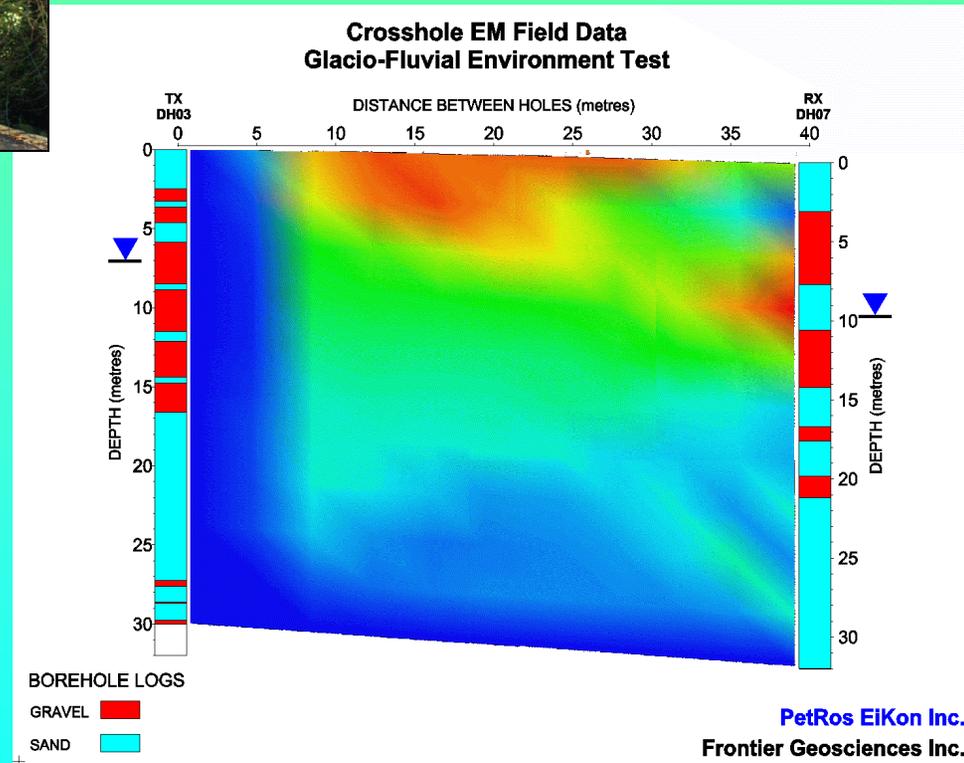


07/24/2004



X-hole Tomography

A new frontier in Equipment and Software



***PetRos EiKon Inc. and
Frontier Geosciences Inc.***



X-hole Tomography



PetRos EiKon

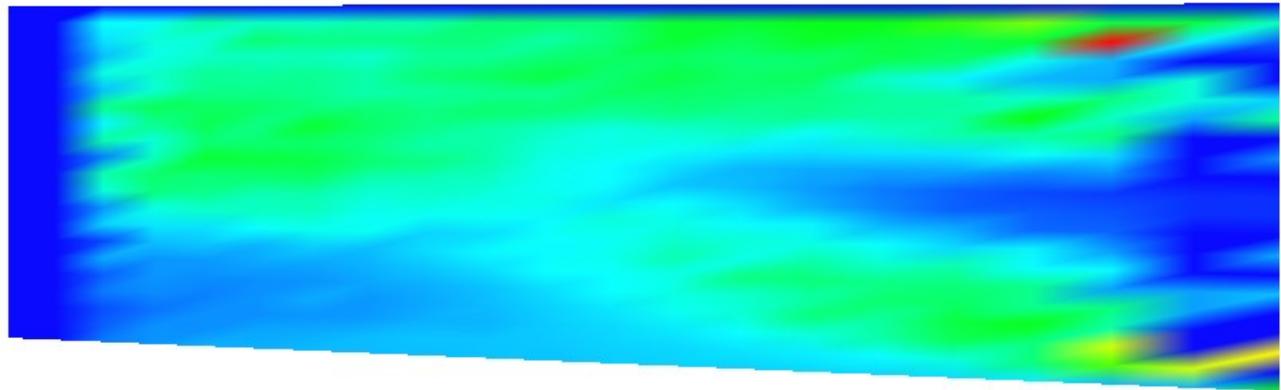
Crosshole
Instrumentation

Interpretation
Systems

Tomography

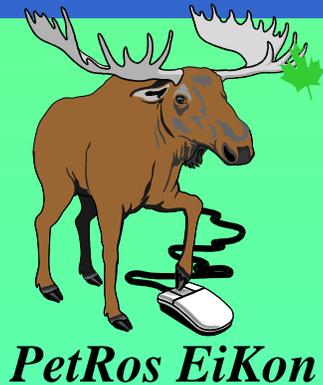
Imaging
between holes

An Electrical Antennae Crosshole Instrumentation and Interpretation System



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X-hole Tomography

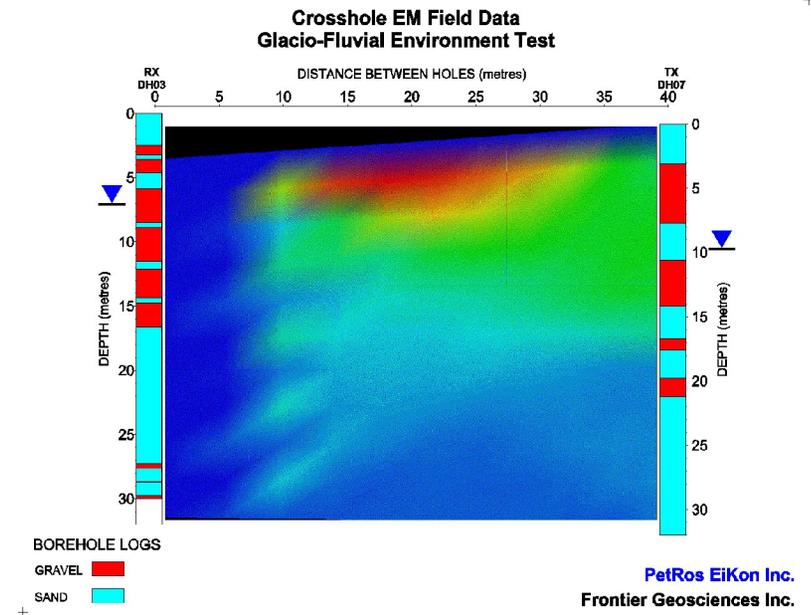


Overview of Development Program Objectives

Applications:

- ▼ Geotechnical
- ▼ Environmental
- ▼ Mine Development
- ▼ Oil Recovery Applications

subsurface structural investigations for
waste site and tailing applications,
ore delineation, reservoir characterization,
rock weaknesses, fluid and viscous boundary investigations
monitoring



X-hole Tomography

Electrical Antennae



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RIM Imaging Technologies

- electromagnetic waves in the radio-frequency band

Electric Field Transmitter and Receiver Antennae

provides sensitivity advantages for a wide range of applications

- weak resistivity contrasts
- permittivity variations
- IP effects and
- discrimination of magnetic structures

Low Frequency to reduce interference with near hole scattering

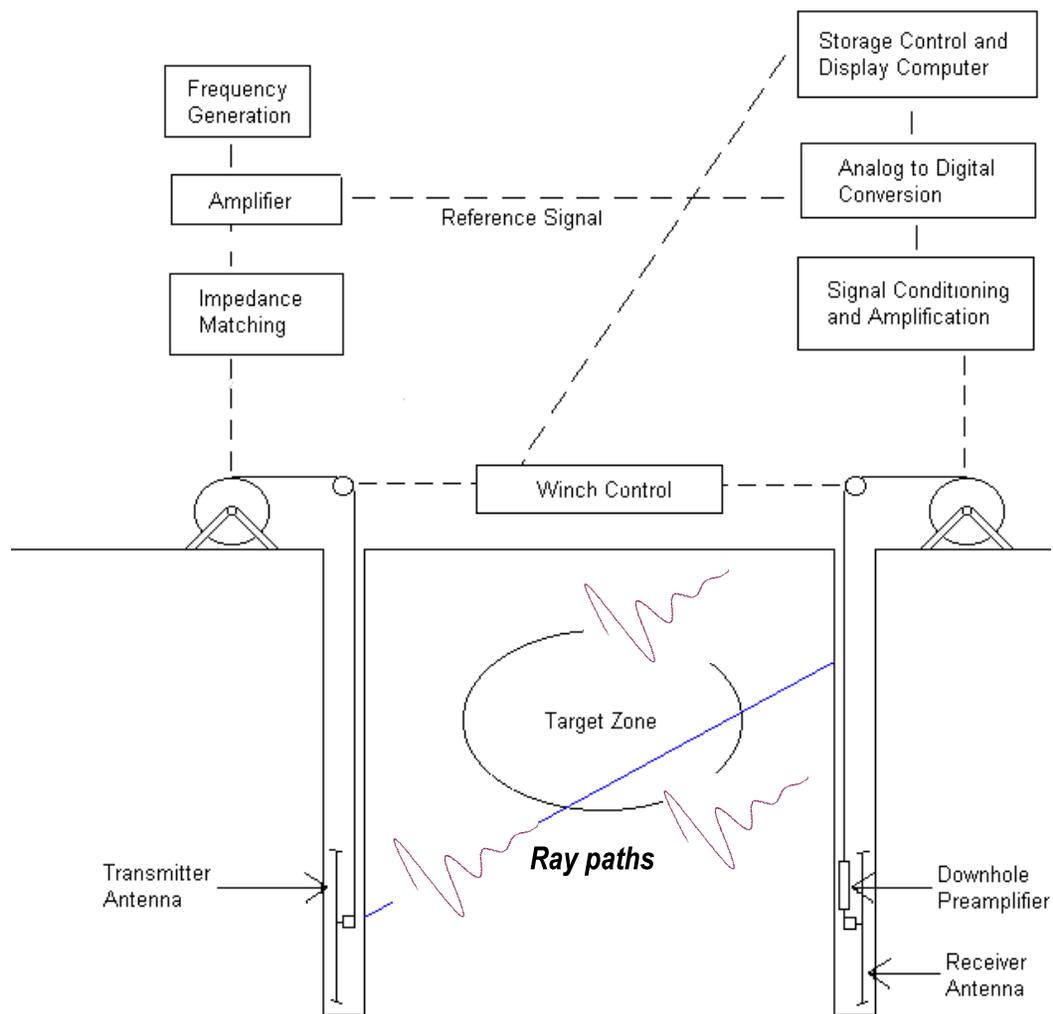
- lower frequencies enables minimization of scattering noise from near-hole fracturing

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Crosshole EM Block Diagram

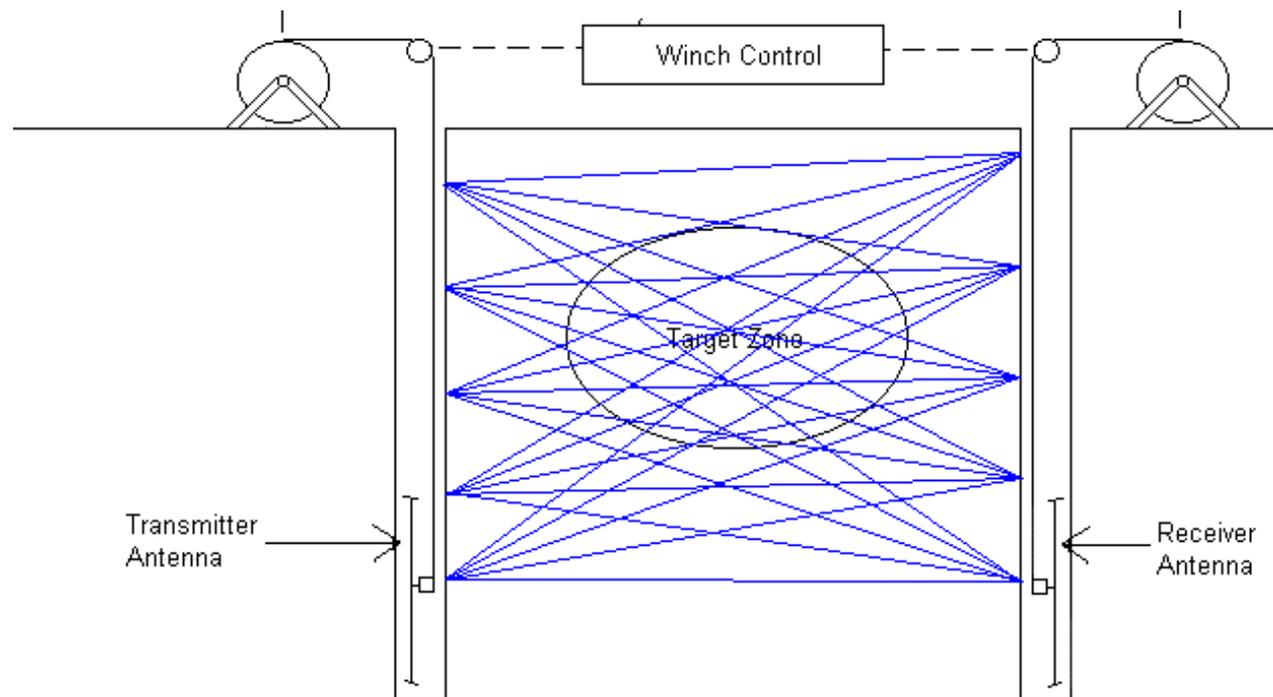


X-hole Tomography



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Cross Borehole Survey Panel



X-hole Tomography

Normal Mode Helical Antennae



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▼ Small antennae
(3m long, 4.-4.5 cm diameter)
effective even for
short, narrow holes

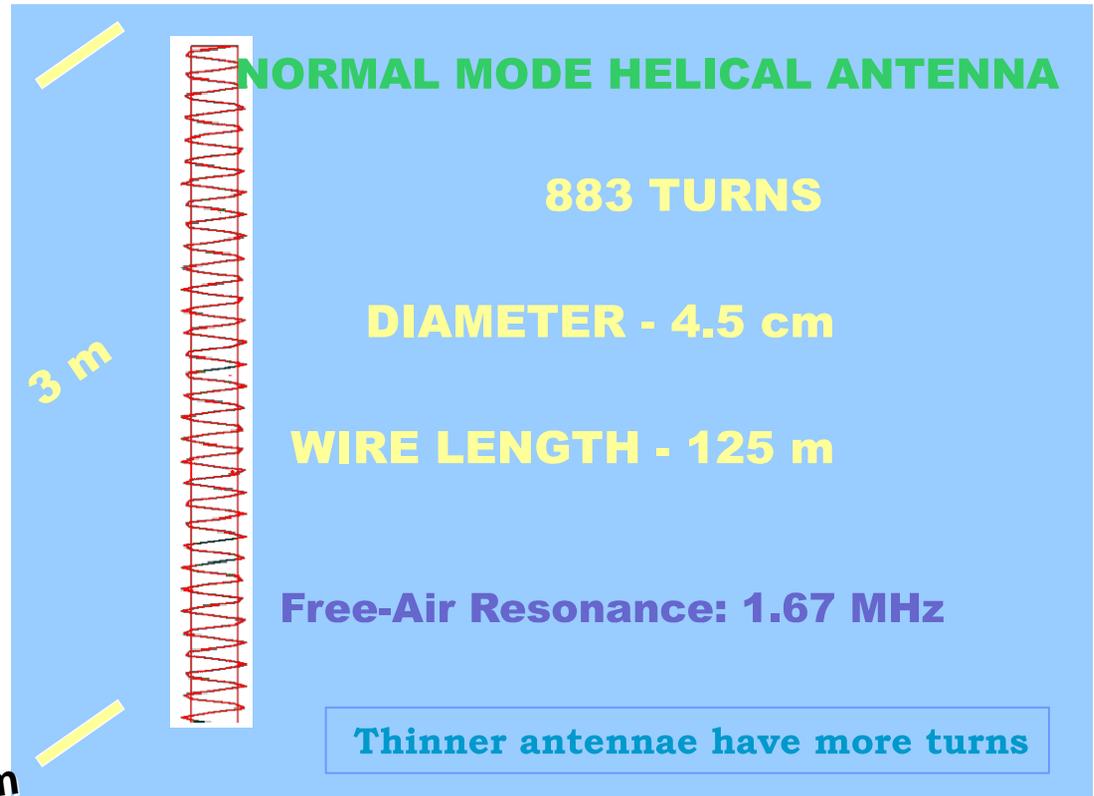
▼ Flexible for twisting holes

▼ Inexpensive design

▼ Depths greater than 600m

▼ Broad band resonance
characteristics (100KHz -
1.5MHz)

▼ Collect multiple frequency
data with a single antennae

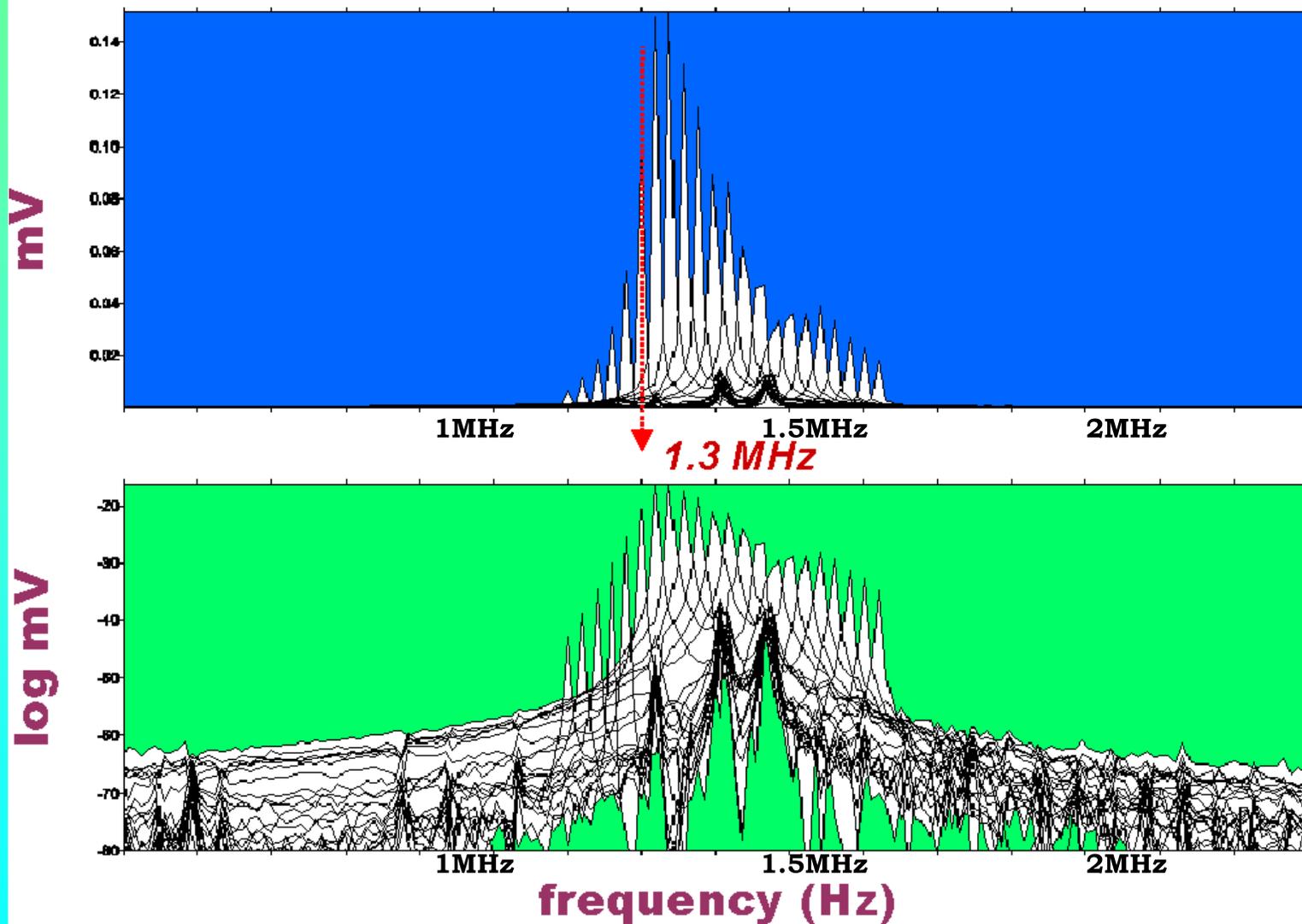


X-hole Tomography



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Free Air Resonance Test



X-hole Tomography

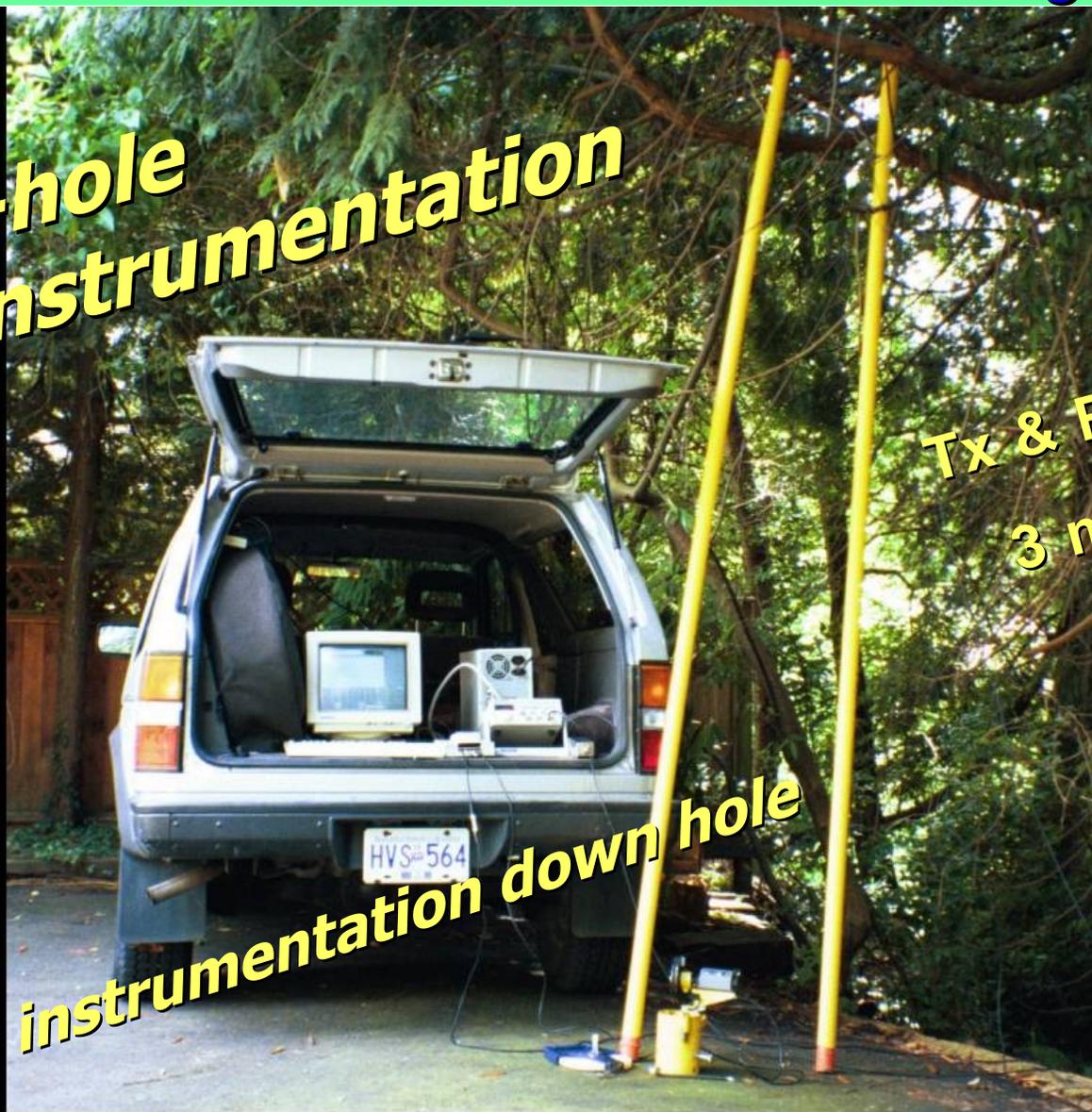


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**X-hole
Instrumentation**

No instrumentation down hole

**Tx & Rx
3 m**



X-hole Tomography



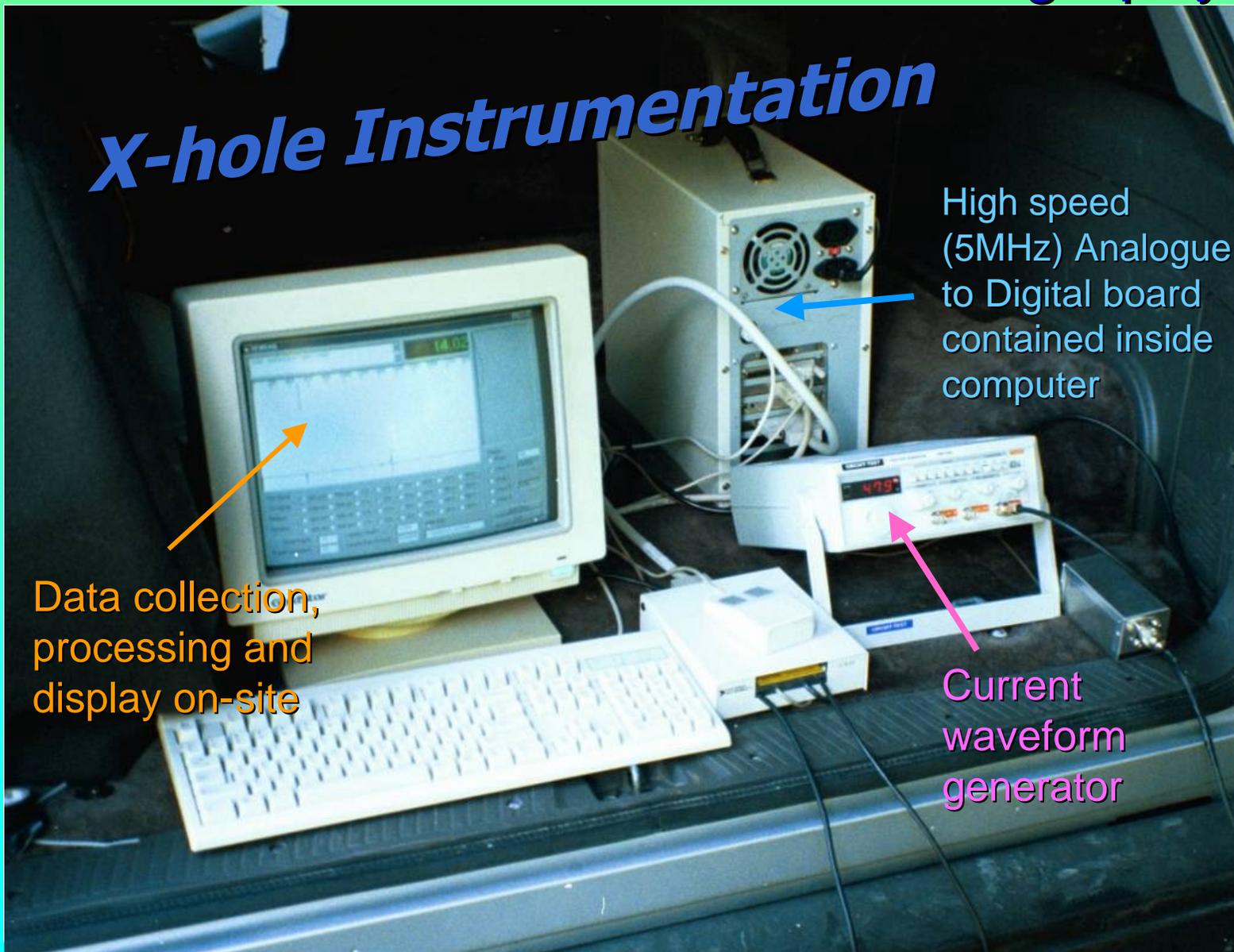
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X-hole Instrumentation

Data collection,
processing and
display on-site

High speed
(5MHz) Analogue
to Digital board
contained inside
computer

Current
waveform
generator





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Data Collection

Rapid Surveying Technique

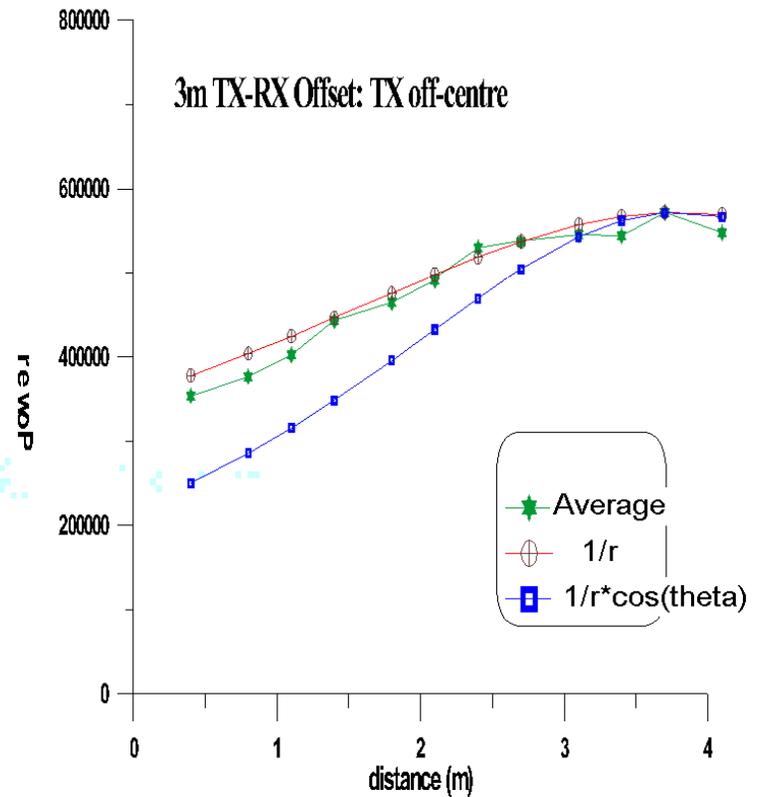
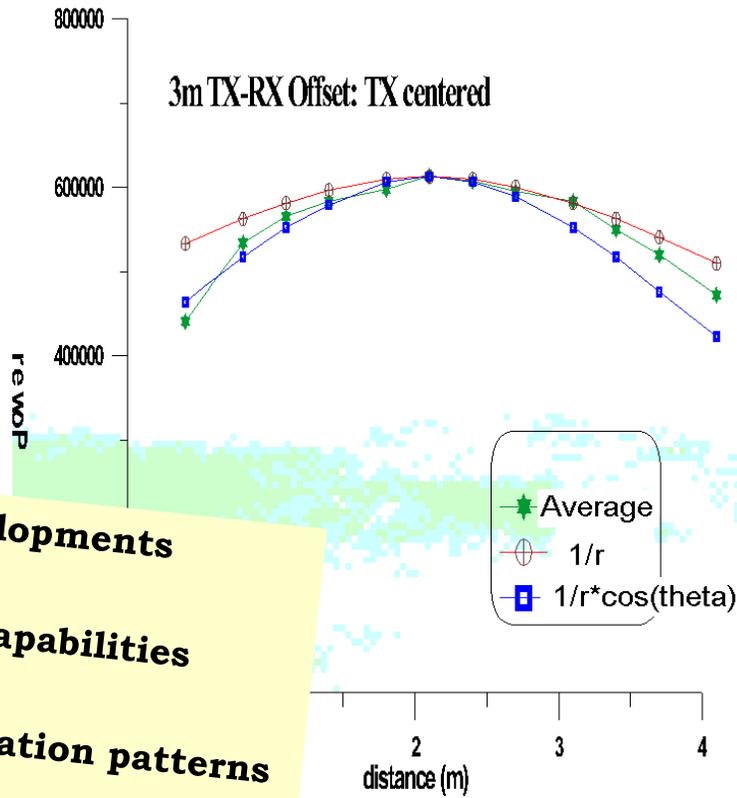
- ▼ Log data as antennae moves virtually in free-fall
- ▼ Monitor reflected voltage from antennae as a function of Tx position in ground
- ▼ Collect data at 0.94 m intervals with automated triggers
- ▼ 1 Data sample every second
- ▼ Log up to 600 m in 15 min
- ▼ Log a 35 m deep Xhole panel with a single frequency in less than an hour

X-hole Tomography



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NMHA FreeSpace Radiation Pattern



Project Developments include Simulation Capabilities for both antennae radiation patterns and scattering effects

Frontier Geosciences

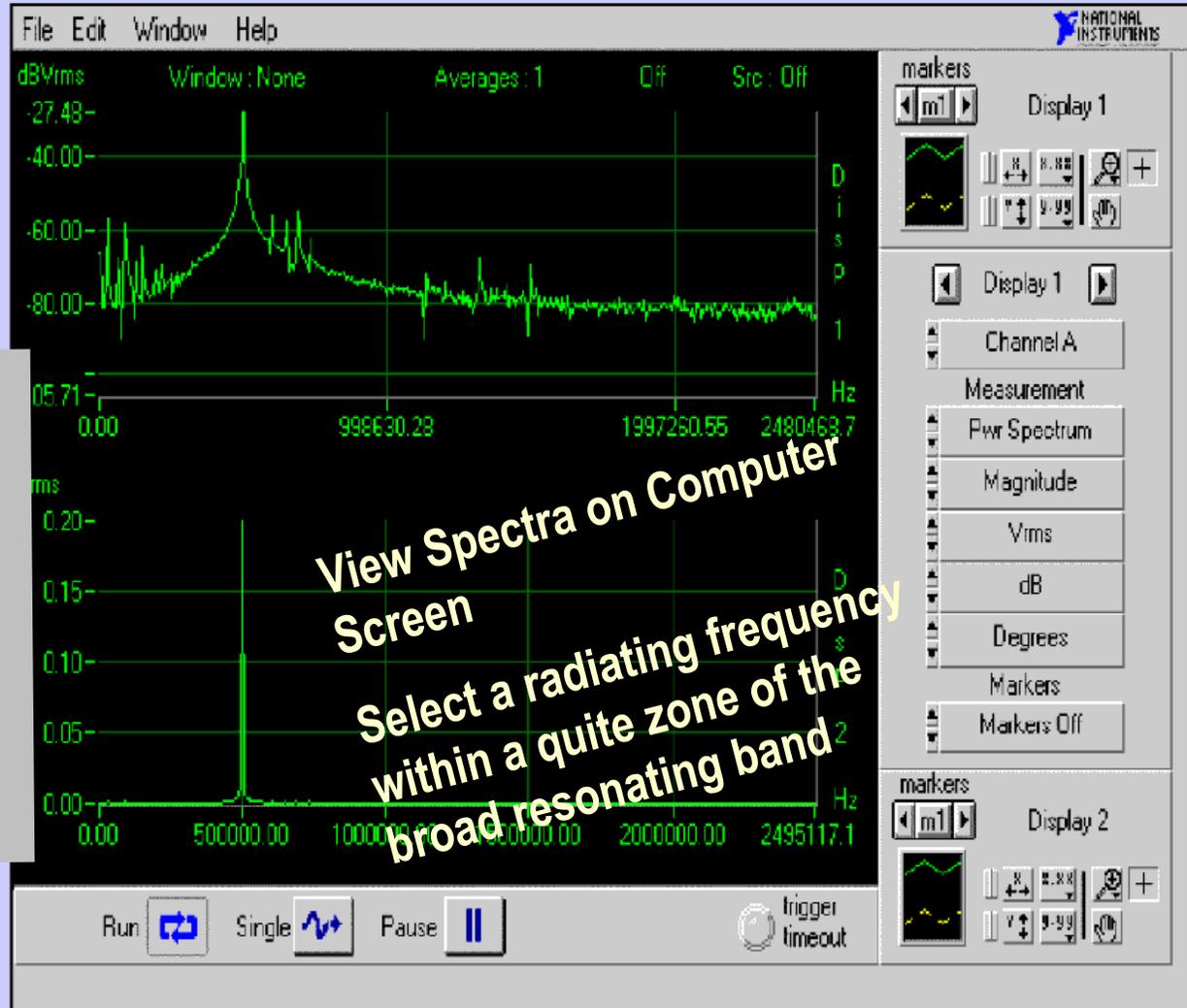
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X-hole Tomography



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IN-FIELD SPECTRA CAPTURE



Digital Signal Analyzer Software

analyze noise characteristics and power

Tune dial to an optimum frequency

View Spectra on Computer Screen
Select a radiating frequency within a quite zone of the broad resonating band



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Test Survey Results:

- 1 Glacio-Fluvial Environment Test
- 2 Earthen Dam Test
- 3 Mine Setting Test
- 4 Municipal Landfill Test Site



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Glacio-Fluvial Environment Test

Tests performed in shallow monitoring holes within glacio-fluvial fill outside a large water-reservoir earthen dam

- One reverse panel of data collected
(first with the TX in one hole and the Rx in the other and then reversing the configuration)

Results:

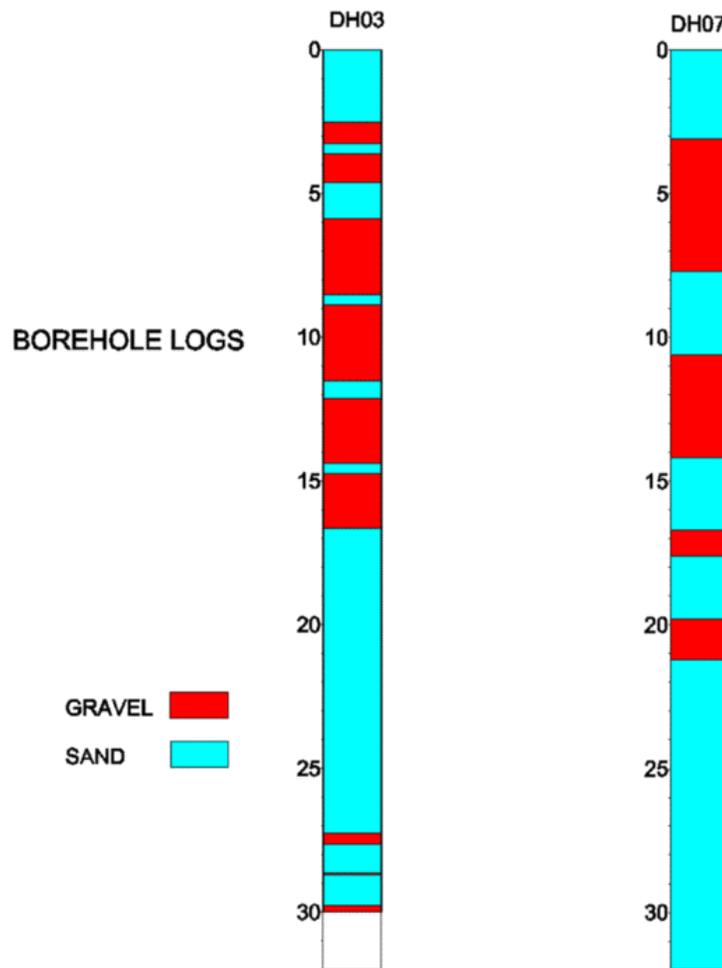
- revealed structure
- indicated several scattering characteristics of the system
- normal mode helical antenna have broad band efficiency in the key range of frequencies when operated in earth materials
- the resonant frequency of the antenna is lowered and made considerably broader when the antennae are operated in earth materials
- provides a wide operating spectra,;the lower range of which are frequencies thought to be most sensitive for dam safety and environmental investigations involving overburden and placer granular materials

X-hole Tomography

Glacio-Fluvial Test



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▼ Relatively low frequency (500 KHz) gives greater sensitivity in this weak contrast environment

▼ Short antennae design (3m) enables use in shallow applications (20 m holes). Other commercially available RIM antennae are 10x longer for low frequencies and 2x longer for high frequencies

▼ Low frequency reduces attenuation allowing for larger hole separations

X-hole Tomography



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Crosshole EM Field Data

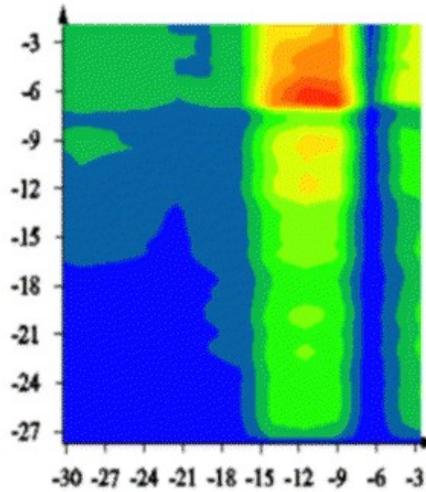
TX in hole DH07

Data Display as a function of
Tx vs Rx Position

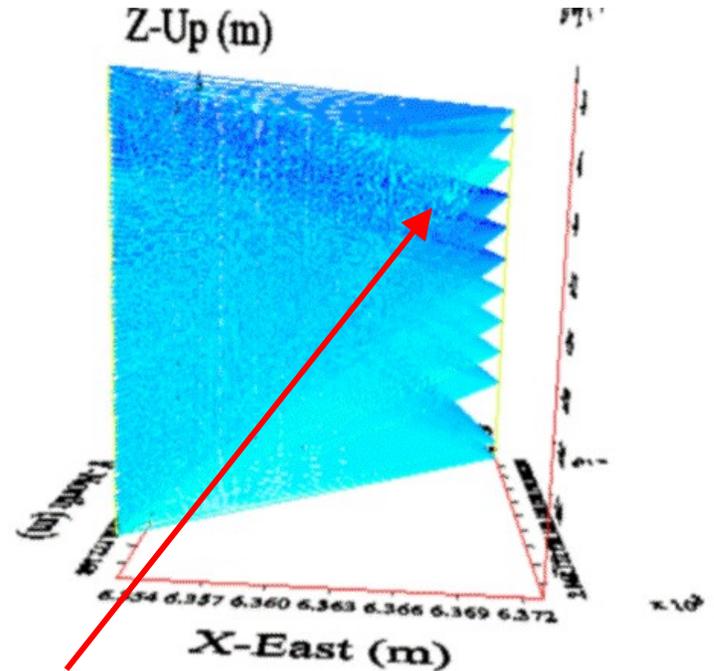
Ray Trace Paths weighted by
amplitude



Tx Depth,m



Rx Depth,m



dark colours =
high amplitude

Tx: Jz
Rx: Ez
Freq# 1
Measured

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Frontier Geoscience

X-hole Tomography



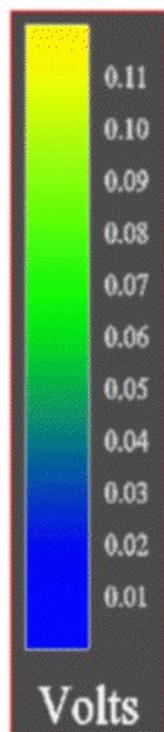
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Crosshole EM Field Data

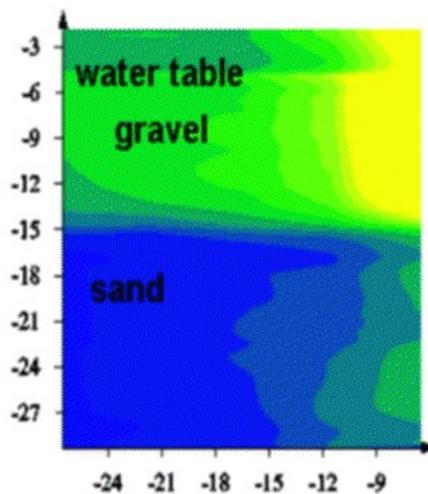
TX in hole DH03

Data Display as a function of

Tx vs Rx Position

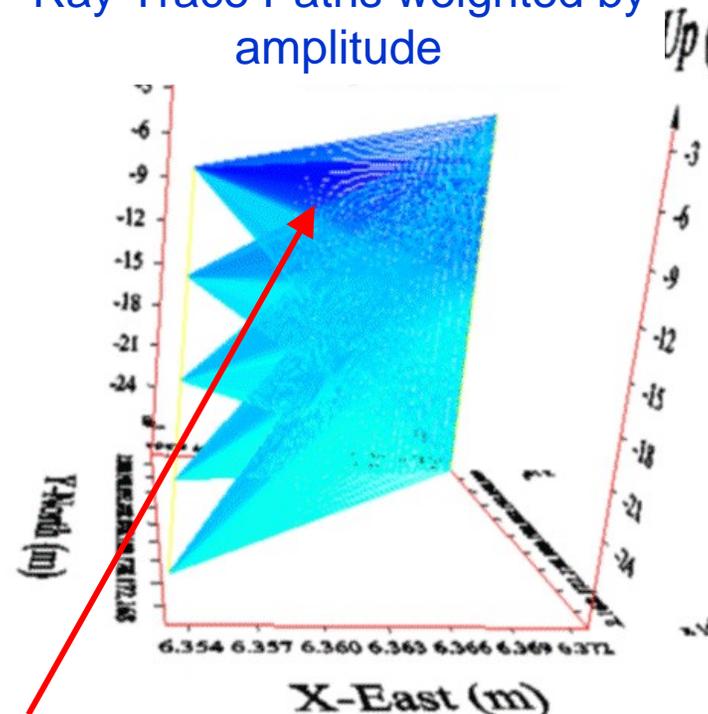


Tx Depth,m



Rx Depth,m

Ray Trace Paths weighted by amplitude



dark colours =
high amplitude

Tx: Jz
Rx: Ez
Freq# 1
Measured

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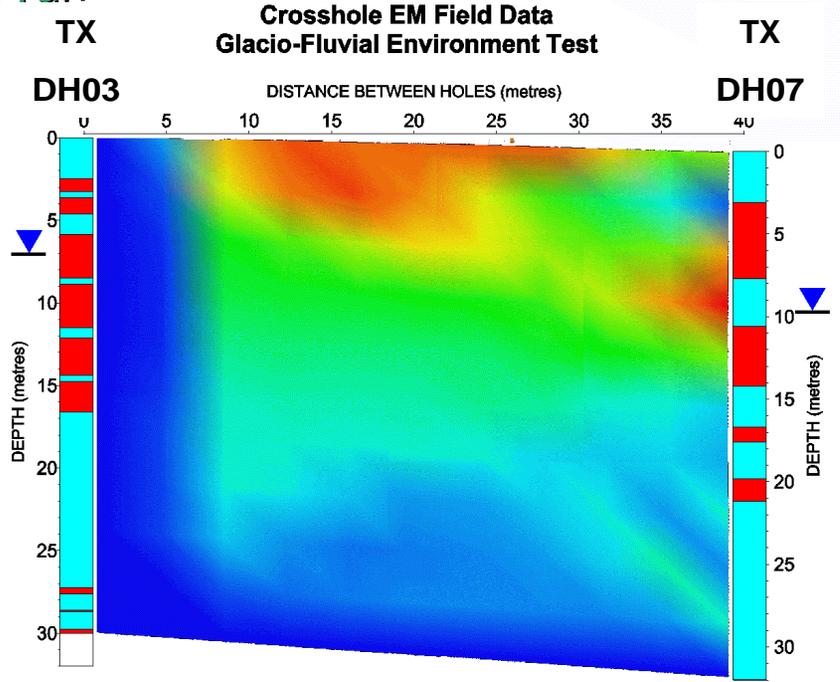
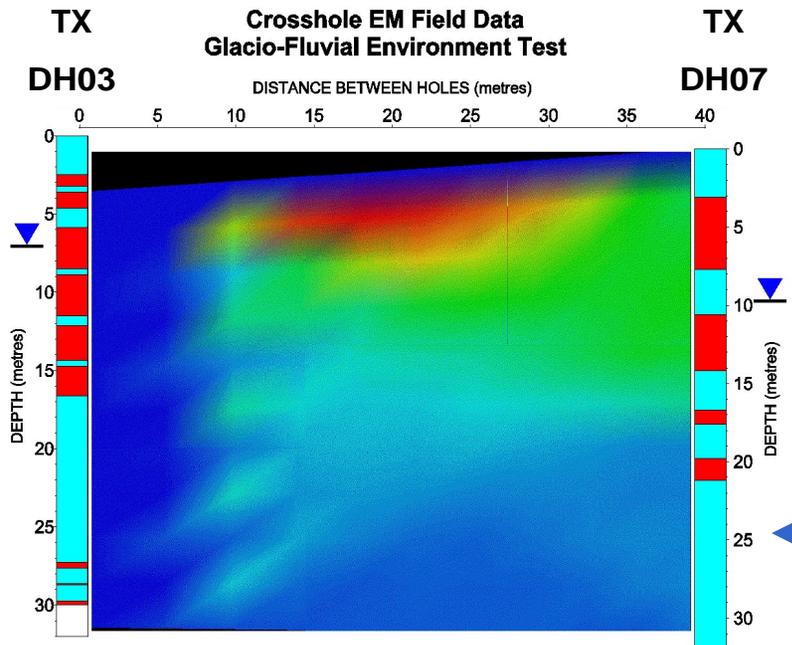
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Reciprocal Surveying

Tx-Rx antennae reversed and re-run in the second panel

X-hole Tomography

Panel 1: 11 Tx positions used



BOREHOLE LOGS

GRAVEL

SAND

BOREHOLE LOGS

GRAVEL

SAND

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Panel 2:
Reduced Resolution
Only 5 Tx positions used

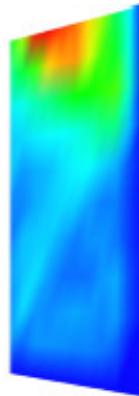
500 KHz frequency used



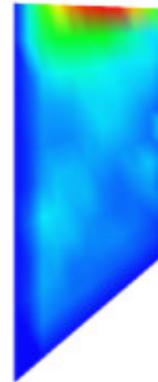
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Earthen Dam Test Site Data

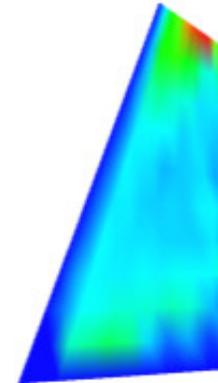
Panel 1



Panel 2



Panel 3



large earth filled dam

- sinkhole was discovered in the dam crest
- a broad range of geophysical approaches, including seismic, electromagnetic, resistivity, magnetics and ground penetrating radar methods failed to characterize the sinkhole due to difficulty in access, dam site surface conditions, culture and impedance contrasts.
- Borehole based geophysics proved to be the most diagnostic technique
- The essential objective is to image changes in the 'core', which consists of medium to fine grained material that has been rendered very dense during placement. The core is encased in very coarse (.5 m plus) shell materials for protection.

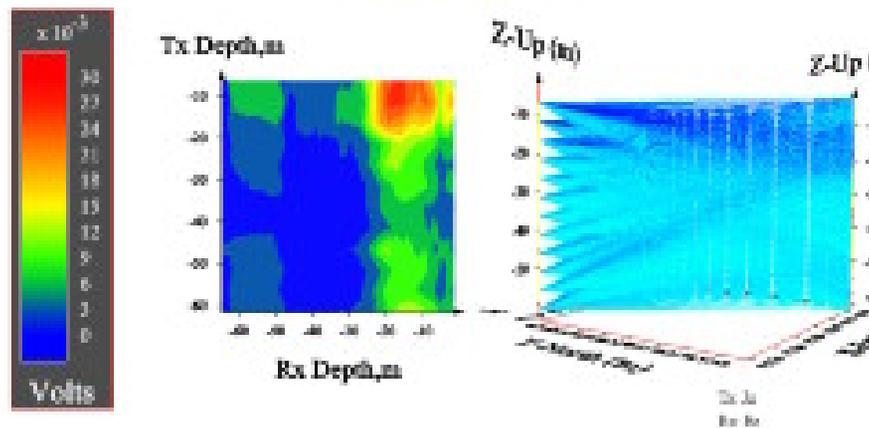
X-hole Tomography



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Earthen Dam Test Site Data

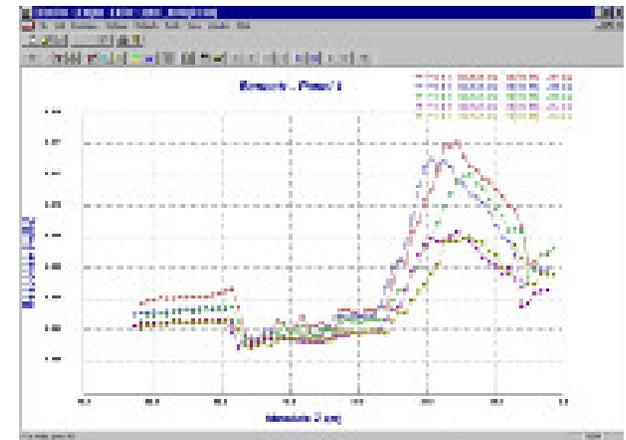
EM_Contour



Panel 1 - Contour Plot Tx vs R

- The surveys in the sinkhole area show a lower attenuation shallow zone that is interpreted to be the coarse shell material in place, and shell materials that collapsed into the sinkhole during a 1996 event.
- the water table is clearly seen in this data

- test crosshole EM surveys were carried out in three borehole pairs. Two of these were in sections through a sinkhole and one was in undisturbed core material.



Panel 1 - X-hole data in volts

X-hole Tomography

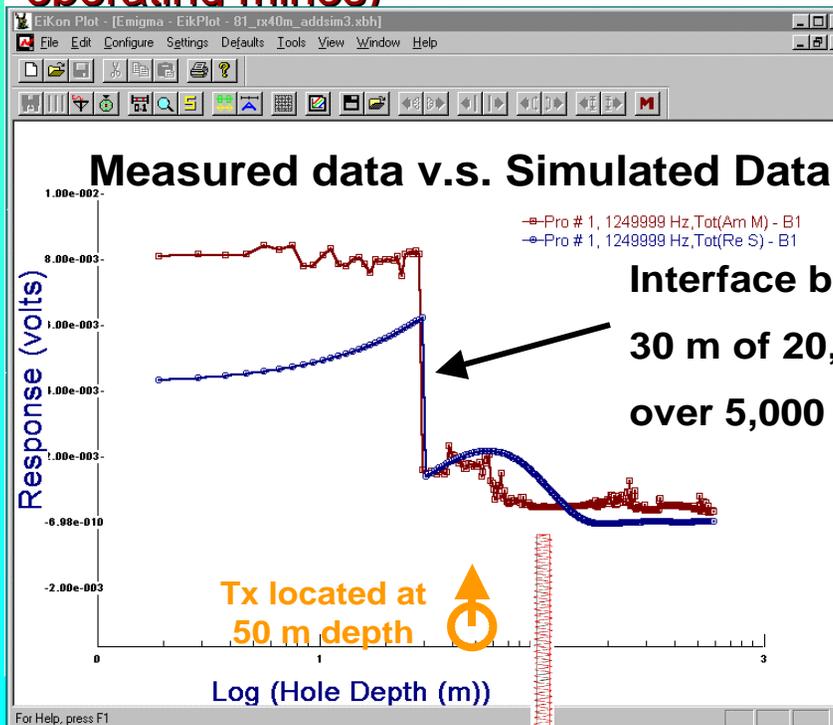


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Mine Test Site Data

Instrumentation performed well with:

- ▼ **Electrically Resistive Environment**
- ▼ **Cold weather conditions (-20C)**
- ▼ **Strong wideband cultural noise present (holes located close and between two operating mines)**
- ▼ **Deep holes (600m)**
- ▼ **Tx,Rx offsets greater than 600m**



Mine Site Data

Xhole data (red)

Simulated data (blue)

X-hole Tomography

contains suspected leachate plumes with the potential to threaten municipal and private water sources and local wildlife

Landfill Test Site Data

Multiple frequency tests - 333, 600, 750 and 1000 KHz

Instrumentation performed well with:

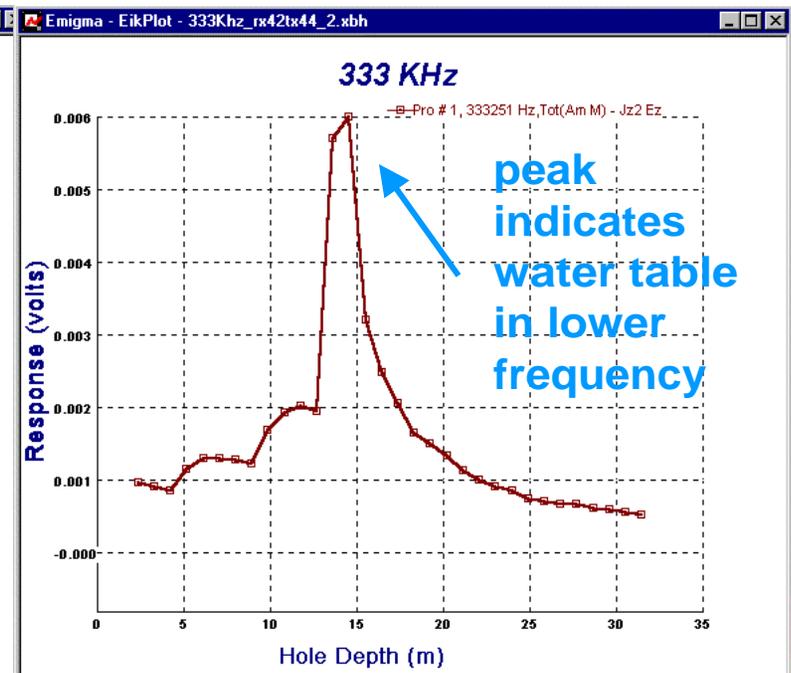
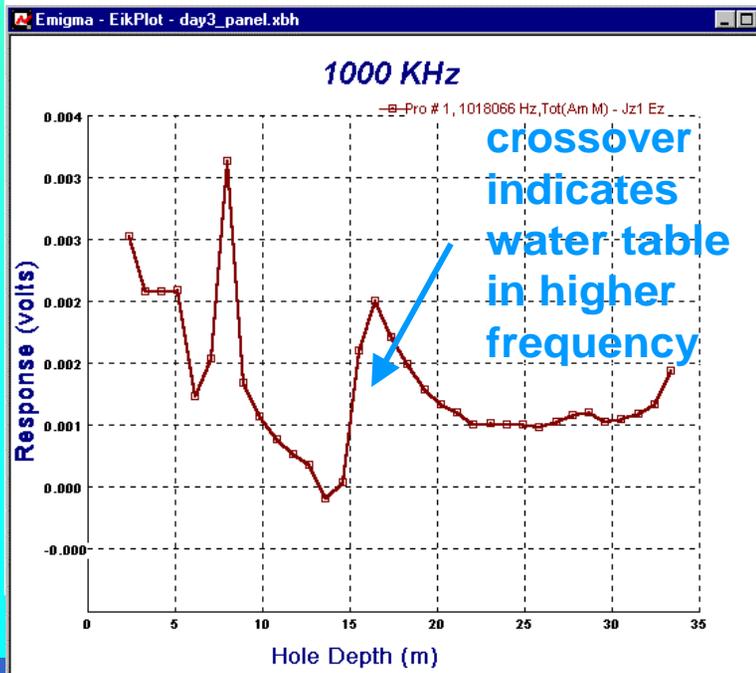
- wide Tx, Rx separations (100m) in conducting soil, till and bedrock
- strong cultural noise present (commercial arc-welding plant within .5 km of site, power lines, buildings, truck traffic)



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▼ Moving Tx configuration in the same hole for 2 frequencies

▼ Receiver position at 3.0 m

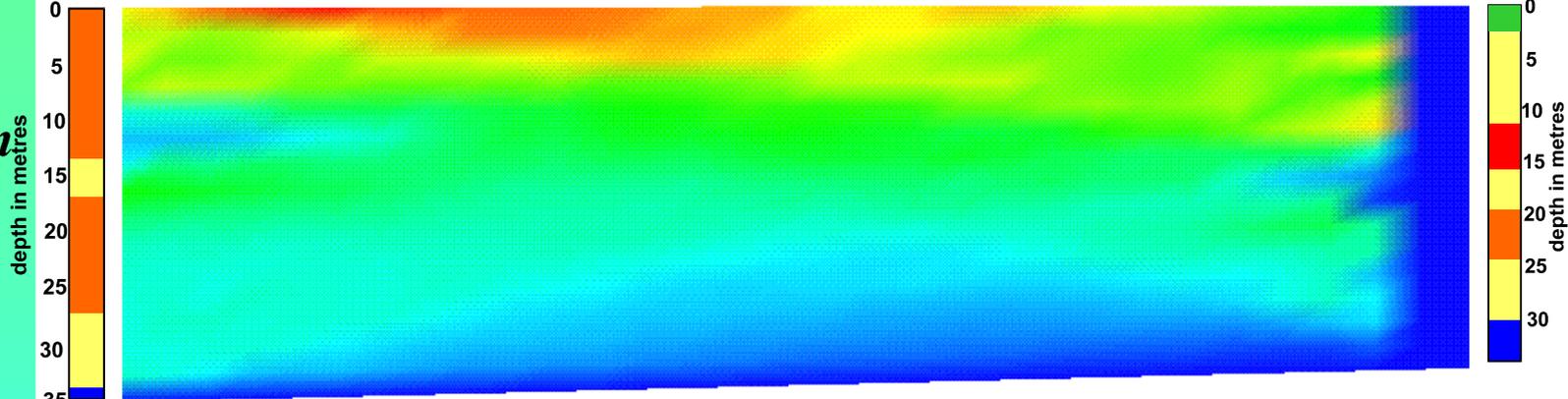


Landfill Test Site Data

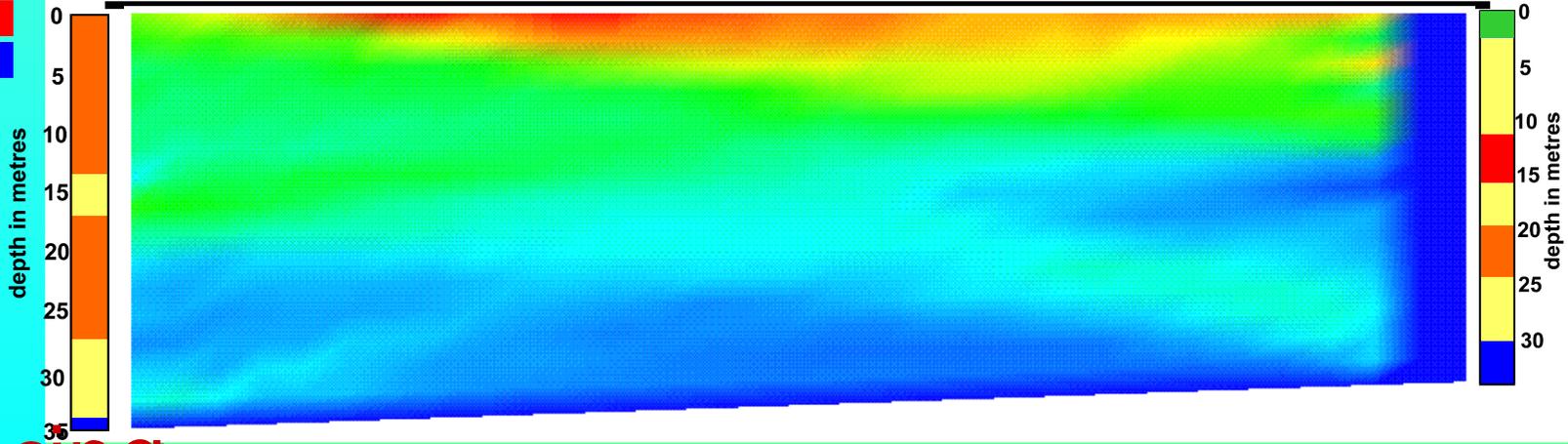
X-hole Tomography



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Reverse Pattern Sampling for the same frequency - 1 MHz



borehole log legend

- FILL 
- SAND 
- SILTY SAND 
- SILT 
- BEDROCK 

Raytracing

Landfill Test Site Data

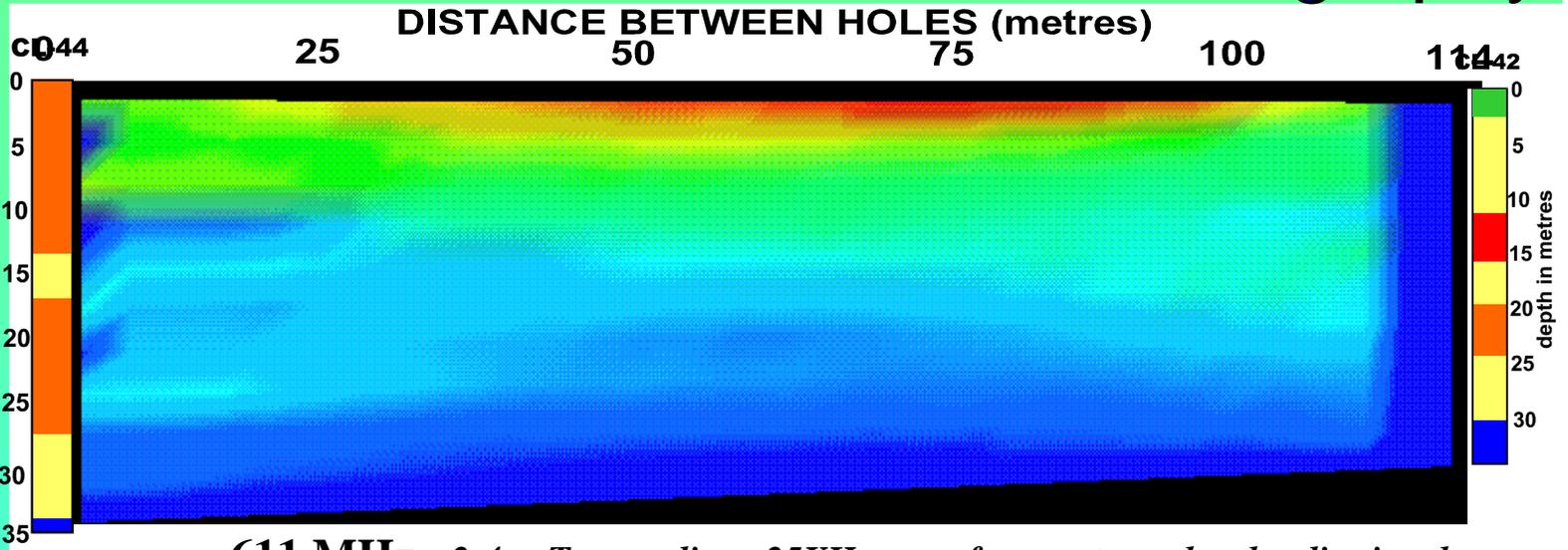
X-hole Tomography



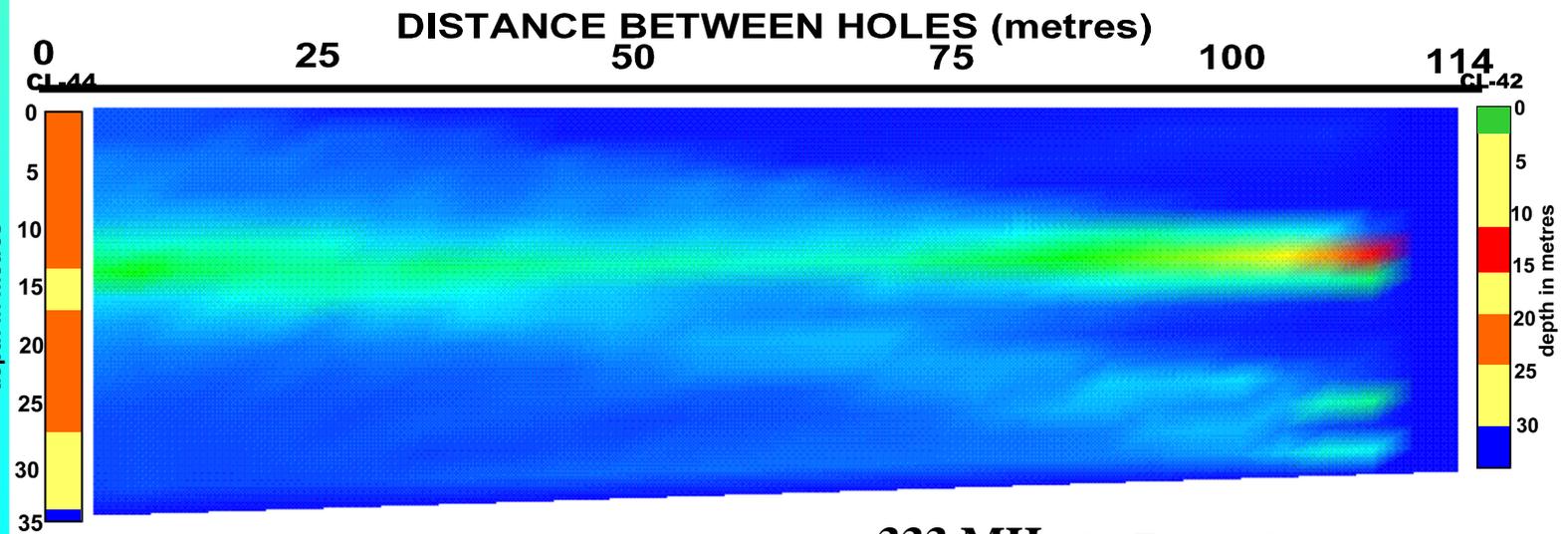
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borehole log legend

- FILL
- SAND
- SILTY SAND
- SILT
- BEDROCK



.611 MHz 2-4 m Tx sampling 25KHz away from a strong local radio signal



.333 MHz 2m Tx sampling

Raytracing

Landfill Test Site Data

X-hole Tomography



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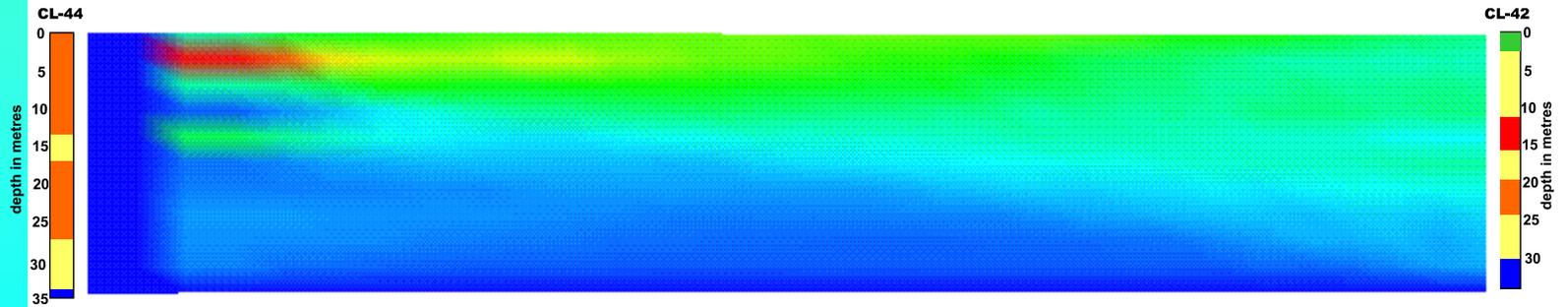
borehole log
legend

- FILL
- SAND
- SILTY SAND
- SILT
- BEDROCK

Raytracing

0 25 50 75 100 114

DISTANCE BETWEEN HOLES (metres)



.750 MHz 2m Tx sampling

Landfill Test Site Data

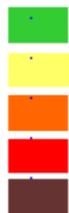
X-hole Tomography



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borehole log
legend

FILL
SAND + GRAVEL
SILTY SAND
SILT
BEDROCK



S Silt
tS Trace Silt
C Clay
tC Clay

CONDUCTIVITY HIGH
CONDUCTIVITY LOW
INTERMITTENT H + L

Raytracing

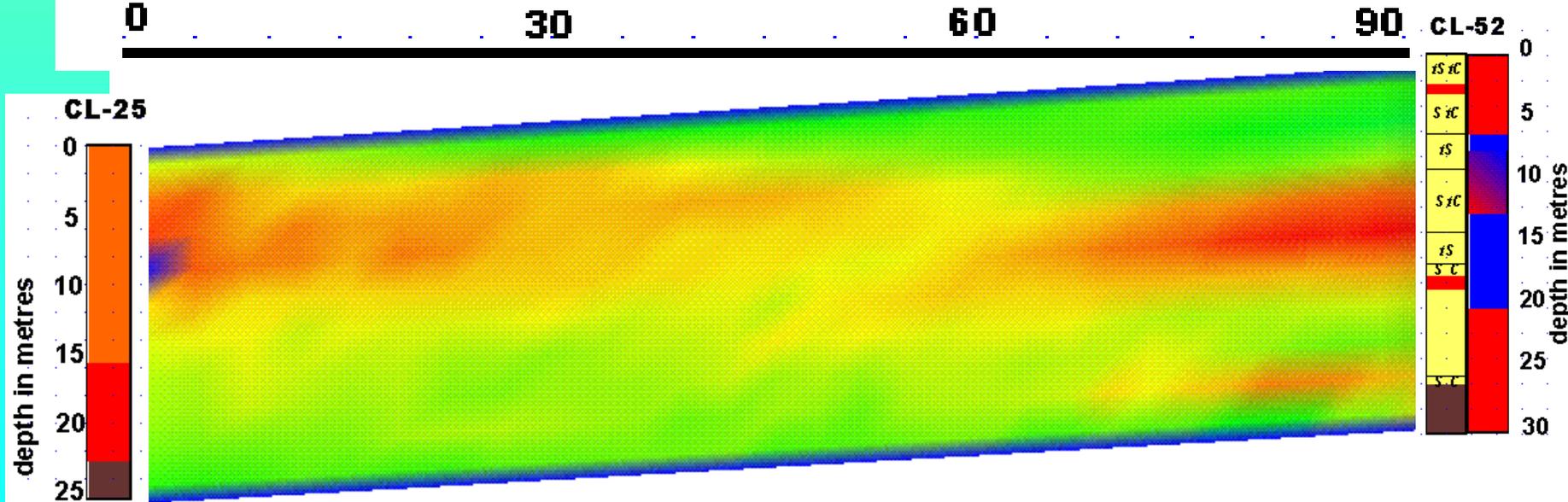
DISTANCE BETWEEN HOLES (metres)

0

30

60

90



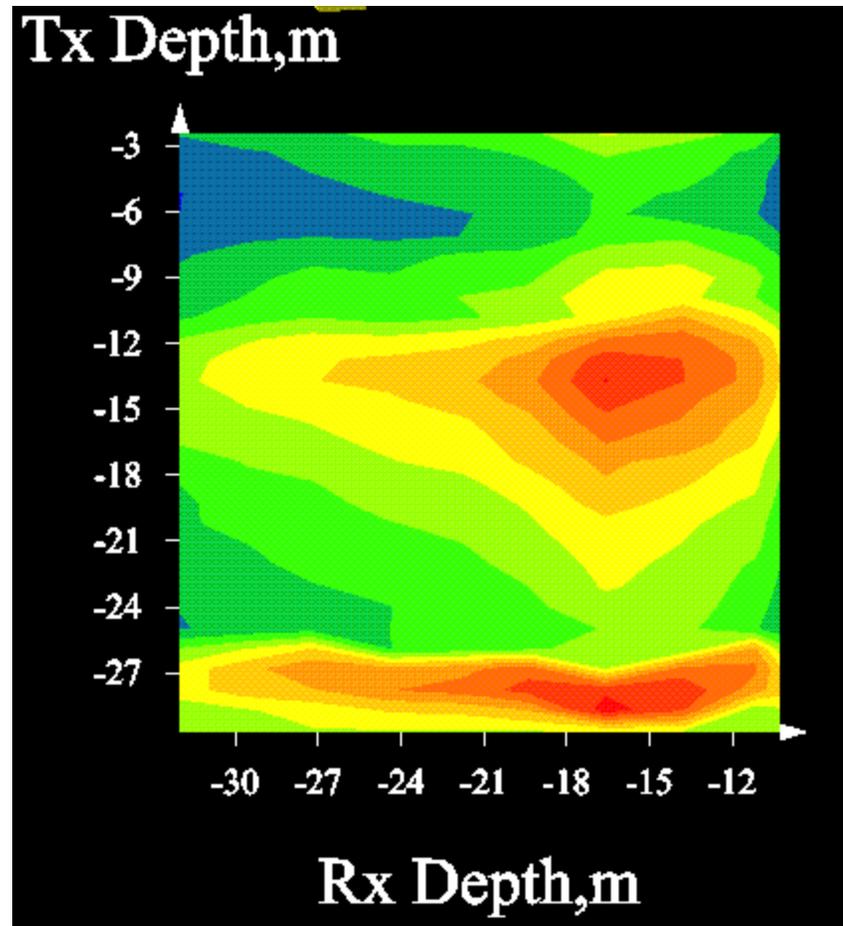
.151 MHz 0.94 Tx sampling

X-hole Tomography



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Contour tx position vs rx





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Conclusions:

- NMHA can operate between low KHz and low MHz using compact broadband antennae
- Rapid data collection with sufficient redundancy for noise estimates

Present Research Focus

- Relationship between freespace resonance and broadband underground
- Radiation pattern in lossy medium for more effective tomography and inversion techniques

X-hole Tomography



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Status:

- 5 test areas studied
 - more than 12 panels of data have been collected
 - initial development extremely successful
 - excellent data repeatability
 - interpretable multi-frequency data
 - developed signal-to-noise estimation procedures to ensure data quality
 - reliable field procedures developed
 - dependable pre-commercialization equipment
 - all necessary software now available
- READY to study scattering processes which are not clearly understood in RIM technology***



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Test Sites Required:

- Additional test sites are sought for
- Environmental detection applications and Mine applications

Major Objectives:

- 1 **Secure additional test sites**
- 2 **Collect more than 4 pairings of data in order to image the subsurface in 3D**

Minor Objectives:

- 1 **Survey holes with greater than 25 m offsets to test the equipment's distance limitations**
- 2 **Survey a site with cultural noise to determine equipment's noise tolerance**

X-hole Tomography



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visit us at:

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3D Inversion on its way
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IP
Resistivity...