GEOPHYSICS

- **Mechanical Wave Measurements**
- **Electromagnetic Wave Techniques**

Geophysical Methods

- **Mechanical Wave Measurements**
  - Crosshole Tests (CHT)
  - Downhole Tests (DHT)
  - Spectral Analysis of Surface Waves
  - Seismic Refraction
  - Suspension Logging
- **Electromagnetic Wave Techniques**
  - Ground Penetrating Radar (GPR)
  - Electromagnetic Conductivity (EM)
  - Surface Resistivity (SR)
  - Magnetometer Surveys (MT)

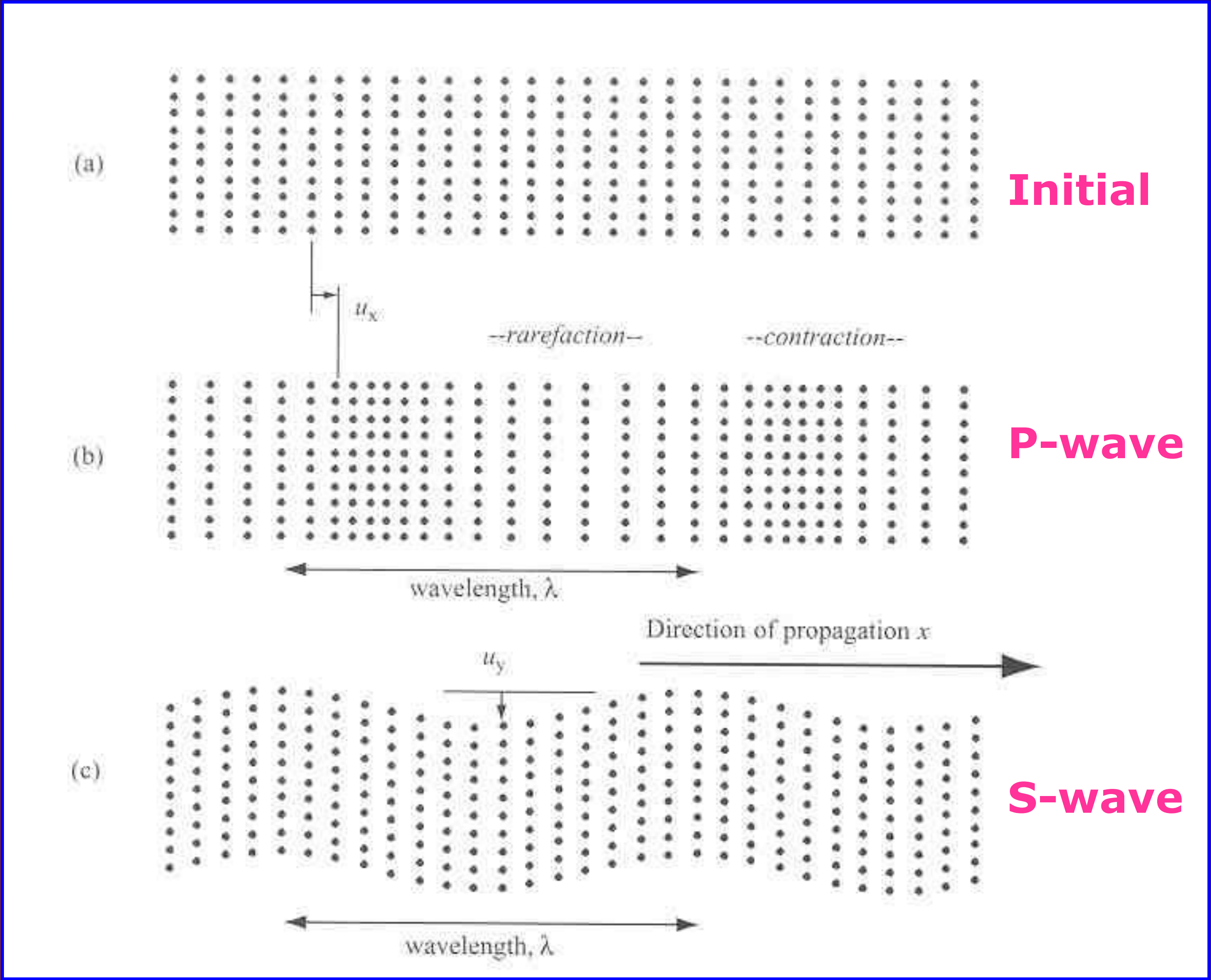
Mechanical Wave Geophysics

- Nondestructive measurements ($\gamma_s < 10^{-4}\%$)
- Both borehole geophysics and non-invasive types (conducted across surface).
- Measurements of wave dispersion: velocity, frequency, amplitude, attenuation.
- Determine layering, elastic properties, stiffness, damping, and inclusions
- Four basic wave types: Compression (P), Shear (S), Rayleigh (R), and Love (L).

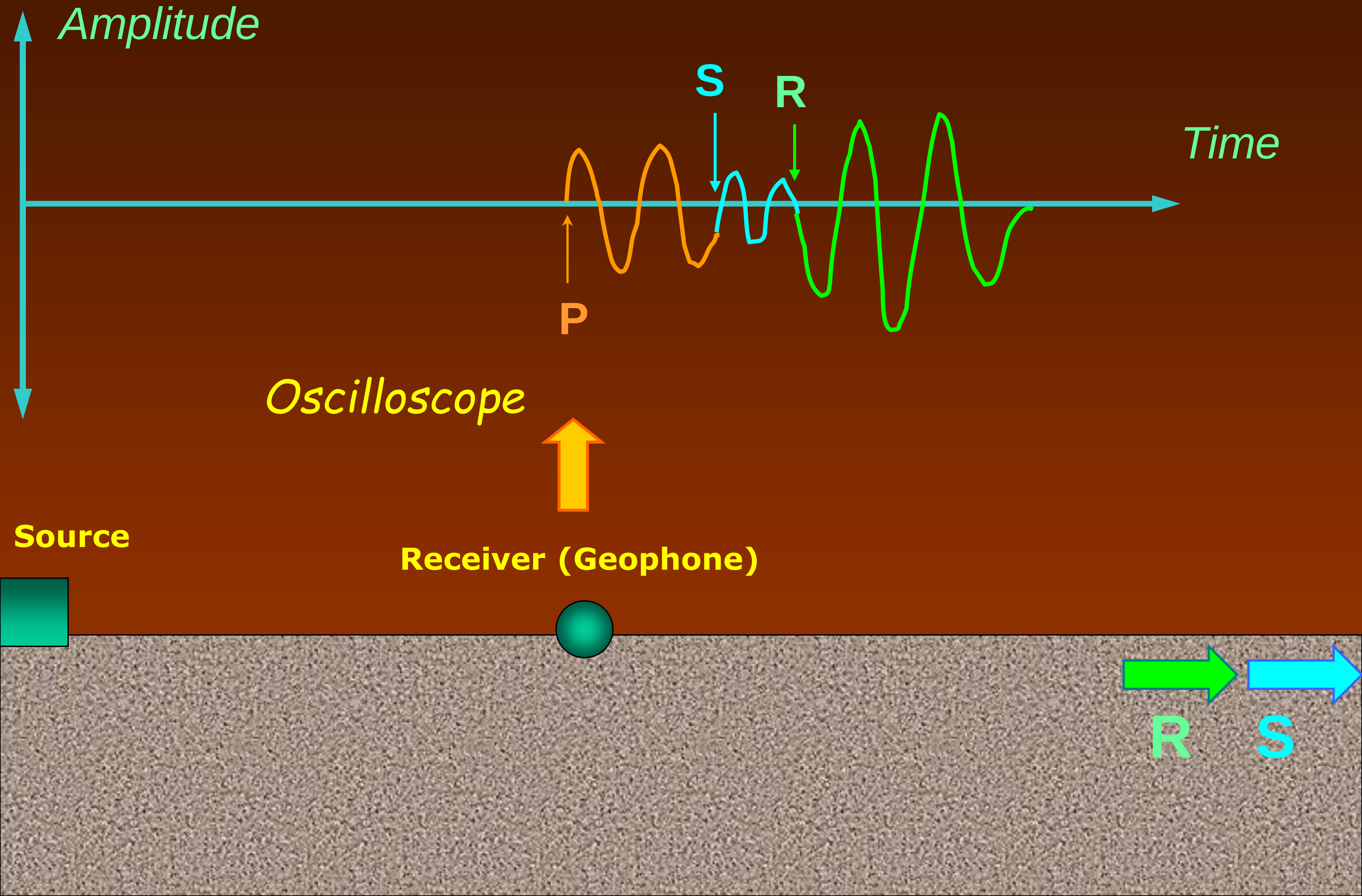
Mechanical Wave Geophysics

- Compression (P-) wave is fastest wave; easy to generate.
- Shear (S-) wave is second fastest wave. Is directional and polarized. Most fundamental wave to geotechnique.
- Rayleigh (R-) or surface wave is very close to S-wave velocity (90 to 94%). Hybrid P-S wave at ground surface boundary.
- Love (L-) wave: interface boundary effect

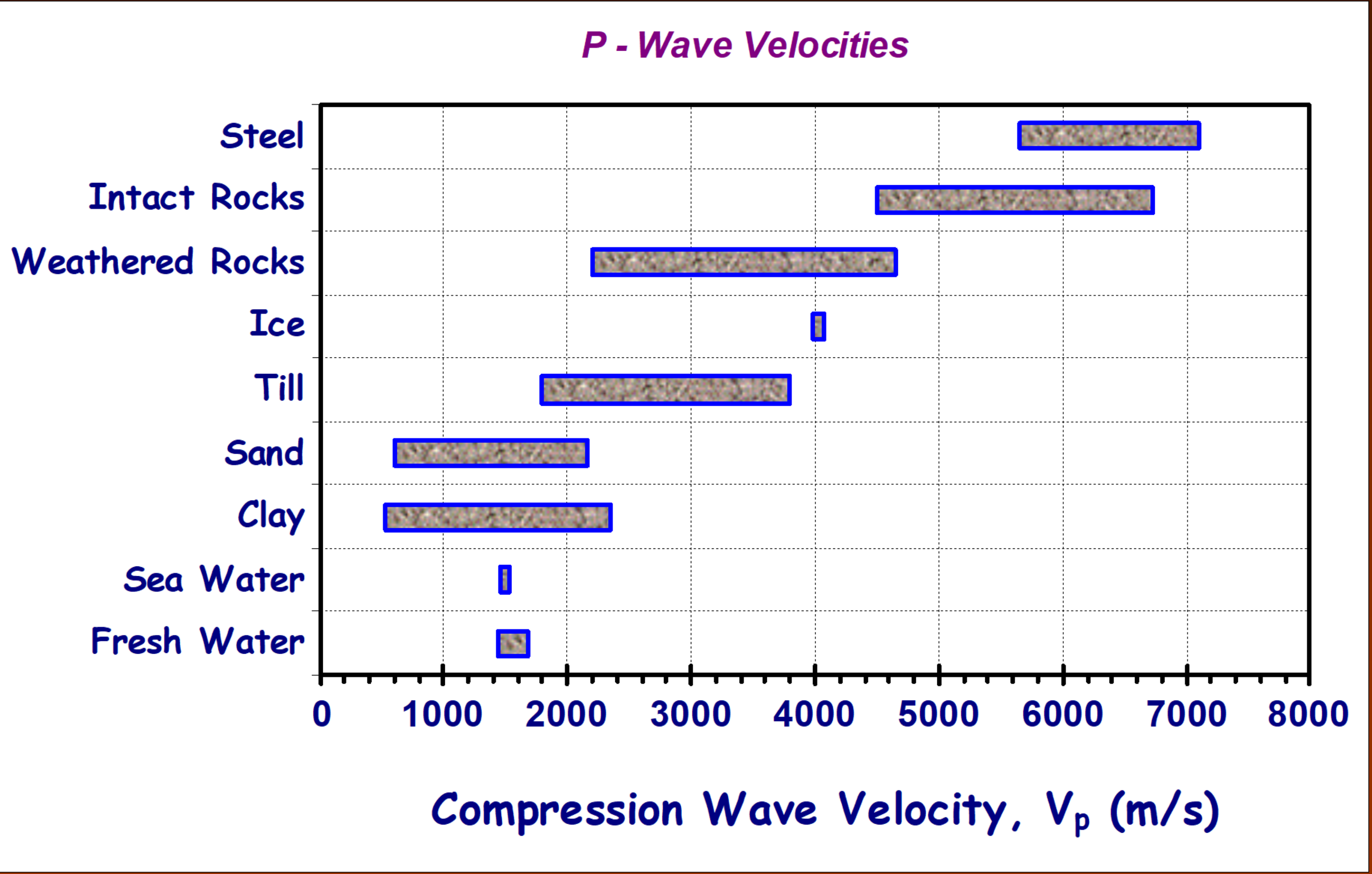
Mechanical Body Waves



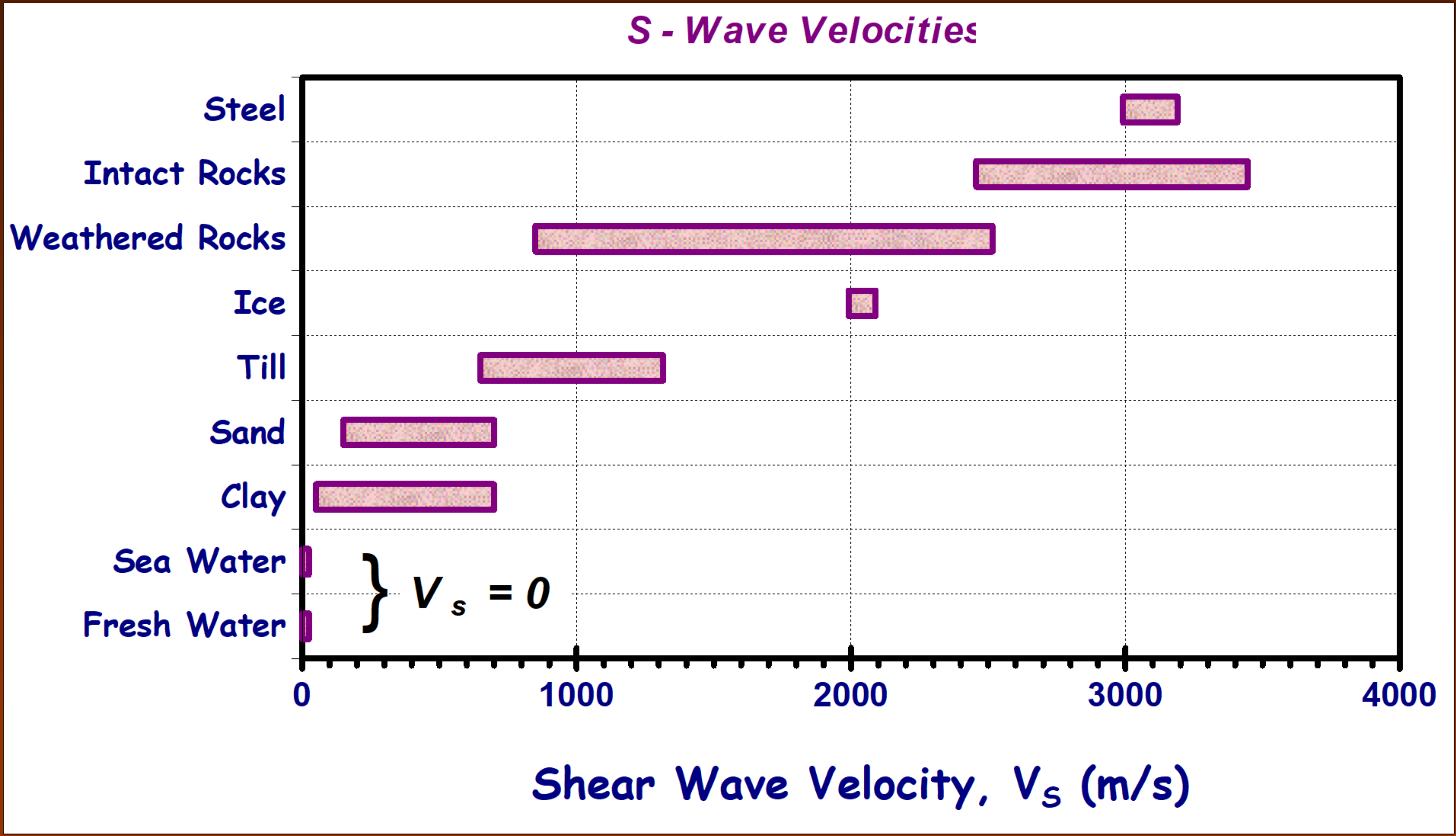
Mechanical Body Waves



Mechanical Waves (Compression)



Mechanical Waves (Shear)



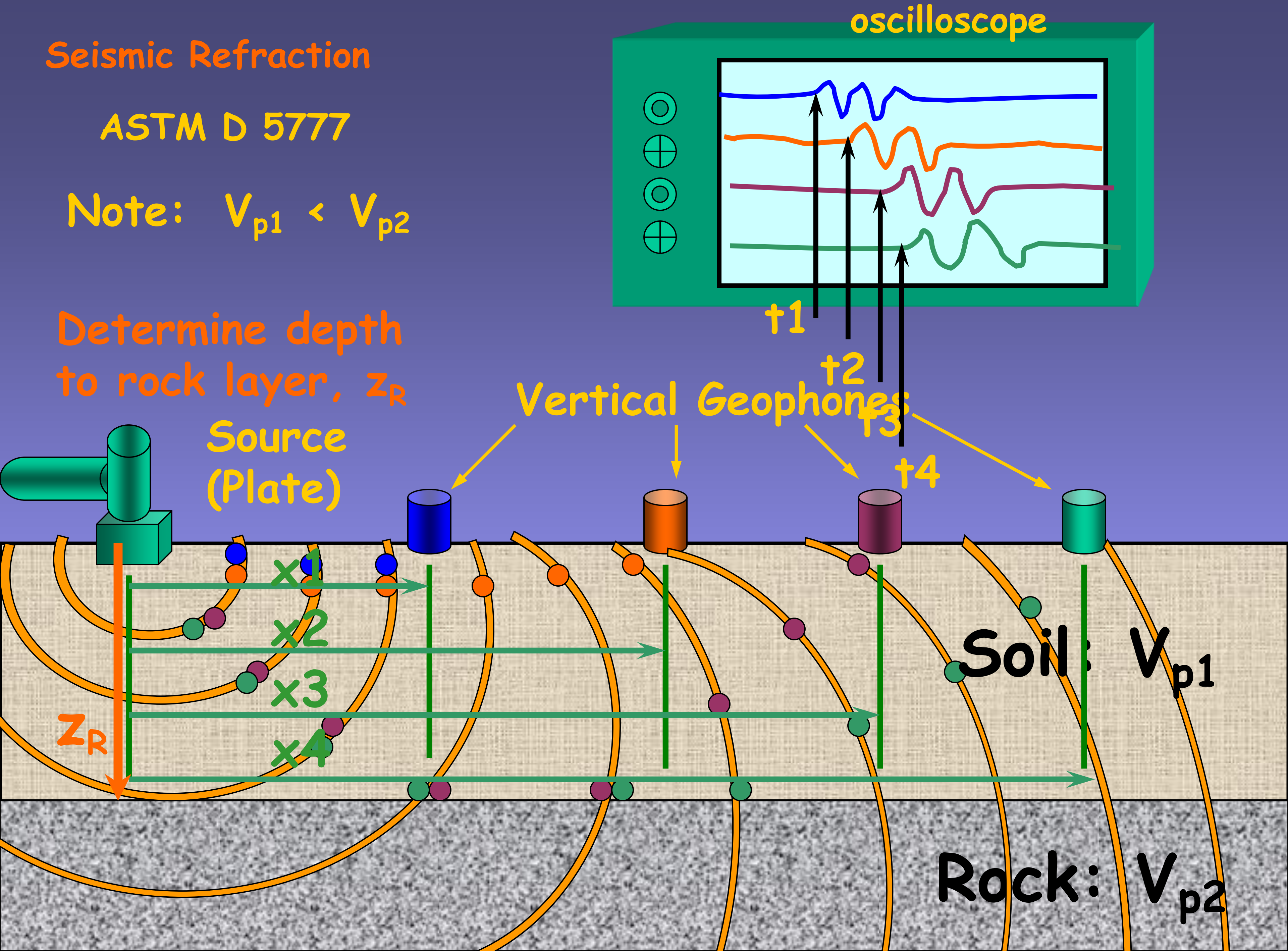
Geophysical Equipment

Seismograph

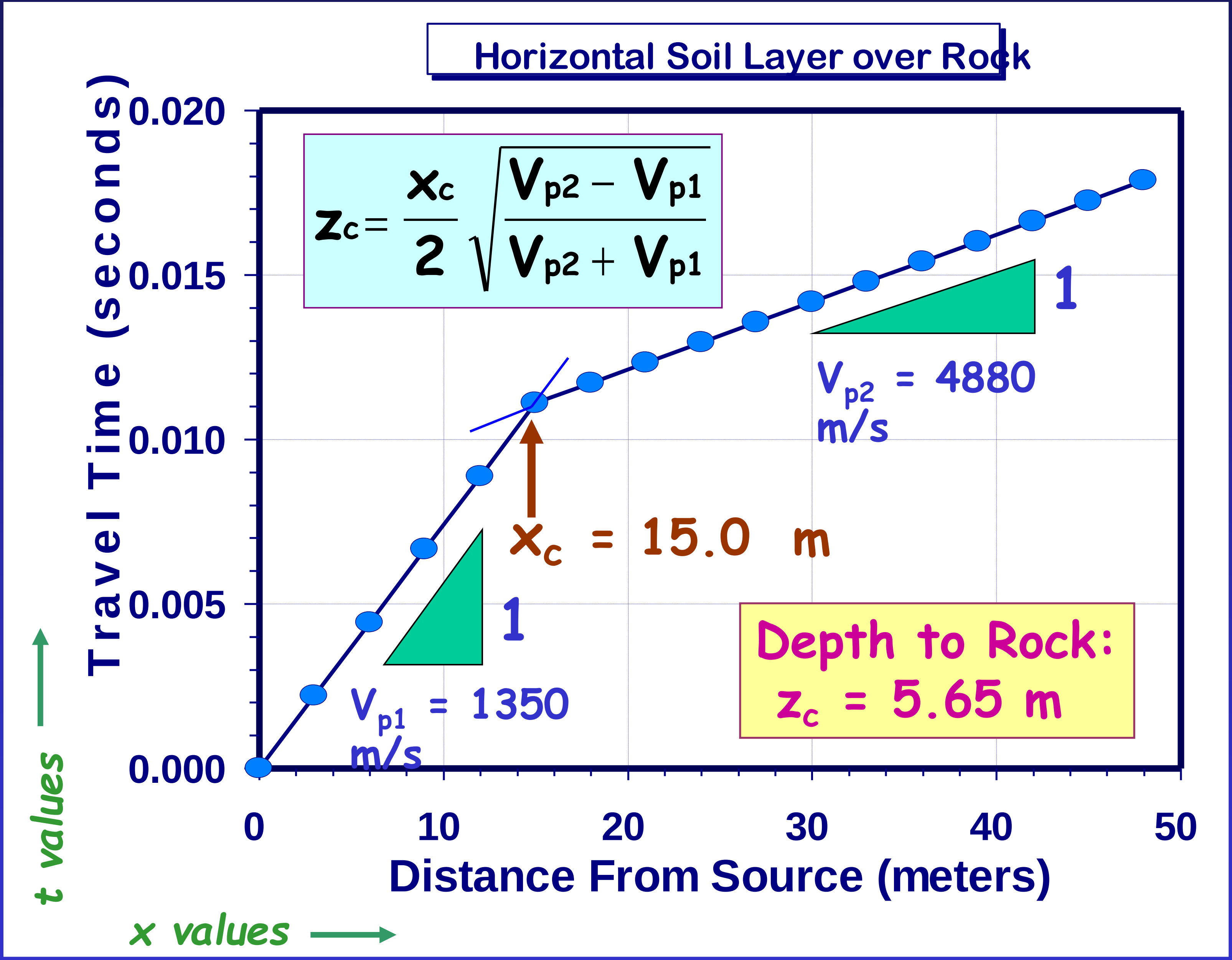
Spectrum Analyzer

Portable Analyzer

Velocity Recorder


Seismic Refraction
ASTM D 5777
Note: $V_{p1} < V_{p2}$
oscilloscope
t1
t2
t3
t4
Determine depth to rock layer, z_R
Vertical Geophones
Source (Plate)
x1
x2
x3
x4
z_R
Soil: V_{p1}
Rock: V_{p2}

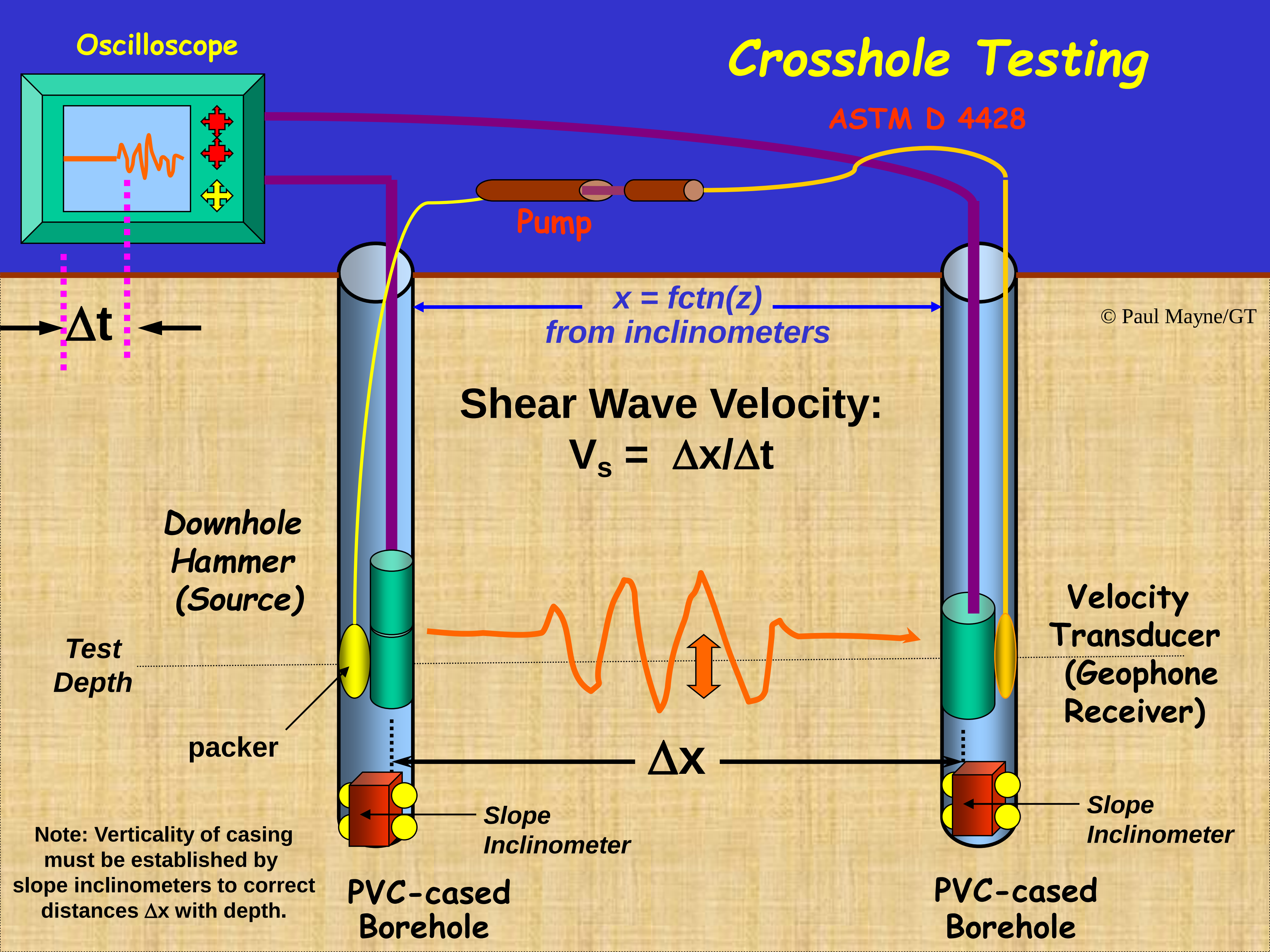
Seismic Refraction



Shear Wave Velocity, V_s

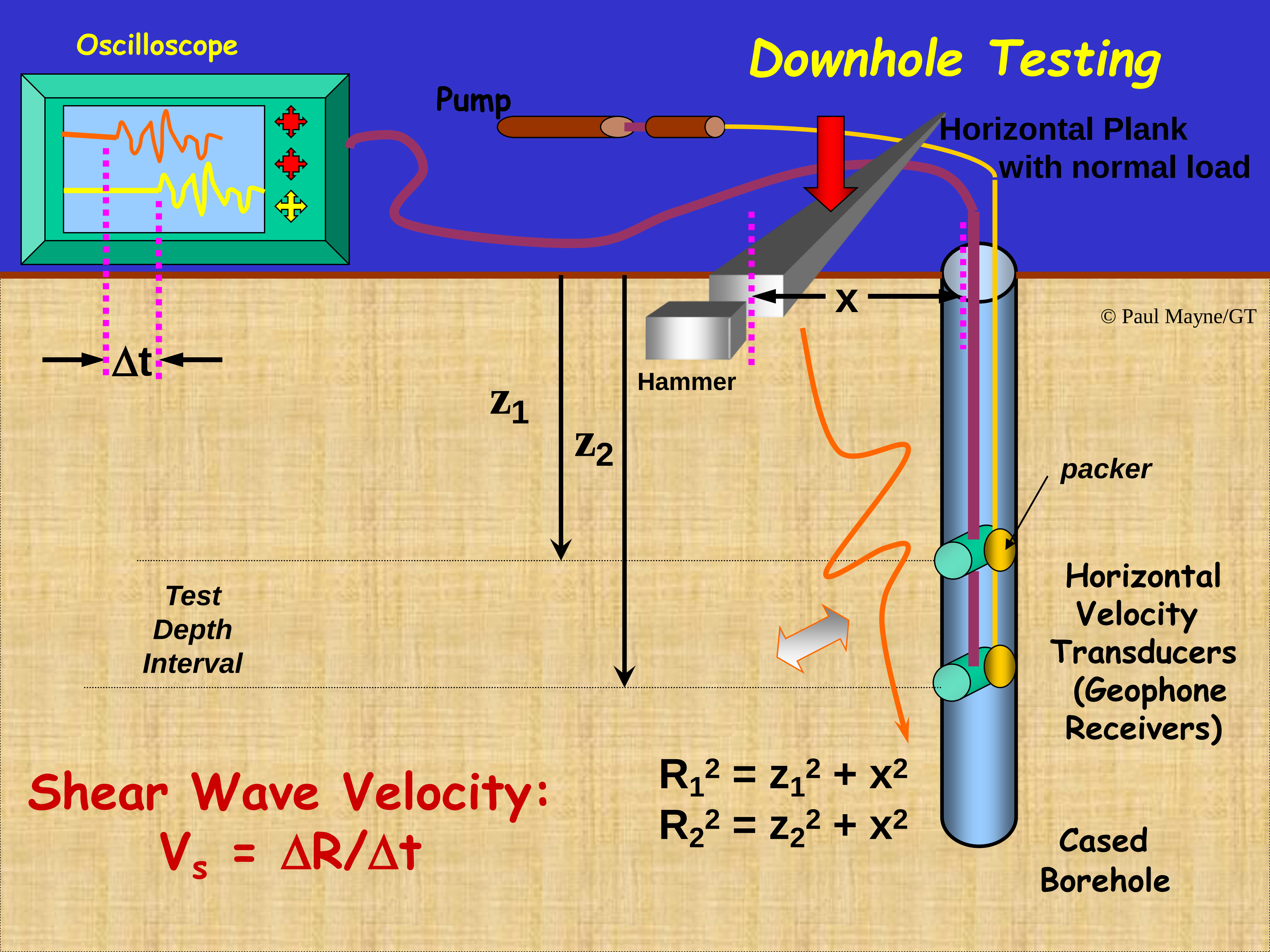
- Fundamental measurement in all solids (steel, concrete, wood, soils, rocks)
- Initial small-strain stiffness represented by shear modulus: $G_0 = \rho_T V_s^2$
  (alias $G_{dyn} = G_{max} = G_0$)
- Applies to all static & dynamic problems at small strains ($\gamma_s < 10^{-6}$)
- Applicable to both undrained & drained loading cases in geotechnical engineering.

Crosshole Seismic Testing Equipment

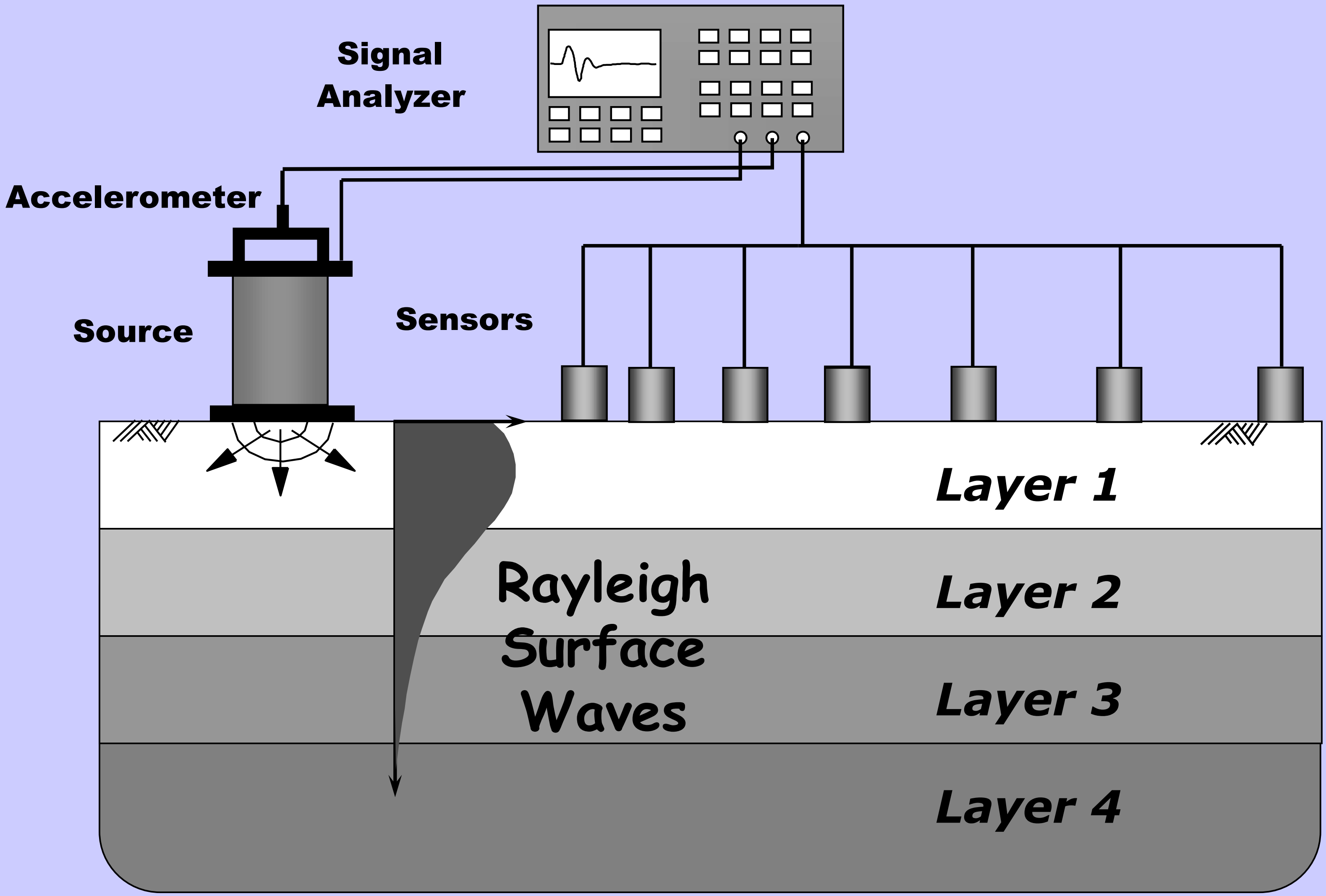


Crosshole Testing
ASTM D 4428
Oscilloscope
Pump
Δt
x = fctn(z)
from inclinometers
© Paul Mayne/GT
Shear Wave Velocity:
$V_s = \Delta x / \Delta t$
Downhole Hammer (Source)
Test Depth
packer
Velocity Transducer (Geophone Receiver)
Δx
Slope Inclinometer
Slope Inclinometer
Note: Verticality of casing must be established by slope inclinometers to correct distances Δx with depth.
PVC-cased Borehole
PVC-cased Borehole

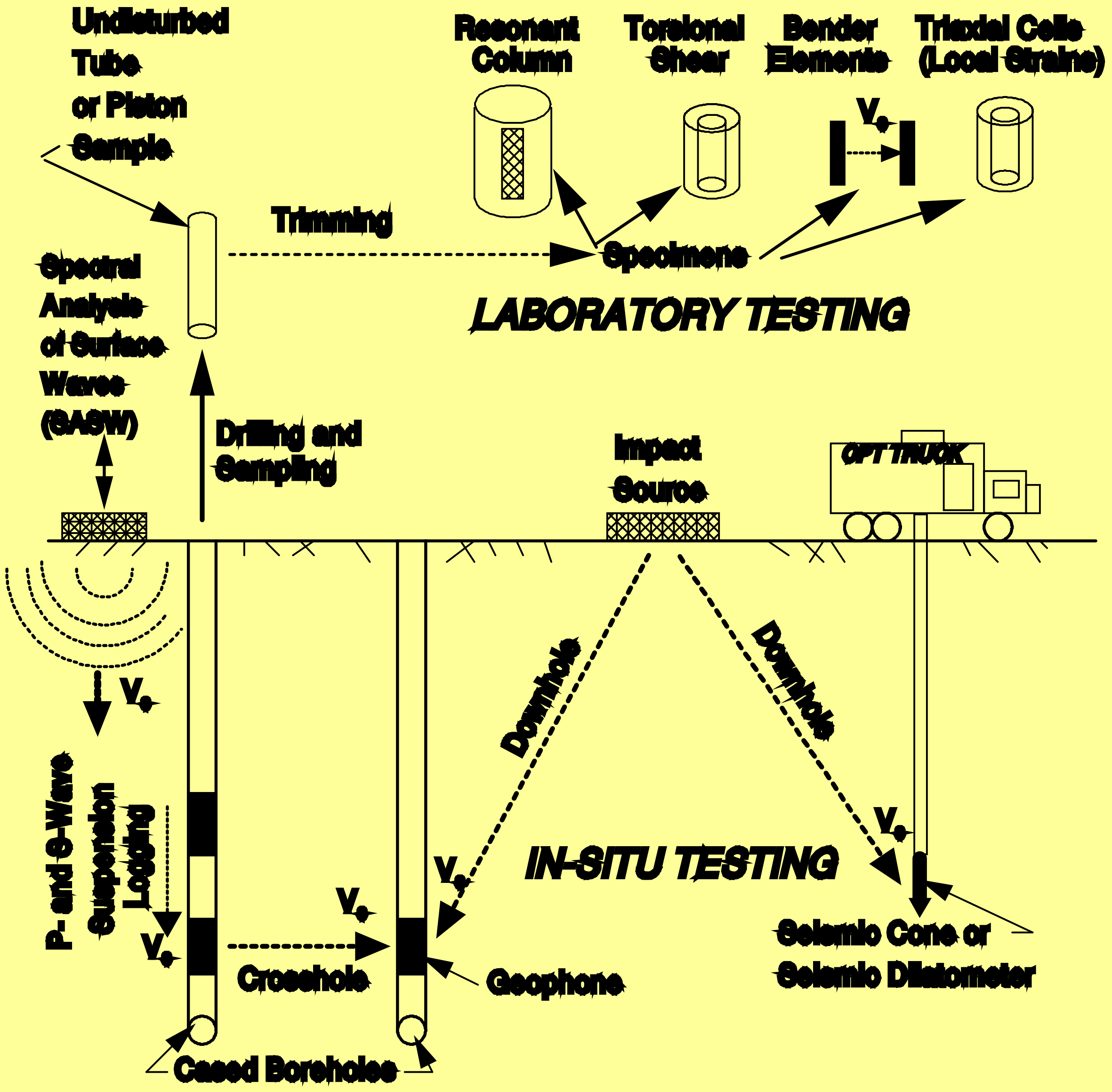
Downhole Seismic Testing Equipment

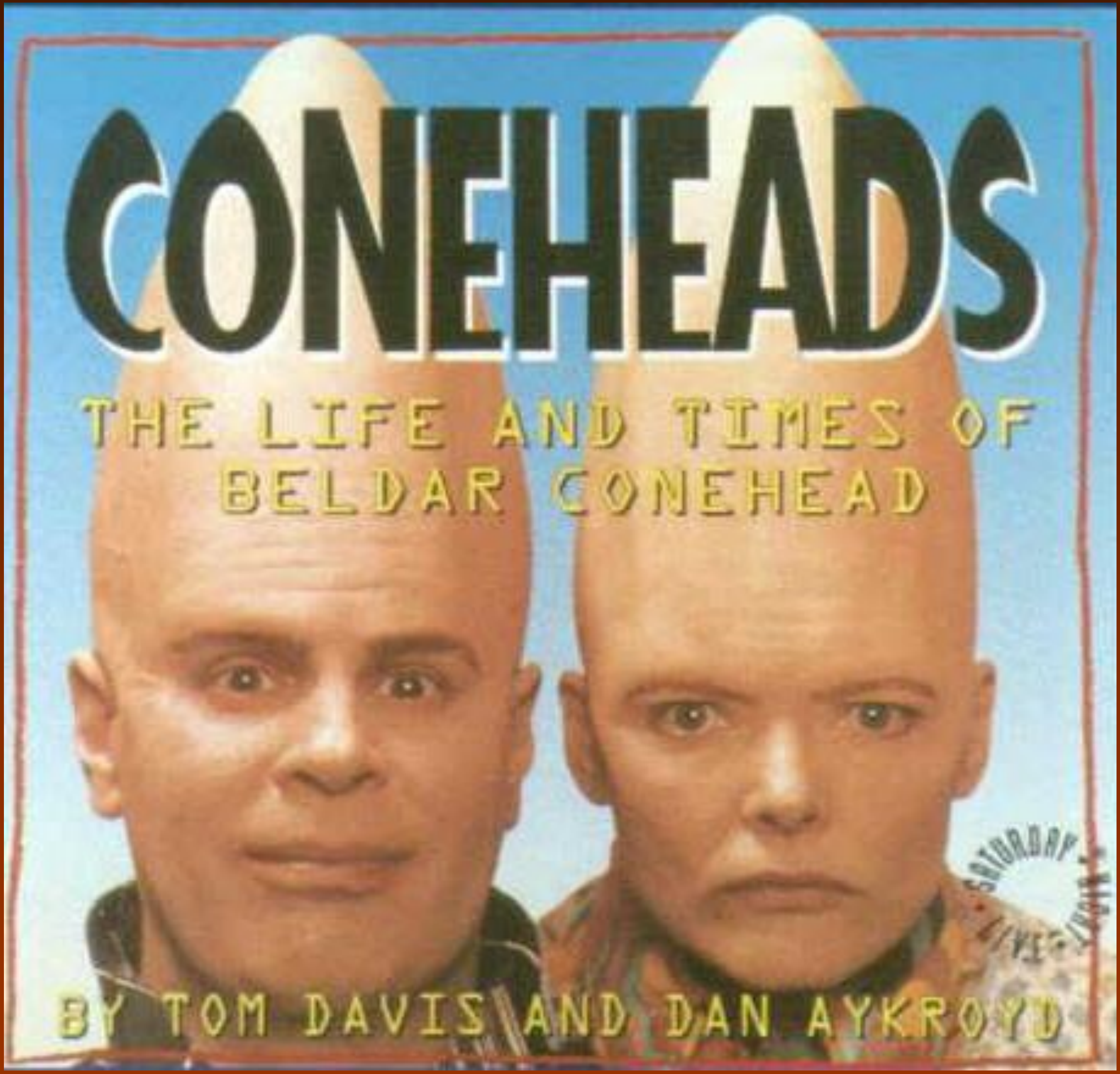

Downhole Testing
Oscilloscope
Pump
Horizontal Plank
with normal load
Δt
x
© Paul Mayne/GT
Hammer
z_1
z_2
packer
Test
Depth
Interval
Horizontal
Velocity
Transducers
(Geophone
Receivers)
$R_1^2 = z_1^2 + x^2$
$R_2^2 = z_2^2 + x^2$
Cased
Borehole
Shear Wave Velocity:
$V_s = \Delta R/\Delta t$

In-Situ Surface Wave Testing

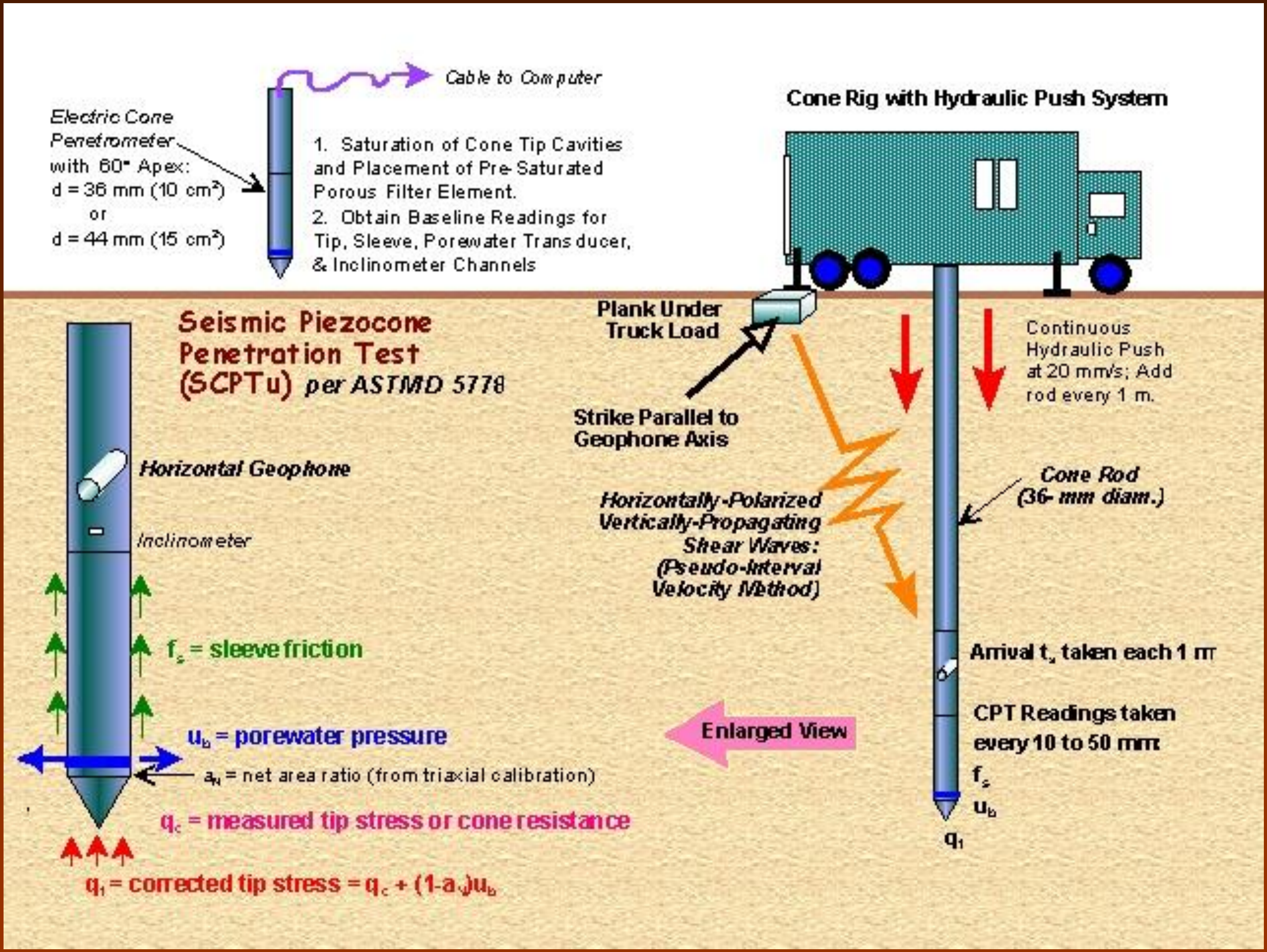


Shear Wave Measurements




CONEHEADS
THE LIFE AND TIMES OF
BELDAR CONEHEAD
BY TOM DAVIS AND DAN AYKROYD
SATURDAY NIGHT LIVE

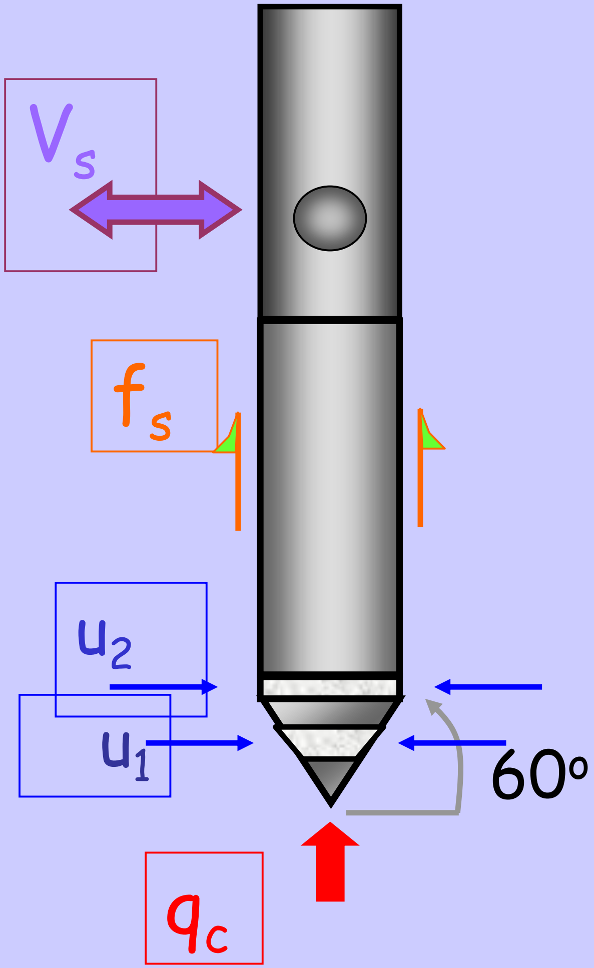
Seismic Piezocone Test (SCPTu)



Seismic Piezocone Test

Obtains Four Independent Measurements with Depth: Hybrid of Penetrometer with Downhole Geophysics

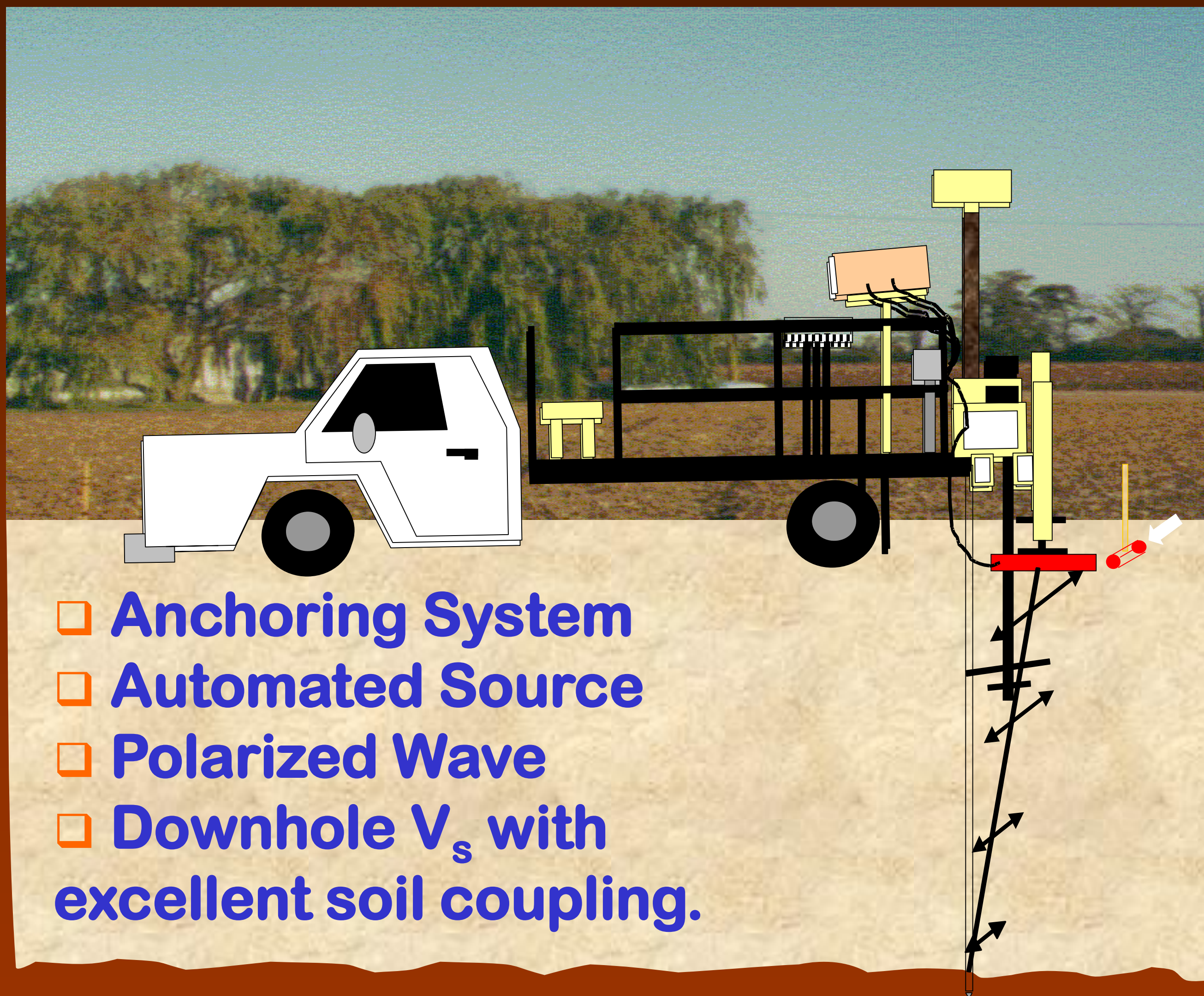
- Cone Tip Stress, q_t
- Penetration Porewater Pressure, u
- Sleeve Friction, f_s
- Arrival Time of Downhole Shear Wave, t_s



Automated Seismic Source

- Electronically-actuated
- Self-contained
- Left and right polarization
- Modified beam uses fin to enhance shear wave generation
- Successfully tested to depths of 20m
- Capable of being used with traditional impulse hammer

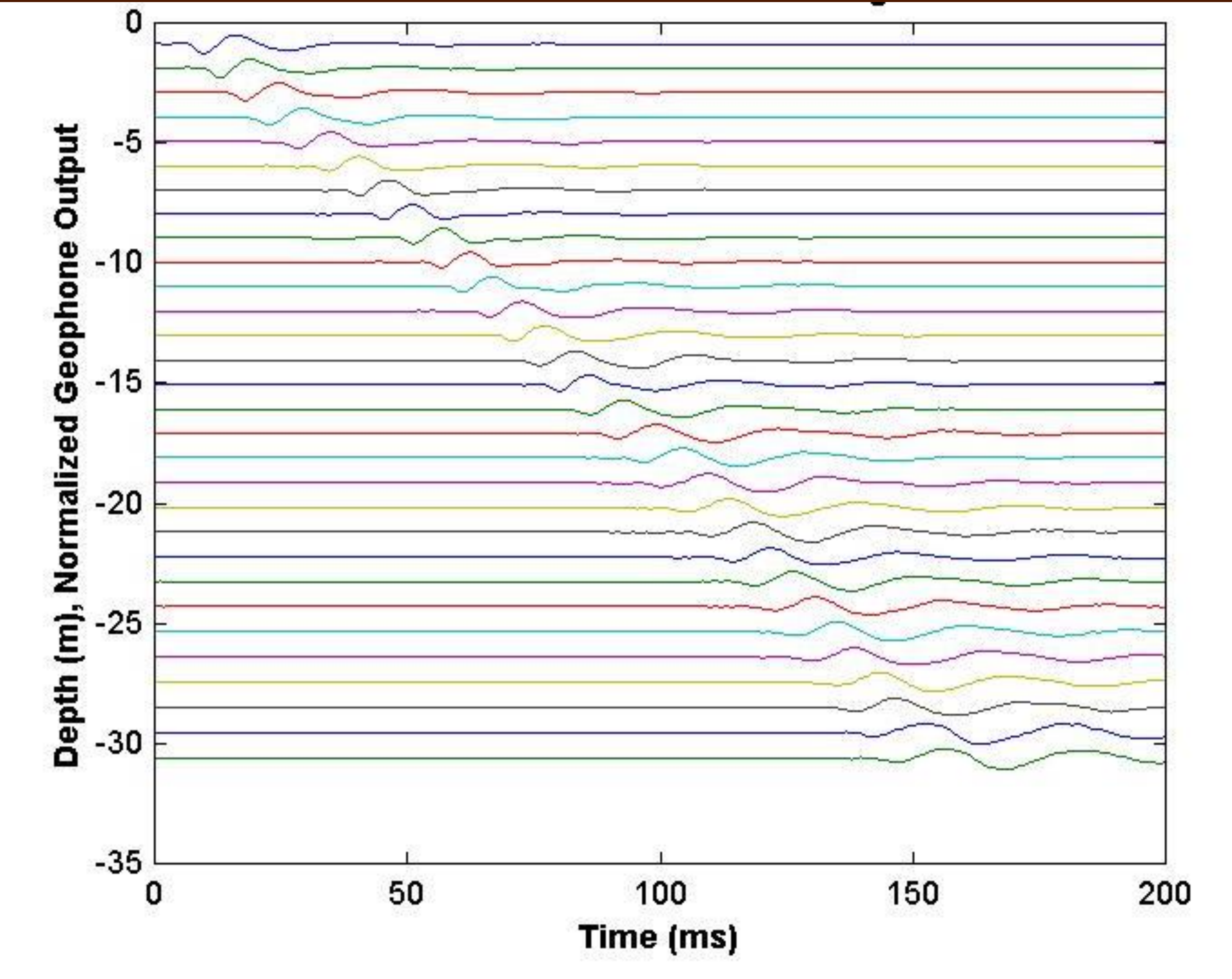
Downhole Shear Wave Velocity



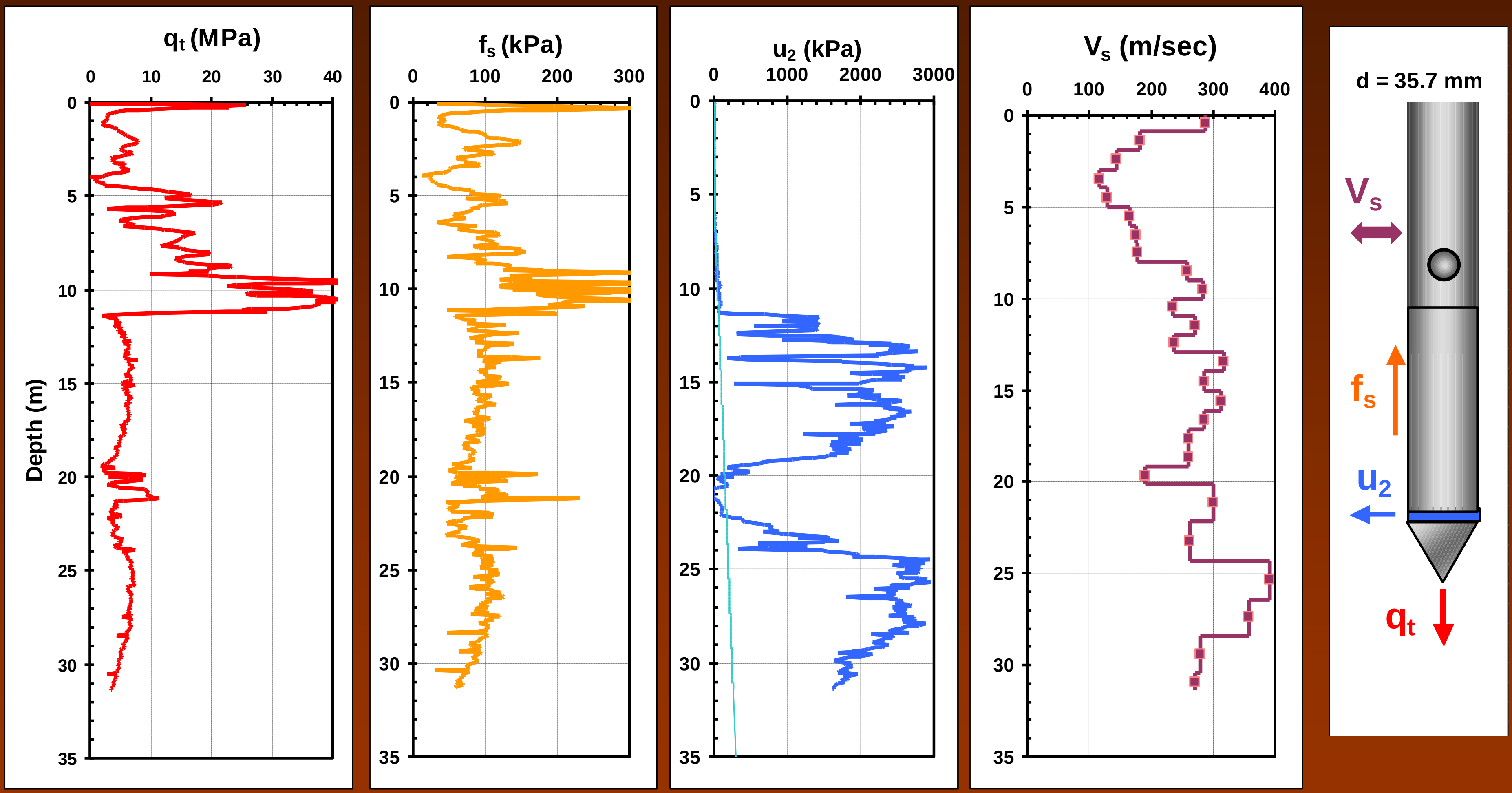
- Anchoring System
- Automated Source
- Polarized Wave
- Downhole V_s with excellent soil coupling.

Complete Set of Shear Wave Trains

Mud Island Site A, Memphis TN

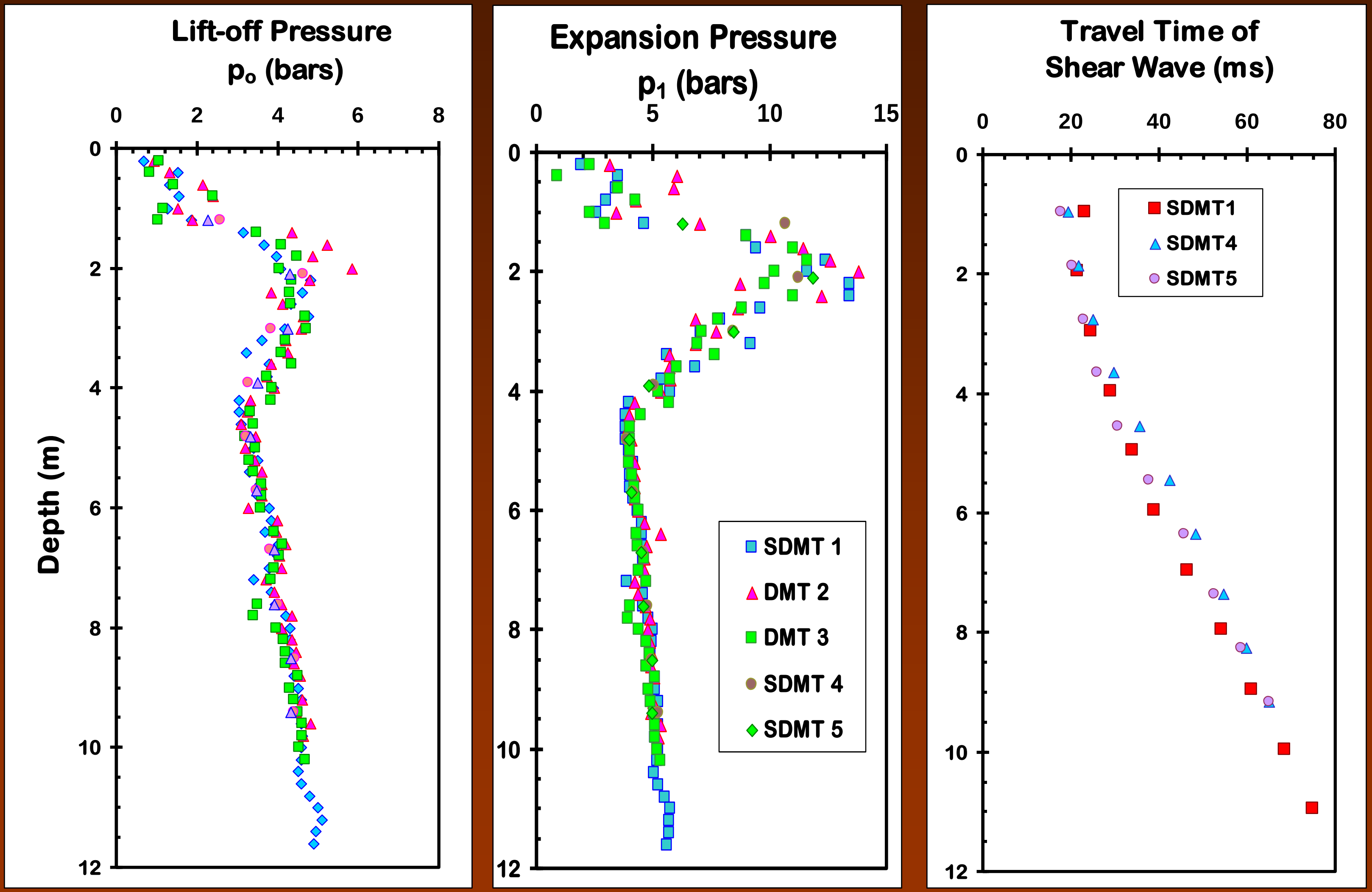


Sounding - Memphis, Shelby County, TN



Seismic Flat Dilatometer (SDMT)

Seismic DMTs at UMASS, Amherst



More Measurements is

More Better

Geophysical Methods

Electromagnetic Wave Techniques

Electromagnetic Wave Geophysics

- Nondestructive methods
- Non-invasive; conducted across surface.
- Measurements of electrical & magnetic properties of the ground: resistivity (conductivity), permittivity, dielectric, and magnetic fields.
- Cover wide spectrum in frequencies (10 Hz $< f <$ 10^{22} Hz).

Electromagnetic Wave Geophysics

- **Surface Mapping Techniques:**
  - Ground Penetrating Radar (GPR)
  - Electrical Resistivity (ER) Surveys
  - Electromagnetic Conductivity (EM)
  - Magnetometer Surveys (MS)
- **Downhole Techniques**
  - Resistivity probes, MIPs, RCPTu
  - 2-d and 3-d Tomography

Ground Penetrating Radar (GPR)

- GPR surveys conducted on gridded areas
- Pair of transmitting and receiver antennae
- Short impulses of high-freq EM wave
- Relative changes in dielectric properties reflect differences in subsurface.
- Depth of exploration is soil dependent (up to 30 m in dry sands; only 3 m in wet saturated clay)

Ground Penetrating Radar (GPR)

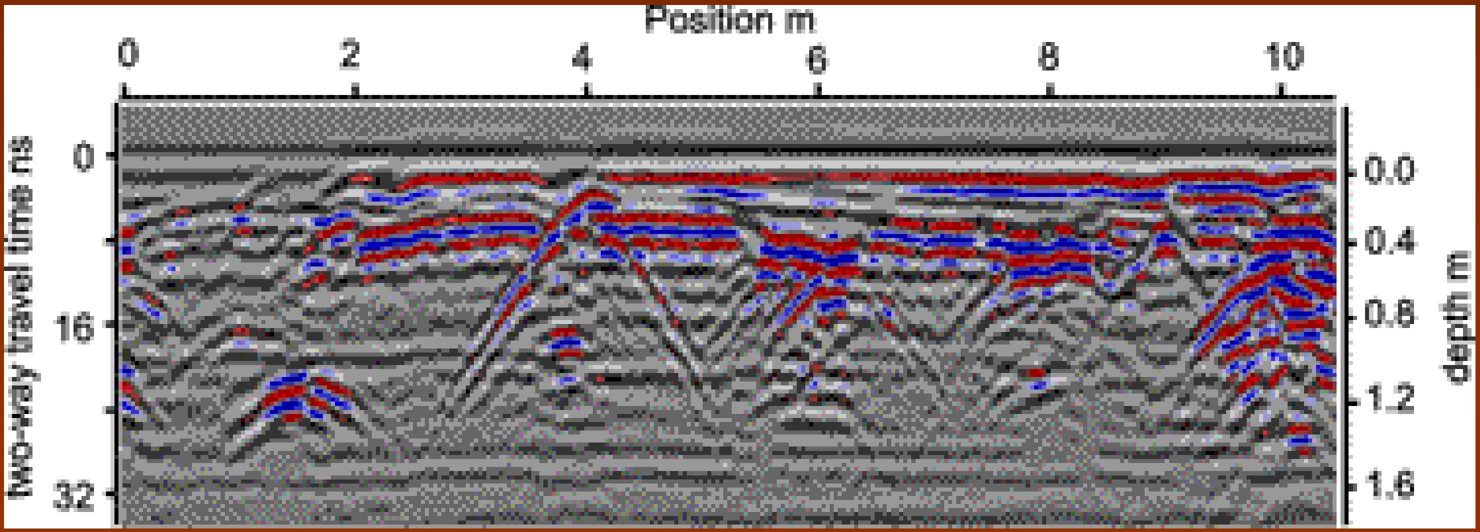
Xadar

Sensors & Software

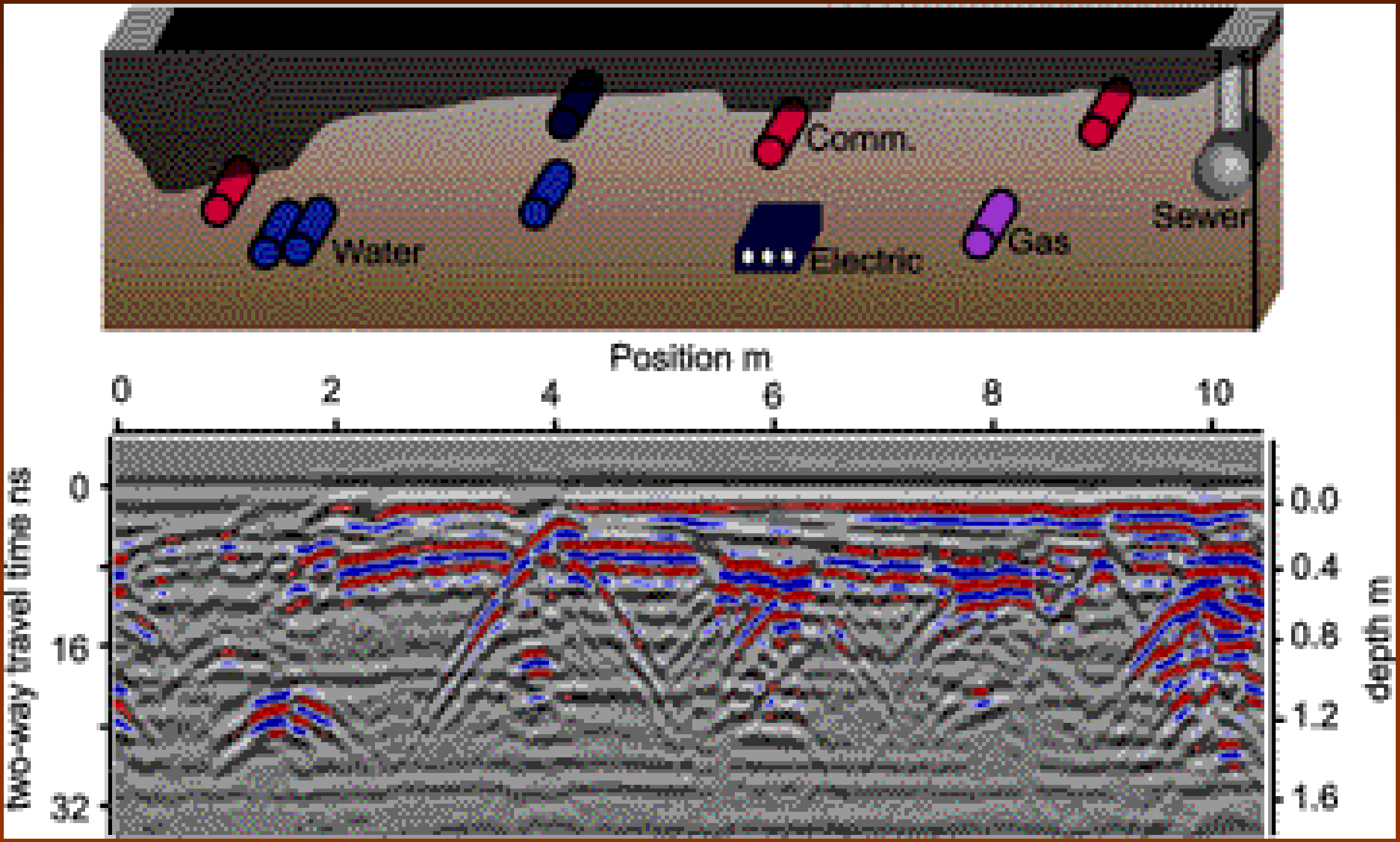
GeoRadar

Illustrative Results from Ground Penetrating Radar (GPR)

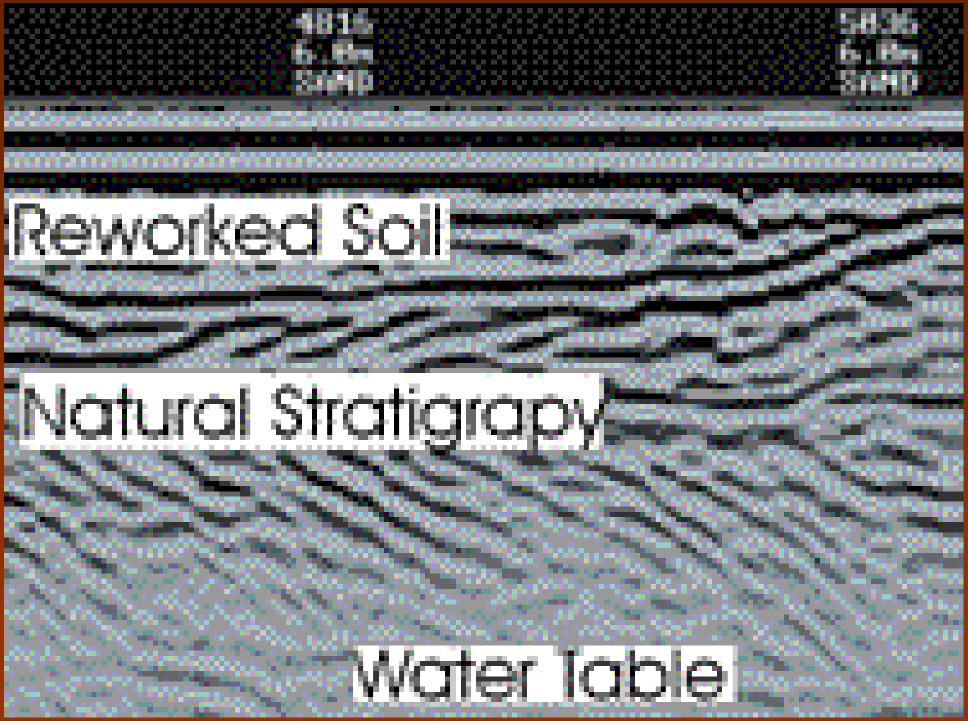
Crossing an underground utility corridor



Illustrative Results from Ground Penetrating Radar (GPR)



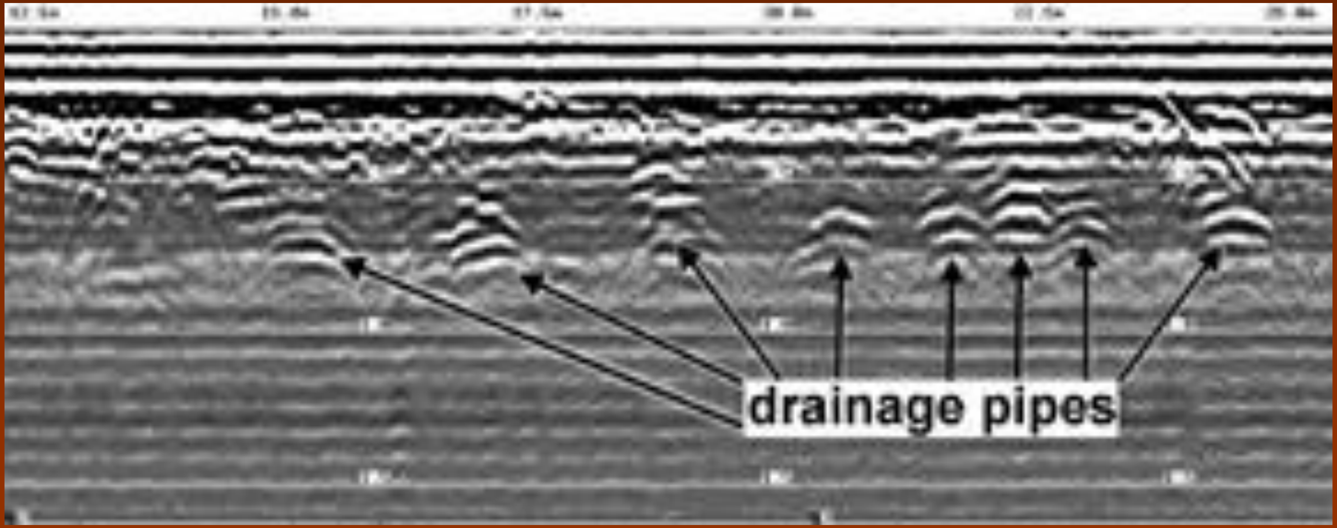
Illustrative Results of Ground Penetrating Radar (GPR)



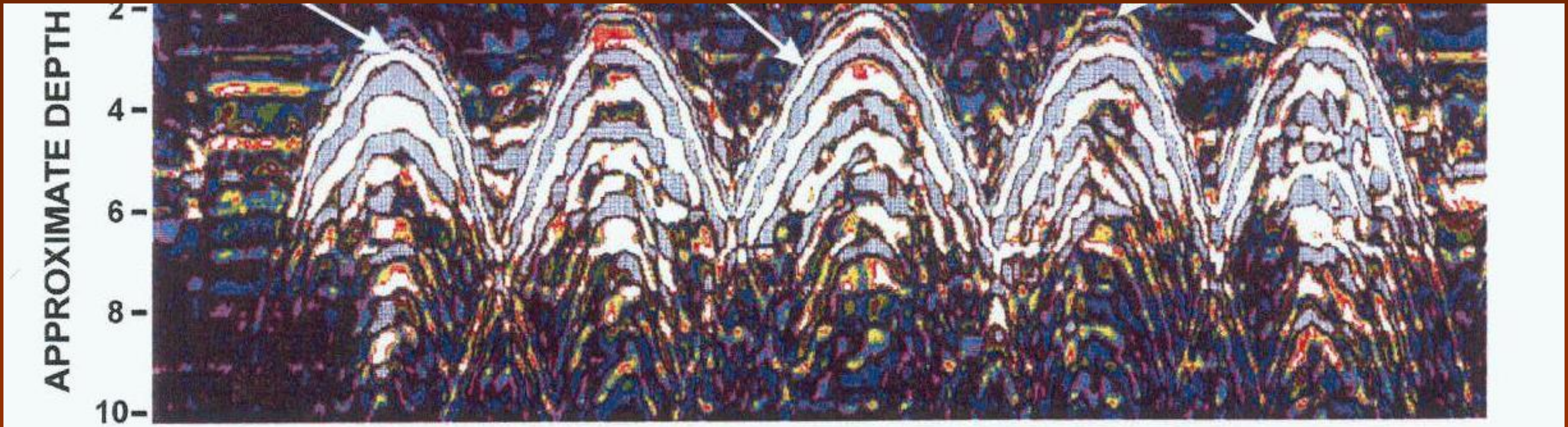
Geostratigraphy

Examples of Ground Penetrating Radar (GPR)

Useful in Locating Underground Utilities

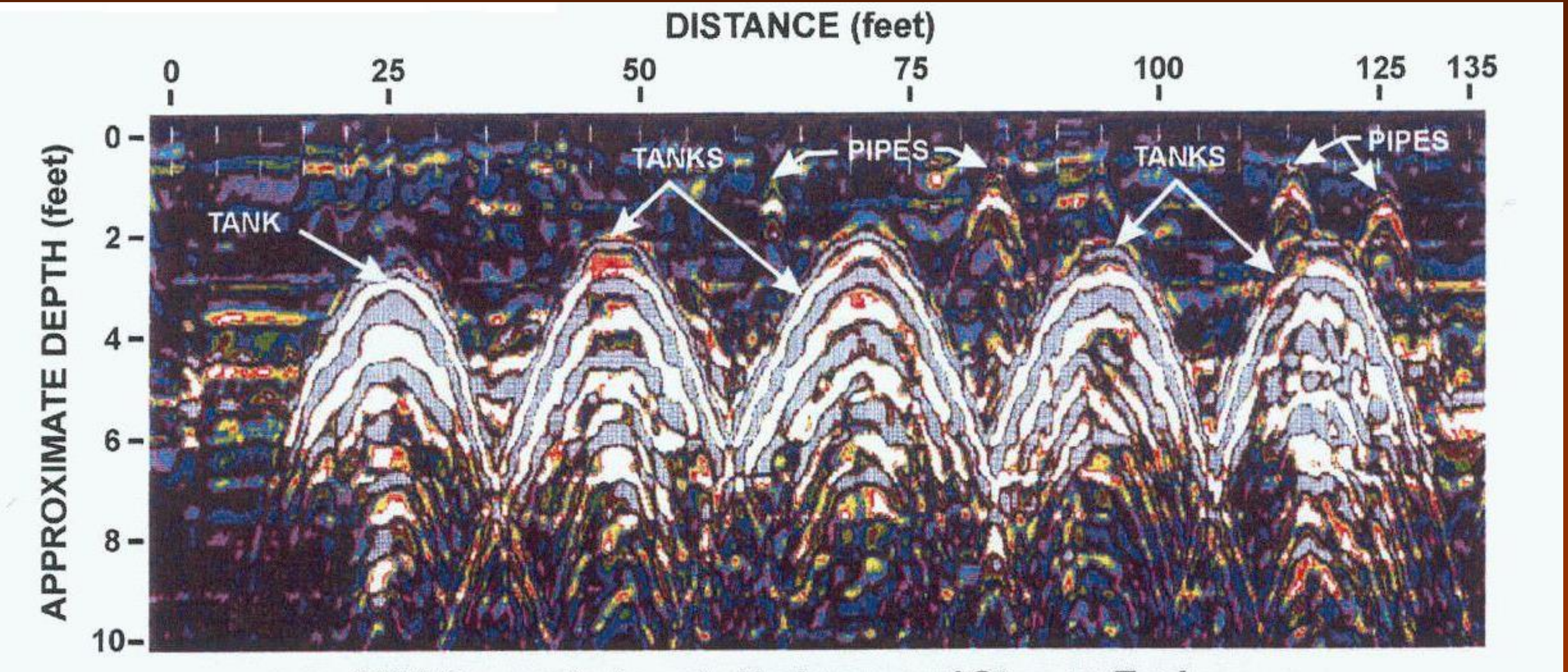


Results from Ground Penetrating Radar (GPR)



GPR Survey to Locate Underground Storage Tanks

Results from Ground Penetrating Radar (GPR)



GPR Survey to Locate Underground Storage Tanks

Electrical Resisitivity Measurements

OYO McOHM 21 RESISTIVITY SYSTEM

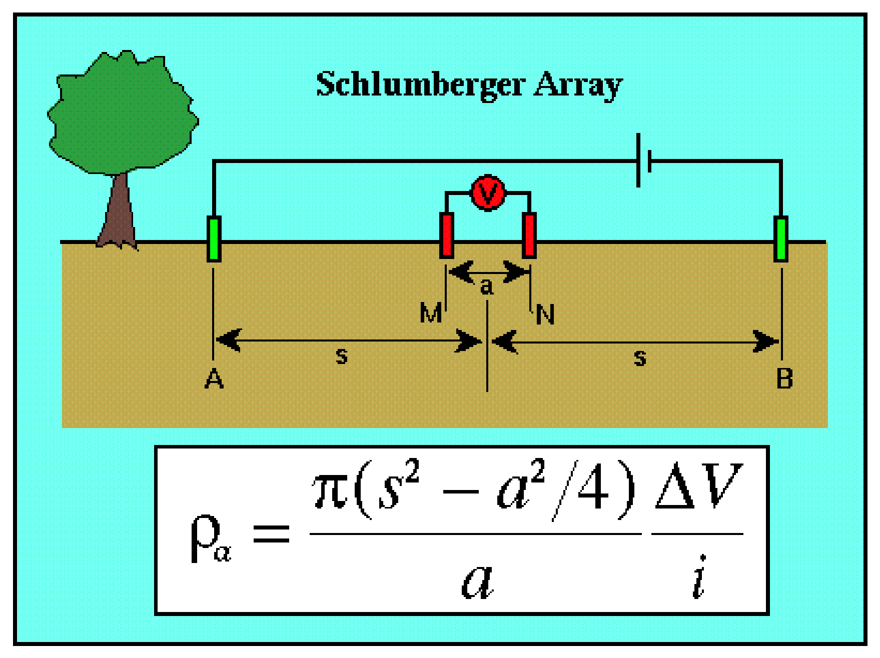
Electrical Resistivity (ER) Surveys

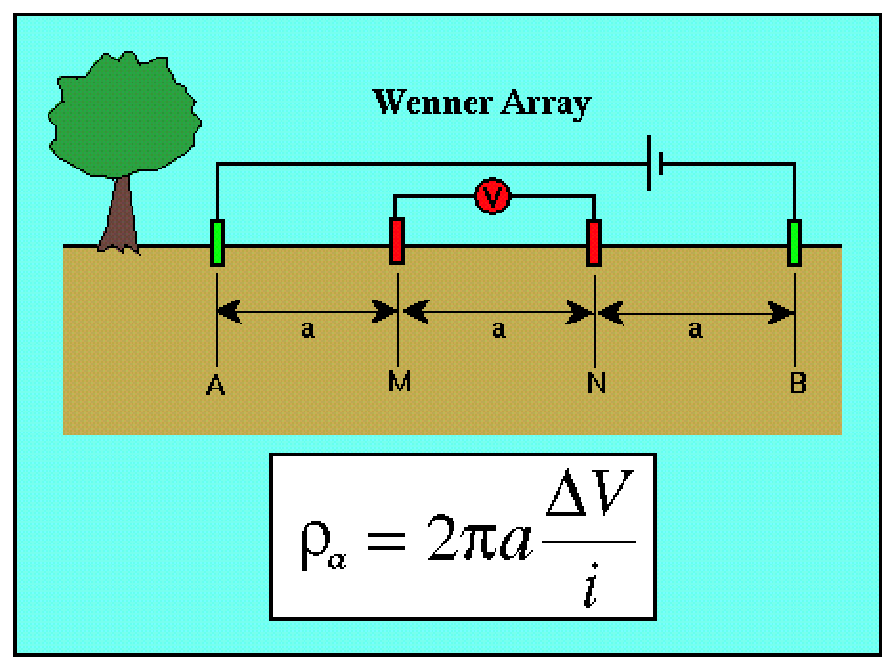
- Resisitivity ρ_R (ohm-m) is an electrical property. It is the reciprocal of conductivity
- Arrays of electrodes used to measure changes in potential.
- Evaluate changes in soil types and variations in pore fluids
- Used to map faults, karst features (caves, sinkholes), stratigraphy, contaminant plumes.

Electrical Resisitivity Measurements

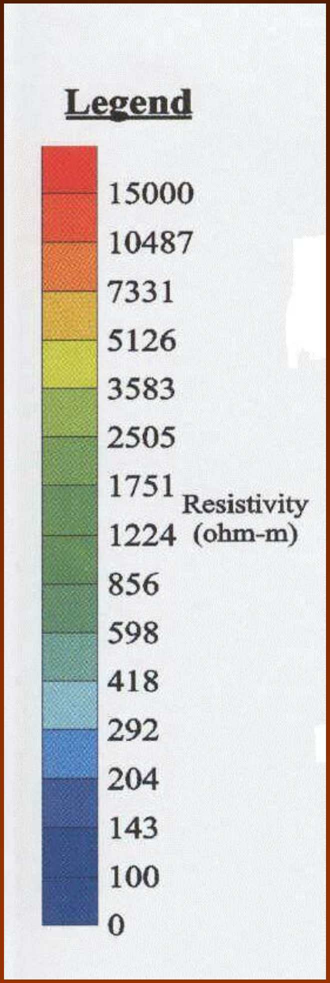
What will be gained by changing electrode spacing?

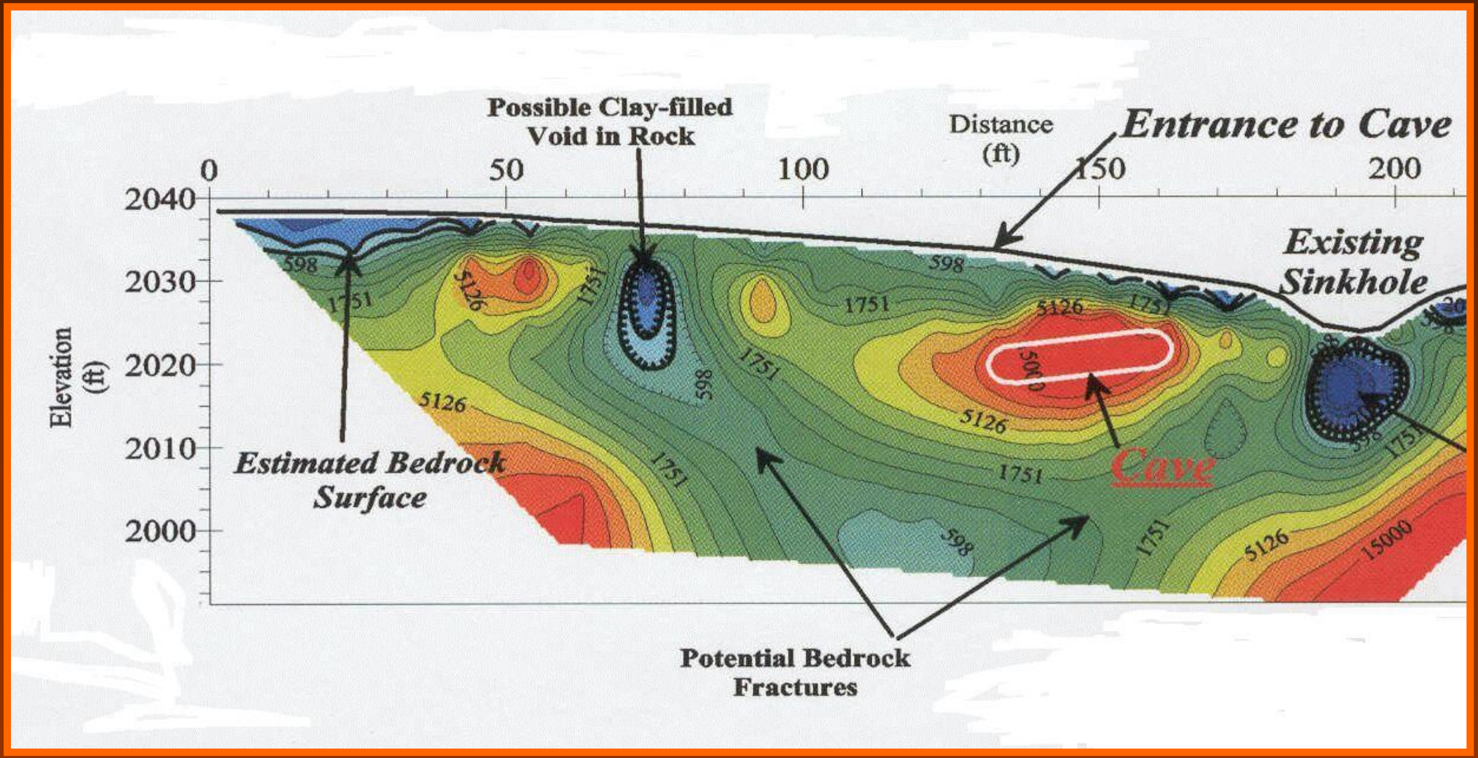
Depth of ER survey: i.e., greater spacing influences deeper



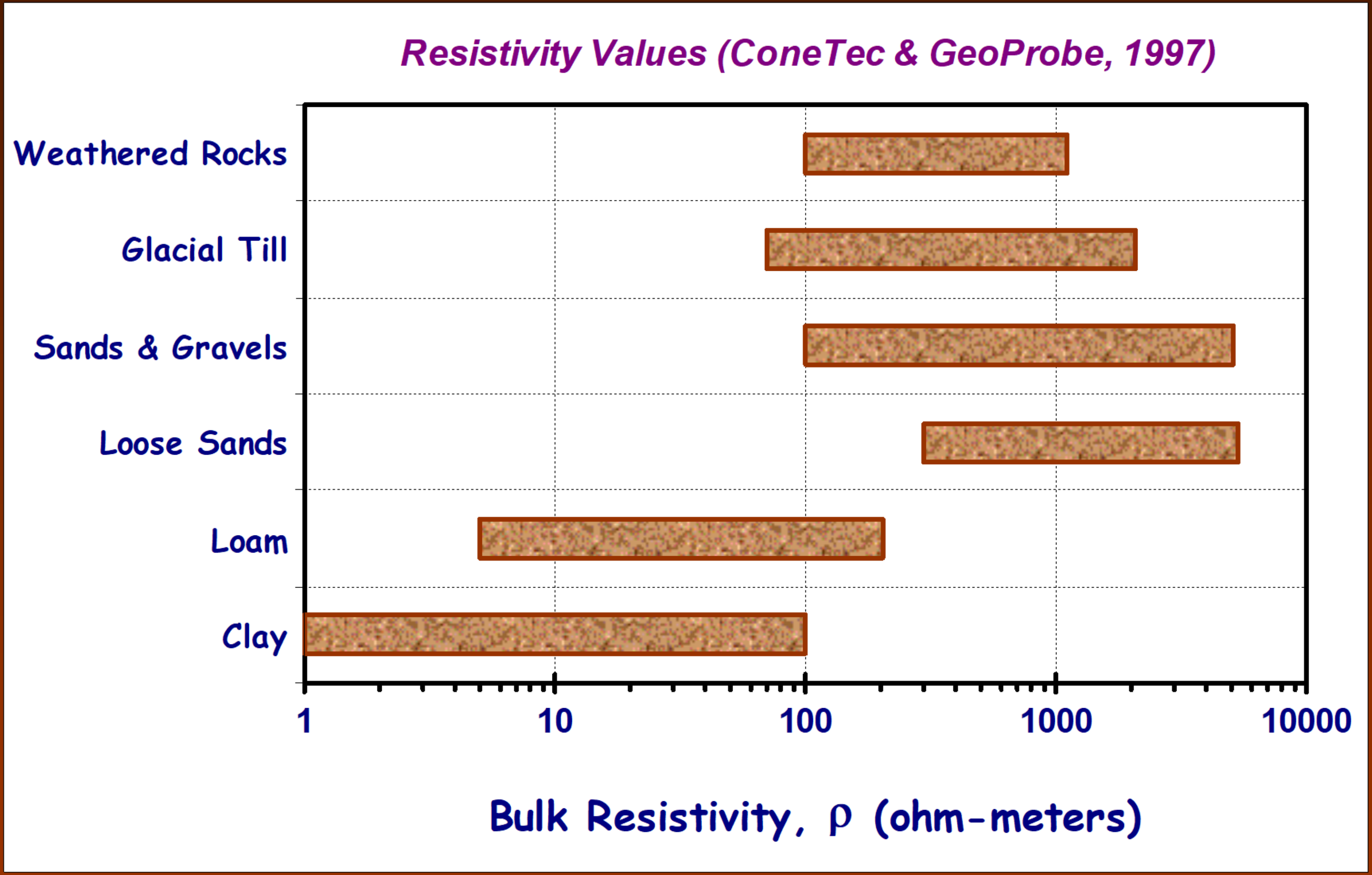


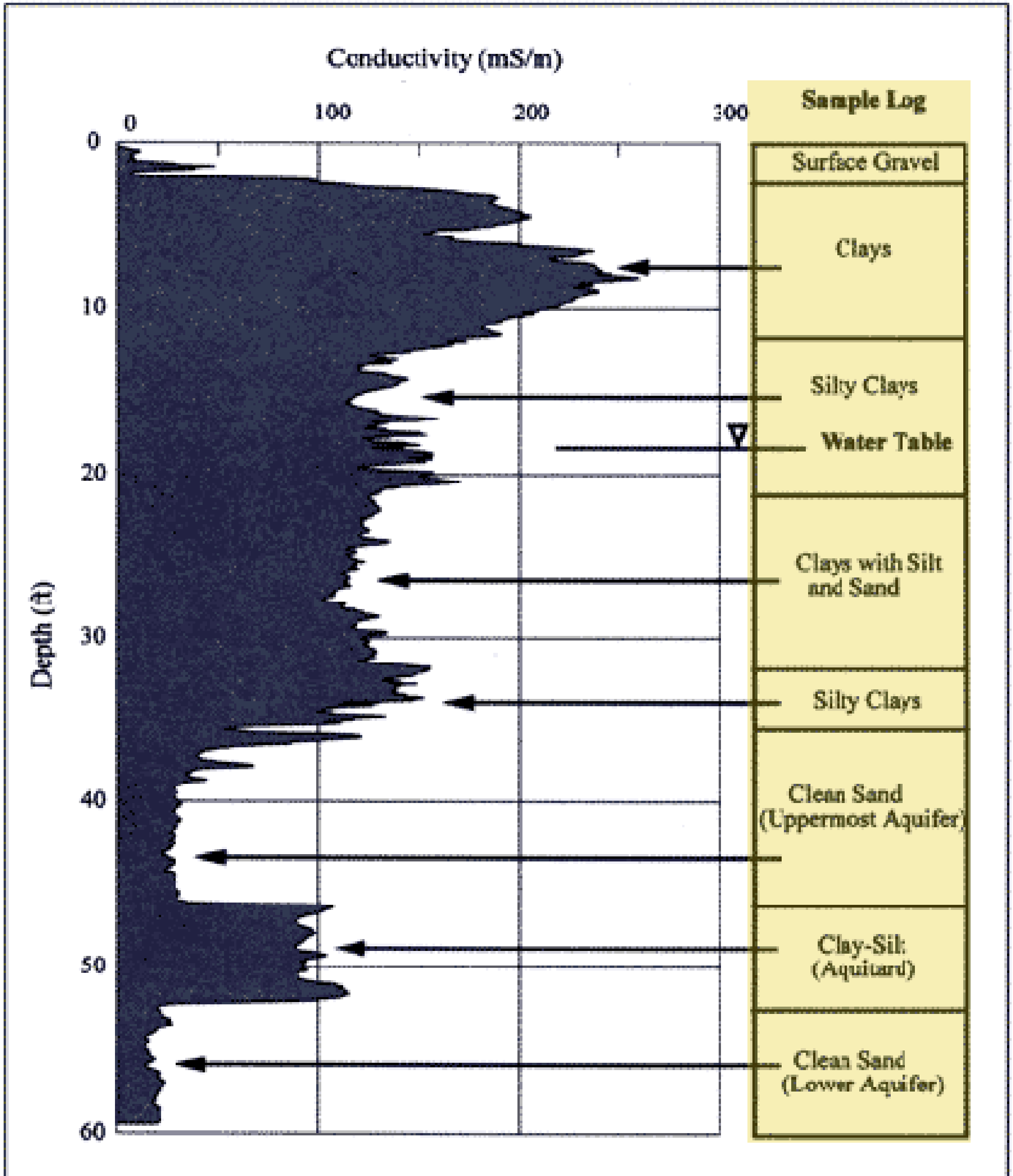
Electrical Resisitivity Measurements



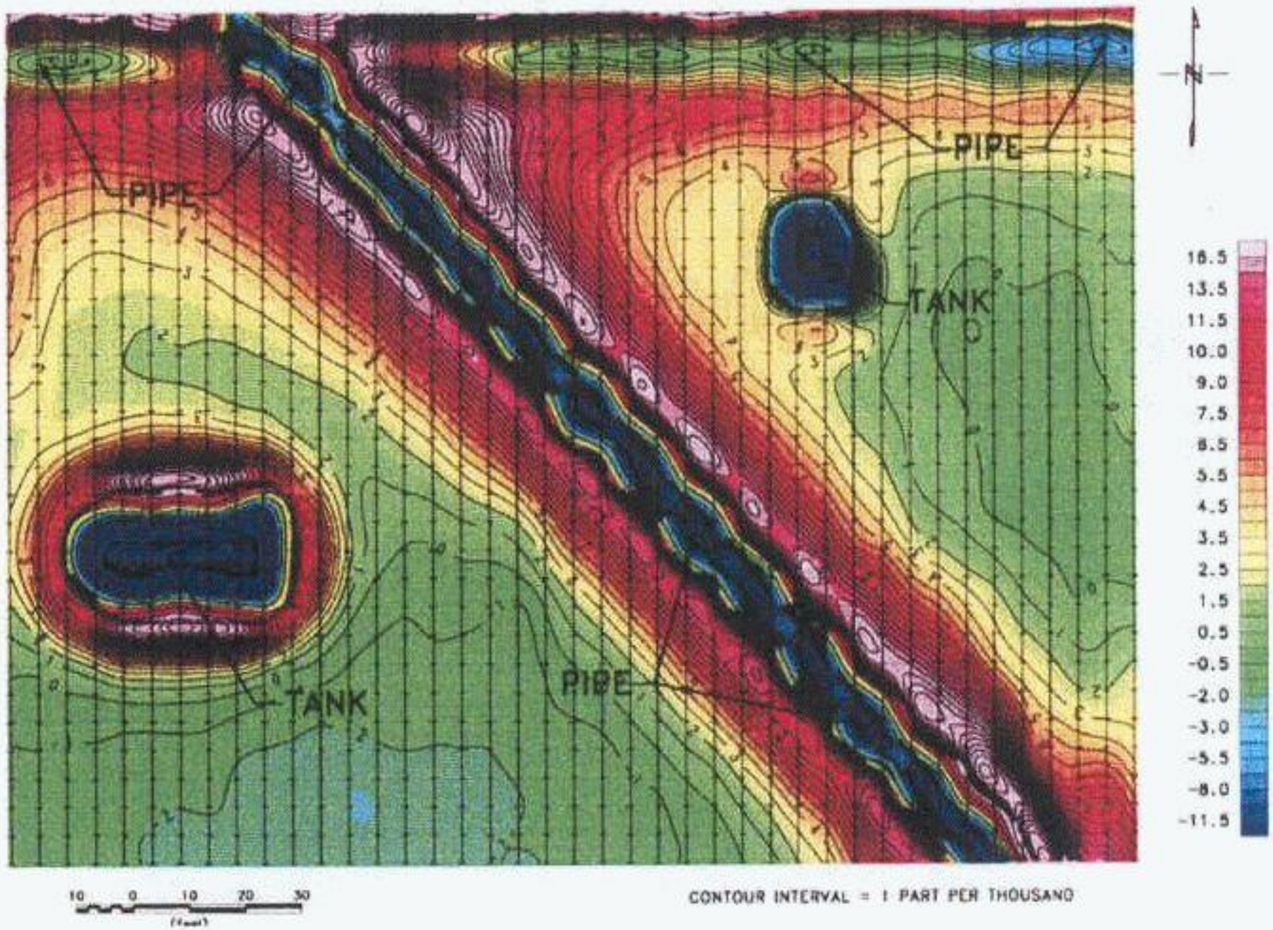


Electrical Resisitivity Measurements




Conductivity (mS/m)
0
100
200
300
Sample Log
Depth (ft)
0
10
20
30
40
50
60
Surface Gravel
Clays
Silty Clays
Water Table
Clays with Silt and Sand
Silty Clays
Clean Sand (Uppermost Aquifer)
Clay-Silt (Aquitard)
Clean Sand (Lower Aquifer)

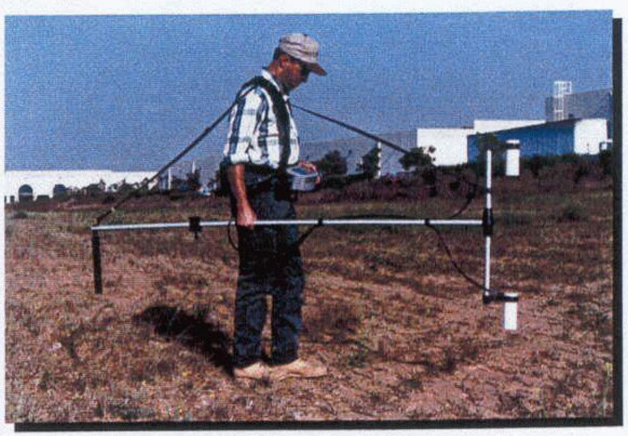
Electromagnetic Conductivity (EM)



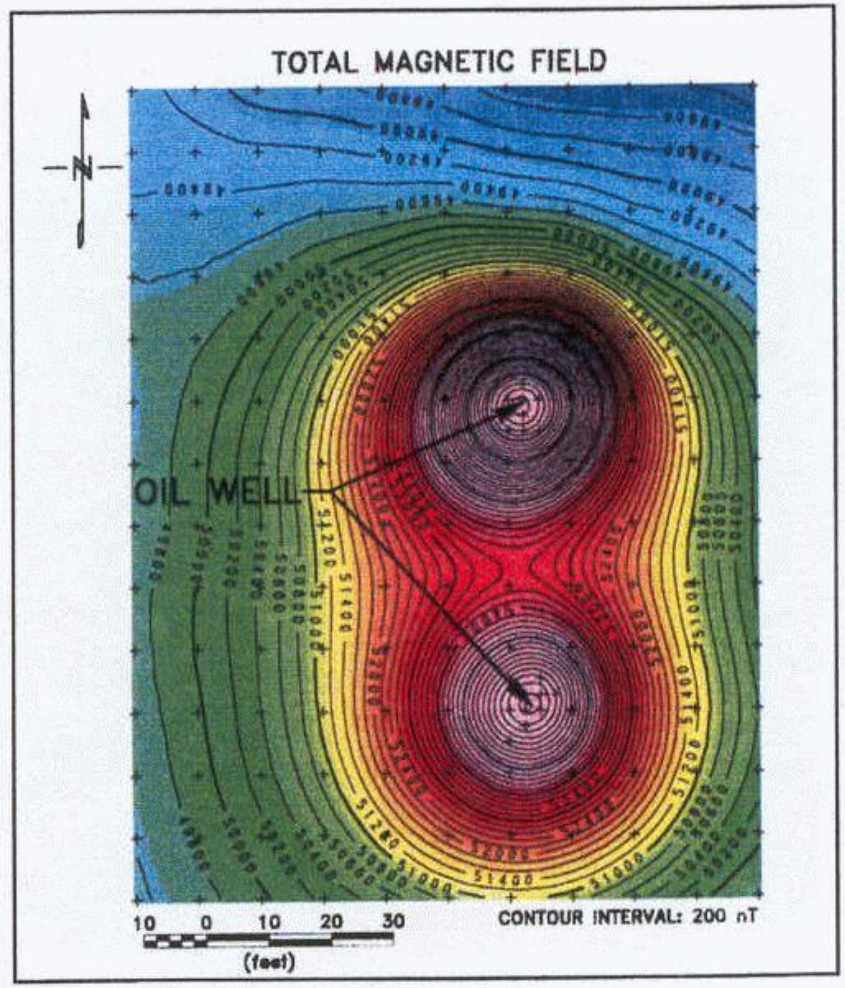
Geonics EM-31 Survey to Locate Underground Storage Tanks

Magnetometer Surveys (MS)

Measure relative changes in the earths' magnetic field across a site.

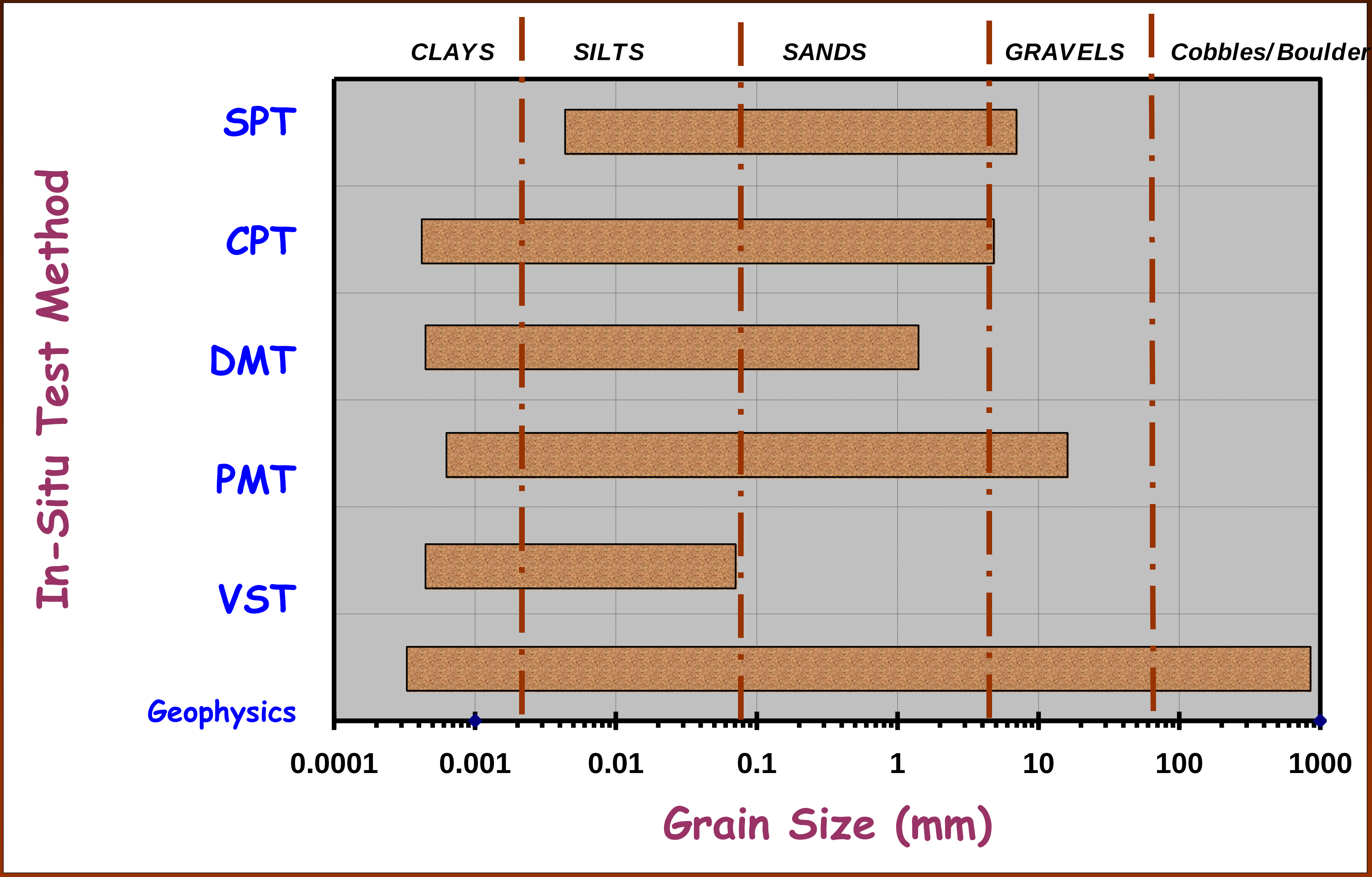


Geometrics G-858 Magnetometer



Magnetic Survey to Locate Abandoned Oil Wells

Applicability of In-Situ Tests



In-Situ Testing - Objectives

- Select in-situ tests for augmenting, supplementing, and even replacing borings.
- Realize the applicability of various in-situ methods to different soil conditions.
- Recognize the complementary nature of in-situ direct push methods with conventional rotary drilling & sampling methods.
- Recognize values for utilizing these methods and quality implications for their underuse.

A.P. Van den Berg Track Truck