Signal processing enhancements of GPR data in a carbonate environment

CREWES Sponsors Meeting

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Julie A. Aitken and Robert R. Stewart

Outline

- Objectives
- Geographical setting
- GPR Methodology
- Field work and results
- Further research
- Conclusions and acknowledgements

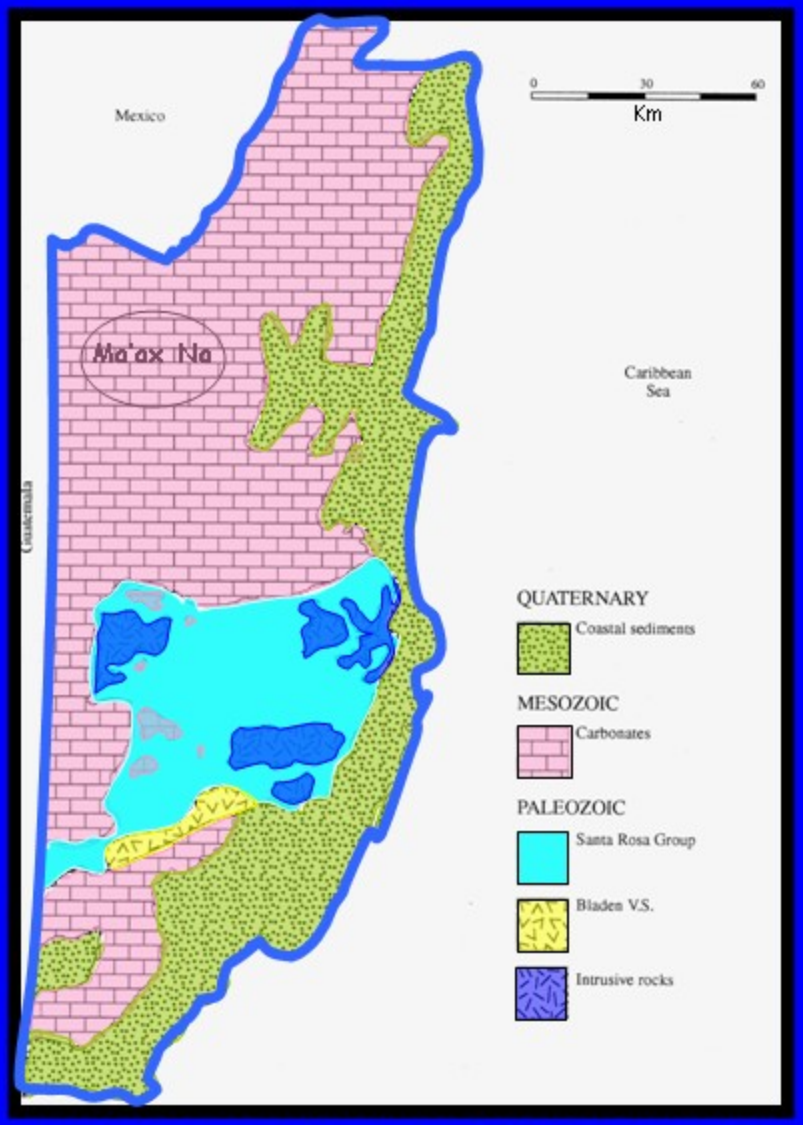
Objectives

- Improve quality of the 2-D and 3-D GPR images through signal processing enhancements and acquisition methodology
- Interpret near-surface structure and stratigraphy
- Highlight possible anomalies or buried features for excavation

Geographical Setting

Belize is located in south-eastern Central America neighbouring the countries of Mexico and Guatemala

(Reader's Digest, 1993)



(Reproduced from GPOMS, 1995)

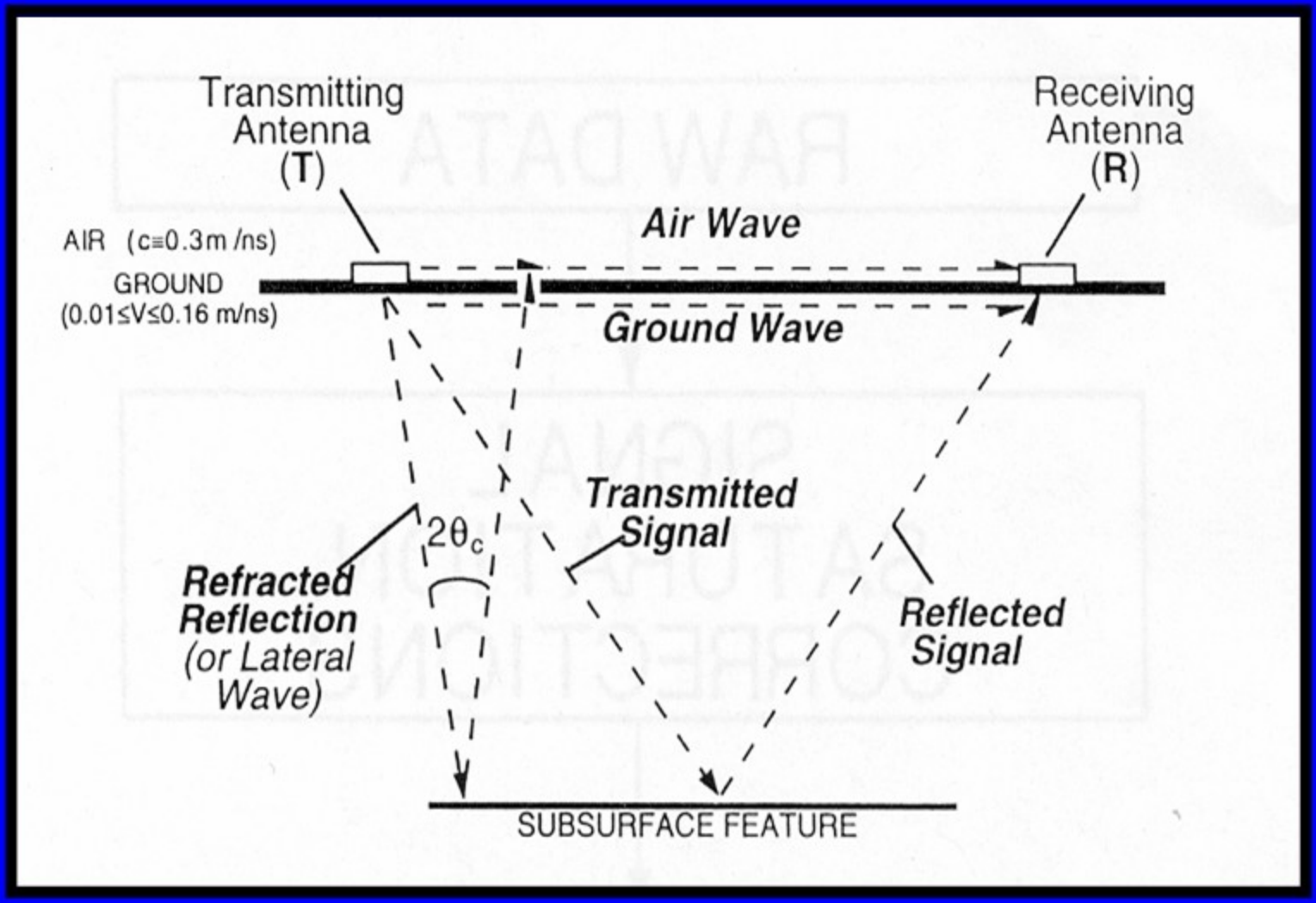
Maax Na is built on the Eocene age limestone platform that comprises the Yucatan Peninsula

GPR Methodology

(Photo - Claire Allum)

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

How GPR works



(J.M Reynolds, An Introduction to Applied and Environmental Geophysics, 1997)

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

Conversely, this may be written as:

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

where V = velocity,

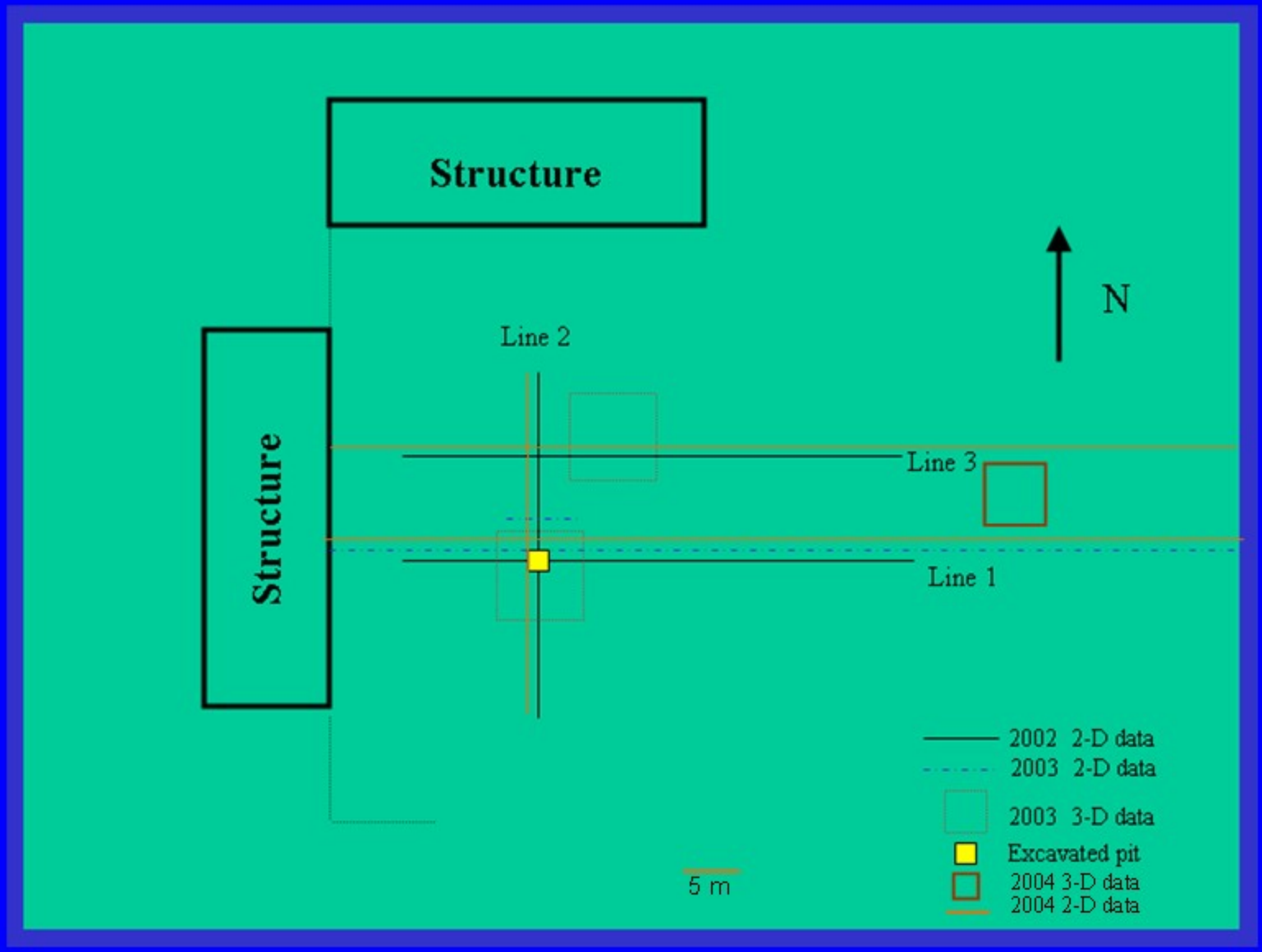
C= speed of light = 0.3 m/ns and

ε_r = relative dielectric permittivity (RDP)

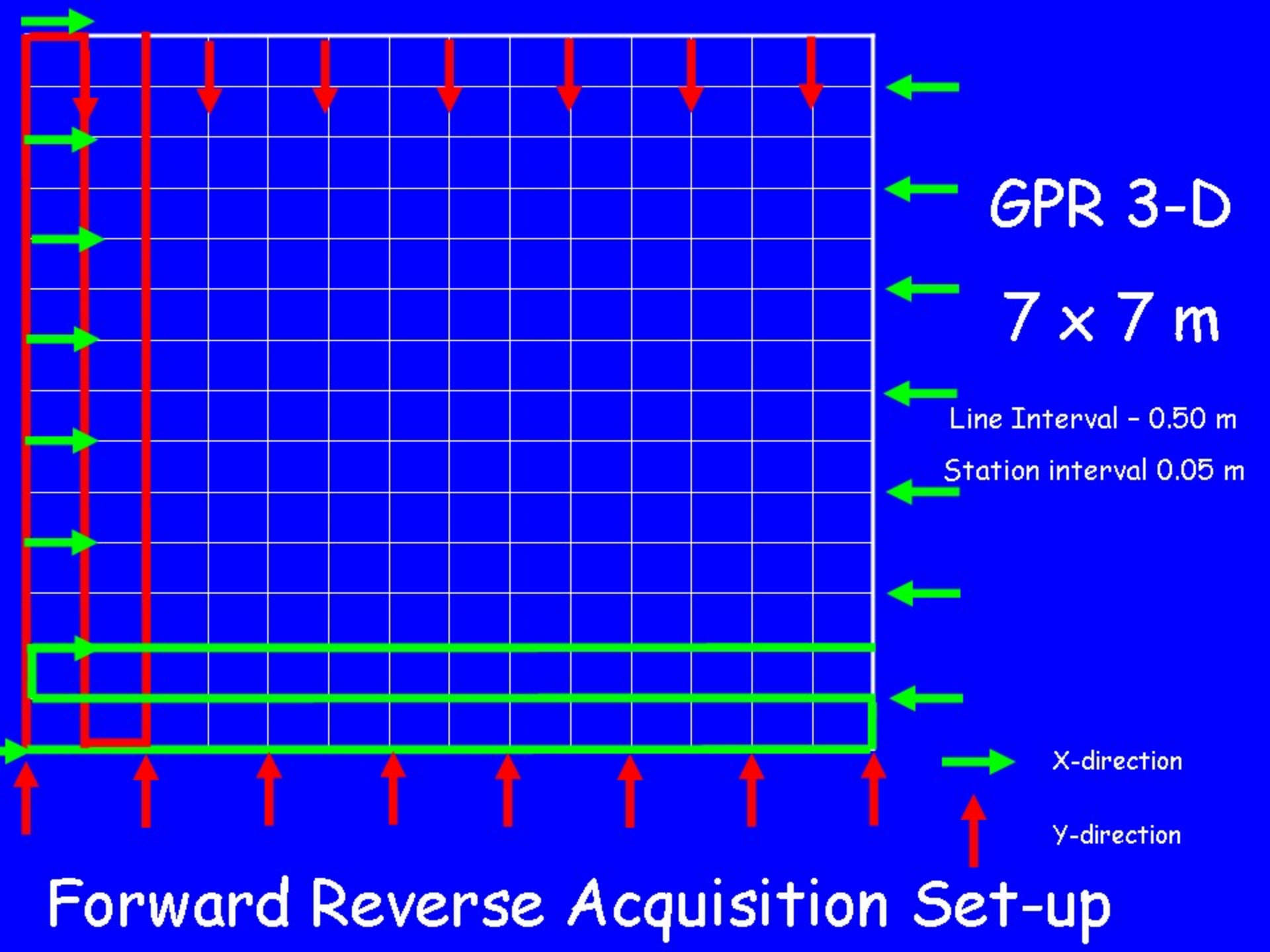
Material	Dielectric Constant
Air	1
Fresh water	80
Ice	3-4
Sea water	81-88
Permafrost	4-5
Sand (dry)	3-6
Sand (saturated)	20-30
Silt (dry)	3-30
Silt (saturated)	10-40
Shales	5-15
Clays	5-40
Humid soil	30
Cultivated soil	15
Average surface soil	12
Rocky soil	7
Sandy soil (dry)	3
Sandy soil (saturated)	19
Clayey soil (dry)	2
Clayey soil (saturated)	15
Sandstone (saturated)	6
Limestone (dry)	7
Limestone (saturated)	4-8
Basalt (saturated)	8
Granite (dry)	5
Granite (saturated)	7
Volcanic ash/pumice	4-7
Coal	4-5
Dry, sandy coastal land	10
Forested land	12
Rich agricultural land	15
Concrete	6
Asphalt	3-5

Conyers and Goodman, 1997

The dielectric permittivitties for common near surface materials.



Acquisition layout over the last three field seasons



Forward Reverse Acquisition Set-up

Field Observations

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

* Depth of penetration = 1.8 m

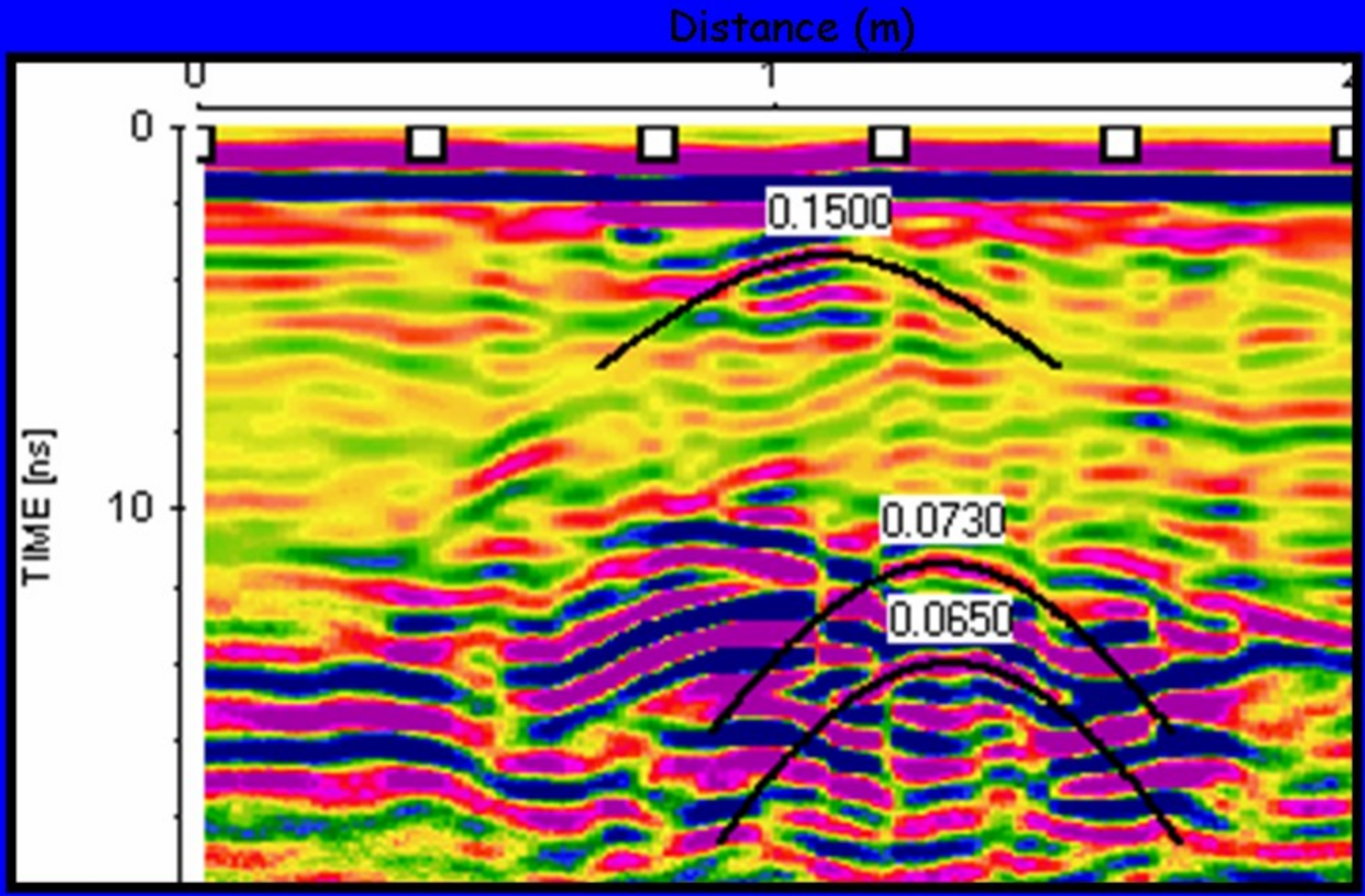
- 2003 observed velocities = 0.122 - 0.140 m/ns (drought conditions)

* Depth of penetration = 3.4 m

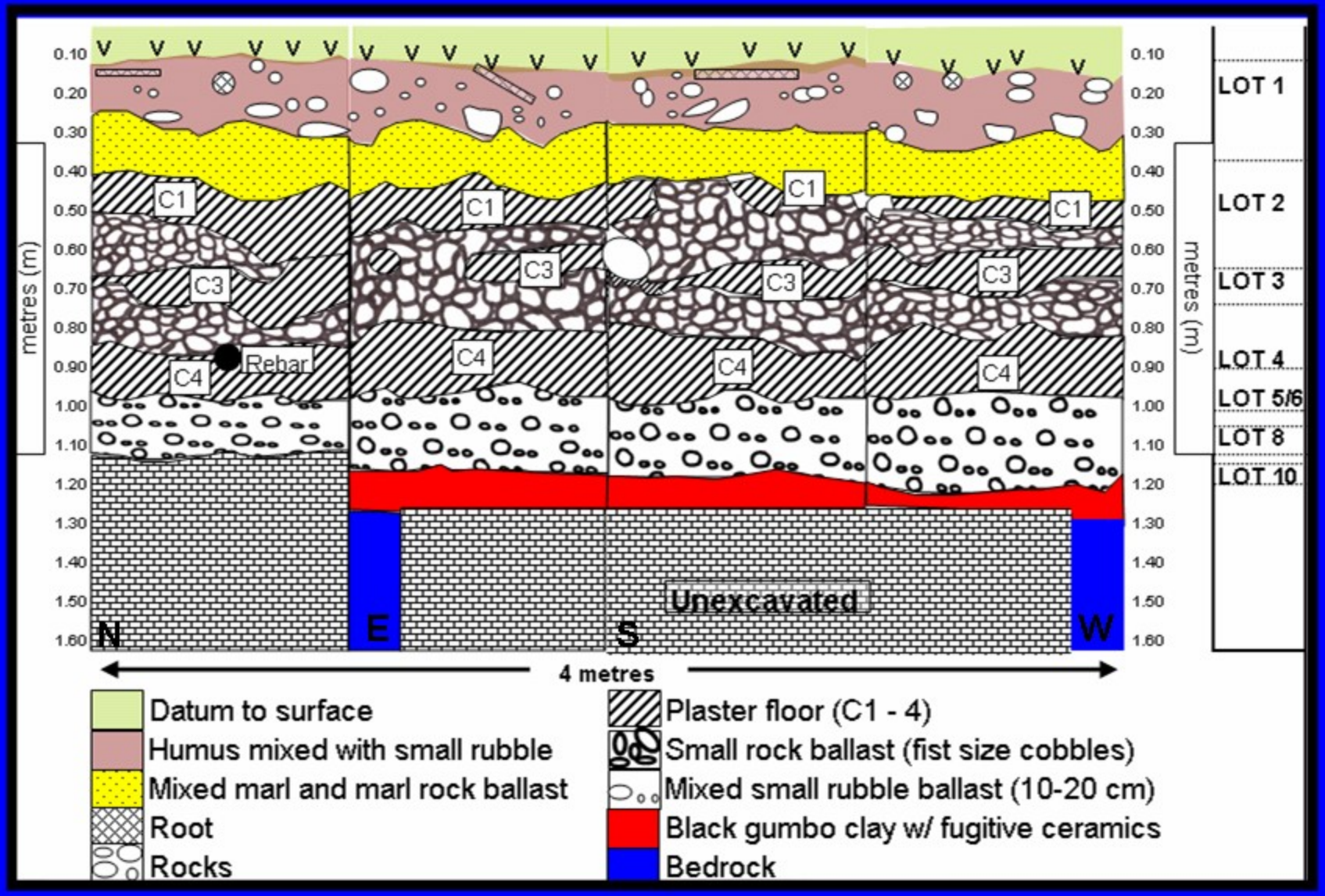
- 2004 observed velocities = 0.058 - 0.084 m/ns (saturated conditions)

* Depth of penetration = 1.8 m

* based on a 50 ns record



Velocity determination from curve fitting using Reflexw



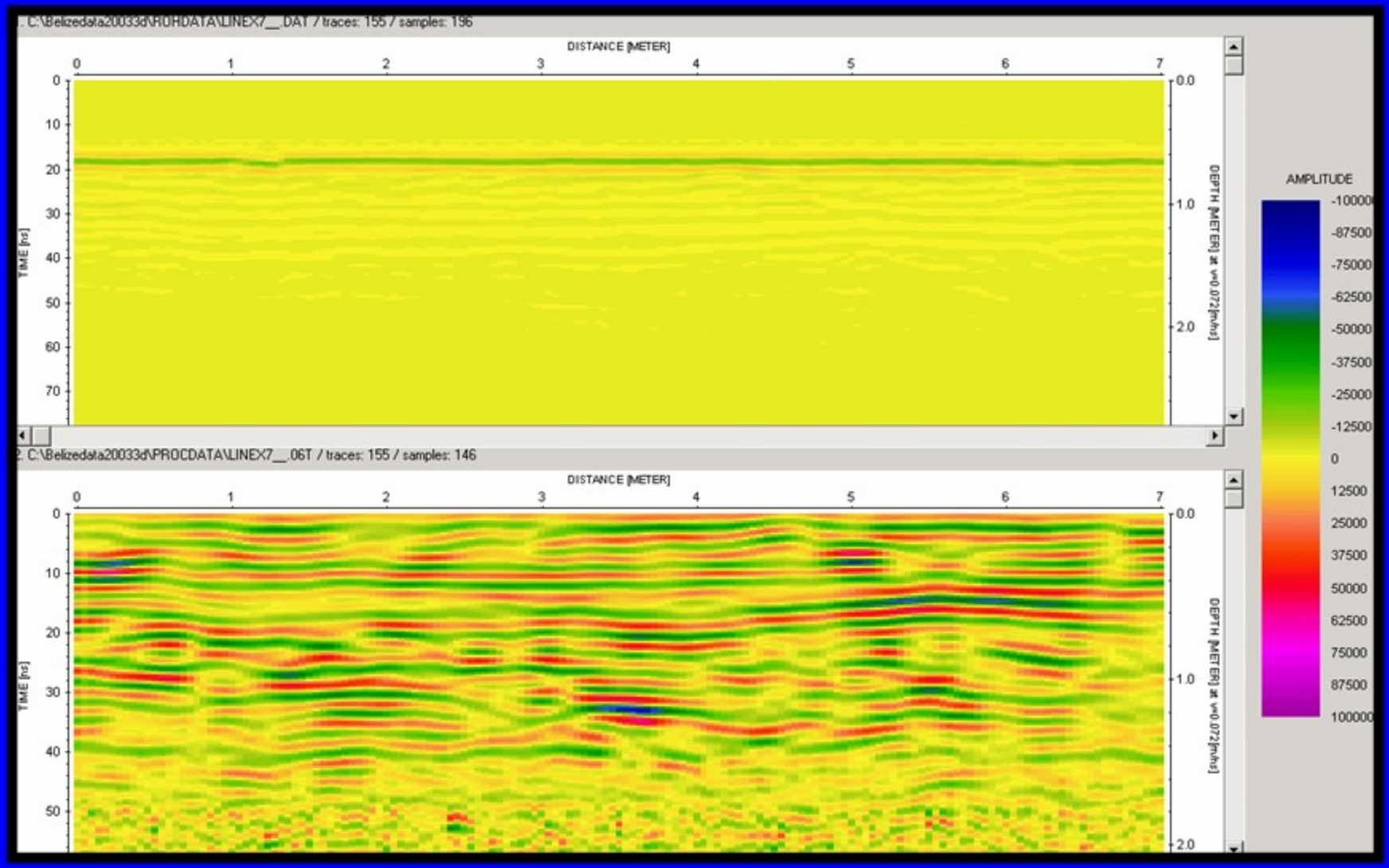
Schematic of excavated pit reproduced from work by E. King

Field Work and Results

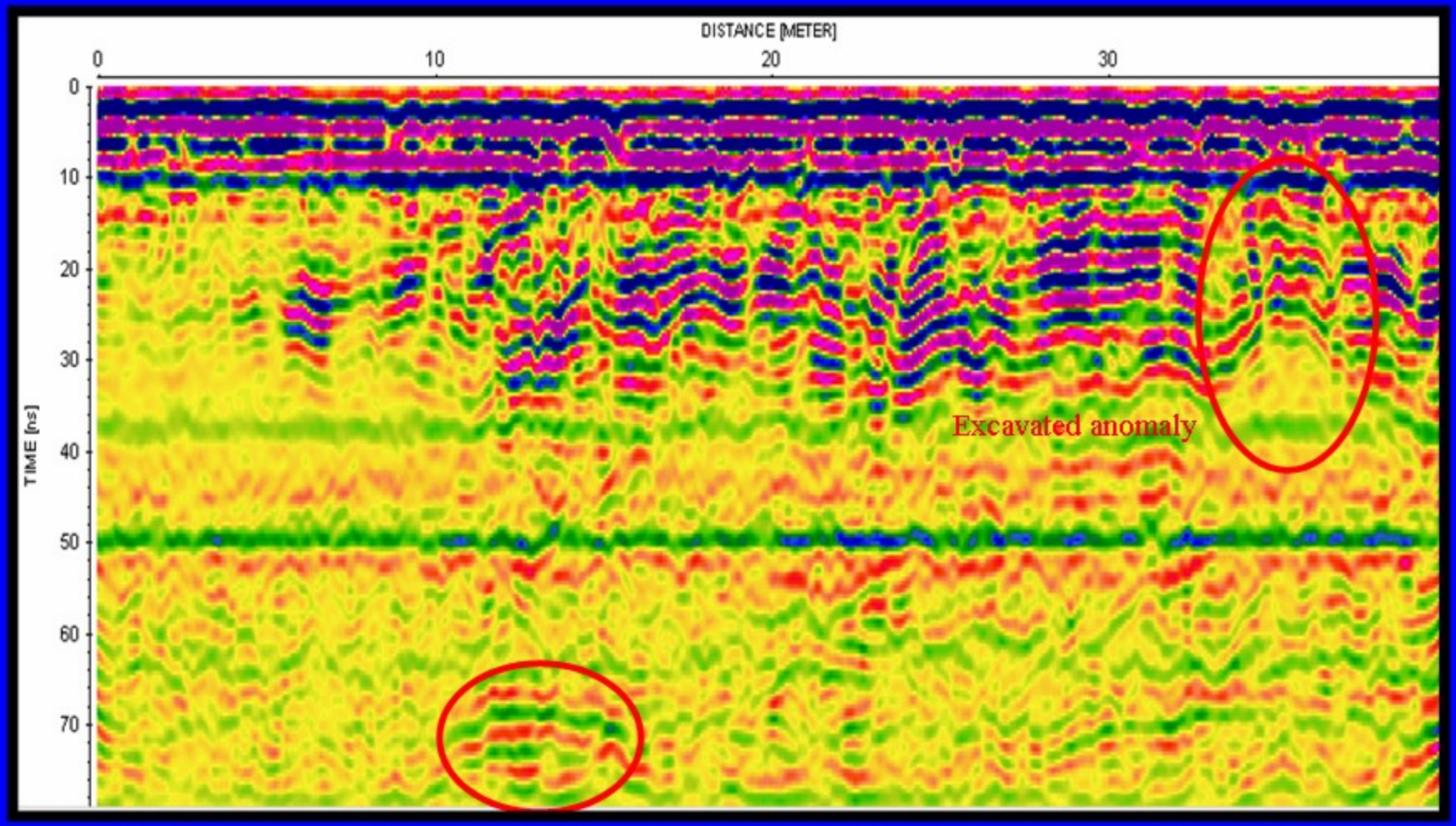
2003-2004

Processing flow using Reflexw

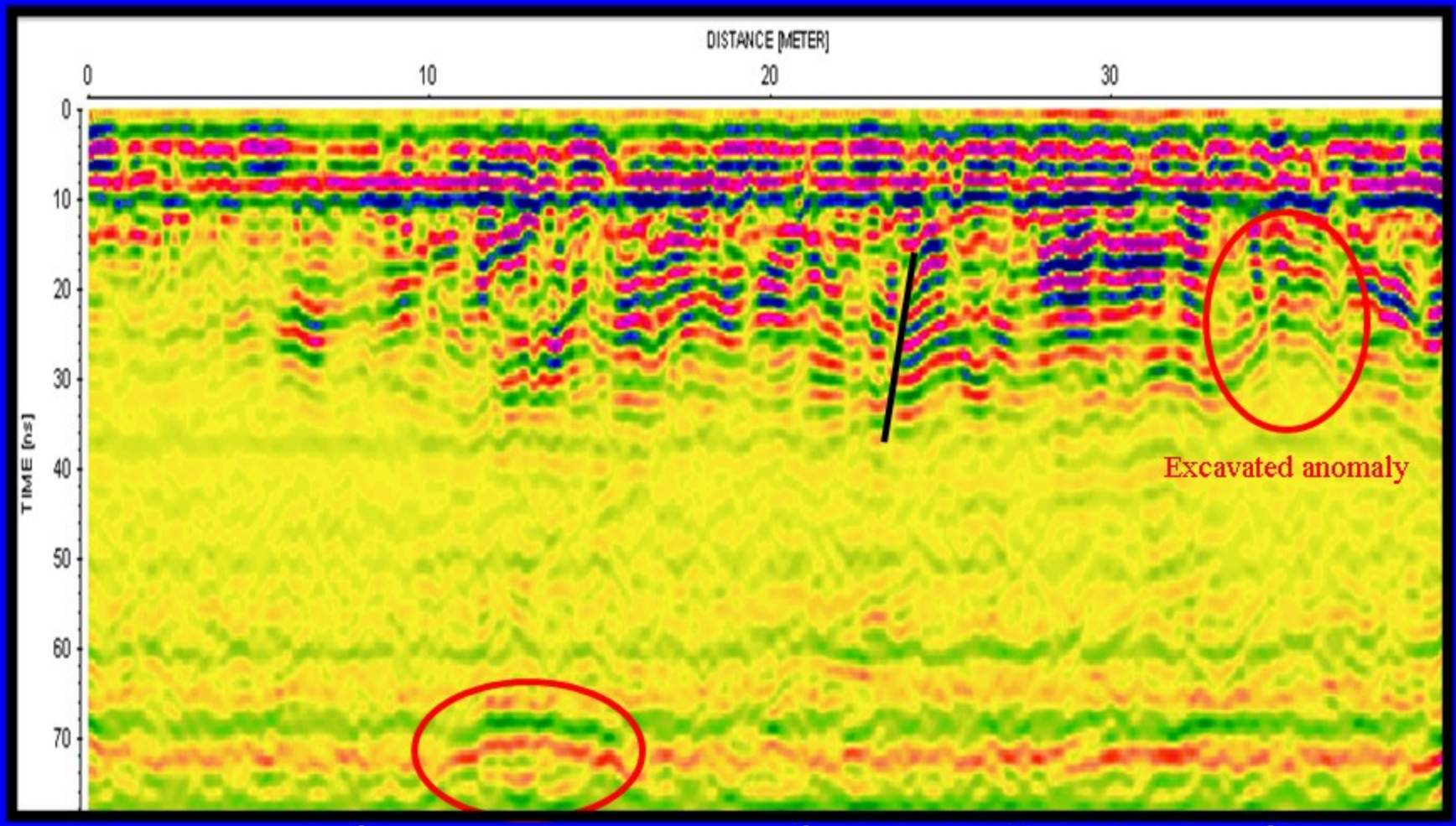
- Static shift to zero time
- Make traces equidistant
- Dewow filter (eliminates a low frequency component)
- Gain - energy decay function
- Spatial filter (running average)
- Migration (diffraction stack)
- Bandpass filter



Before and after images of Line X7 using the Reflexw processing flow

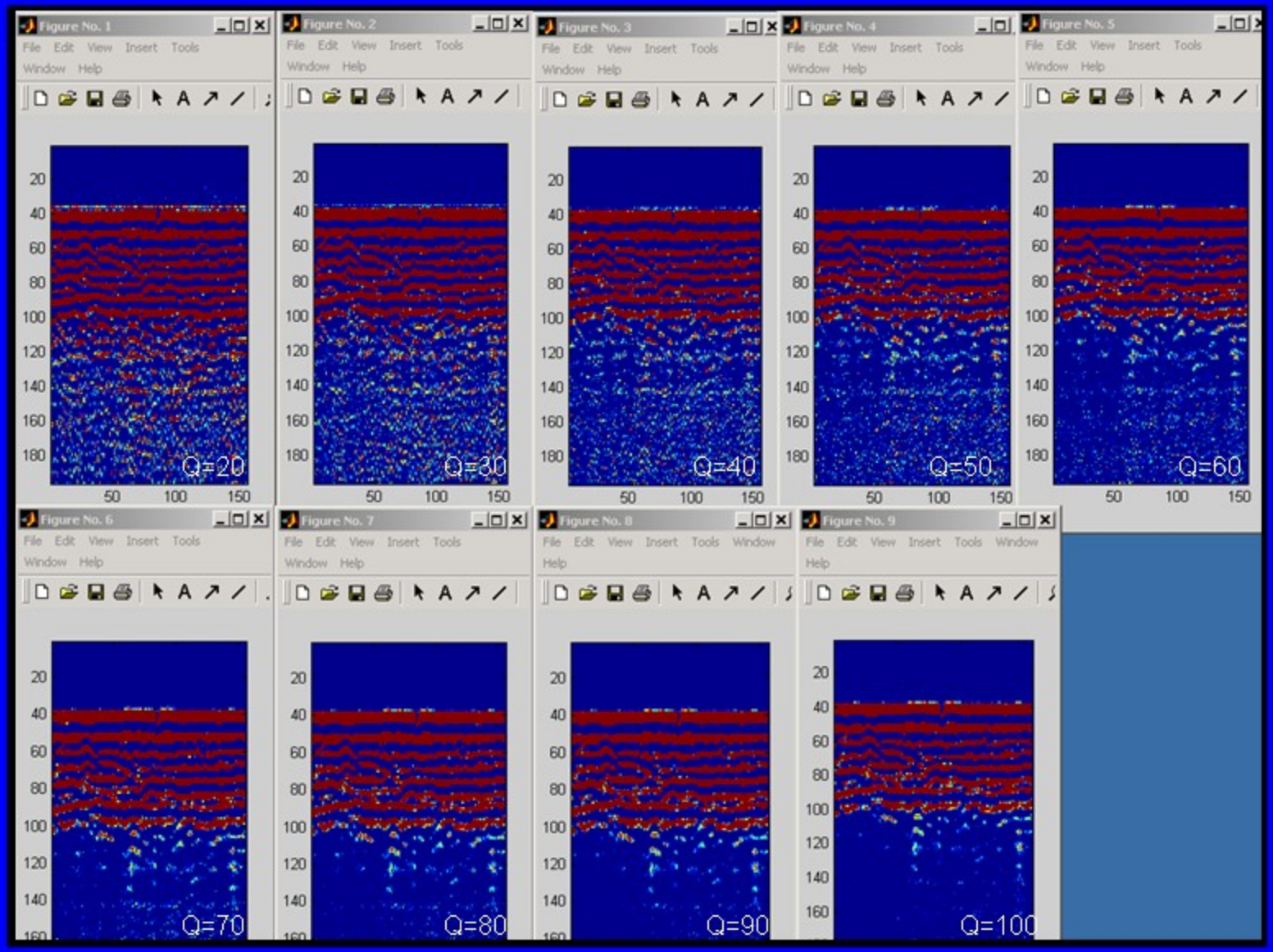


2004 GPR data (Line 2) using a manual gain function

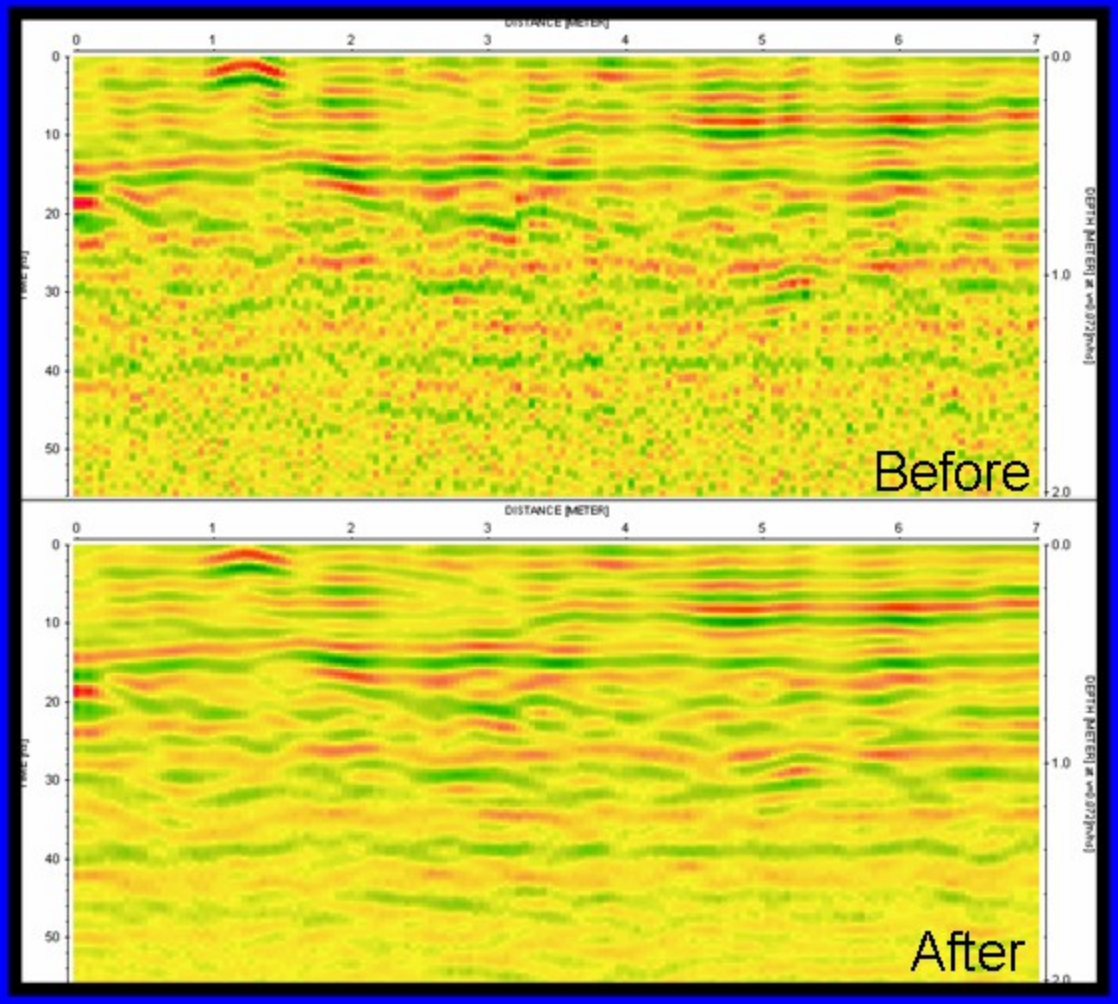


Correctly processed 2004 GPR data (Line 2) at Maax Na with anomalies highlighted

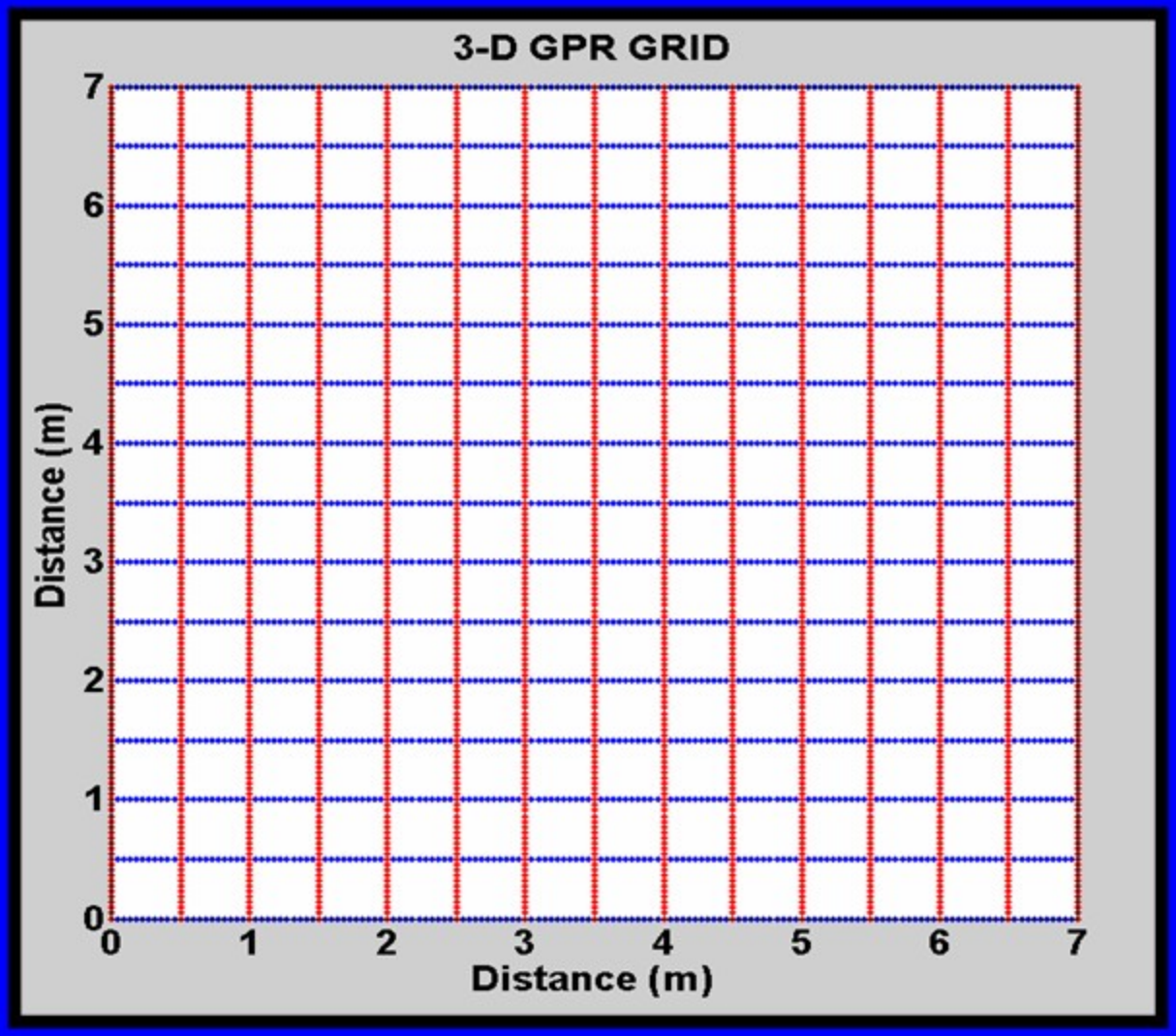
Further Research



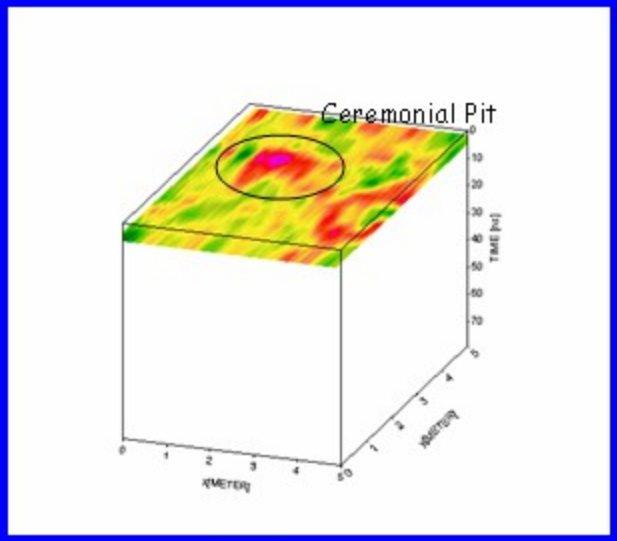
The testing of various Q-filters to improve data resolution at depth.



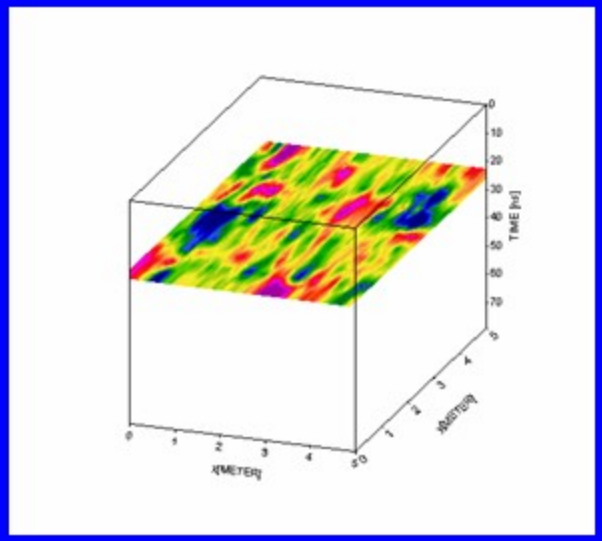
Improvement in LineX0 after the application of a Q-filter and a spatial filter



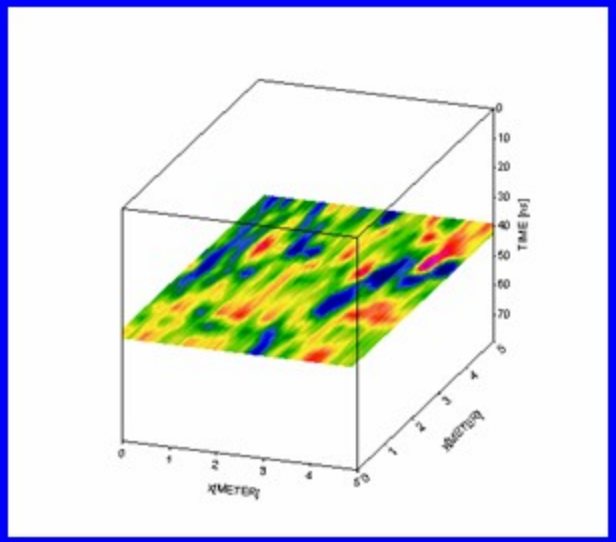
Actual data points collected with GPR survey.
The center of the grids contain no information.
Interpolation tries to fill in these gaps.



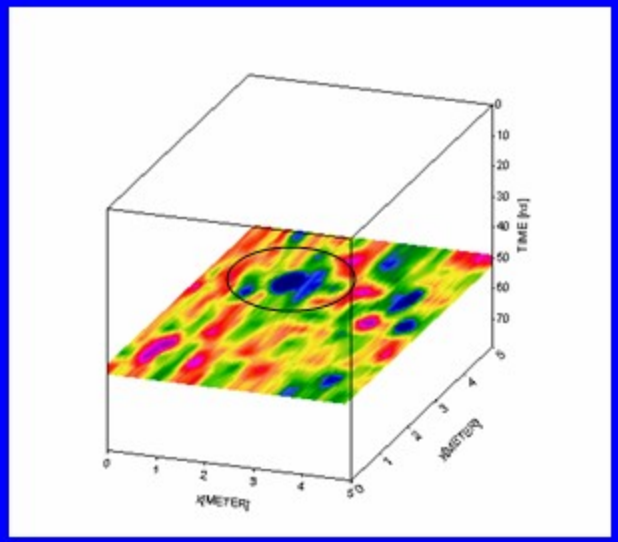
Time slice at 4 ns



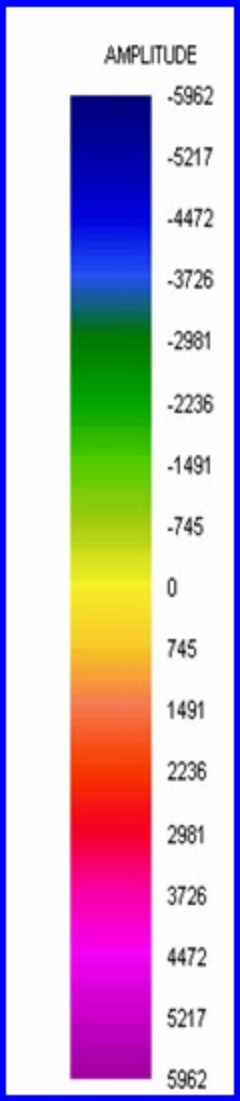
Time slice at 25 ns



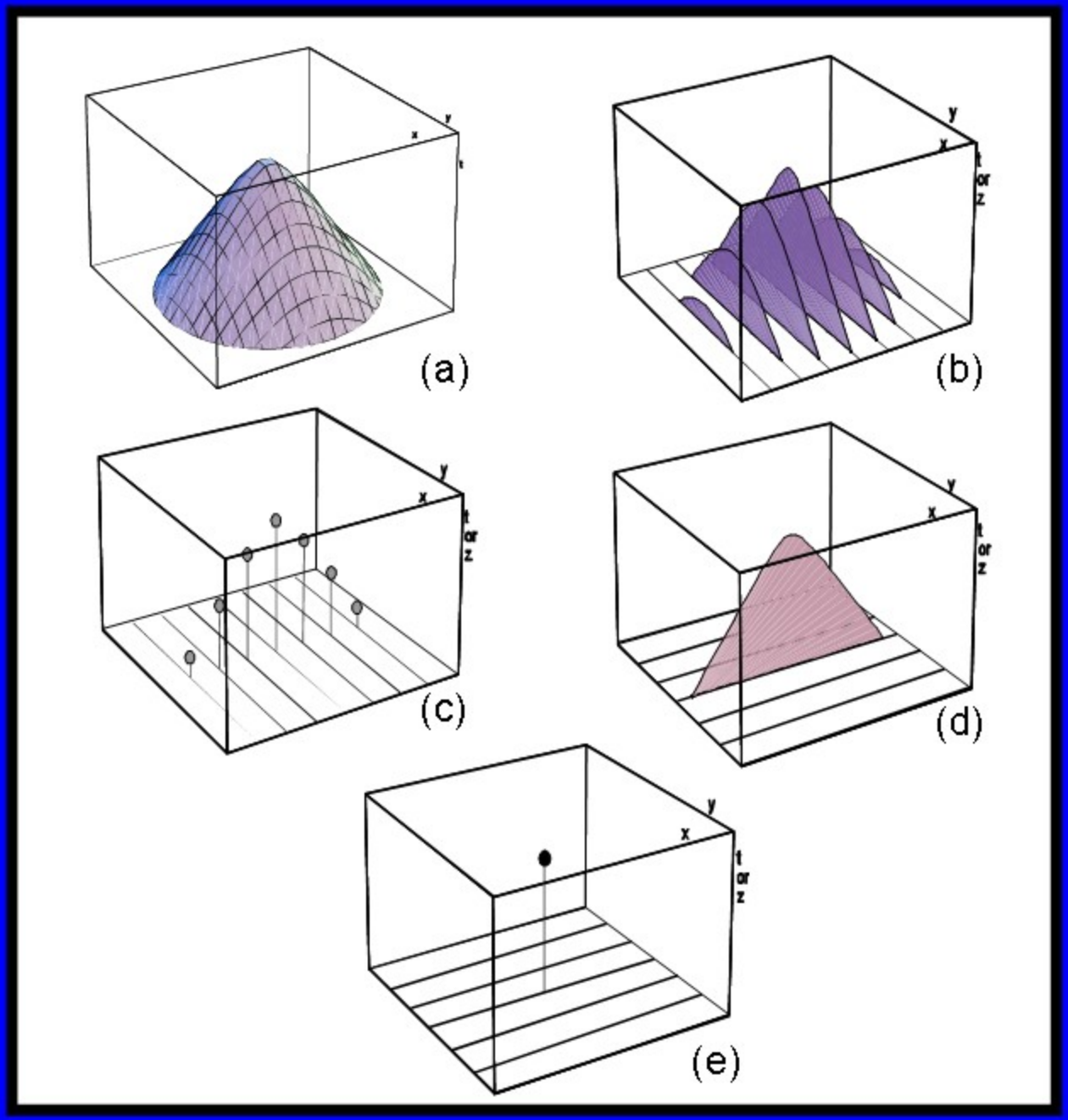
Time slice at 42 ns



Time slice at 52 ns

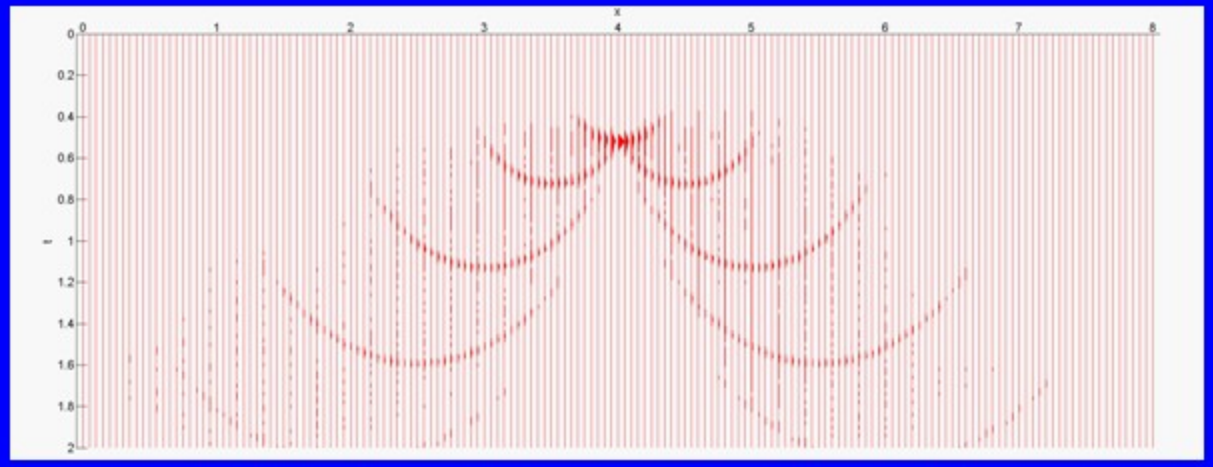


Amplitude time slices from 2004 GPR 3-D volume

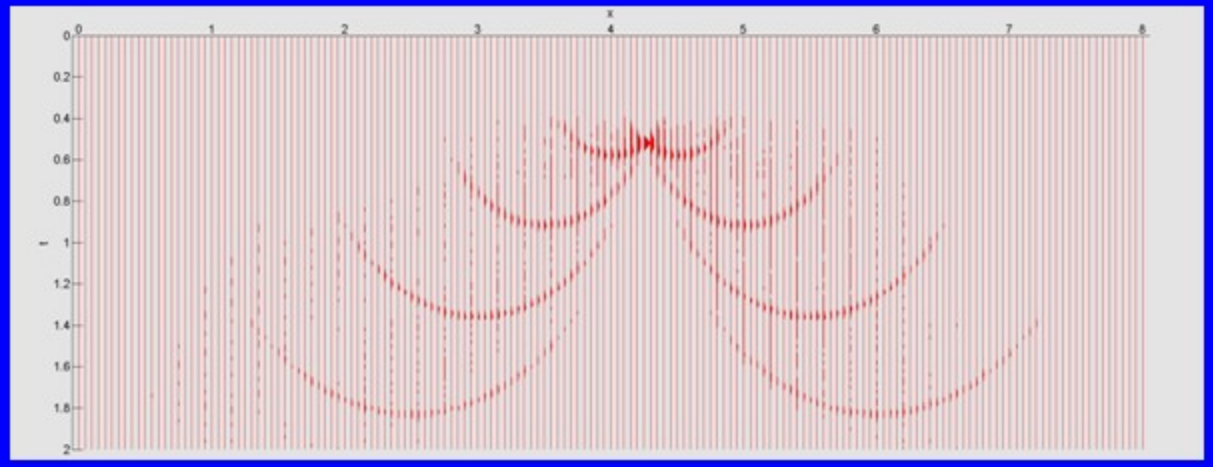


Synopsis of two pass 3-D Kirchoff Time Migration

Preliminary results using migration as an interpolator (x lines)



Migration results from corner of grid or square



Migration results from center of grid or square

Conclusions

- Application of gain functions to data at depth must be applied carefully
- The use of a refined processing flow combined with a Q-filter improves the data dramatically at depth
- Interpolation continues to be an important issue and warrants further work. Application of a 3-D Kirchoff time migration appears to be promising.
- Continued research will focus on acquisition parameter selection and comparison of different acquisition directions.

Acknowledgements

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