Shallow GPR and Seismic Surveying in a Carbonate Environment: Belize, Central America

Julie A. Aitken*, Robert R. Stewart

CREWES

Outline

- Objectives
- Geographical setting
- Maya culture and history
- GPR survey and theory
- Modeling and survey results
- Comparison between near-surface methods
- Conclusions

Objectives

- Improve quality of the 2-D and 3-D GPR images
- Interpret near-surface structure and stratigraphy
- Highlight possible anomalies or buried features for excavation
- Evaluate the results from the GPR survey and micro-seismic survey

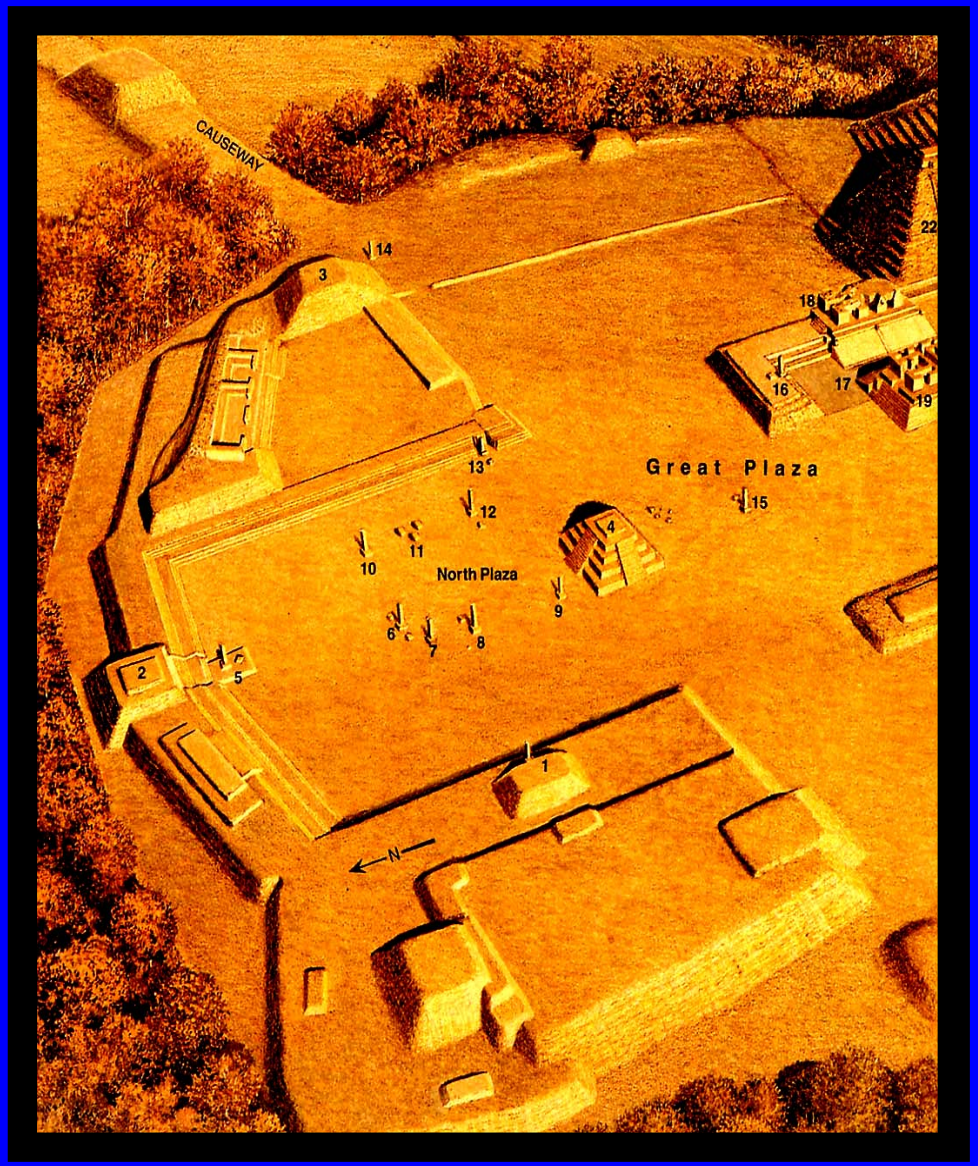
Belize is located in south-eastern Central America.

(Reader's Digest, 1993)

(The Ma'ax Na Archaeology Project, 2001)

Ma'ax Na is one of 800 Maya sites.

Schematic of plaza at Copan and a modern day example at Altun Ha.



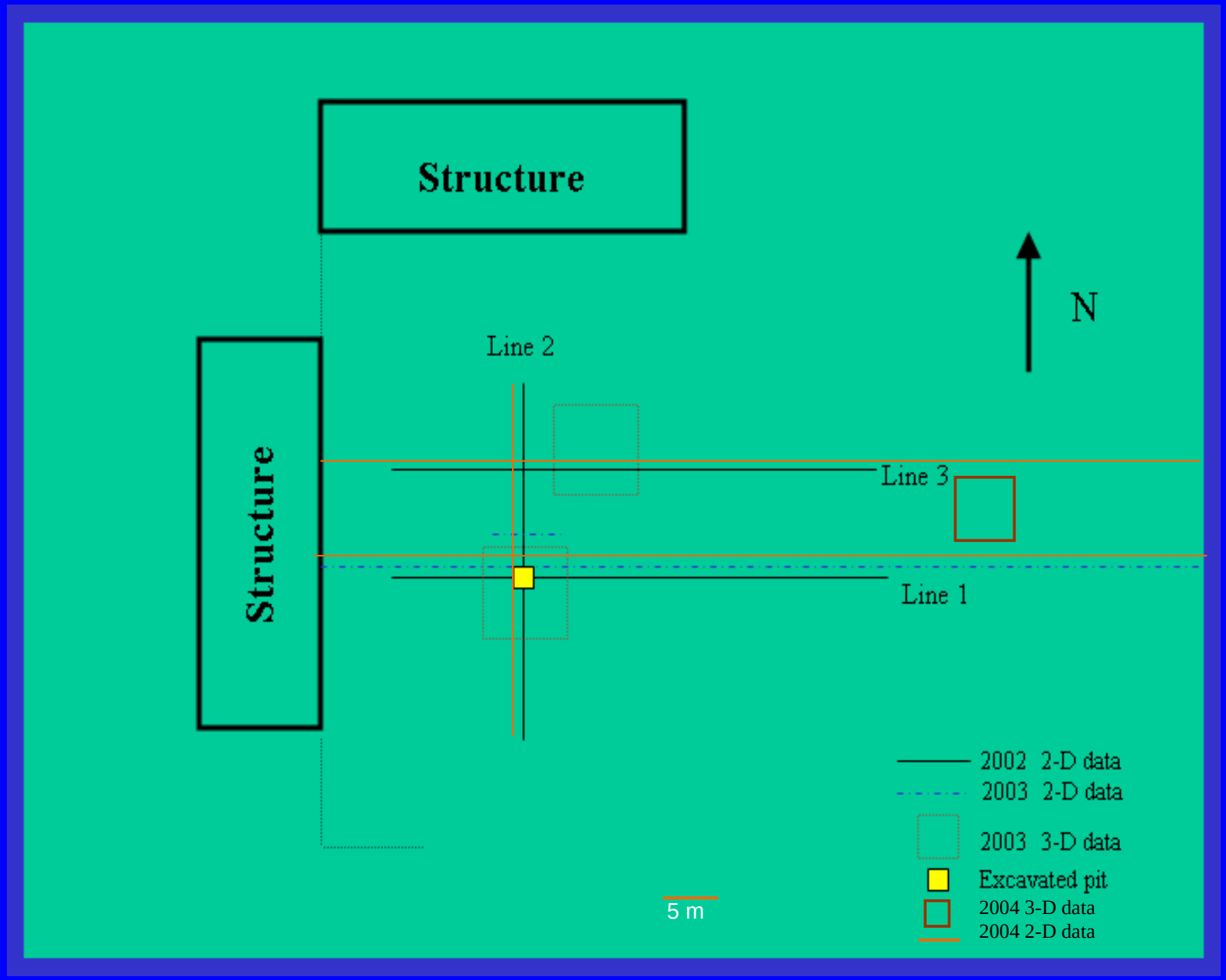
(National Geographic, 1989)

(photo – Rob Stewart)

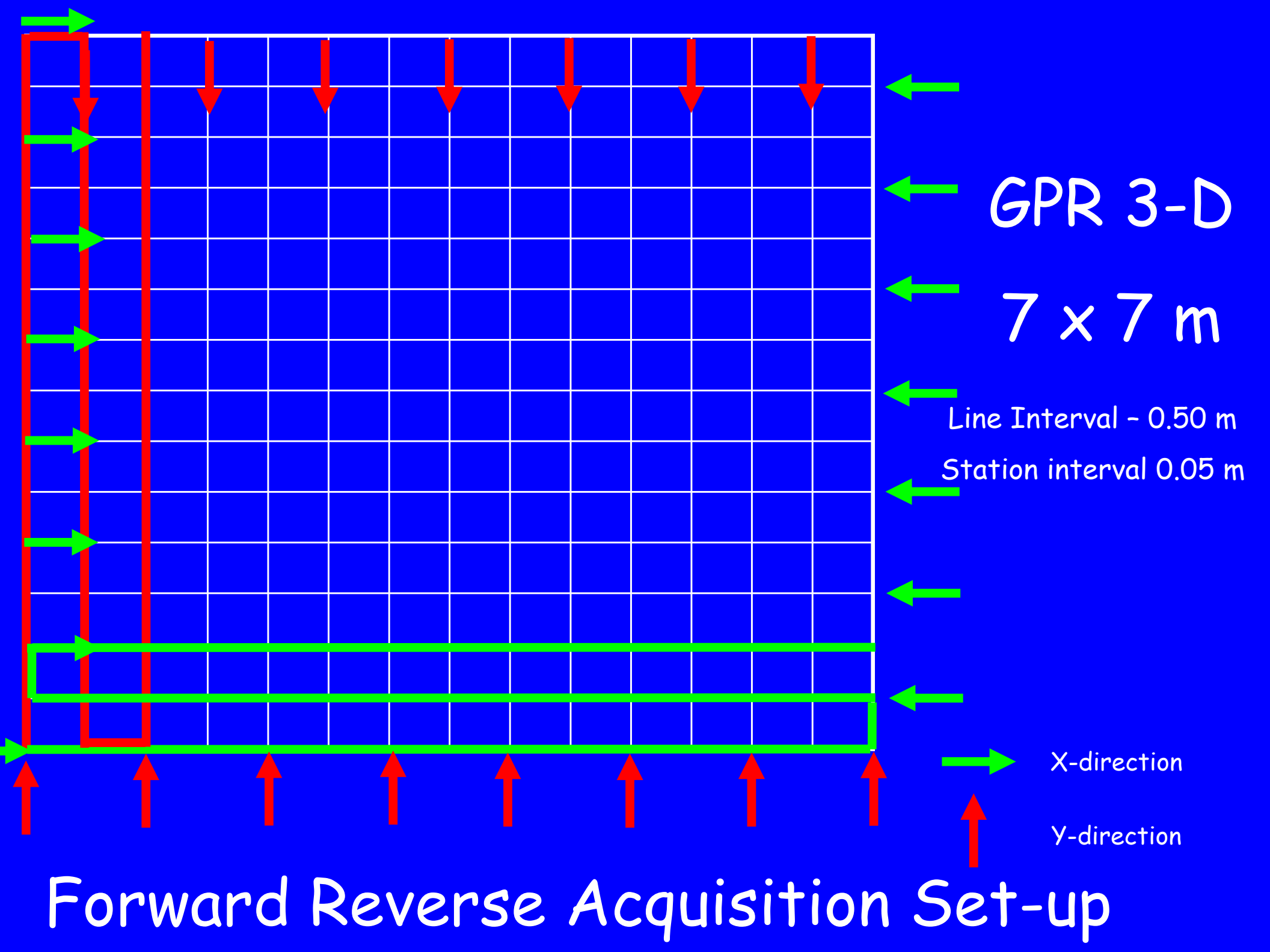
Buried features may contain Maya artifacts such as pottery and ceremonial vessels

(Photo - Claire Allum)

Acquisition of GPR swath using Noggin system with a 250 MHz antenna



Acquisition layout over the last three field seasons


GPR 3-D
7 x 7 m
Line Interval – 0.50 m
Station interval 0.05 m
X-direction
Y-direction
Forward Reverse Acquisition Set-up

Field Observations

- 2002 observed velocities = 0.072 – 0.106 m/ns (saturated conditions)

* Depth of penetration = 1.8 m

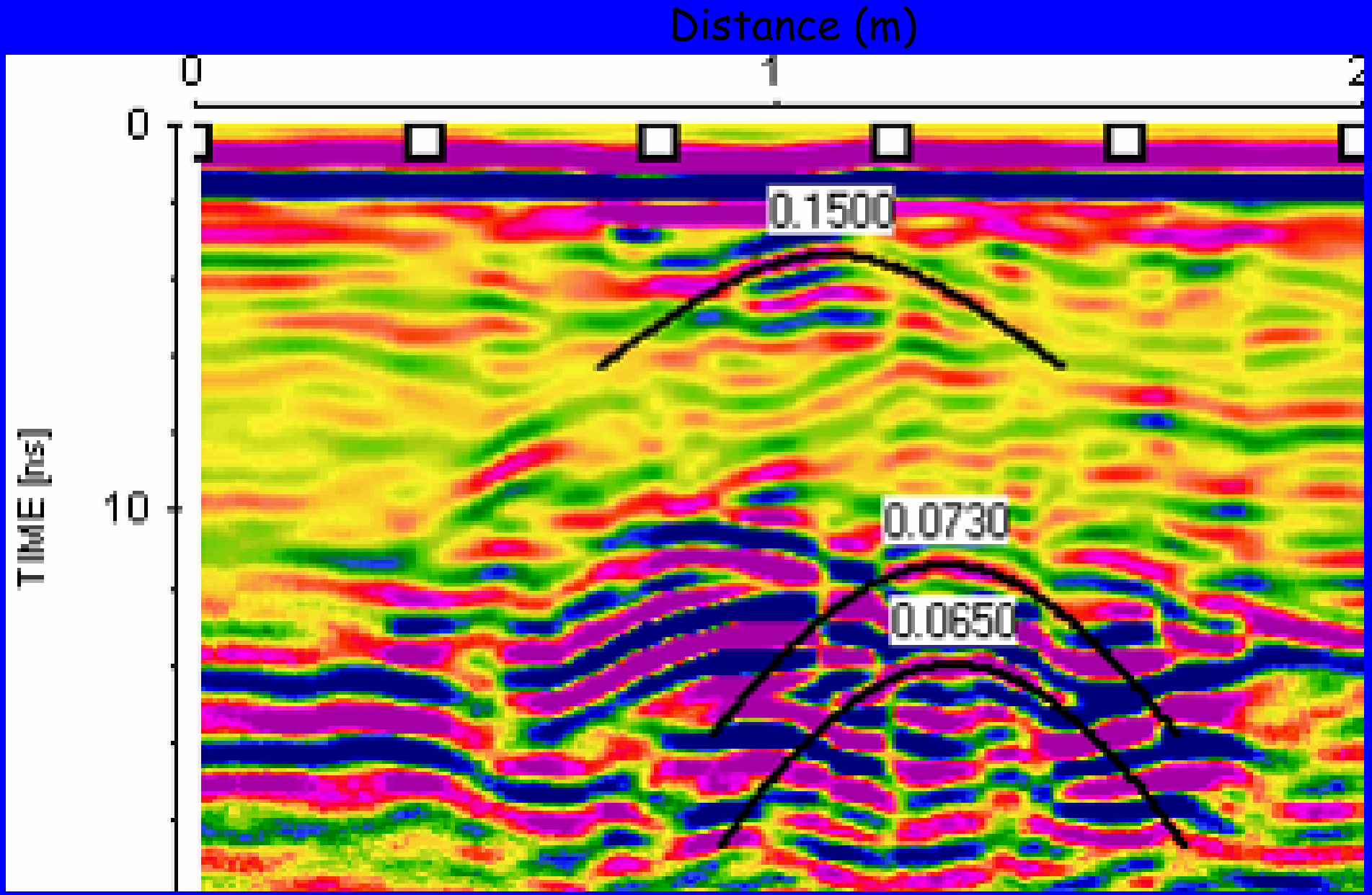
- 2003 observed velocities = 0.122 - 0.140 m/ns (drought conditions)

* Depth of penetration = 3.4 m

- 2004 observed velocities = 0.058 - 0.084 m/ns (saturated conditions)

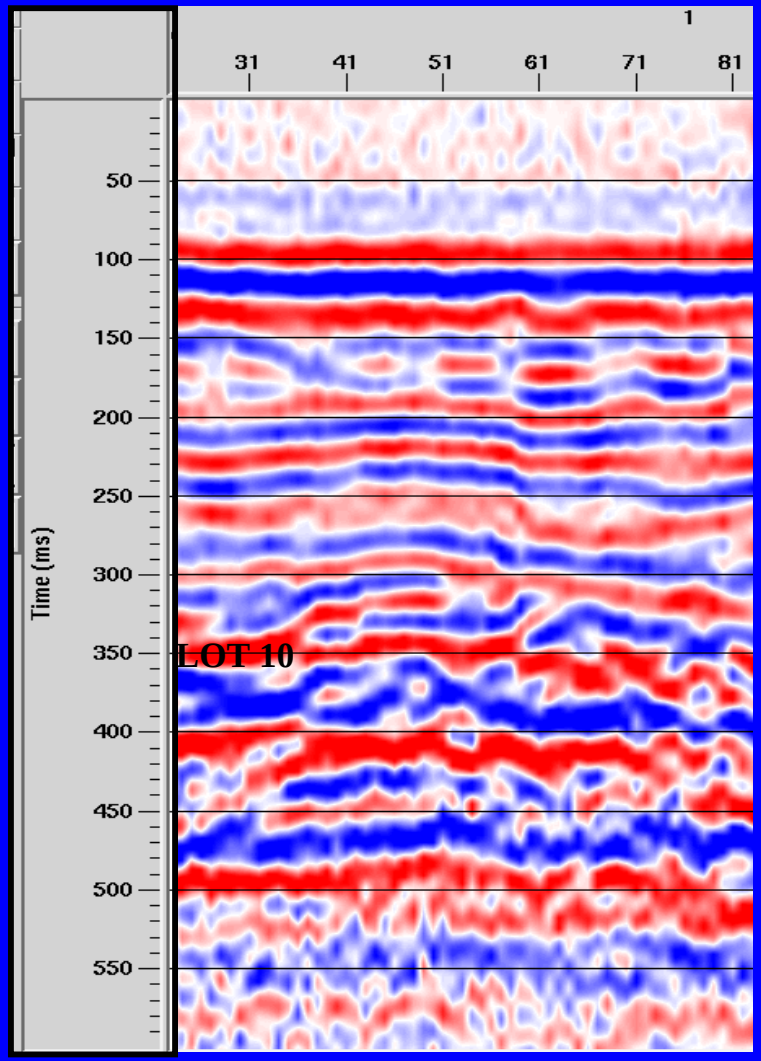
* Depth of penetration = 1.8 m

* based on a 50 ns record



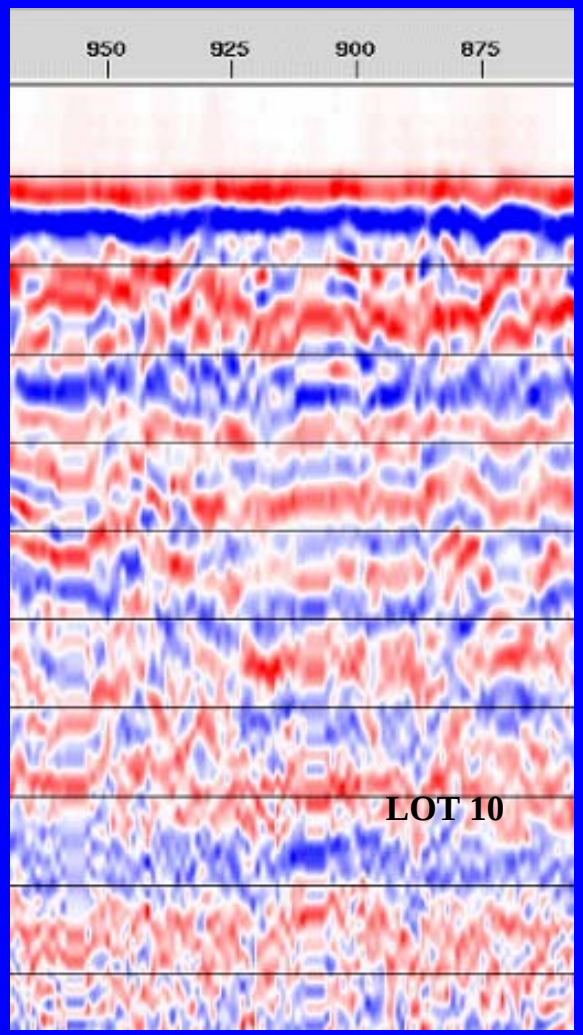
Velocity determination from curve fitting using Reflexw

Filtered deconvolved stacks



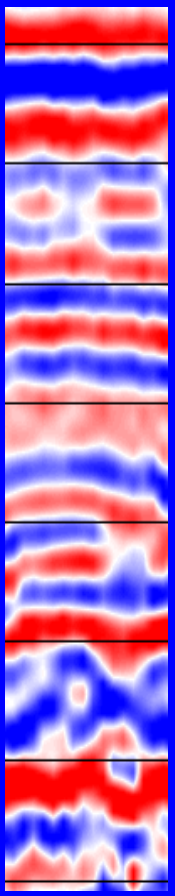
2003 data

(V = 0.122 m/ns)



2002 data

(V= 0.072 m/ns)



Stretched dataset 2003

$$V = \frac{c}{(\varepsilon_r)^{\frac{1}{2}}} = \frac{0.3}{(\varepsilon_r)^{\frac{1}{2}}}$$

Conversely, this may be written as:

$$\varepsilon_r = RDP = \frac{c^2}{V^2} = \frac{0.09}{V^2}$$

Permittivity of humus/soil =16

Velocity of humus/soil = .075 m/ns

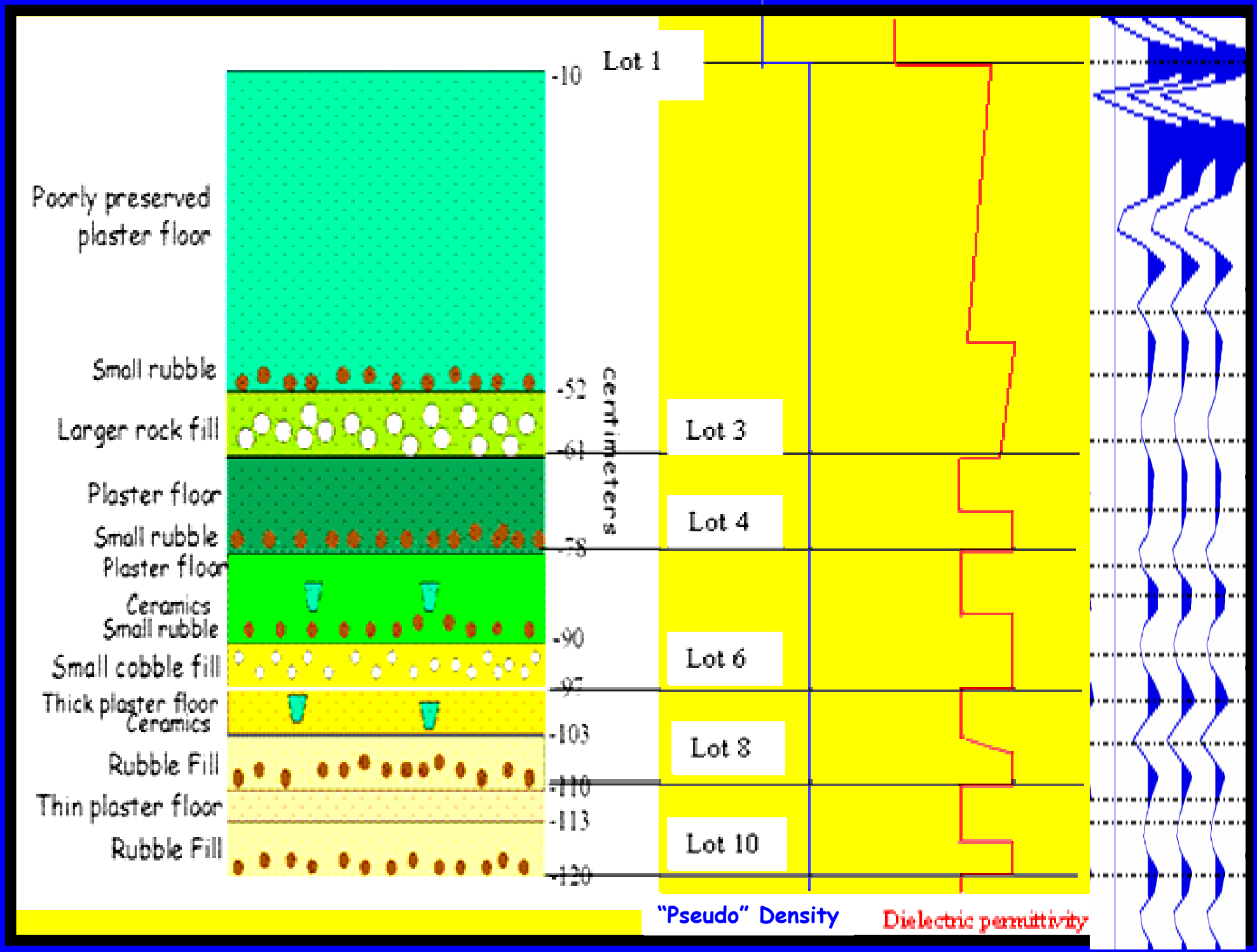
Permittivity of limestone = 8

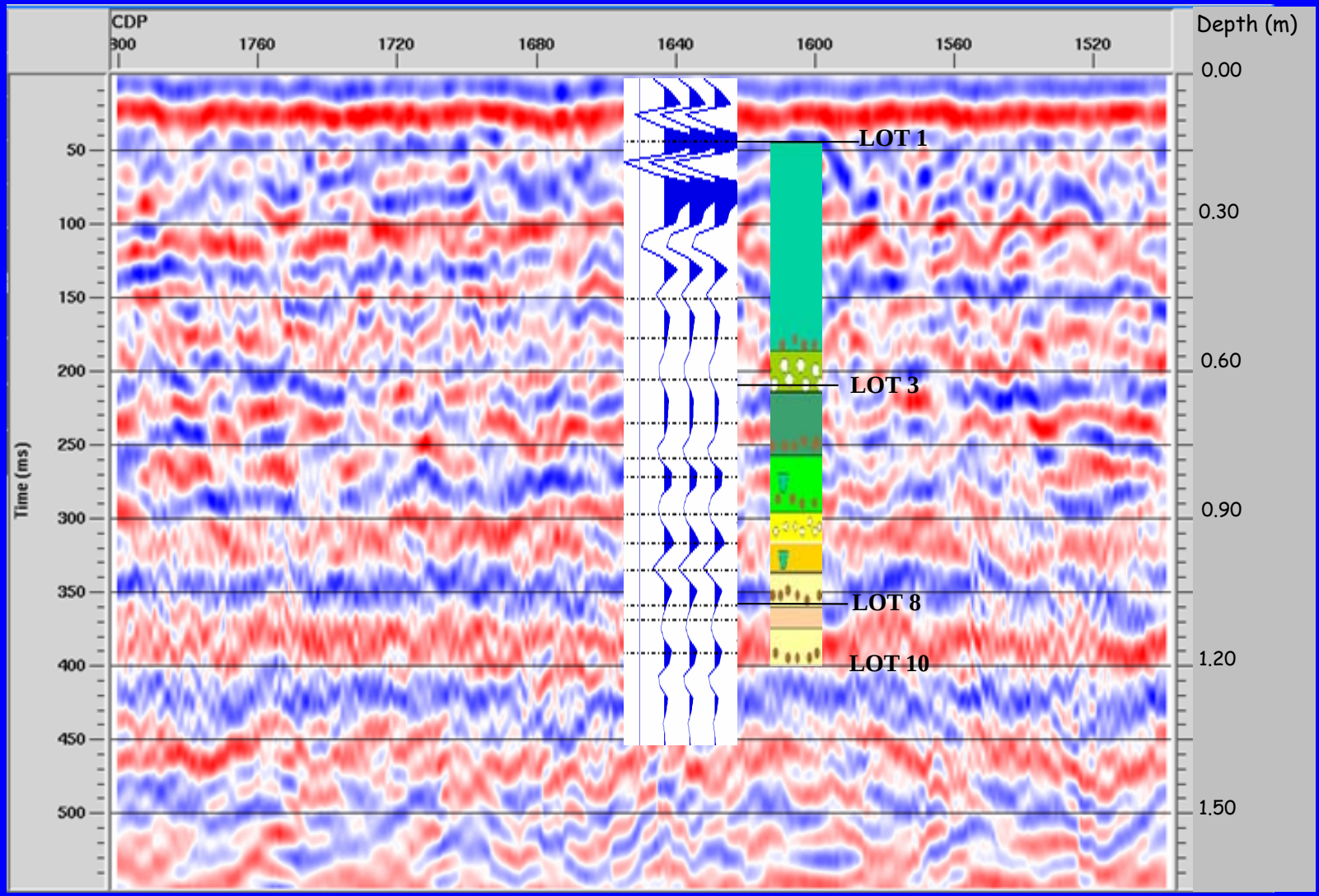
Velocity of limestone = .106 m/ns

Permittivity of water = 80

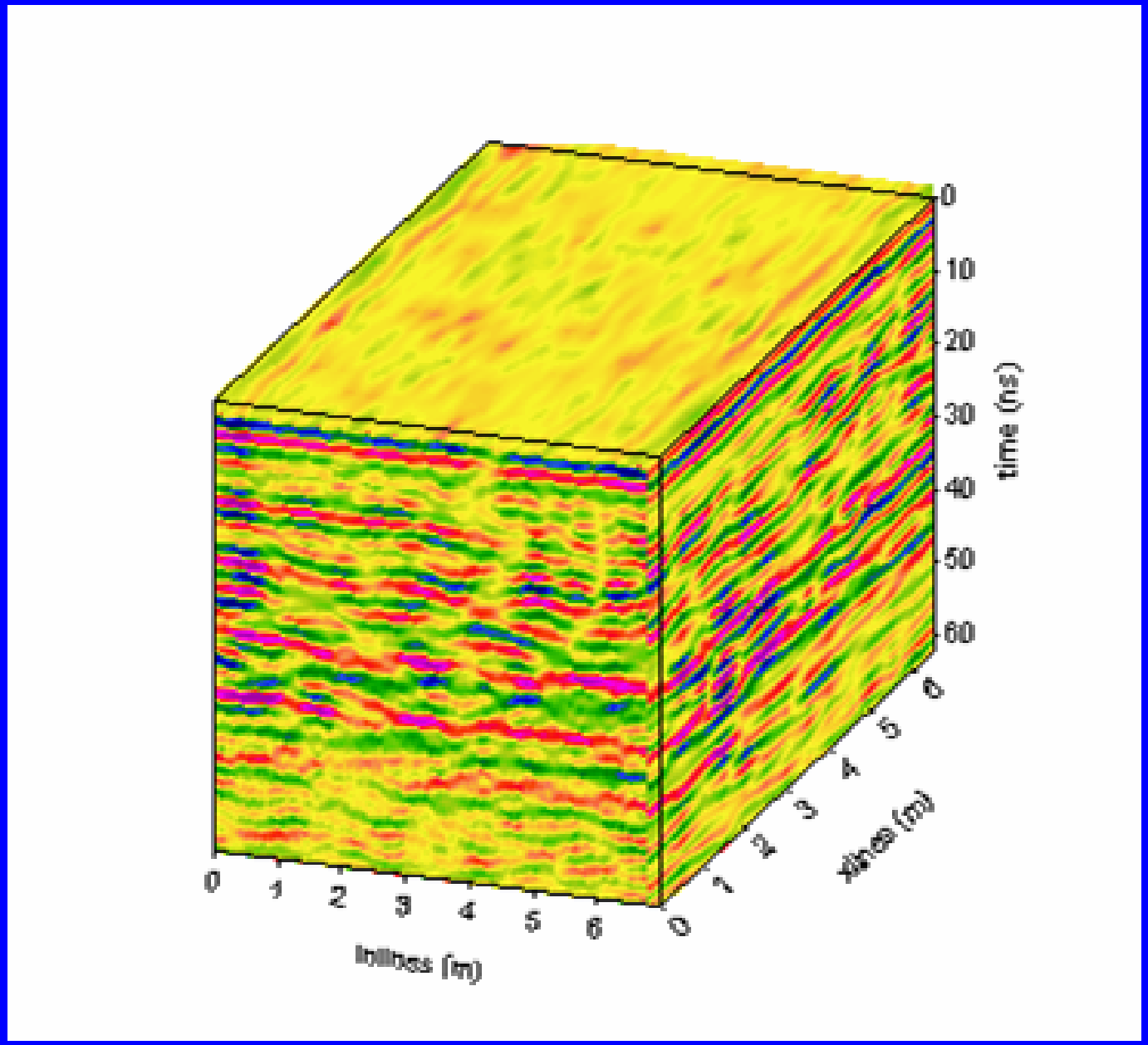
Archaeological pit in Ma’ax Na plaza with Dr. Eleanor King indicating floor level or lot.

(Photo - Rob Stewart)

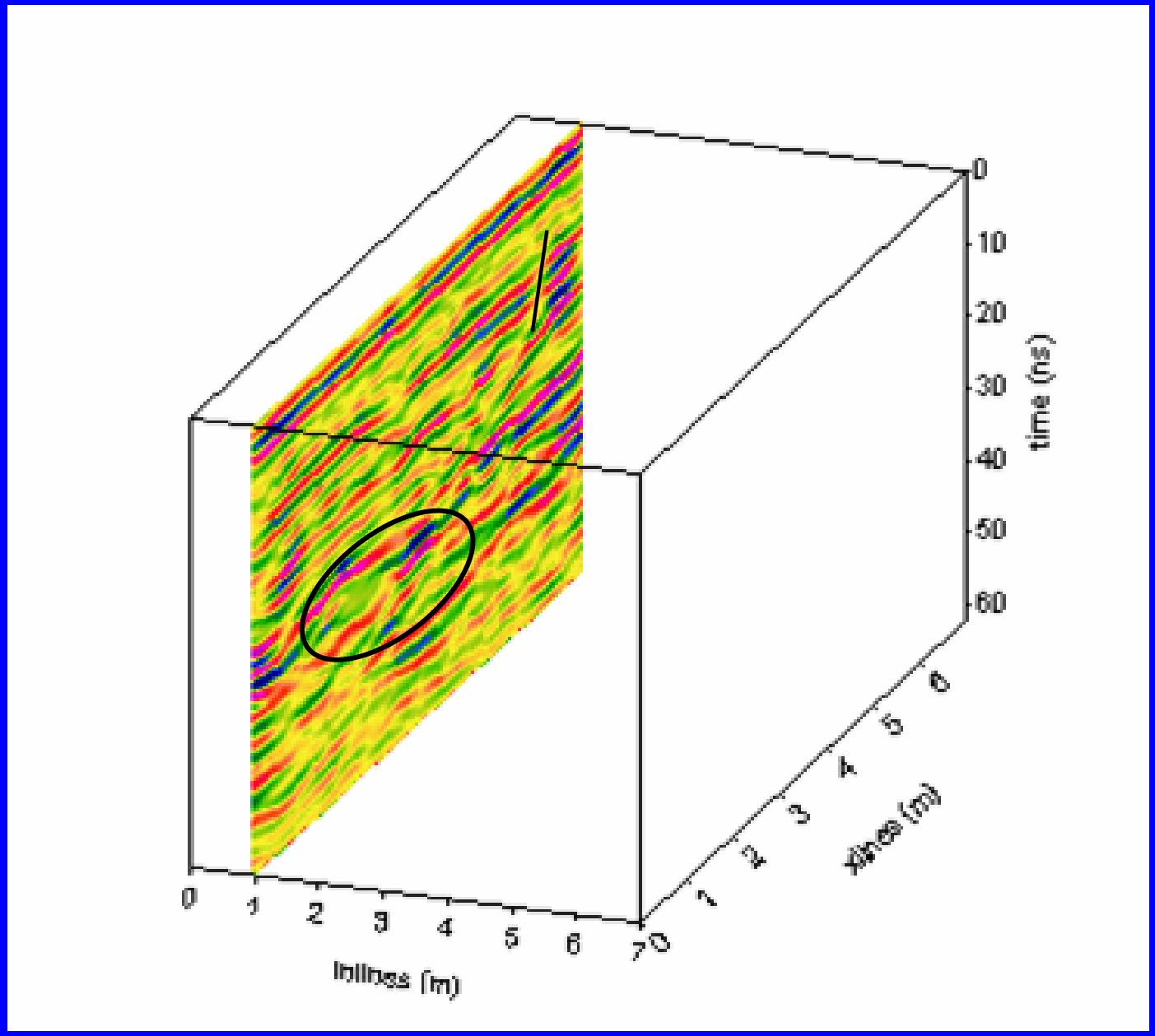

Poorly preserved plaster floor
Small rubble
Larger rock fill
Plaster floor
Small rubble
Plaster floor
Ceramics
Small rubble
Small cobble fill
Thick plaster floor
Ceramics
Rubble Fill
Thin plaster floor
Rubble Fill
-10
-52
-61
-78
-90
-97
-103
-110
-113
-120
centimeters
Lot 1
Lot 3
Lot 4
Lot 6
Lot 8
Lot 10
"Pseudo" Density
Dielectric permittivity

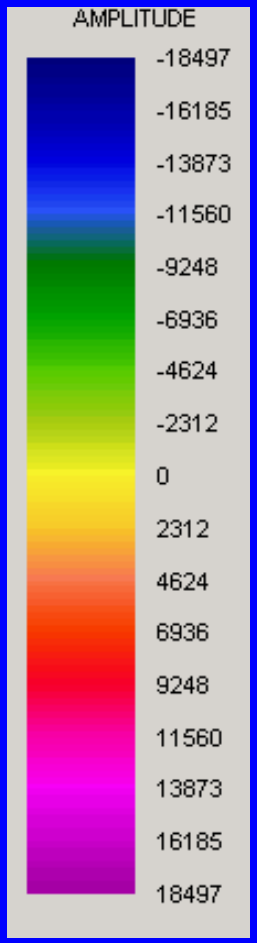


Comparison of filtered, deconvolved and migrated stack of 2002 data with synthetic radargram.

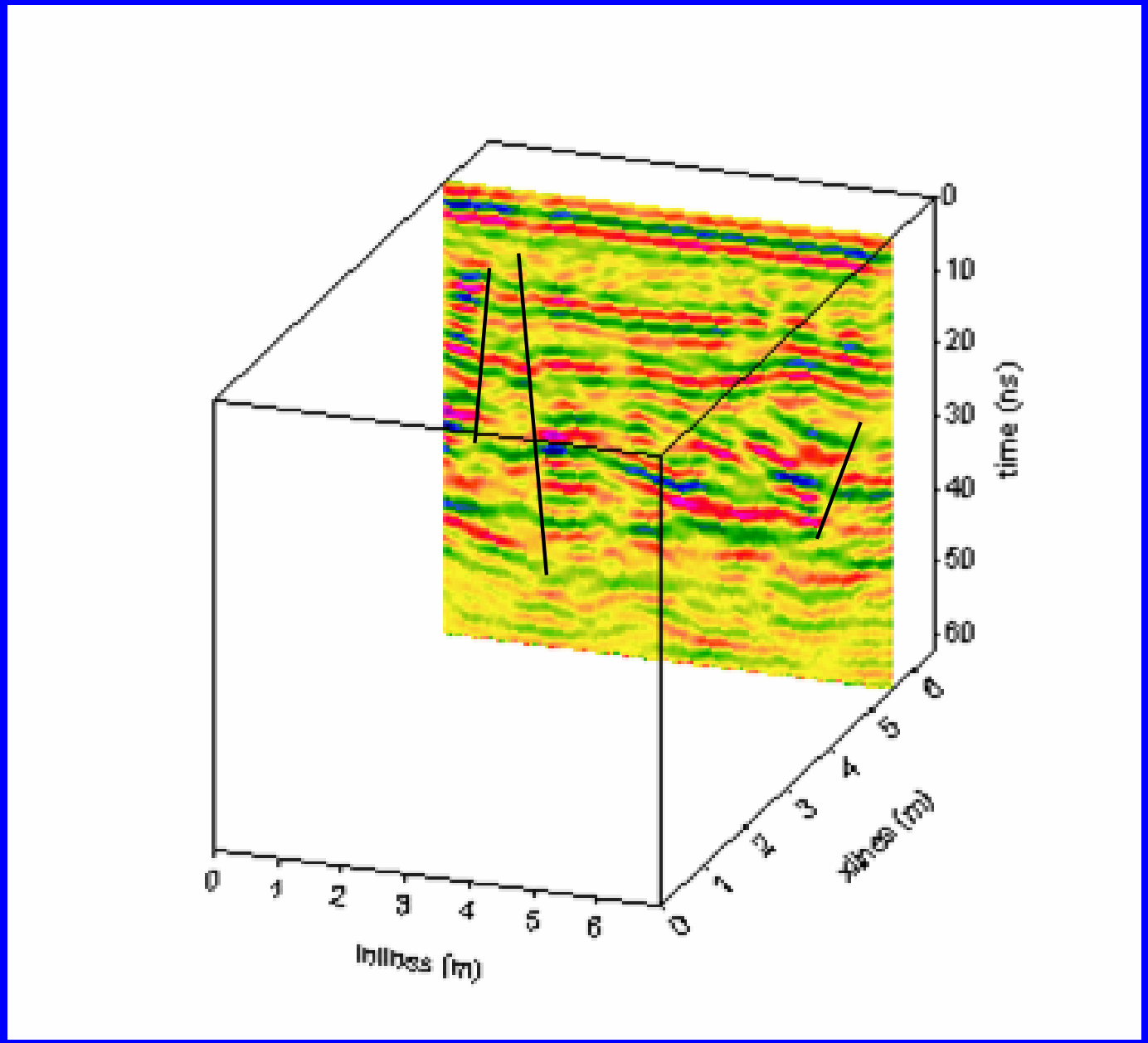


Grid in X- direction

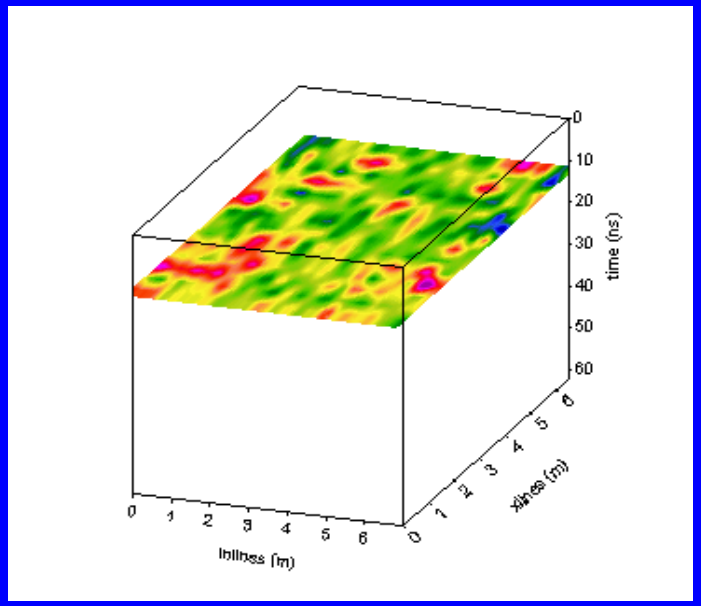




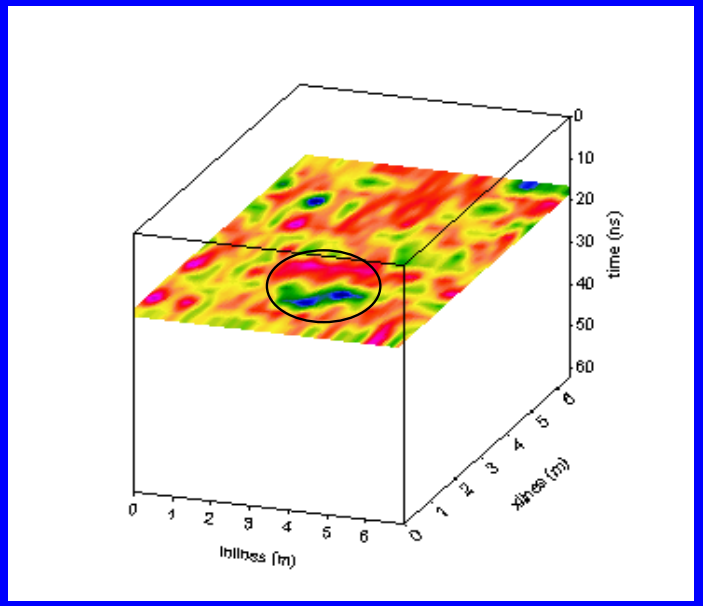
Cross-section in Y-direction



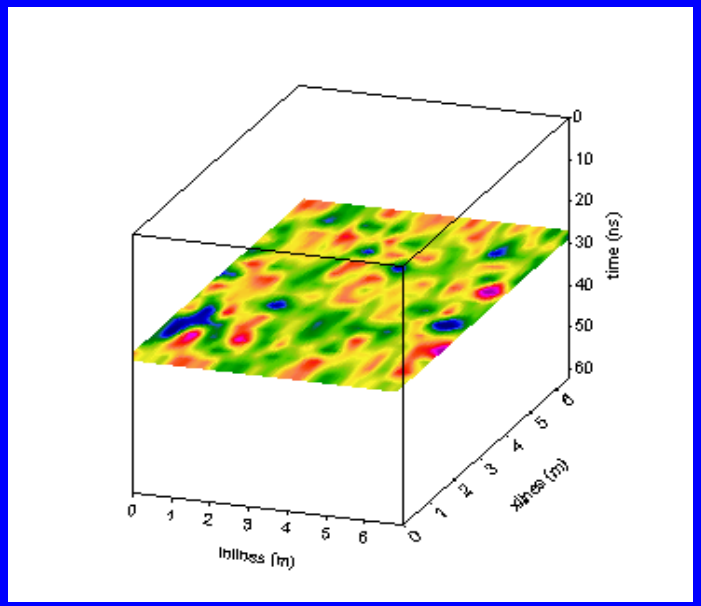
Cross-section in X- direction



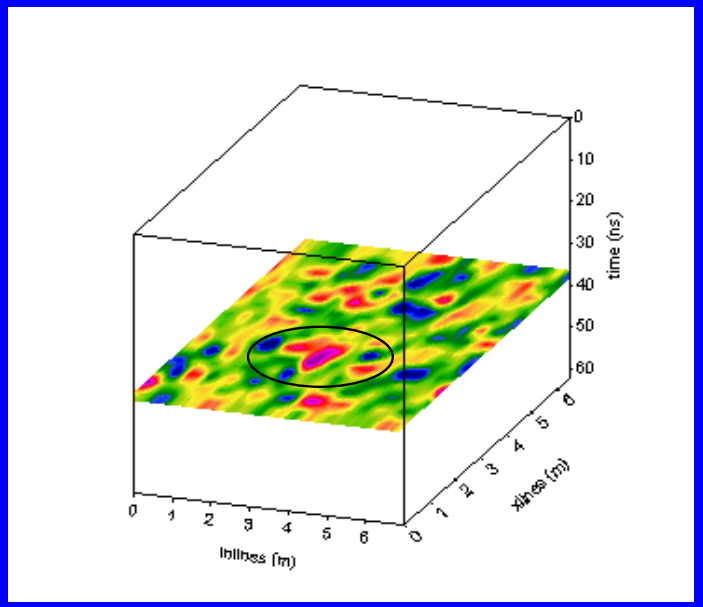
Time slice at 12 ns



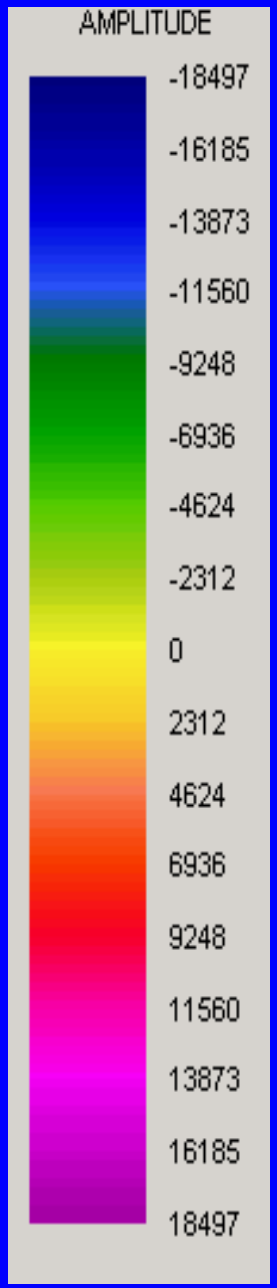
Time slice at 20 ns



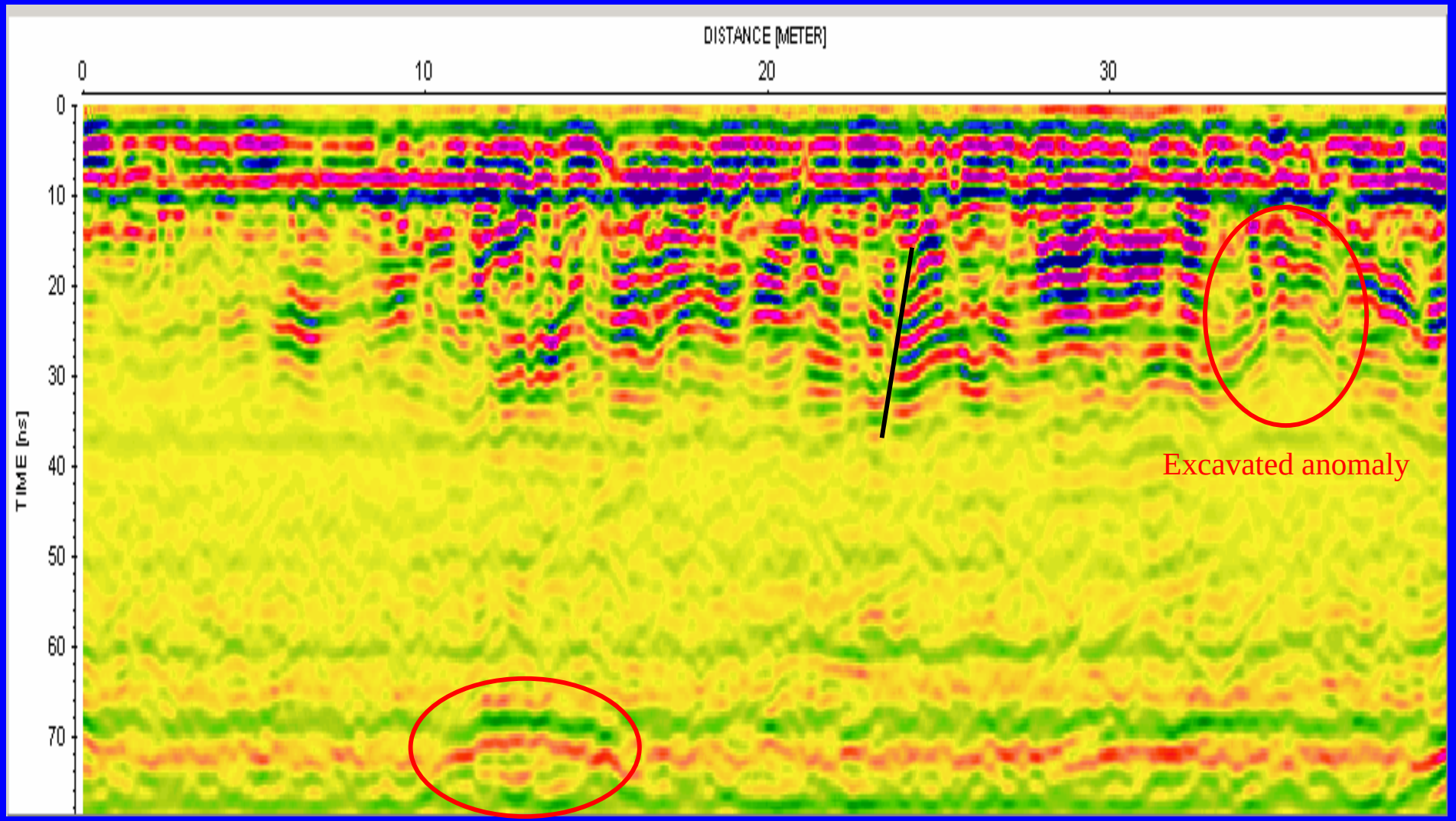
Time slice at 30 ns



Time slice at 38 ns



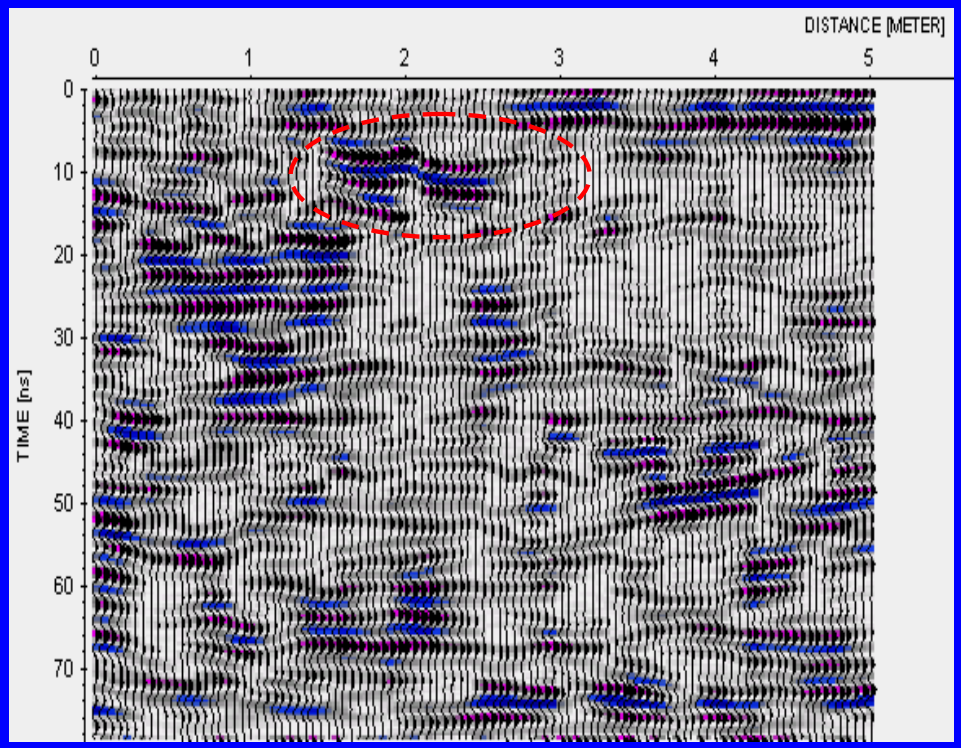
Amplitude time slices from GPR 3-D volume



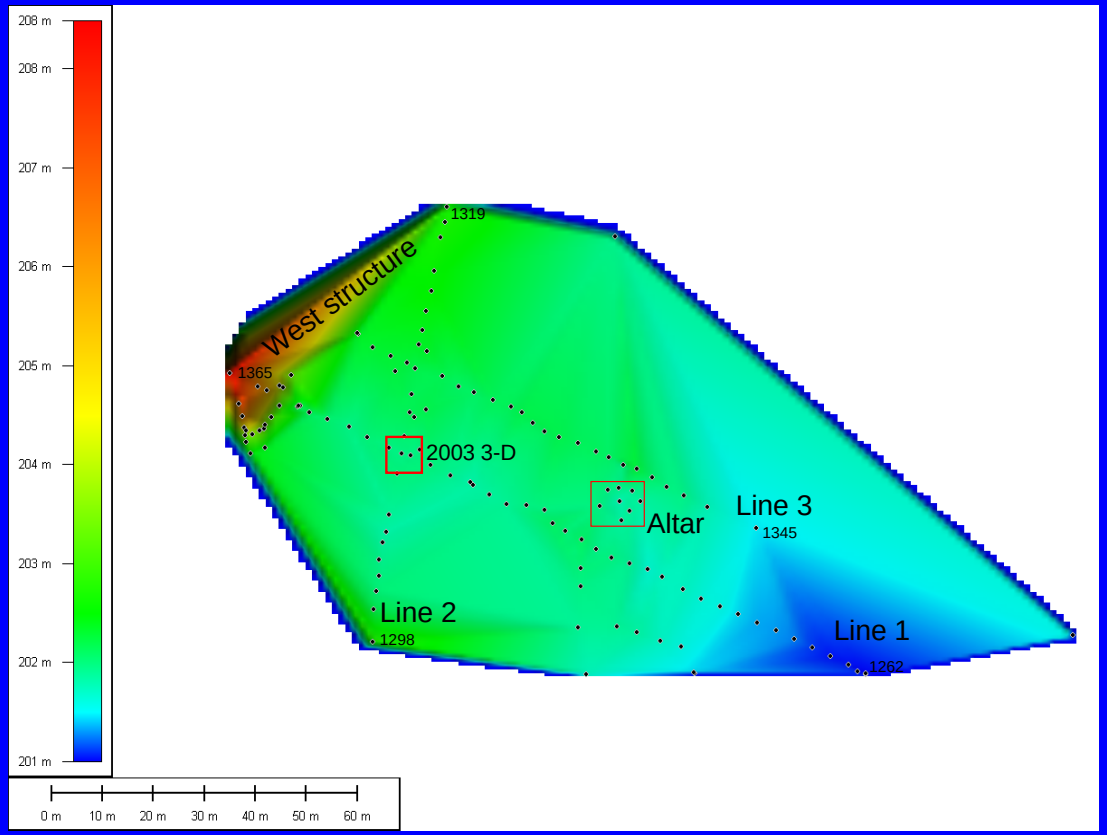
2004 GPR data (Line 2) at Maax Na with anomalies highlighted

(Photo - J. Aitken)

Ceremonial altar discovered on plaza surface

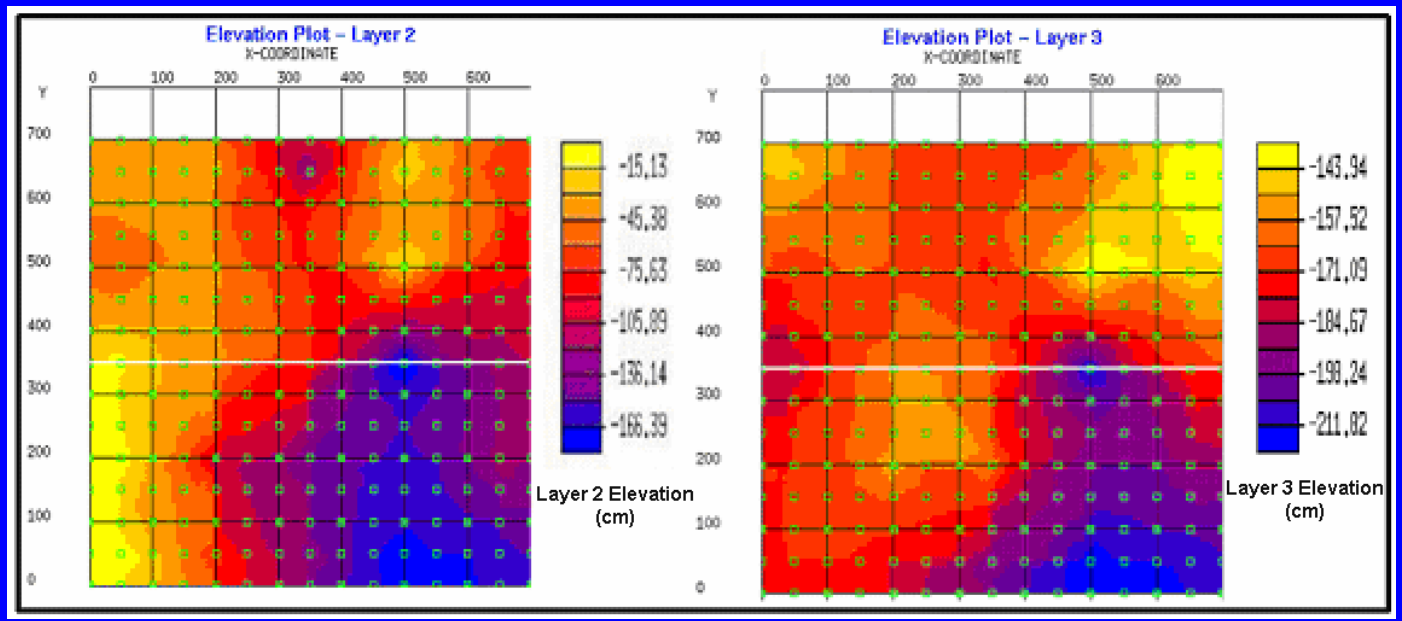


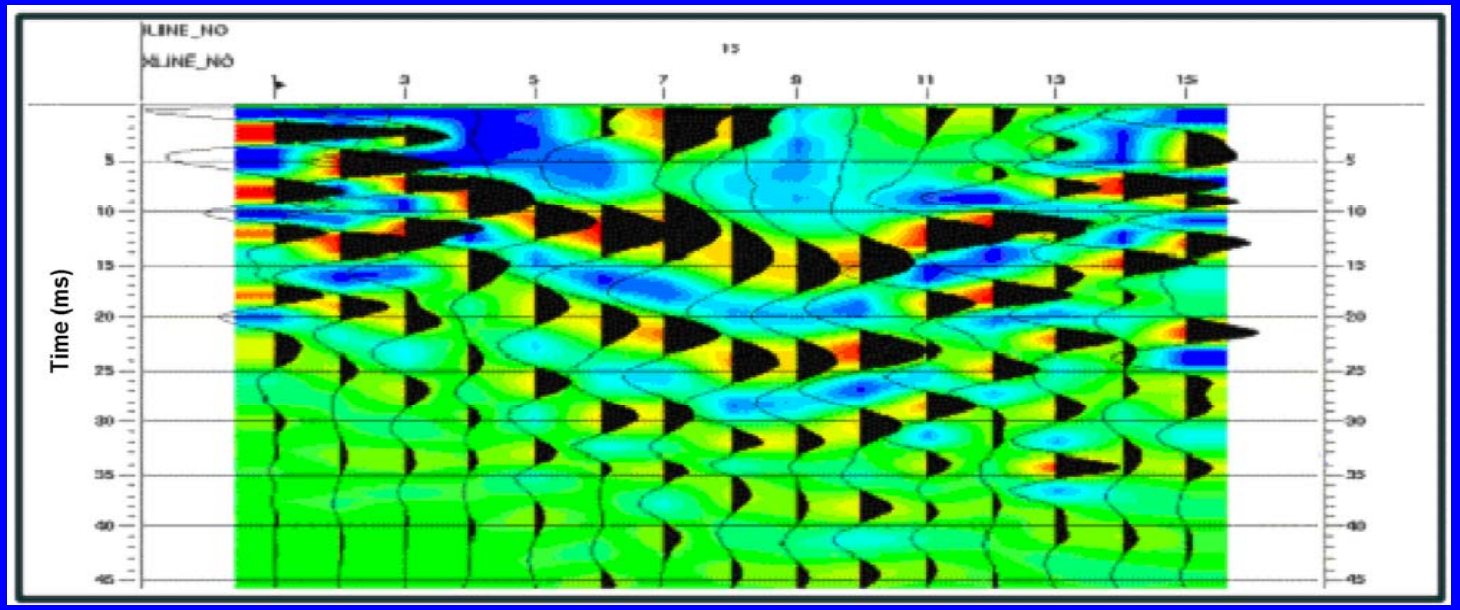
Wiggle trace display of Line 4 showing structural anomaly in vicinity of altar



Elevation and coordinate map of plaza based on the Total Station survey.

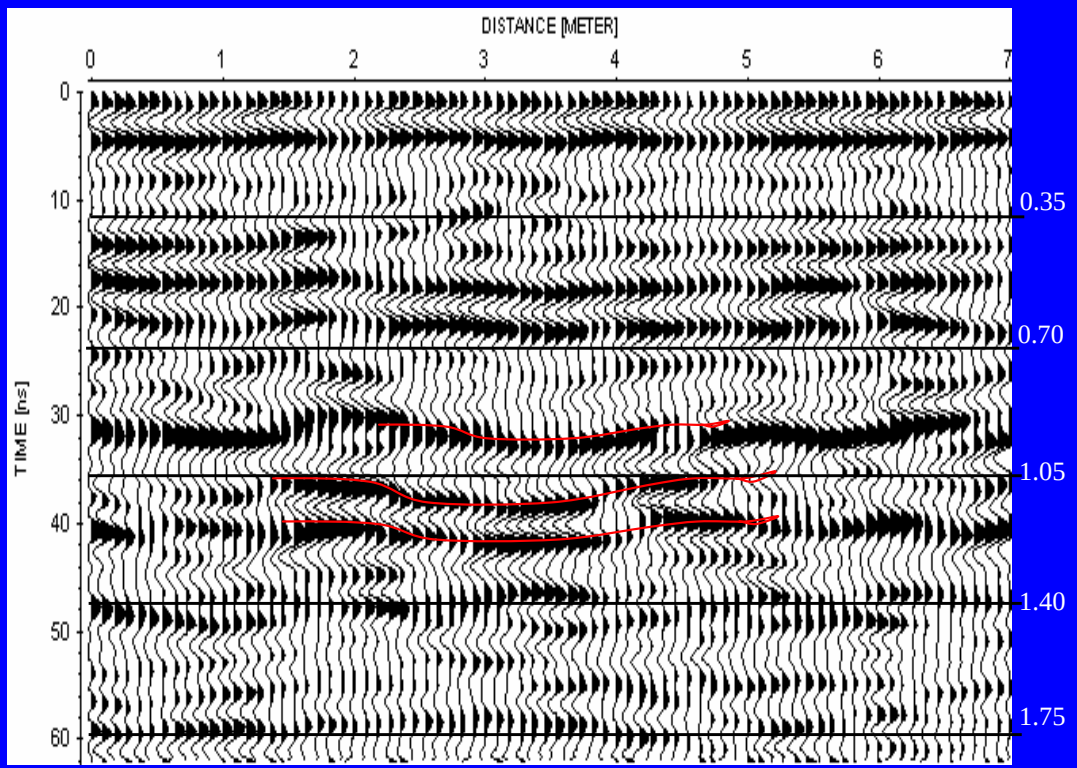
GLI3D Elevation display of 3C-3D micro-seismic survey





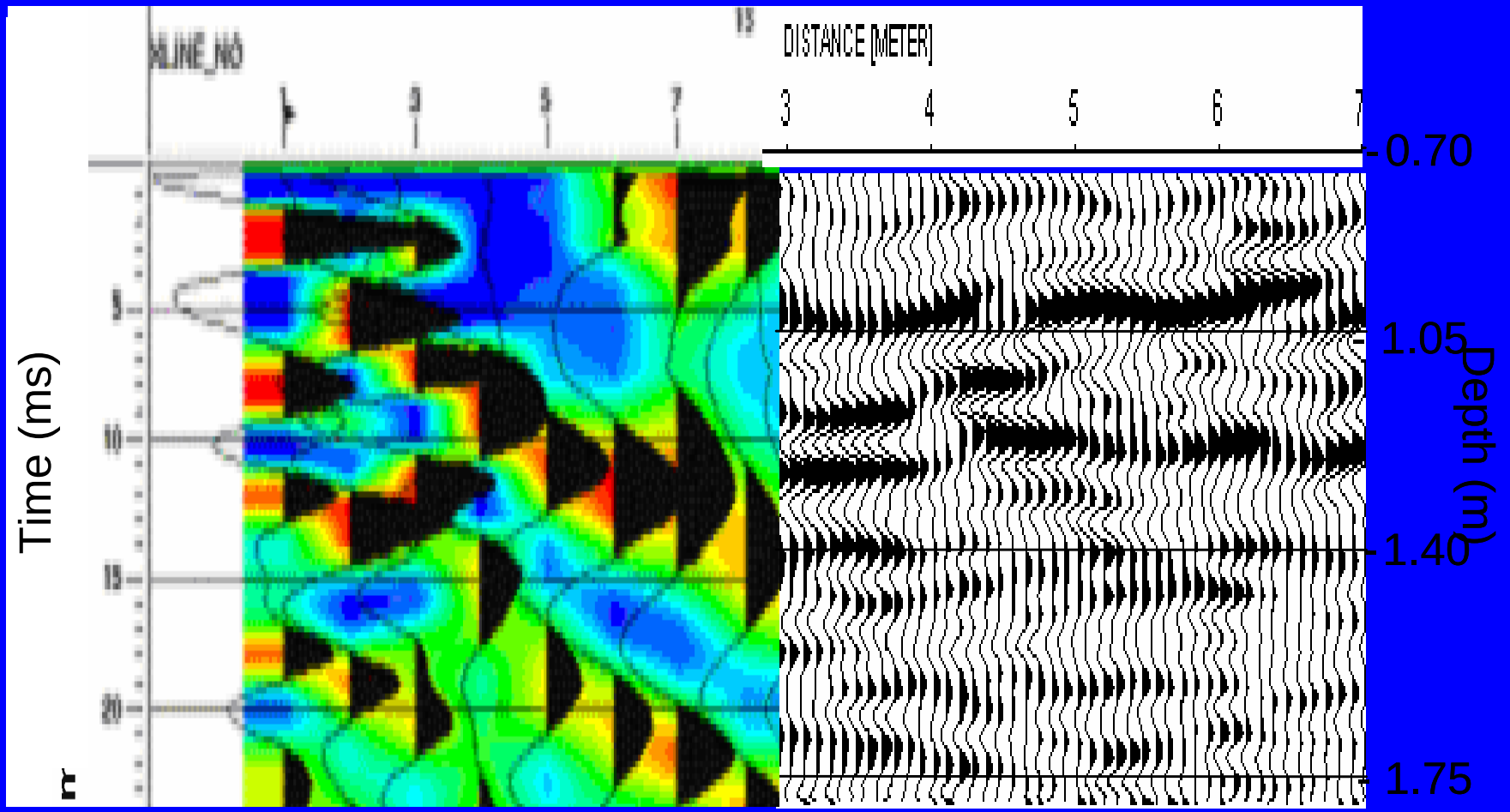
Micro-seismic survey

A comparison between near- surface geophysical surveys



GPR survey

Comparison of the micro-seismic (left) and GPR (right) surveys at depths 0.7 - 1.75 m.



Conclusions

- The GPR method provides coherent and interpretable images of the plaza.
- A number of interesting features have been identified.
- Interpretation should be evaluated using team approach (archaeologist and geoscientist).
- Gain and "programmed" parameters must be monitored during acquisition.
- Potential in combining GPR and seismic surveys to resolve and image deeper into the near-surface.

Acknowledgements

The CREWES Project, University of Calgary

Dr. J. M. Maillol, University of Calgary

Drs. Leslie Shaw, and Claire Allum, Bowdoin College, Maine

Dr. Eleanor King, Howard University, Washington, D.C.

Dr. Fred Valdez, University of Texas at Austin