GPR imaging and interpretation at a Maya plaza ruin: Ma'ax Na, Belize, Central America

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Abstract

During the spring of 2002 and 2003, ground penetrating radar (GPR) surveys were conducted at a plaza in the ancient Maya site of Ma'ax Na in Belize, Central America. The surveys were initiated to interpret near-surface structure and stratigraphy and to highlight possible anomalies or buried features for excavation.

The surveys were acquired using Sensors and Software's Noggin® and Smart Cart® System, with a GPR antennae frequency of 250 MHz. For the 2-D lines, the receiver interval was 5 cm and the lines varied in length. The 3-D grids, surveyed in orthogonal directions, were 7 m x 7 m in area. The line interval was 50 cm, and receiver interval was 5 cm.

Hyperbolic fitting of curves to point diffractors in both survey years resulted in significantly different velocities. These differences were attributed to climatic conditions, namely a wet season in 2002, and near drought conditions in 2003. Measured velocities in 2002 ranged from .072 - .106 m/ns. The maximum penetration depth of the plaza lines was about 1.8 m, and resolution was calculated at about 7.2 cm based on an average velocity of 0.072 m/ns. Conversely velocities ranging from 0.122 – 0.140 m/ns were acquired in 2003. The depth of penetration and resolution based on an average velocity of 0.122 m/ns resulted in values of 3.4 m and approximately 12.2 cm respectively.

The data processing flow consisted of a bulk shift, application of a gain function, deconvolution, and band-pass filtering. The merging and interpolation of the 3-D grids, and migration algorithms are currently being tested using F-K migration, pre-stack migration, and inversion.

The GPR images show reasonable quality records with good signal penetration. Modeling of the excavated pit revealed that those levels containing rubble or small cobbles can be imaged and resolved, and that a reasonable correlation exists between the GPR radargram, and the 3-D data.

Introduction and Background

Ma'ax Na is one of a number of Maya sites in the Rio Bravo Conservation area of Belize. Maya complexes consisted of several elevated structures such a pyramids and temples that were linked by great plaza areas. As new pyramids or structures were built, the plaza was refurbished resulting in multiple levels.

The near-surface layering of the plaza is comprised mainly of soil, and limestone detritus. Construction materials included soil, limestone cobbles and boulders, large crudely chiseled limestone blocks, and stucco (Wilson and Wilson, 1990). The Maya determined that if the limestone fragments were burned and the resulting powder mixed with water, a durable white powder was created (Coe, 1975). This plaster was then used for the surface of the plazas and to coat the numerous temples and pyramid structures.

Our current research is focussed on improving the quality of the GPR images generated from several 2-D Ma'ax Na plaza lines, and two GPR 3-D grids. Standard seismic algorithms within the PROMAX processing system were adapted to process the GPR data. Modelling of the sections based on the archaeological information from an excavated pit was accomplished using CREWES packages, LOGEDIT and SYNTH.

GPR Survey

Ground penetrating radar (GPR) involves the propagation of a series of short pulses of electromagnetic energy into the subsurface. The success of GPR surveys is dependent on the composition of near-surface materials and conditions. The clay content of soils, the presence of saline fluids, and the saturation level of the material in general play key roles in obtaining interpretable images of the earth.

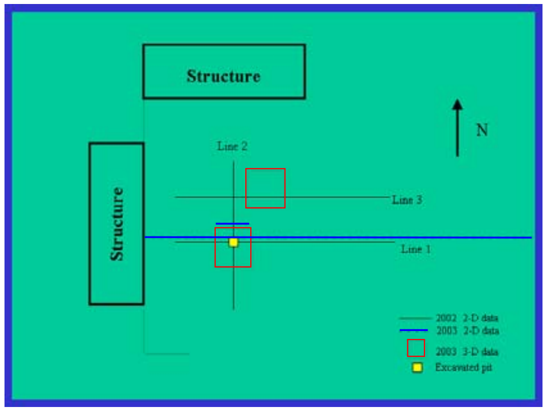

FIG. 1 Layout of GPR lines at the Ma'ax Na plaza complex.

As shown in Figure 1, several 2-D lines and two 3-D grids were surveyed at the Ma'ax Na plaza. The surveys were acquired using Sensors and Software's Noggin® and Smart Cart® System, at a GPR antennae frequency of 250 MHz. For the 2-D lines, receiver interval was 5 cm and the lines varied in length. The 3-D grids were 7 x 7 m in area. The line interval was 50 cm, and receiver interval was 5 cm. The temporal sampling (sample rate) was set at 0.4 nanoseconds. The excavated pit was at the intersection of several lines and within one of the 3-D grids.

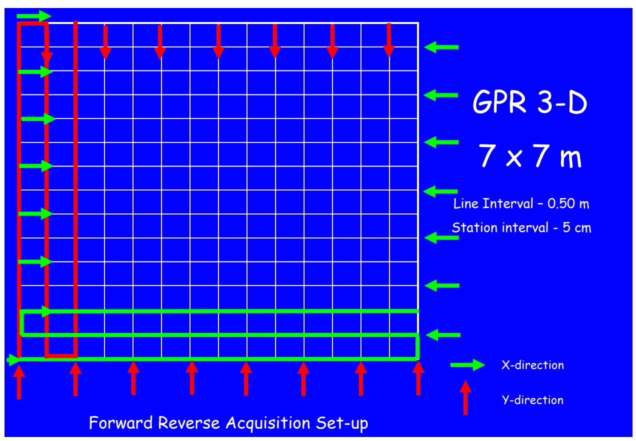

FIG. 2 Acquisition layout of the 3-D grids.

Processing and Modelling

The processing flow consisted of a bulk shift, application of a gain function, deconvolution and band-pass filtering. As previously discussed the merging and interpolation of the 3-D grids, and migration algorithms are currently being tested.

The excavation of a one-by-one meter pit at the plaza revealed detailed information about its composition. At least seven previous levels of plaza construction were evident. Based on the theoretical resolution of the GPR data, it may be possible to identify some of these levels. Rubble zones provide permeable horizontal pathways and are considered to be major conduits for fluid flow (Hubbard, et al, 1997). Large property changes may be created by water saturation.

Modelling of the GPR radargram was generated using LOGEDIT and SYNTH. Because GPR is an electro-magnetic method and its properties differ from that of seismic, it was necessary to manipulate the velocity and the density curves. The density log was replaced by a constant pseudo- density log using a value of 2.2 g/cm. As there is a direct relationship between velocity and dielectric permittivity, the velocity or slowness log was manipulated to represent the dielectric permittivity log. The pseudo-dielectric permittivity log was created by increasing the dielectric permittivity values by 20% over those areas in the excavated pit that contained rubble or small rocks. The logs were then convolved with a 250Hz minimum phase wavelet. The resultant GPR synthetic, is aligned with the archaeological information, the pseudo-density log (blue) and the pseudo-dielectric permittivity log (red) for comparison (Figure 3).

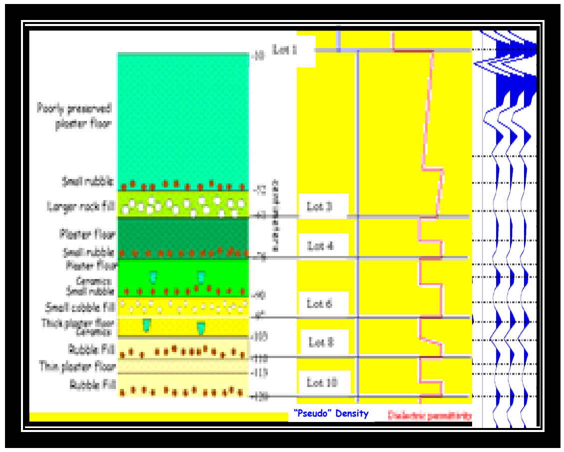

FIG. 3 Archaeological information from the excavated pit based on a description by Shaw (2002). The updated pseudo-density log (blue) and the pseudo-dielectric permittivity log (red) is superimposed.

Interpretation

Based on the GPR synthetic or radargram, it was possible to make an initial interpretation of the 2002 and 2003 data. The lines used for comparison purposes were generated by Geo-X Systems at a ratio of 1 ns equal to 10 ms. As shown, the radargram based on the archaeological information from the excavated pit, ties fairly well with the 2003 GPR 3-D image (Figure 4).

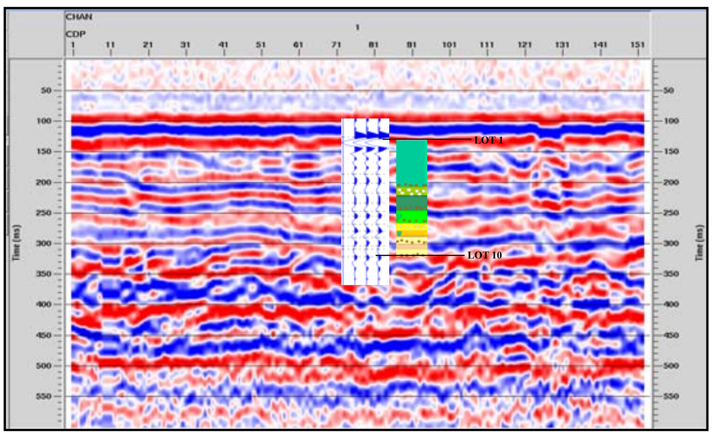

FIG. 4 Comparison of a line from the 3-D grid with radargram.

A comparison of the data from 2002 and 2003 as seen in Figure 5, represents how a dramatic change in velocity affects the interpretation. In order to tie Lot 10 for instance for both the 2002 and 2003 GPR data, the 2003 radargram was stretched. The data now ties reasonably well.

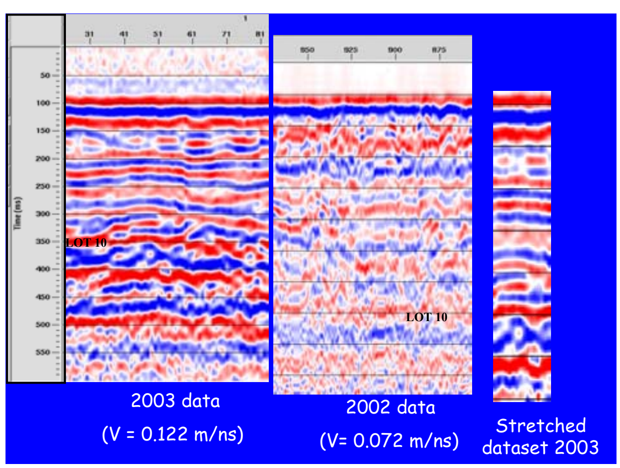

FIG. 5 Comparison of the two datasets and the dramatic change in interpretation due to velocity changes.

Interpolation and Merging

Figures 6 and 7 represent the 3-D volumes acquired in orthogonal directions using the VISTA processing package. Merging the X and Y 3-D grids is the main focus of the research at present. Manipulation of the records to create a 3-D database, and a suitable interpolation technique has not been identified. Various migration algorithms being tested include F-K migration, pre-stack migration, and inversion.

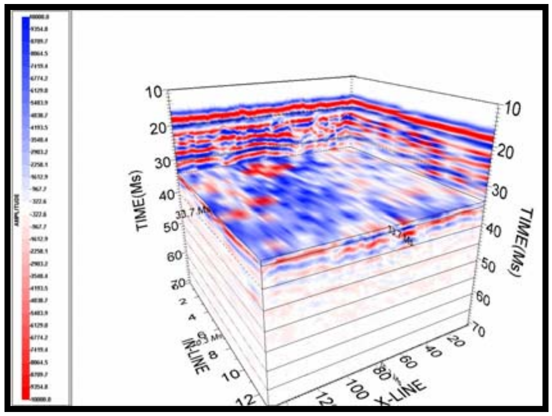

FIG. 6 3-D grid from the X-direction or inline direction.

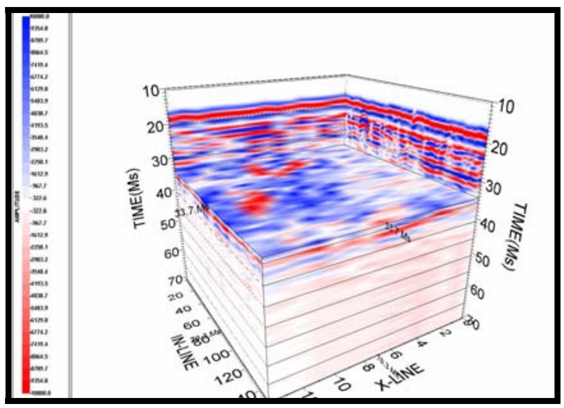

FIG. 7 3-D grid from Y-direction or xline direction.

Conclusions

GPR presents some challenges with respect to processing especially merging and interpolation of the 3-D grids. However the GPR method provides coherent and interpretable images of the subsurface of the plaza and a number of interesting features have been identified. The depth of penetration is dependent on the subsurface velocities. In 2002, the depth of penetration was about 1.8 m, and the vertical resolution was approximately 7.2 cm. For 2003, the depth of penetration was about 3.4 m, and the vertical resolution was about 12.2 cm. Processing and modelling flows need to be further refined.

References

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