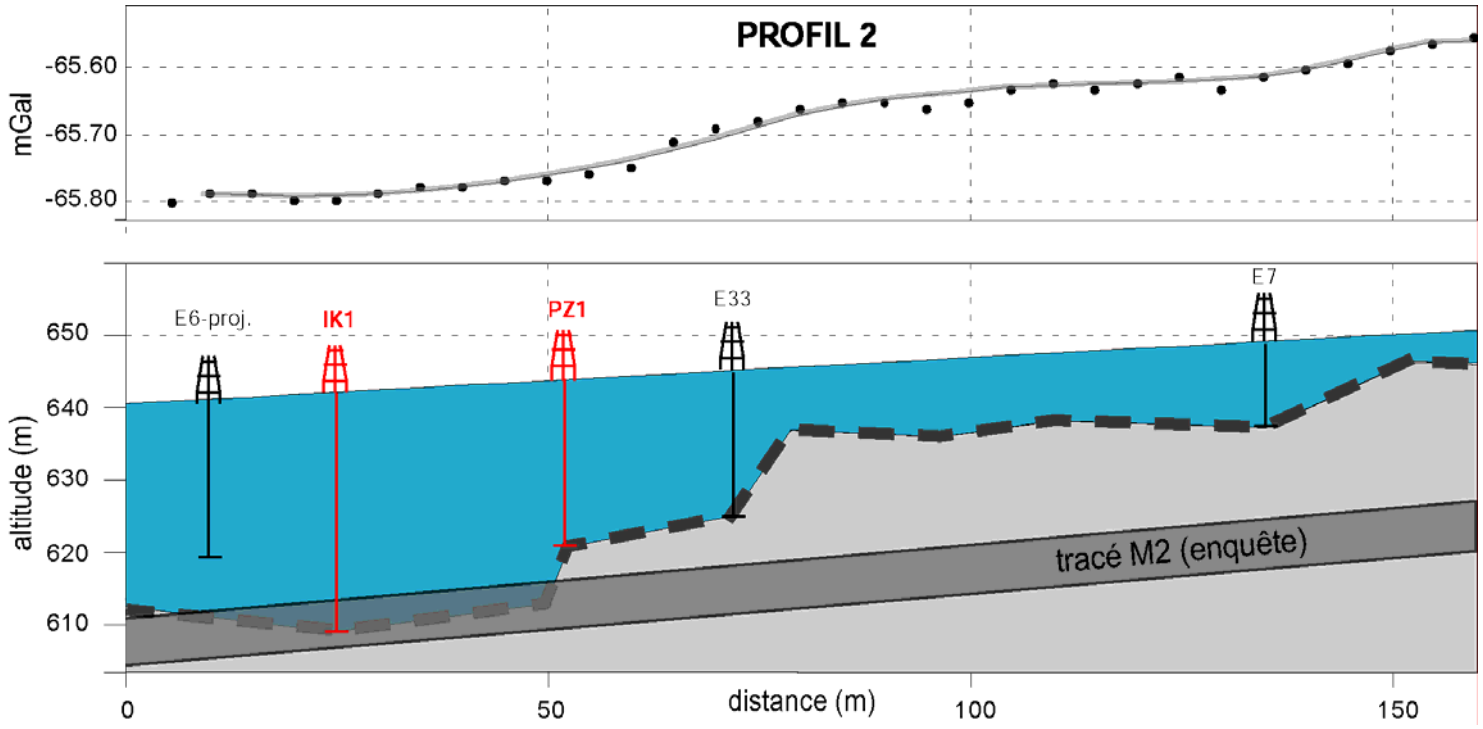
	Depth to bedrock	*Bulk modulus, shear modulus*	*Faults, cavities*	*Permafrost*	*Pipes, cables*
Gravity methods	+	-	+	-	-
Magnetic m.	o	-	+	o	+
Geoelektrical m.	+	-	+	+	o
Electromagnetic m.	+	-	+	+	+
Georadar	+	-	+	+	+
Seismic m.	+	+	o	o	-

+ appropriate method o partly appropriate method - inappropriate method

Noise in geophysical data acquisition



Gravity

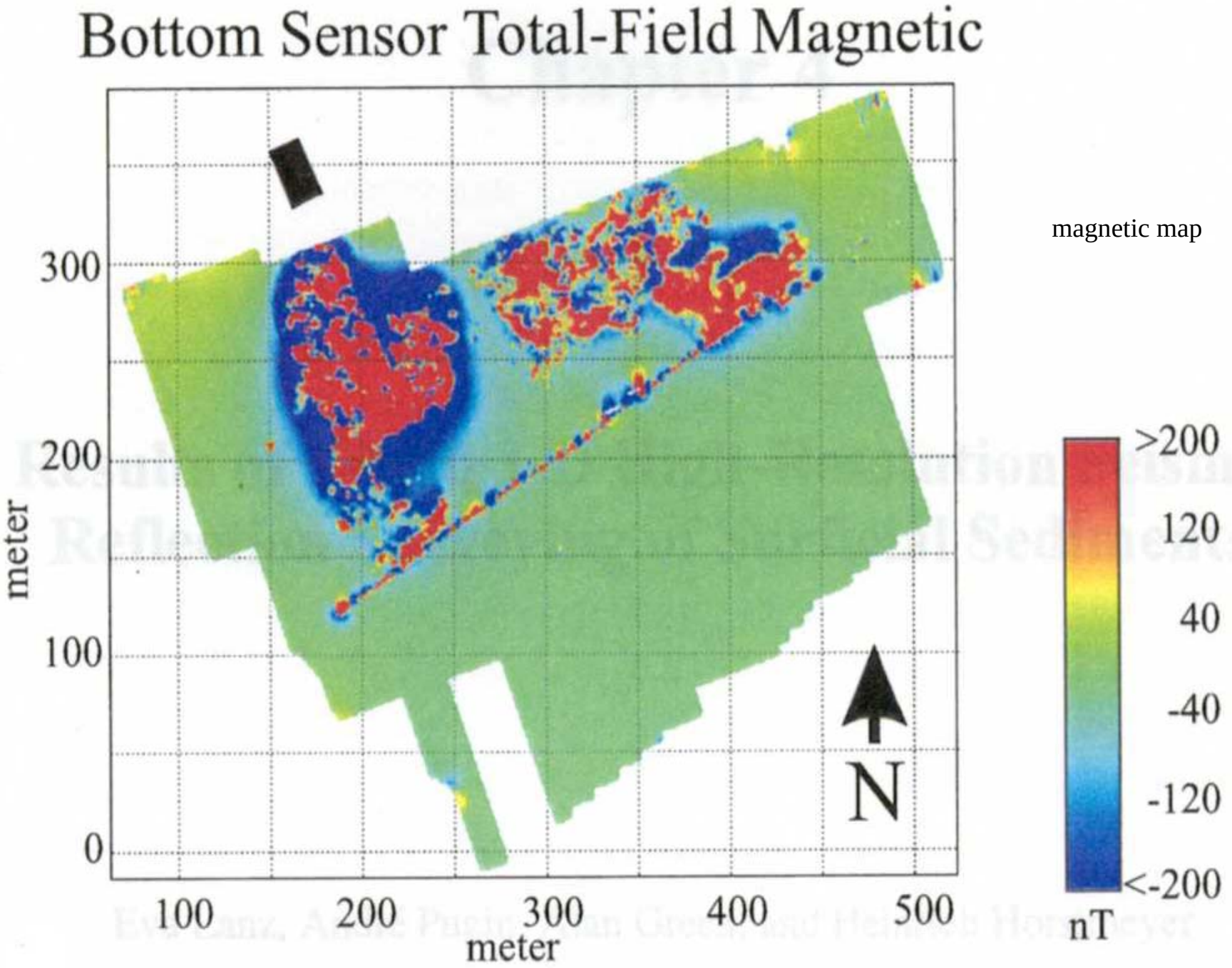


micro-gravimetry in urban environment

Source: P. Radogna, University of Lausanne

Magnetic

magnetic surveys
on landfills

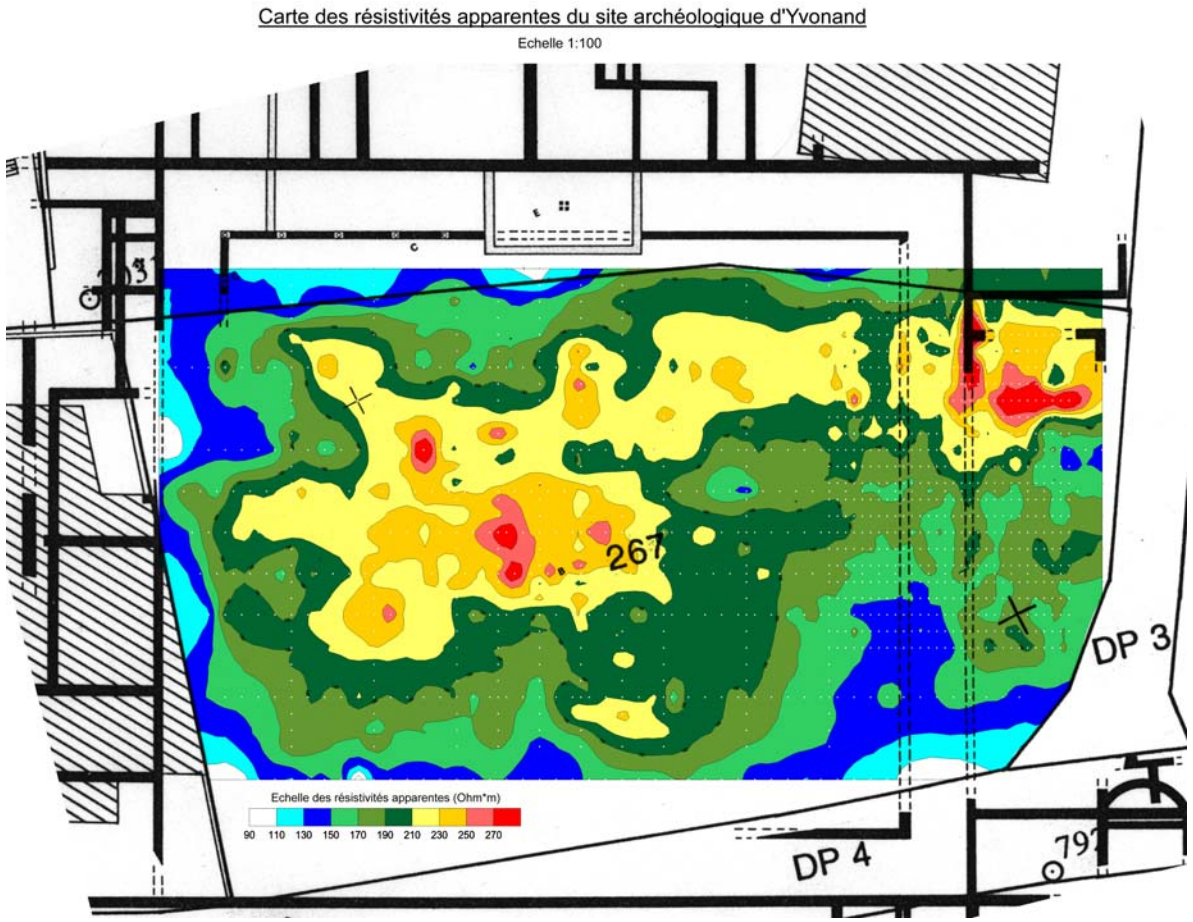


magnetic map

Electrical methods

resistivity mapping
in the Alps

Electrical methods

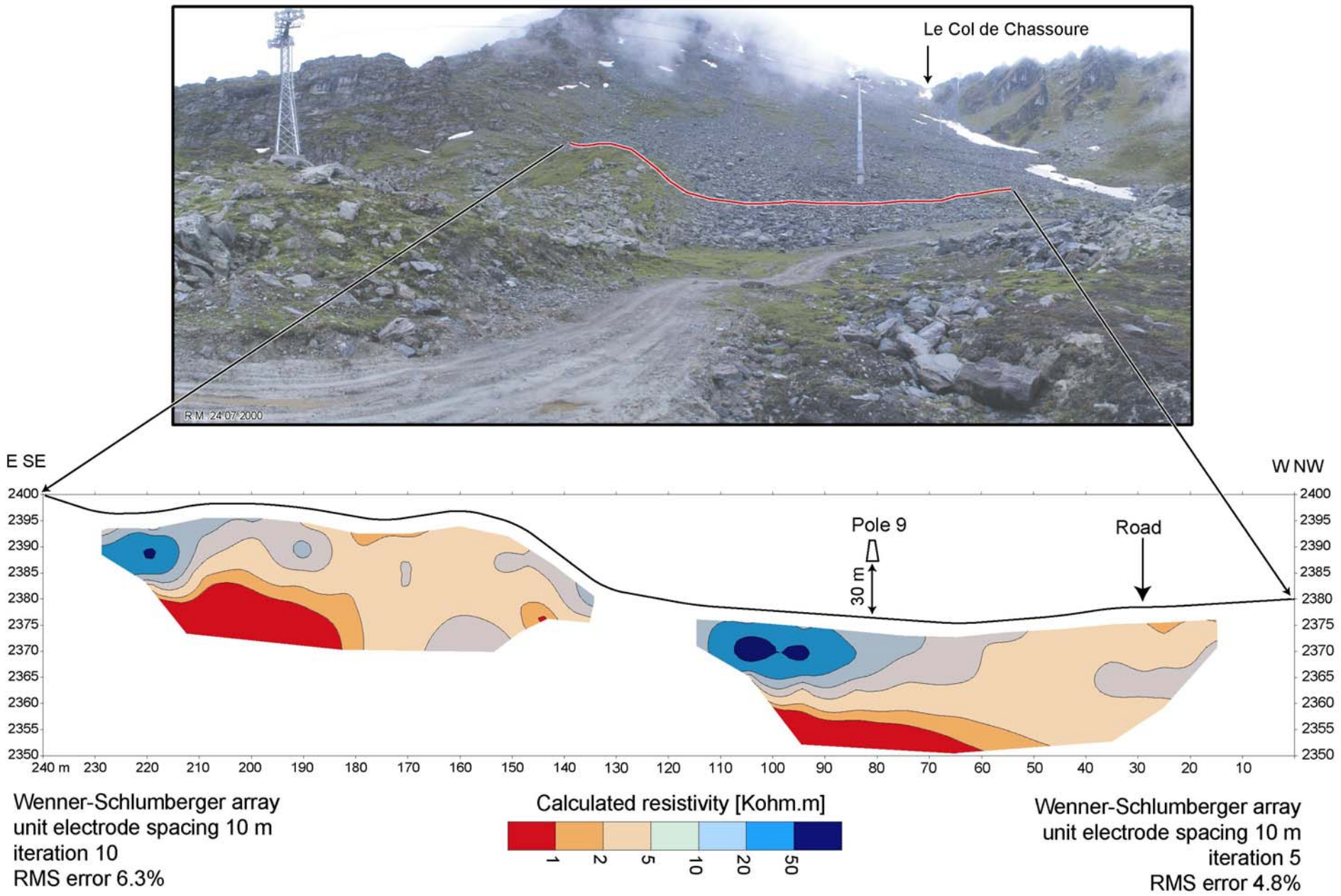


apparent resistivity map
AB=4m

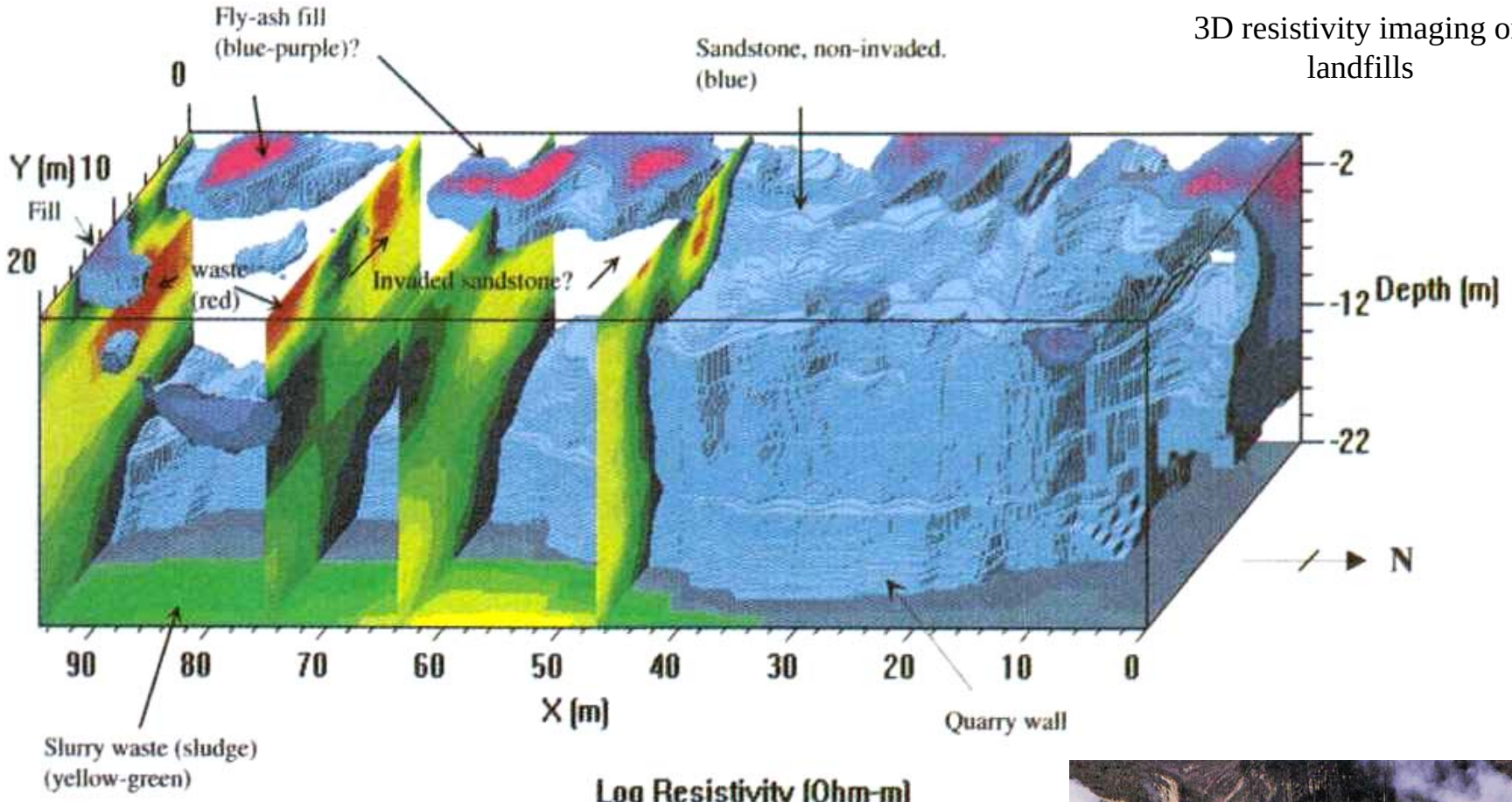
Electrical methods

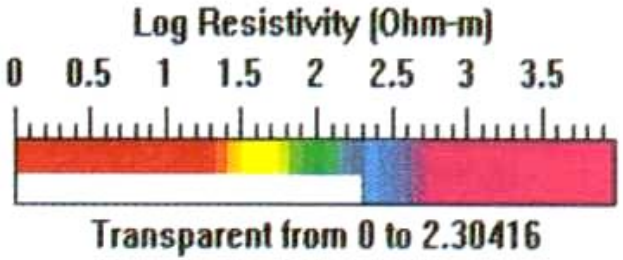
resistivity imaging
on a rock glacier

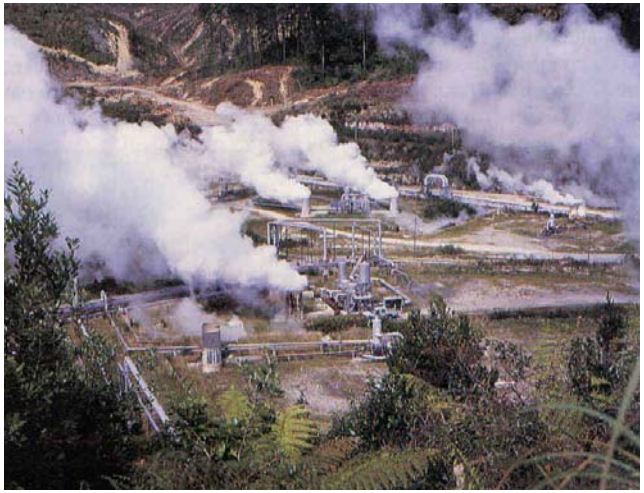
inverted resistivity 2D profiles



3D resistivity imaging on landfills

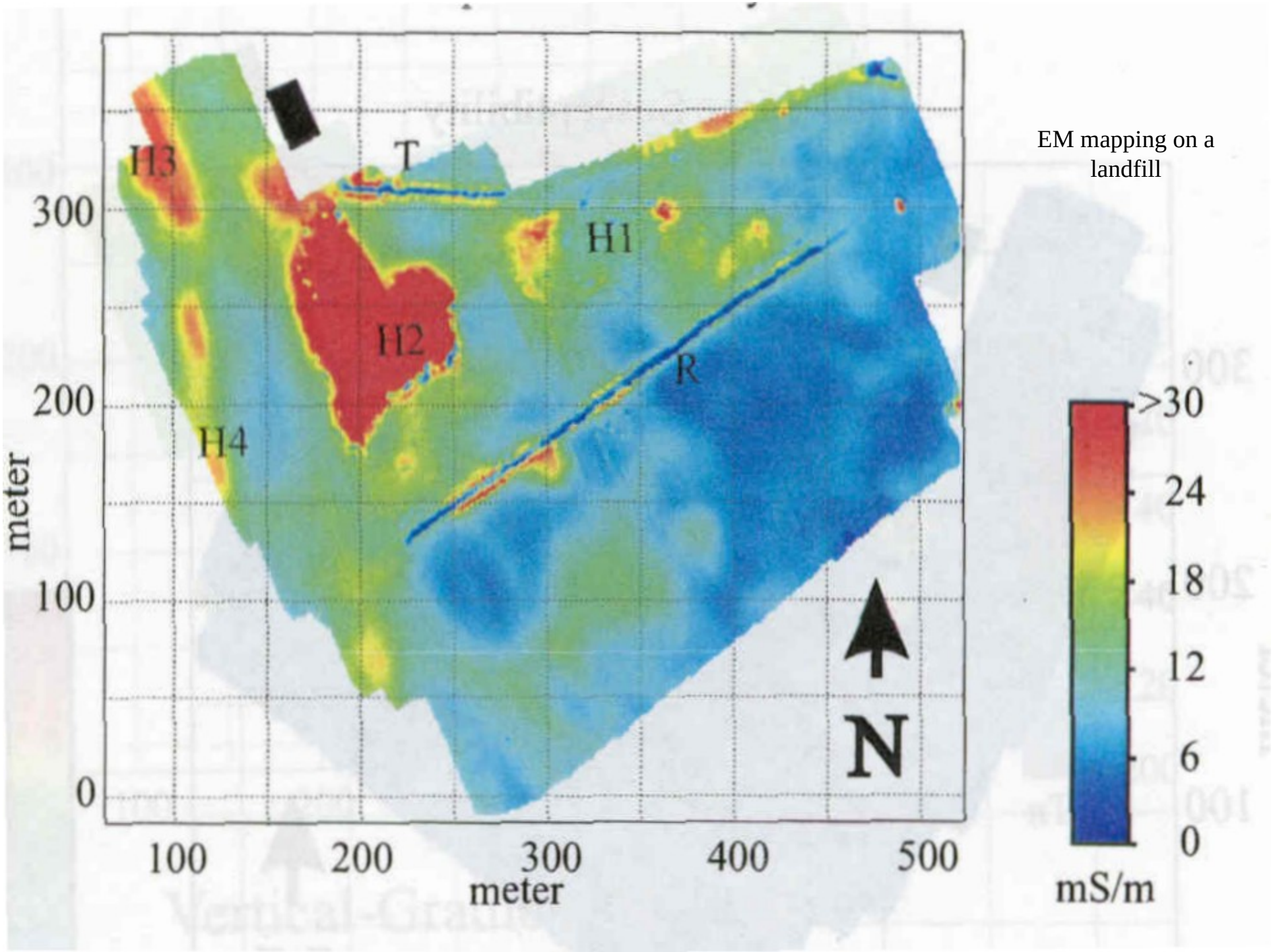




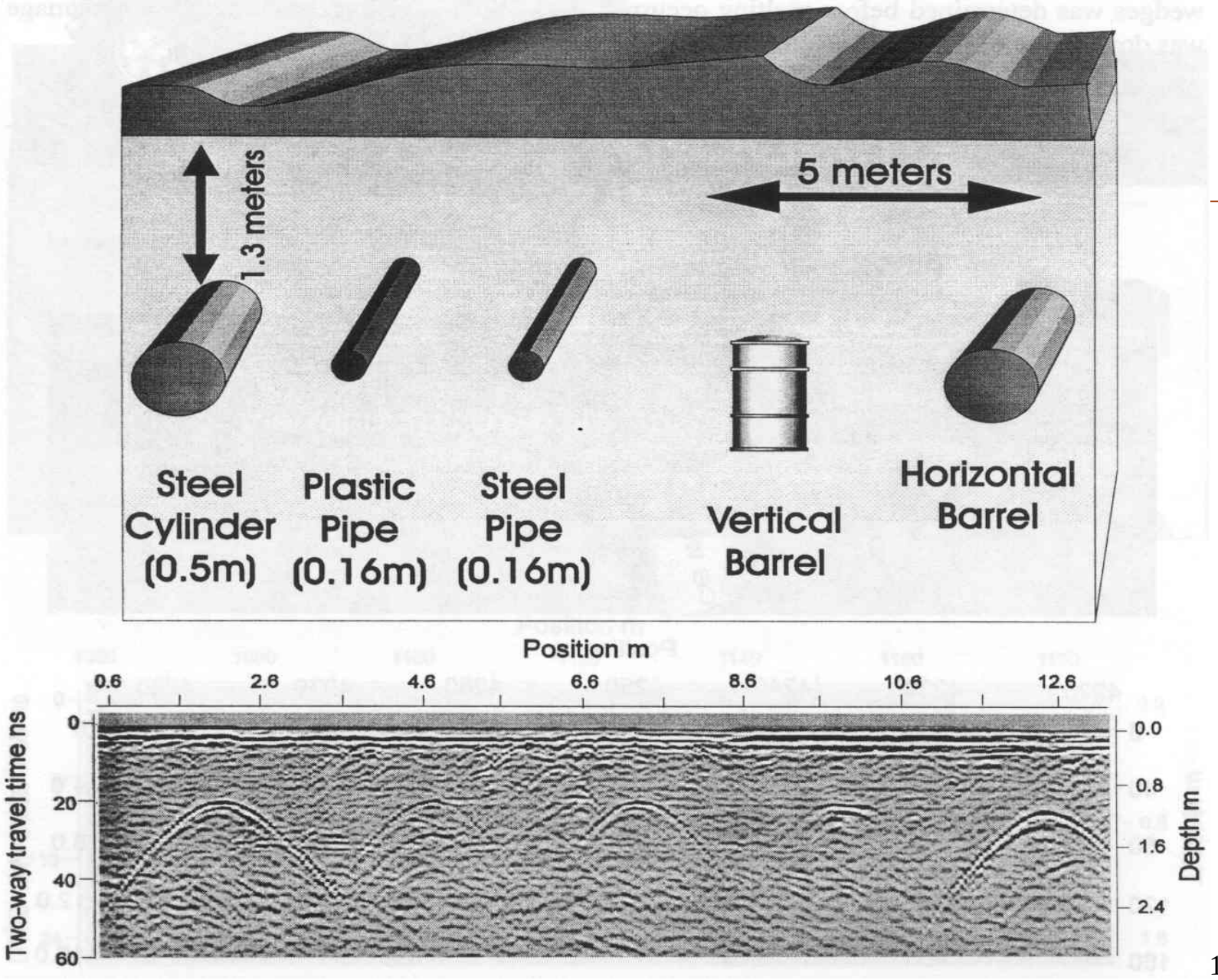


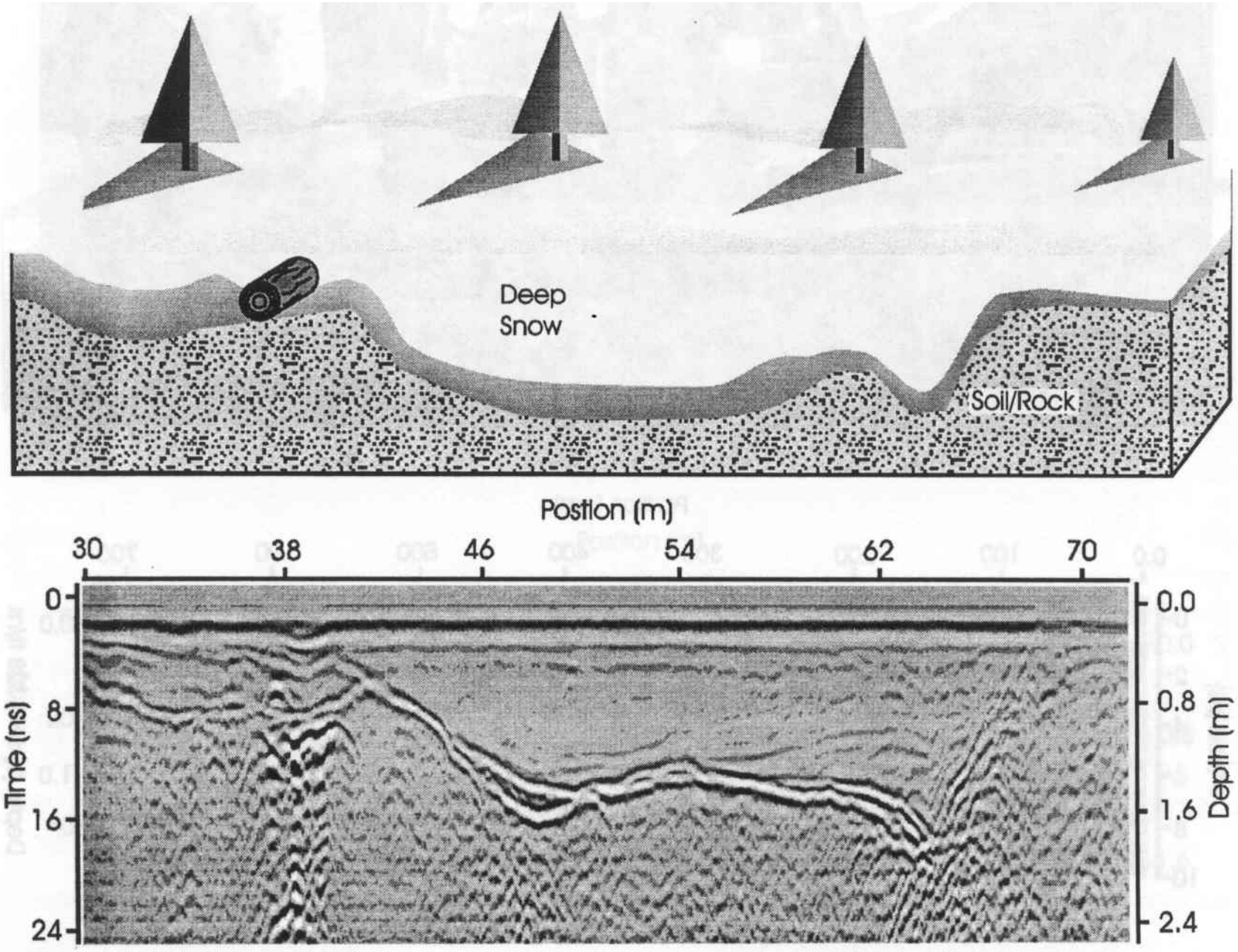
Electromagnetic methods

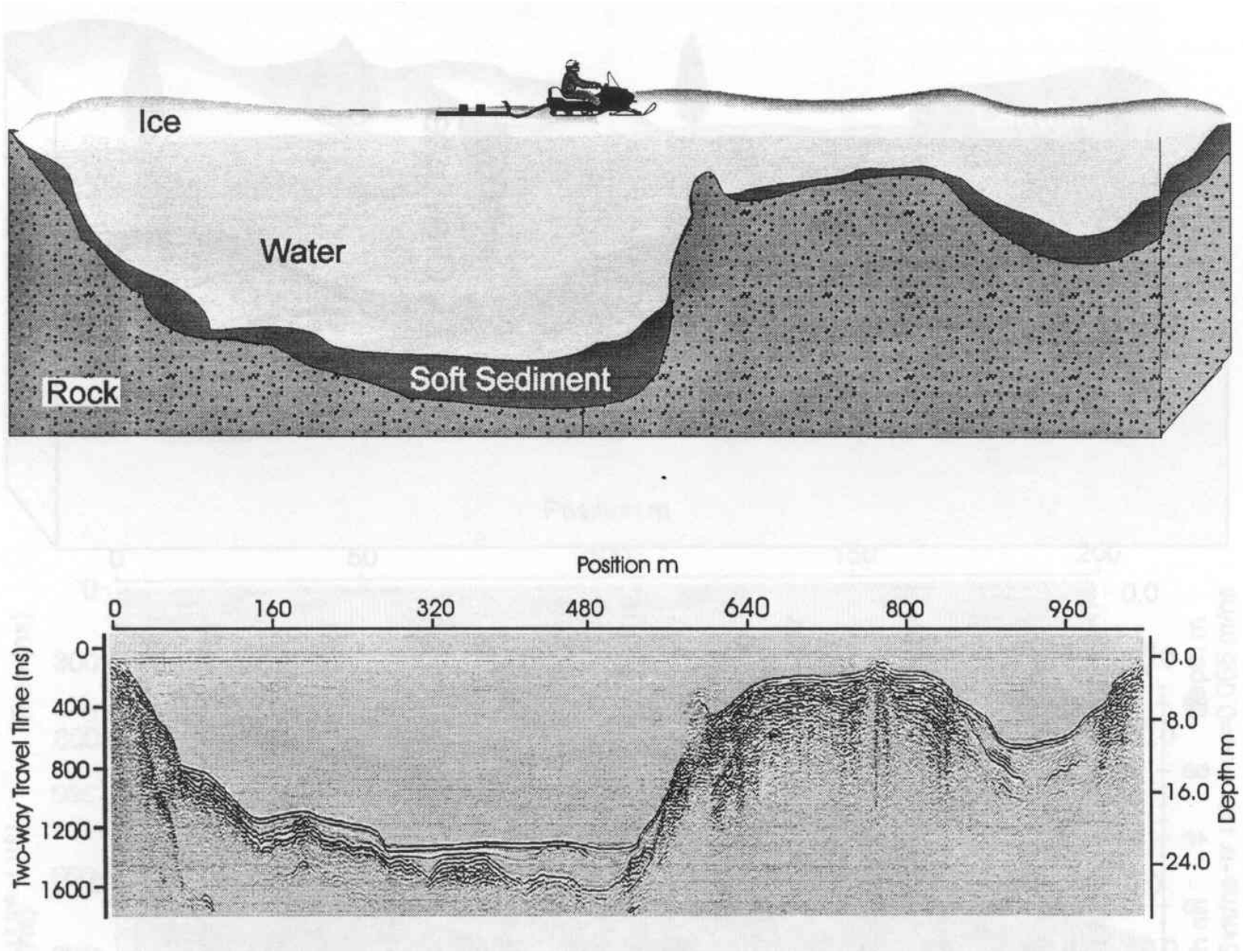
EM survey tools

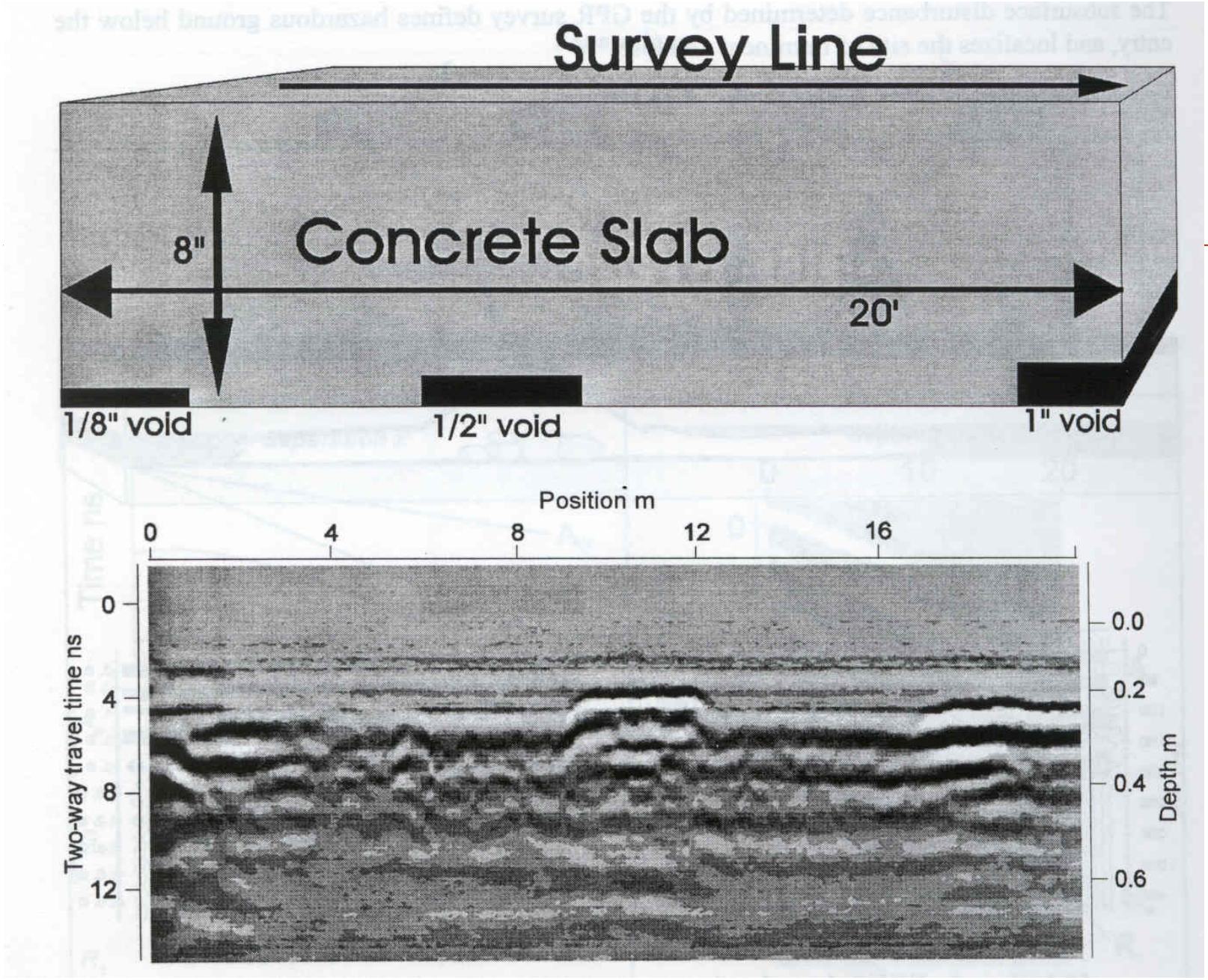

EM mapping on a landfill
H3
T
H1
H2
R
H4
N
meter
300
200
100
0
100
200
300
400
500
meter
>30
24
18
12
6
0
mS/m

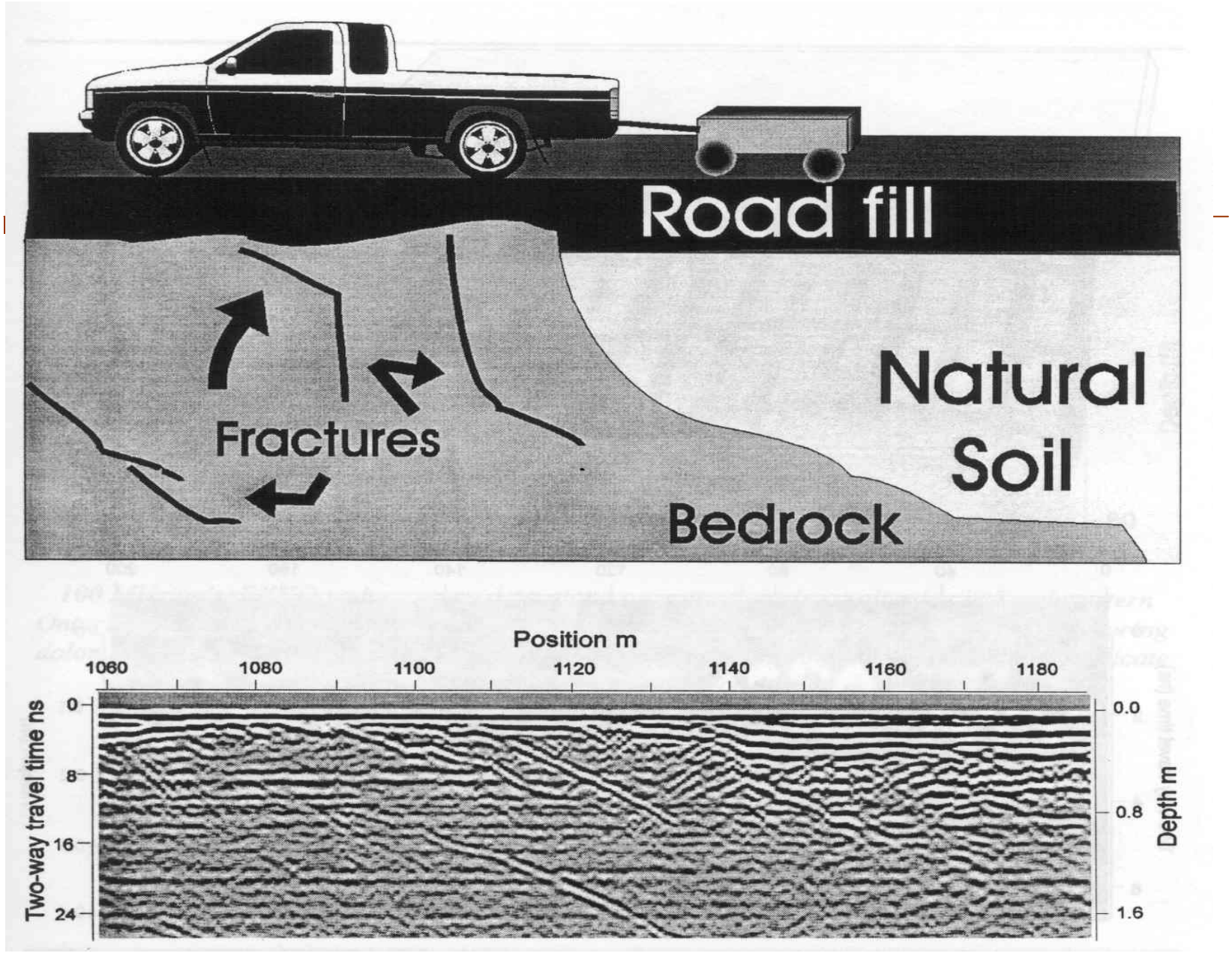
Georadar

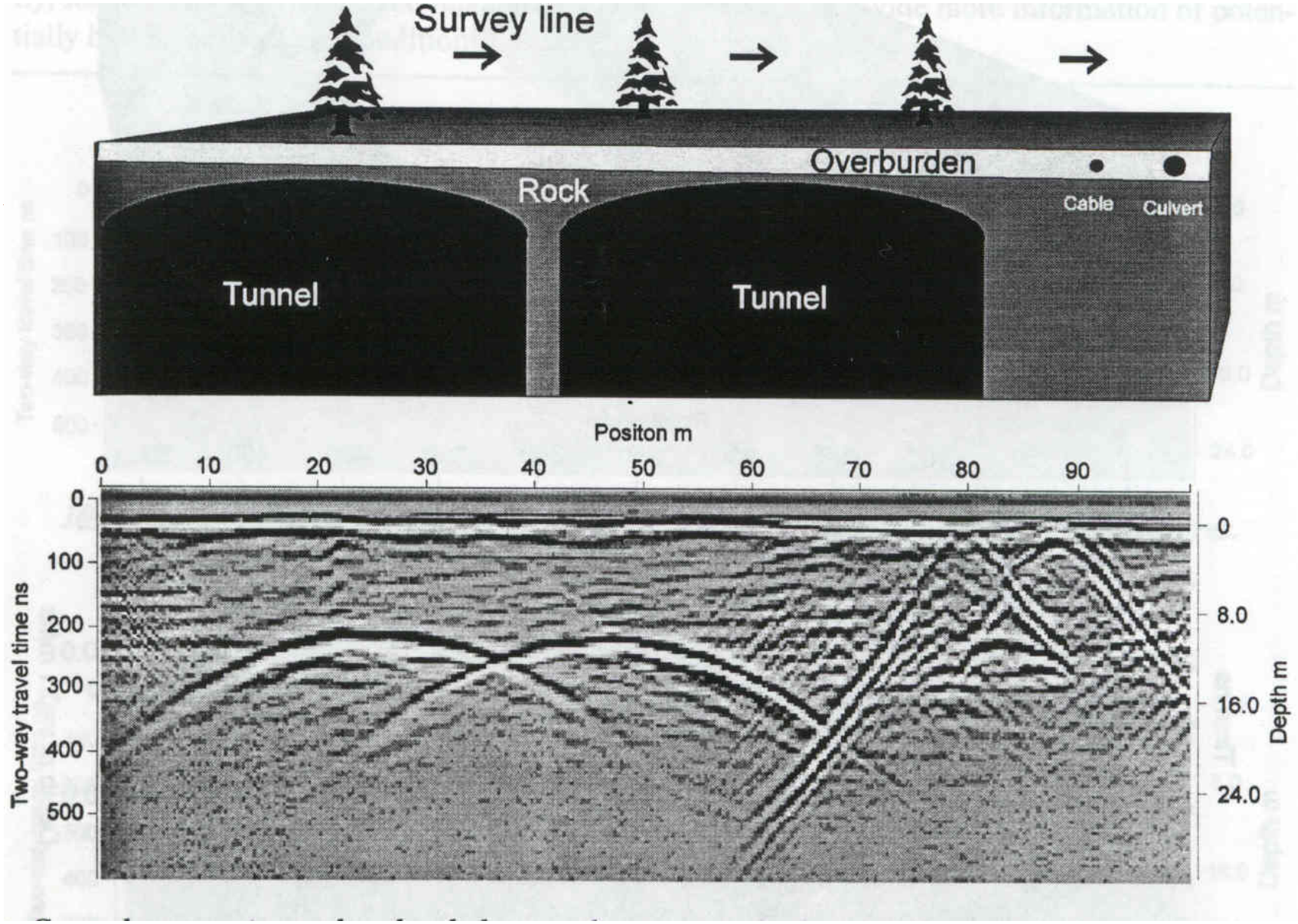

1.3 meters
5 meters
Steel Cylinder (0.5m)
Plastic Pipe (0.16m)
Steel Pipe (0.16m)
Vertical Barrel
Horizontal Barrel
Position m
0.6
2.6
4.6
6.6
8.6
10.6
12.6
Two-way travel time ns
0
20
40
60
Depth m
0.0
0.8
1.6
2.4

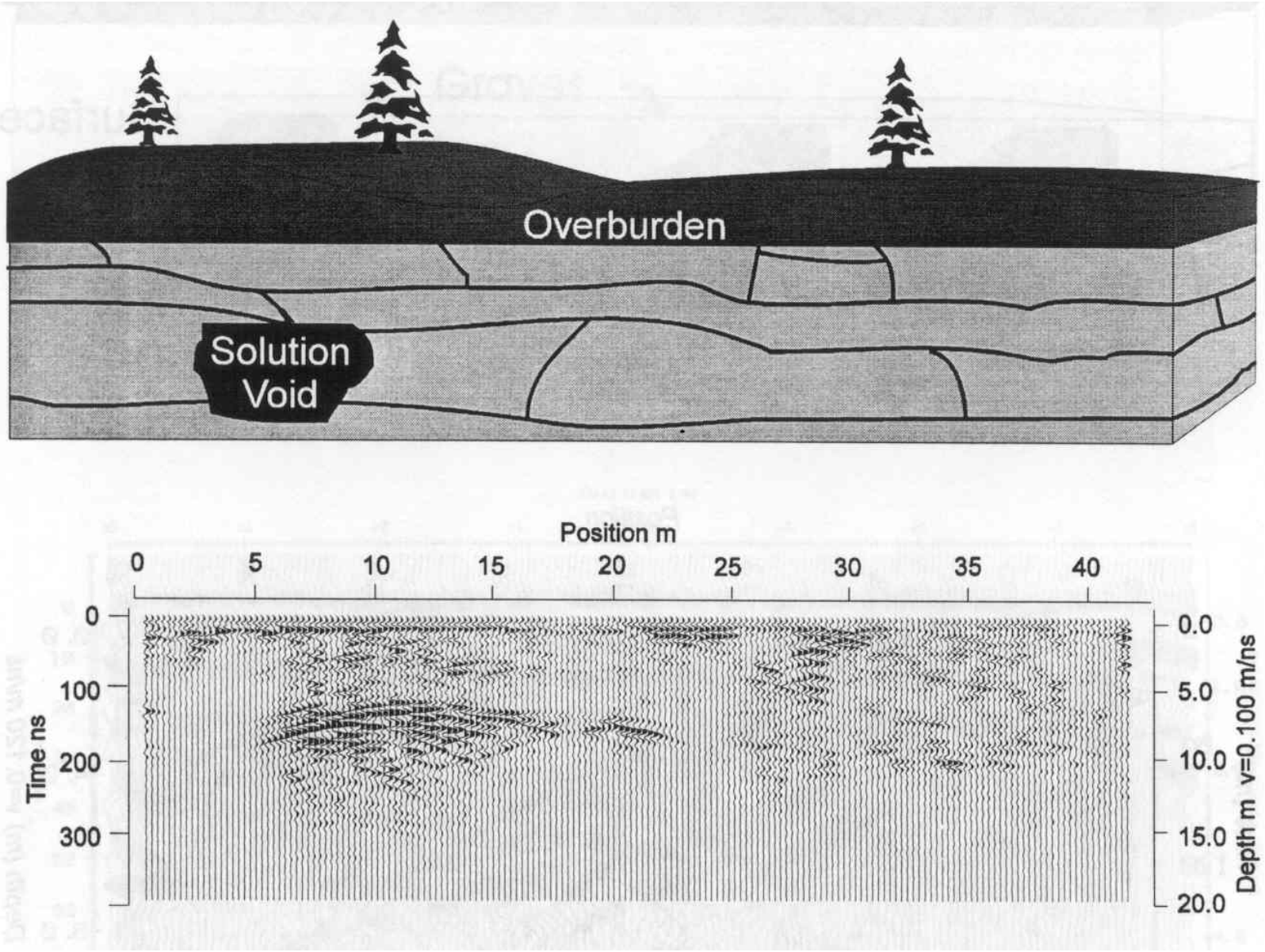

Deep
Snow
Soil/Rock
Postion (m)
30
38
46
54
62
70
0
8
16
24
Time (ns)
0.0
0.8
1.6
2.4
Depth (m)

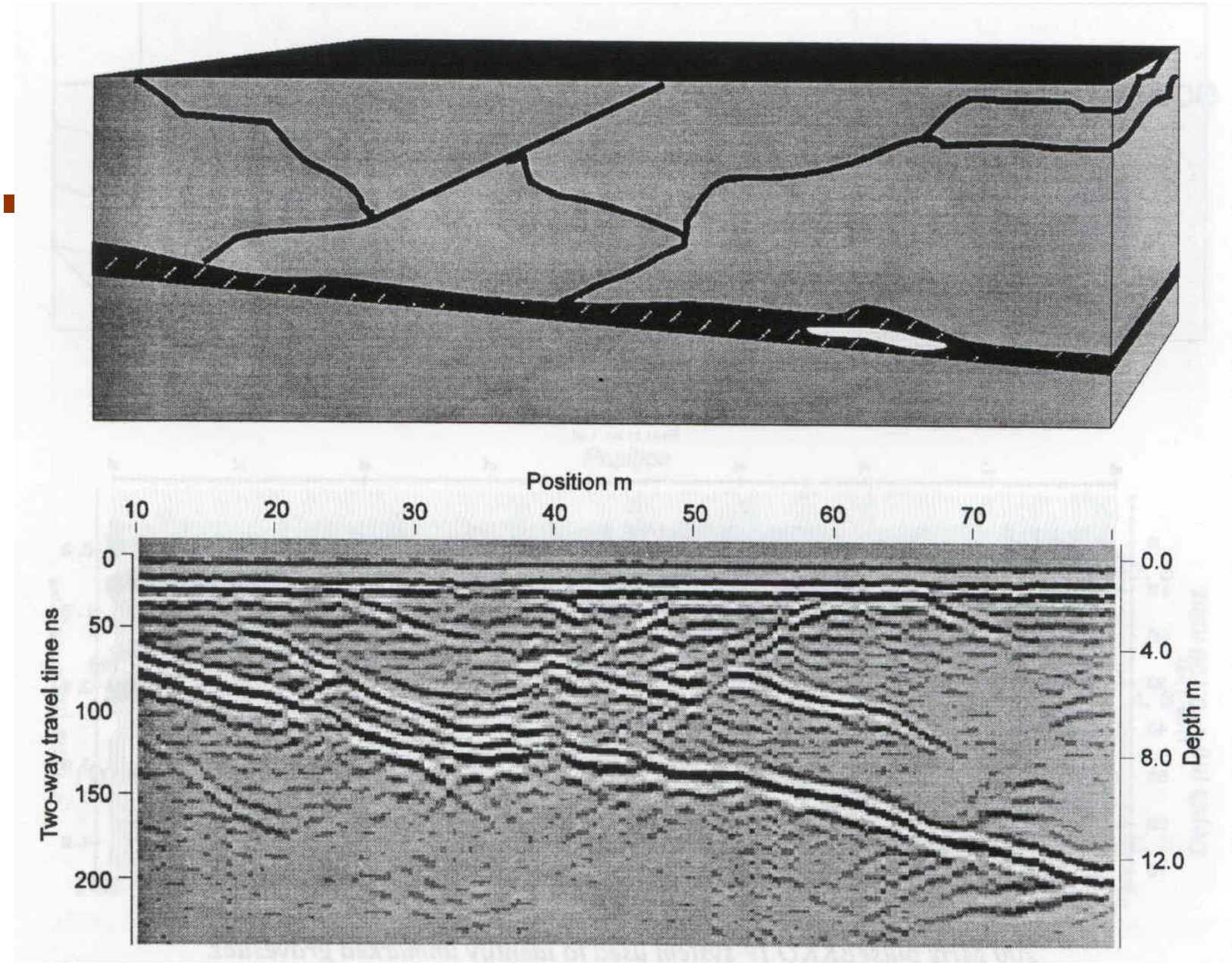

Ice
Water
Soft Sediment
Rock
Position m
0
160
320
480
640
800
960
Two-way Travel Time (ns)
0
400
800
1200
1600
0.0
8.0
16.0
24.0
Depth m


Survey Line
8"
Concrete Slab
20'
1/8" void
1/2" void
1" void
Position m
0
4
8
12
16
Two-way travel time ns
0
4
8
12
0.0
0.2
0.4
0.6
Depth m

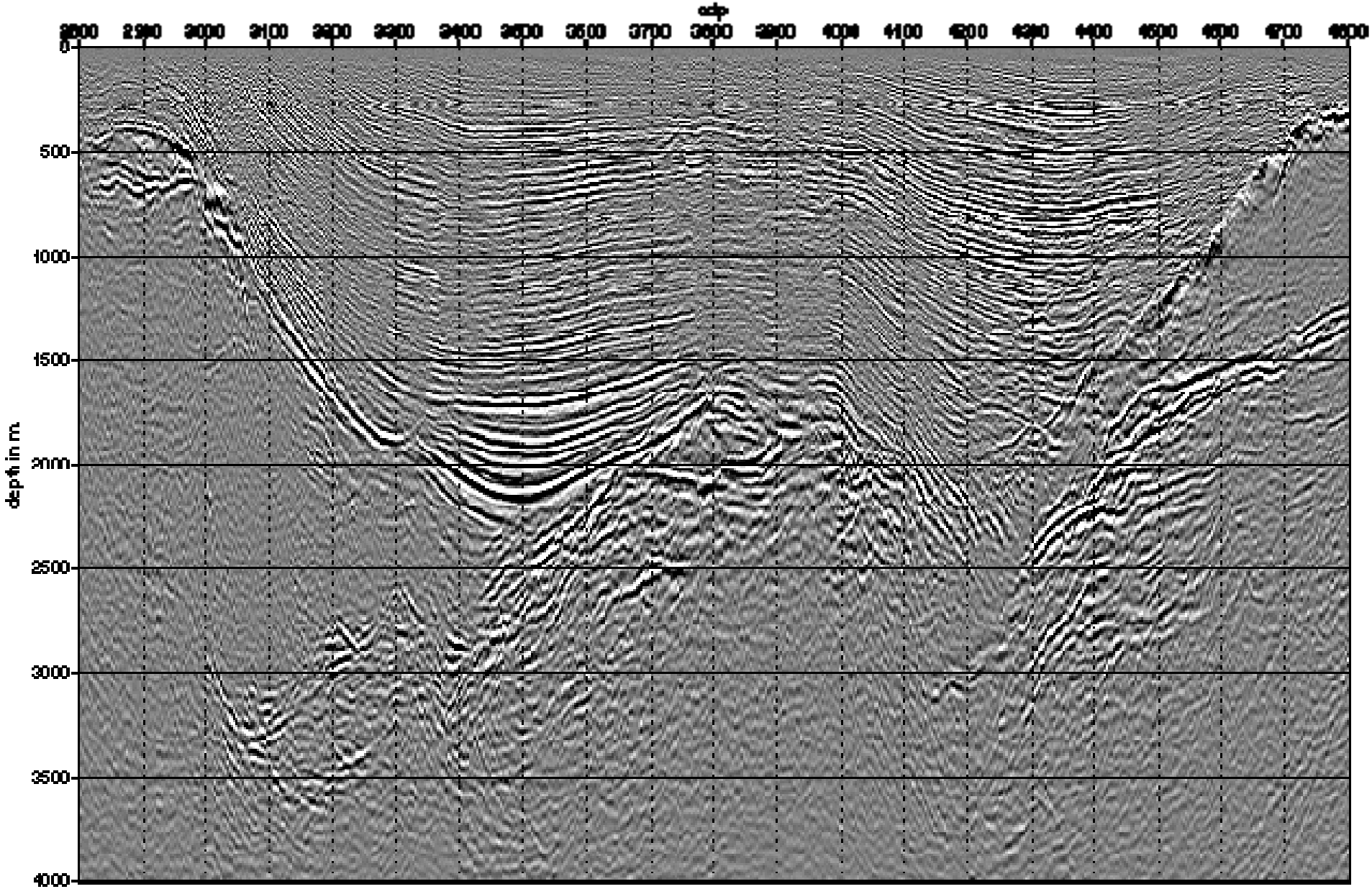

Road fill
Fractures
Natural
Soil
Bedrock
Position m
1060
1080
1100
1120
1140
1160
1180
Two-way travel time ns
0
8
16
24
0.0
0.8
1.6
Depth m


Survey line
Overburden
Rock
Cable
Culvert
Tunnel
Tunnel
Positon m
0
10
20
30
40
50
60
70
80
90
Two-way travel time ns
0
100
200
300
400
500
0
8.0
16.0
24.0
Depth m

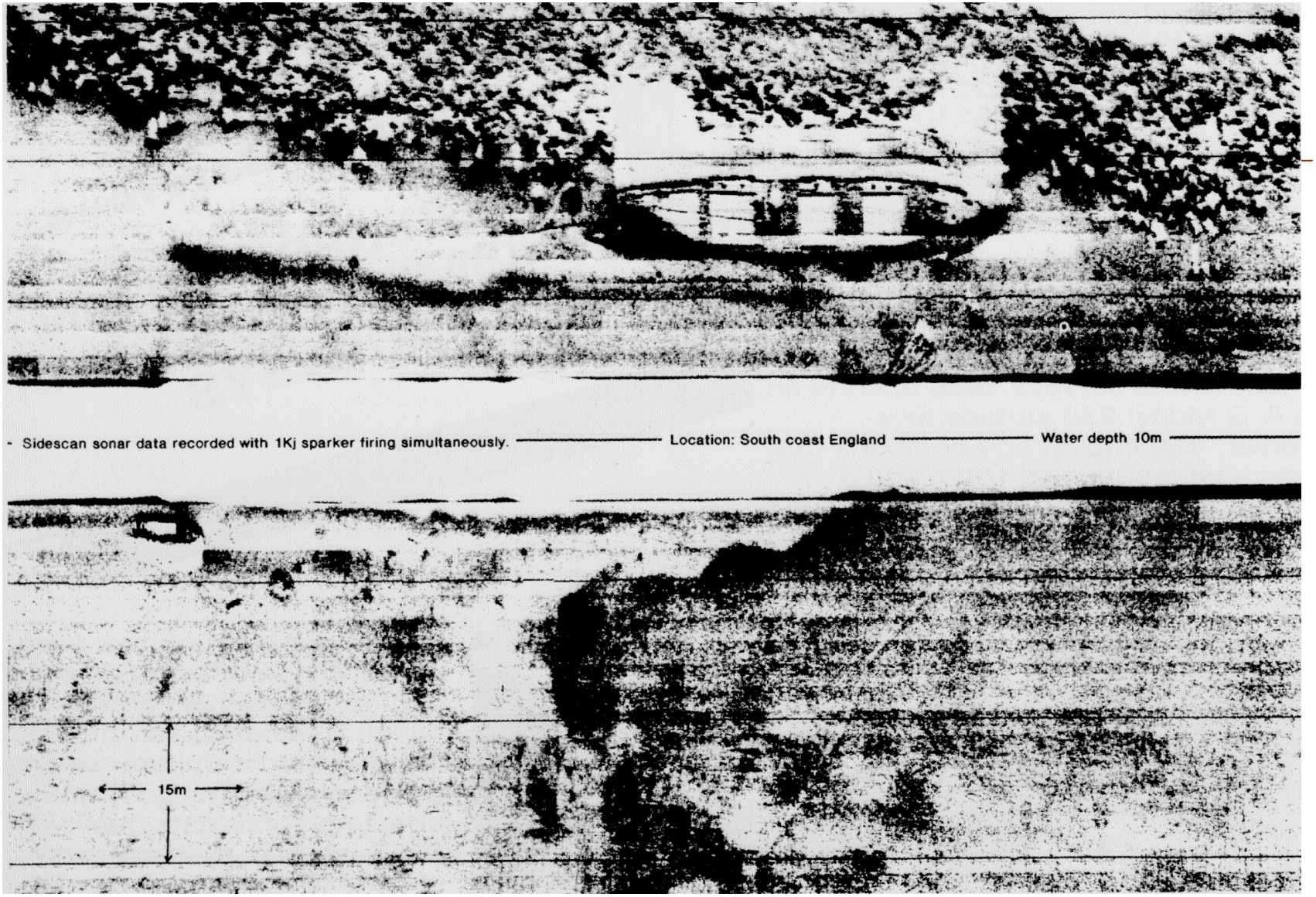

Overburden
Solution
Void
Position m
0
5
10
15
20
25
30
35
40
Time ns
0
100
200
300
Depth m v=0.100 m/ns
0.0
5.0
10.0
15.0
20.0


Position m
10
20
30
40
50
60
70
0
50
100
150
200
Two-way travel time ns
0.0
4.0
8.0
12.0
Depth m

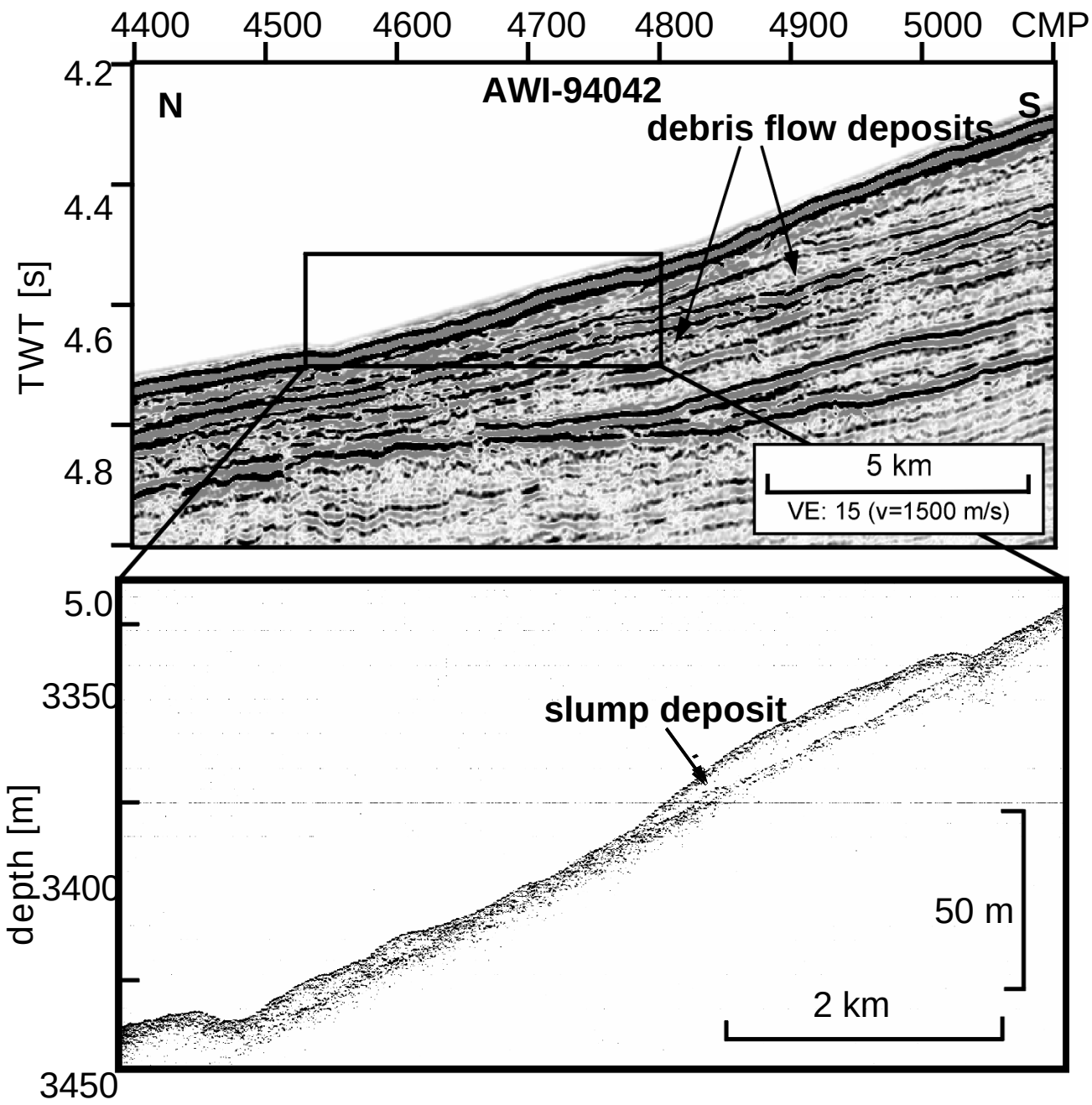
Seismic methods


cdp
depth in m.
0
500
1000
1500
2000
2500
3000
3500
4000

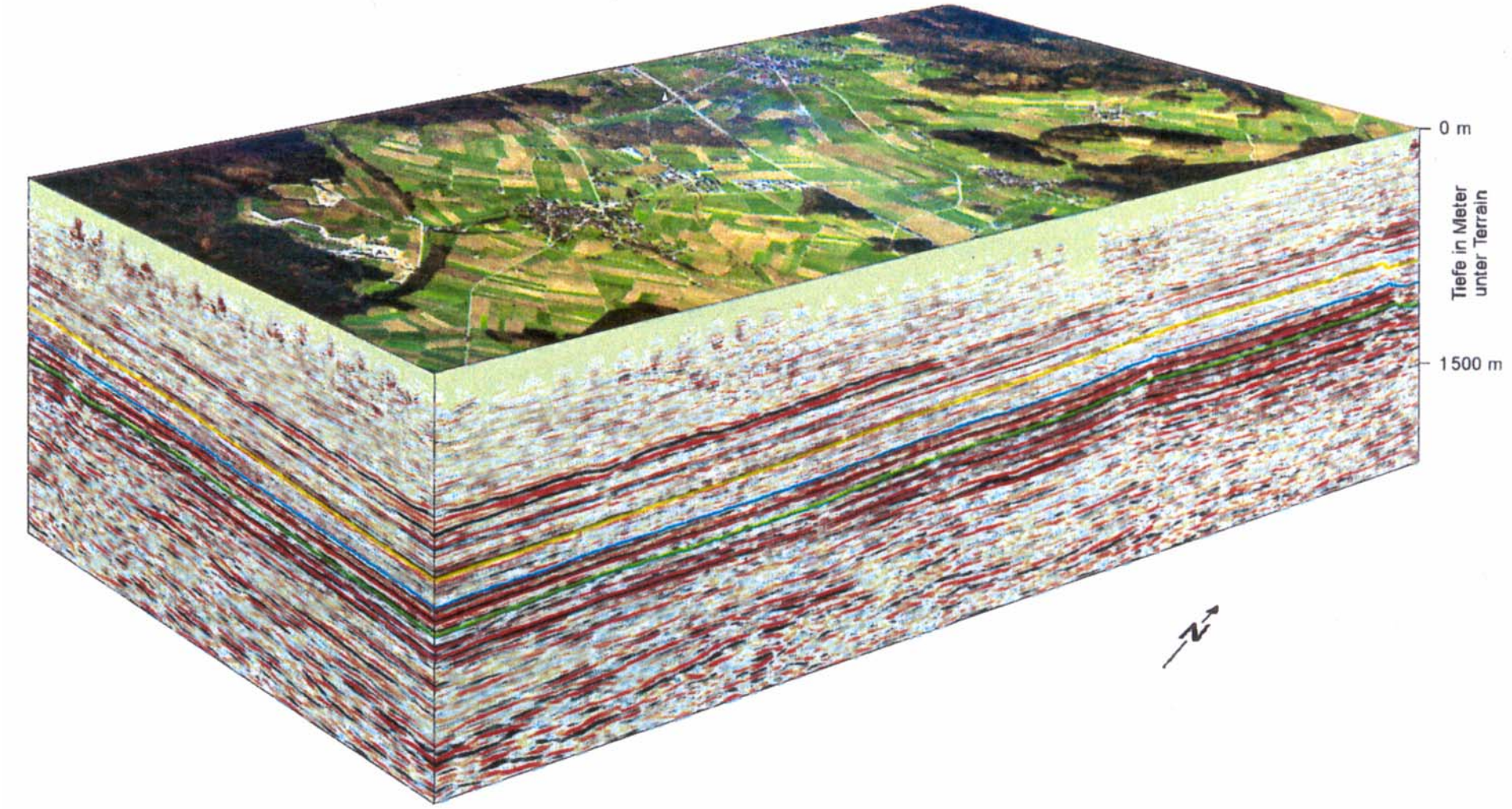
Sidescan sonar data



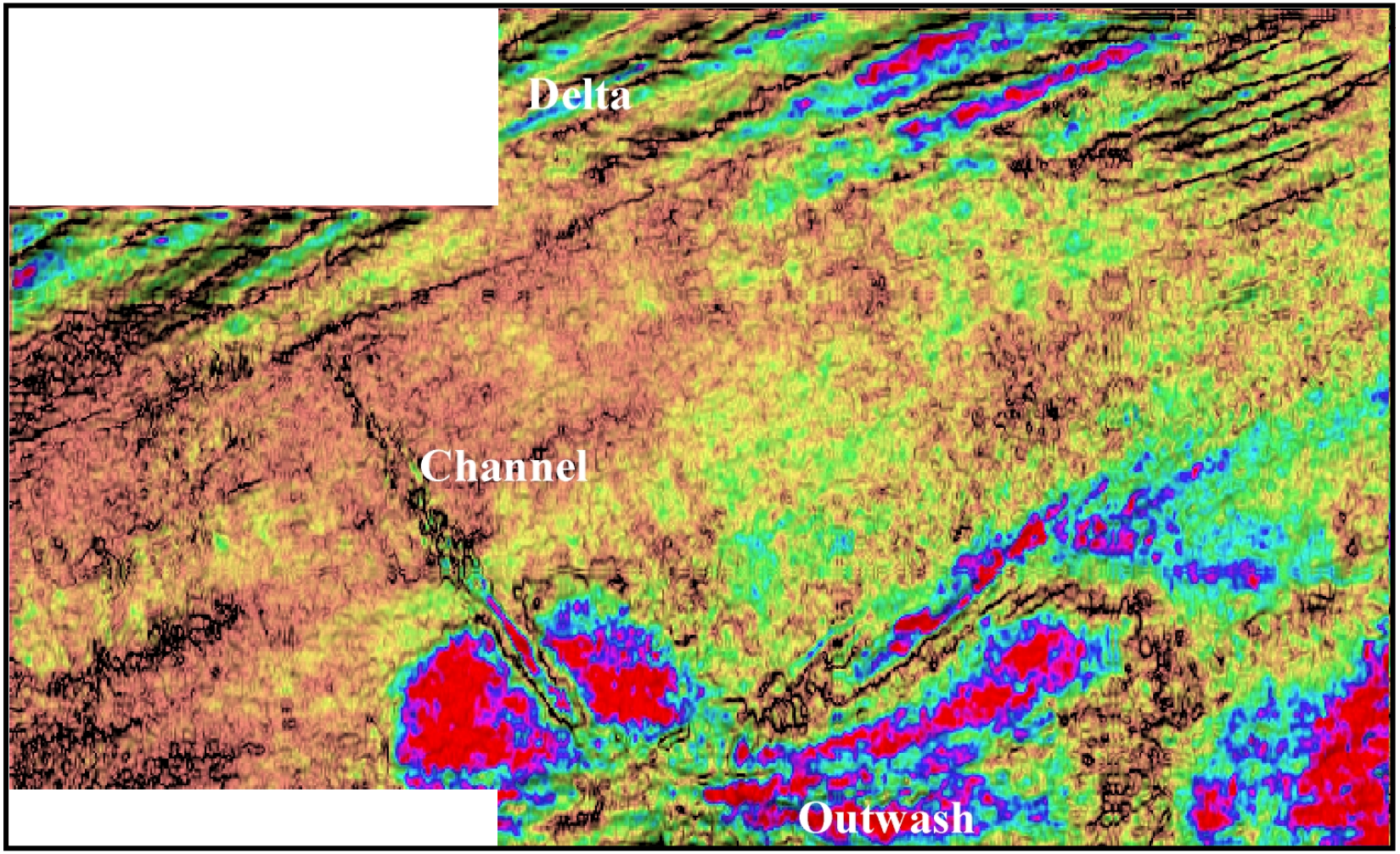
(Example British Geological Survey - BGS)



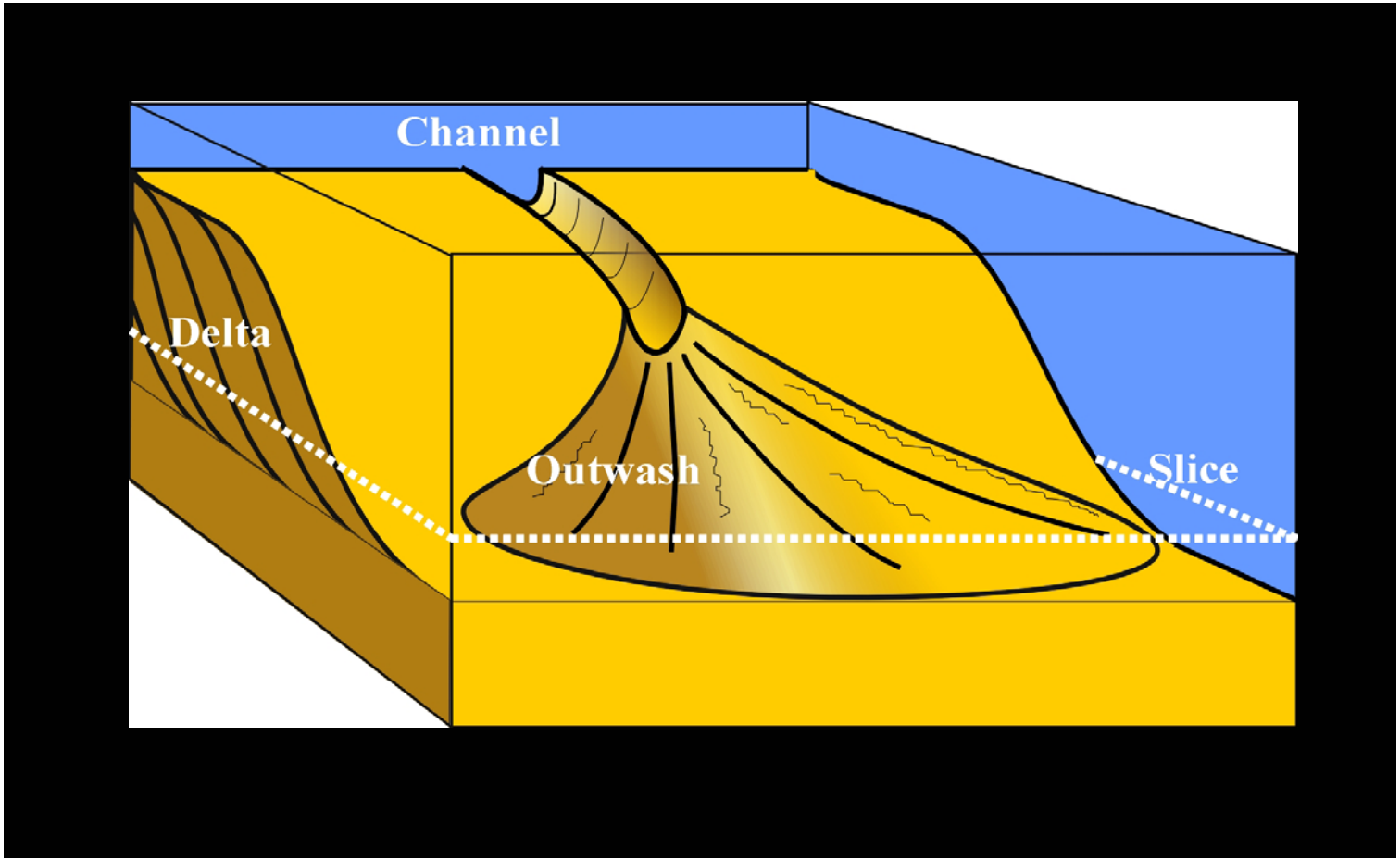
Comparison between airgun and Parasound


0 m
Tiefe in Meter
unter Terrain
1500 m
N

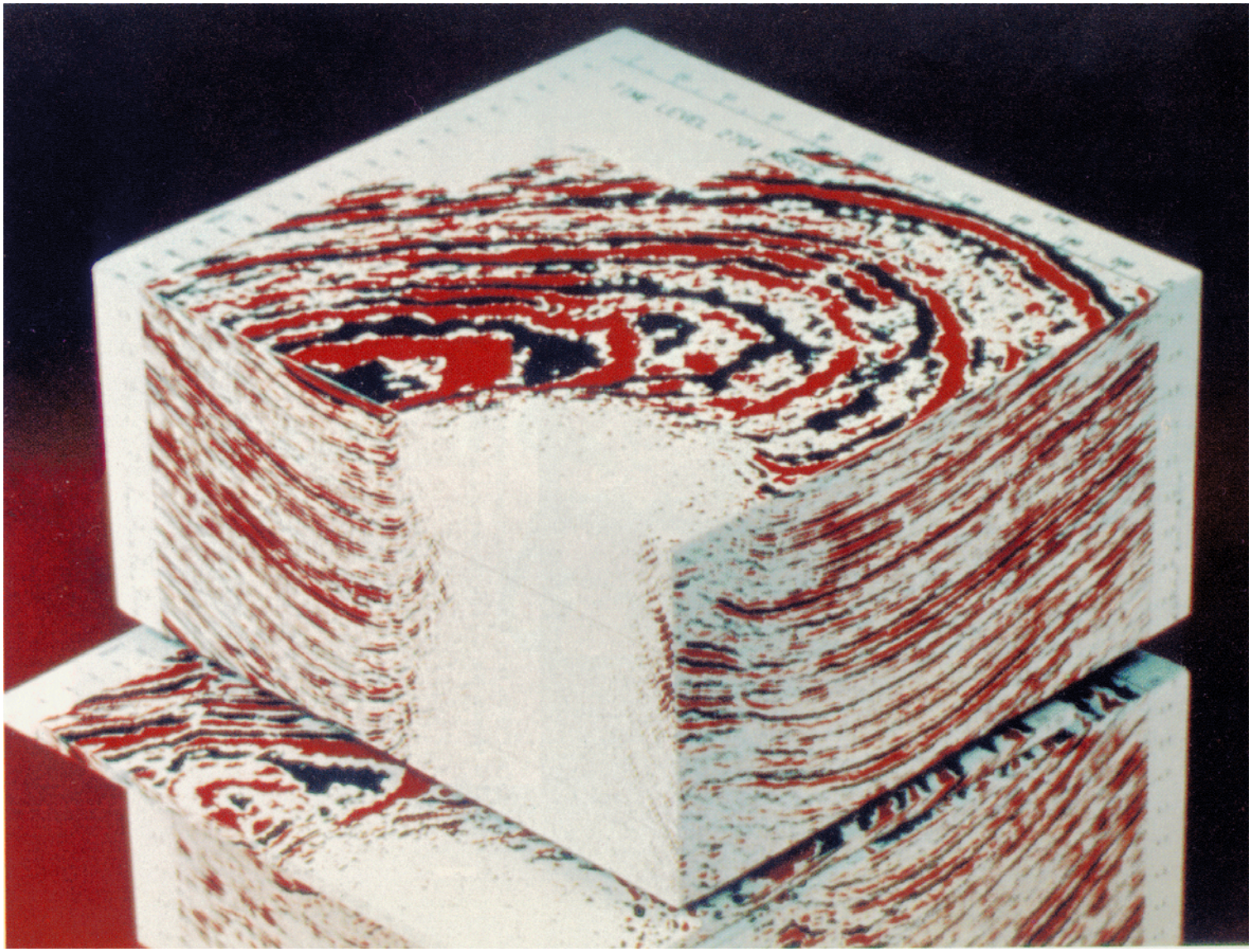
Depth slice



Geological interpretation

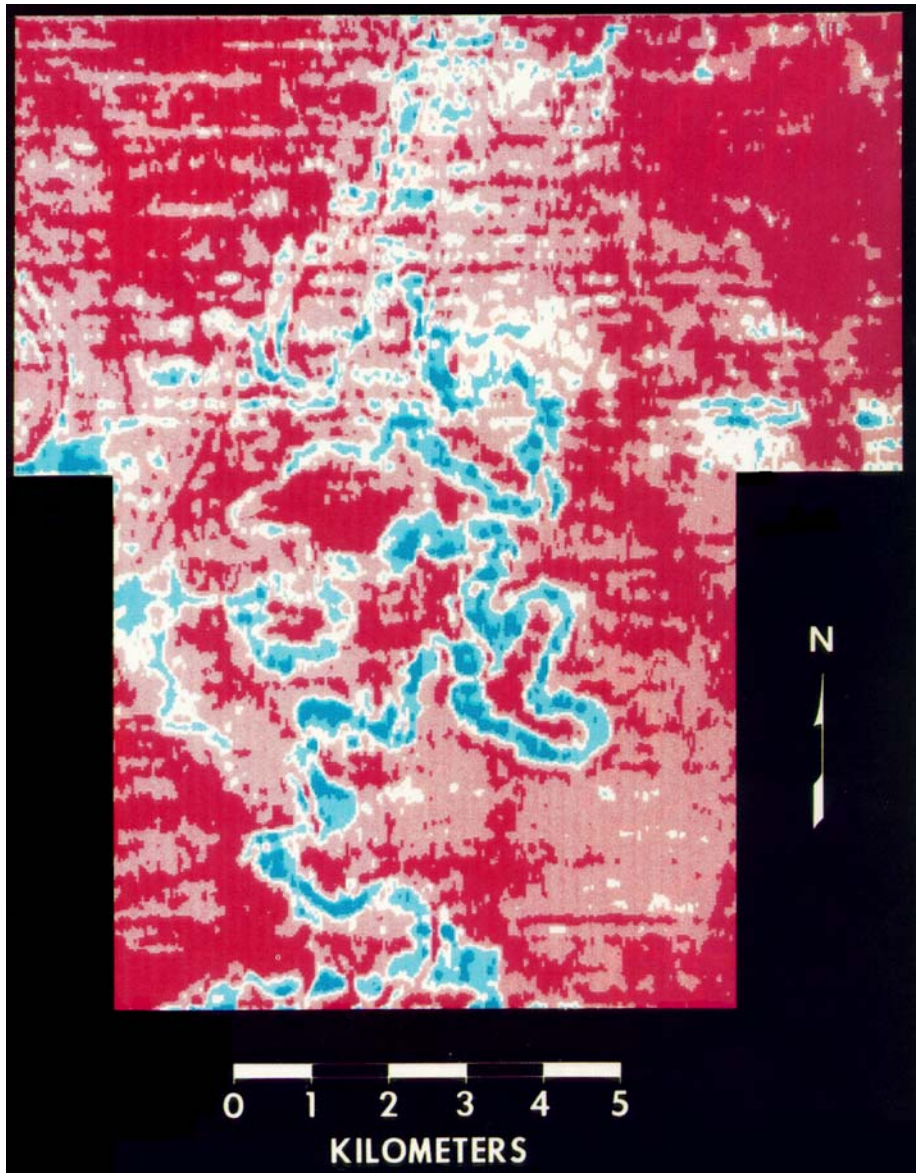


Three-dimensional data volume (Gulf of Mexico)



(from Keary and Brooks, 1991)

Time slice through a 3D seismic data set



(from Kearey and Brooks, 1991)

Literature

Philip Keary, Michael Brooks, Ian Hill

An Introduction to Geophysical Exploration

2002, 3rd Edition, Blackwell Science

~ 49 Euro (Amazon Deutschland)

ISBN 0-632-04929-4

Various

Slides on the internet: **www.aug.geophys.ethz.ch: teaching**

Contact:

laurent@aug.ig.erdw.ethz.ch (potential & diffusive methods)

jvdkruk@aug.ig.erdw.ethz.ch (wavefield methods)

Date	Subject
27-09-2007	Introduction,
	Gravity
	Microgravity
04-10-2007	Magnetic
	Gravity + Magnetic: exercises
	Electrical methods: resistivity of Rocks
11-10-2007	Electrical methods: exercises 1
	Electrical methods: resistivity mapping and sounding
18-10-2007	Electrical methods: resistivity imaging
	Electrical methods: exercises 2
	Electrical methods: Induced Polarization and Self Potential
25-10-2007	Electrical methods: exercises 3
	Electromagnetic
	Electromagnetic: exercises
01-11-2007	30 min Exam (33%, 1A4 zettel mit Notizen)
	Wave propagation: Seismics and GPR
	interfaces, R + T coefficients

Date	Topic
08-11-2007	Huygens Principle,
	Geometrical analysis: Reflection & Refraction,
15-11-2007	Amplitudes
	Recording of measured data, Acquisition,
22-11-2007	sources and receivers
	Seismogram, Resolution, Preprocessing,
29-11-2007	Amplitude correction, Frequency filter,
	Deconvolution, Velocity analysis
06-12-2007	Normal Move-Out (NMO) correction, Stacking
	Wavenumber-frequency (kf) transformation, tau-p transformation
13-12-2007	Migration,
	Interpretation, Vertical Seismic profiling (VSP), New developments
	Discussion about which method should be used for which problem?
20-12-2007	60 min Exam (67%, 3A4 zettel mit Notizen)
	Demonstrations: -100 electrodes measurements, -120 channel Seismic measurements, 3D GPR, 3D Seismic processing