Ground Penetrating Radar Survey on Portions of Theus Plantation, Beaufort County, South Carolina

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By Daniel T. Elliott

The LAMAR Institute, Inc.
Savannah, Georgia

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Introduction

This report presents the findings of the LAMAR Institute’s Ground Penetrating Radar survey on portions of the Theus plantation site in Beaufort County, South Carolina. These archaeological sites are located within the Palmetto Bluff development project, which has been the subject of archaeological study by Integrated Archaeological Services, Inc. (IAS) and others (Baluha and Hill 2004; Shlasko and Socci 2007). The Theus site, 38Bu1376, was originally located by Brockington and Associates, Inc. who recommended the historic component as eligible for the NRHP, although they did not recommend the prehistoric component as contributing to the site’s NRHP eligibility (Baluha and Hill 2004:107). Their assessment of the site was based on a total of 187 shovel tests, including 48 that contained artifacts.

Phase II testing at 38Bu1376 consisted of the excavation of 1,288 shovel tests, which included 348 tests containing artifacts or shell. Shovel test results indicated that the site had a meaningful artifact assemblage and the possibility of intact subsurface features. IAS recommended the site as eligible for listing in the National Register of Historic Places (NRHP) (Shlasko and Socci 2007:5). Readers are directed to the most recent report by Shlasko and Socci for detailed background information about the site and its environment.

The GPR survey by the LAMAR Institute was intended as a demonstration project to show the usefulness of GPR technology in mapping buried archaeological deposits. Archaeological excavation by IAS was underway at the time of the GPR survey and the findings from the GPR survey were used by IAS to direct the placement of Phase III excavation units. GPR data was collected from one sample block on Area A of the Theus plantation site (38BU1376) and these data represent the basis of this report (Shlasko and Socci 2007:63, Figure 17, Reproduced below in Figure 1).

This effort is the initial study of the GPR application potential on archaeological sites at Palmetto Bluff and one of only a few studies in Beaufort County. The main purpose of the GPR study is to generate data that would help guide the placement of formal excavation units. The results were exciting and several promising areas within the sample block were indicated for additional study. This research was not required by the cultural resources permitting process but was offered as independent research by the LAMAR Institute gratis, in an effort to promote the use of GPR technology on sites in coastal South Carolina.
Figure 1. Site 38BU1376 Plan with GPR Block A Shown in Green (Shlasko and Socci 2007:63).
Methods

Ground Penetrating Radar, or GPR, uses high frequency electromagnetic waves to acquire subsurface data. The device uses a transmitter antenna and closely spaced receiver antenna to detect changes in electromagnetic properties beneath them. The antennas are suspended just above the ground surface and the antennas are shielded to eliminate interference from sources other than directly beneath the device. The transmitting antenna emits a series of electromagnetic waves, which are distorted by differences in soil conductivity, dielectric permittivity, and magnetic permeability. The receiving antenna records the reflected waves for a specified length of time (in nanoseconds, or ns). The approximate depth of an object can be estimated with GPR, by adjusting for electromagnetic propagation conditions. The GPR signals that are captured by the receiving antenna are recorded as an array of numerals, which can be converted to gray scale (or color) pixel values. The radargrams are essentially a vertical map of the radar reflection off objects and other soil anomalies. It is not an actual map of the objects. The radargram is produced in real time and is viewable on a computer monitor, mounted on the GPR cart.

The GPR sample blocks in this study area were composed of a series of parallel transects, or traverses, which yielded a two-dimensional cross-section or profile of the radar data. These samples are termed radargrams. This two-dimensional image is constructed from a sequence of thousands of individual radar traces. A succession of radar traces bouncing off a large buried object will produce a hyperbola, when viewed graphically in profile. Multiple large objects that are in close proximity may produce multiple, overlapping hyperbolas, which are more difficult to interpret. For example, an isolated historic grave may produce a clear signal, represented by a well-defined hyperbola. A cluster of graves, however, may produce a more garbled signal that is less apparent.

GPR has been successfully used for archaeological and forensic anthropological applications to locate relatively shallow features, although the technique also can probe deeply into the ground. The machine is adjusted to best probe to the depth of interest by the use of different frequency range antennas. Higher frequency antennas are more useful at shallow depths, which is most often the case in archaeology. Also, the longer the receiving antenna is set to receive GPR signals (measured in nanoseconds, or ns), the deeper the search.

The effectiveness of GPR in various environments on the North American continent is widely variable and depends on solid conductivity, metallic content, and other pedo-chemical factors. Conyers noted that GPR, “works best in sandy and silty soils that are not saturated with water”, and that it does not work, “in areas where soils are saturated with salt water” (Conyers 2002). Generally, South Carolina’s coastal soils have moderately good properties for its application. GPR has been used to a limited extent on archaeological sites in South Carolina. It has been used effectively on several historic sites in Beaufort County. The LAMAR Institute’s previous experience using GPR technology on archaeological sites includes the Beaufort National Cemetery Expansion
project (Battle and Battle 2004; Elliott 2006d). That work identified a number of 19th and early 20th century graves that were previously unknown. Another recent study by the LAMAR Institute sampled a small portion of the Bull plantation on Coosaw Island. It identified one large anomaly, which may represent a historic period feature, possibly associated with the Bull family’s enslaved living quarters.

GPR signals cannot penetrate large metal objects and the signals are also significantly affected by the presence of salt water. Although radar does not penetrate metal objects, it does generate a distinctive signal that is usually recognizable, particularly for larger metal objects, such as a cast iron cannon or man-hole cover. The signal beneath these objects is often canceled out, which results in a pattern of horizontal lines on the radargram. For smaller objects, such as a scatter of nails, the signal may ricochet from the objects and produce a confusing signal. Rebar-reinforced concrete, as another example, generates an unmistakable radar pattern of rippled lines on the radargram.

GPR is particularly well suited for the delineation of historic cemeteries. Historic graves are often easy to recognize in radargrams, as evidenced by a pronounced hyperbola. When 3-D slices intersect these hyperbolas the graves are usually clearly evident in plan view. When a series of graves are closely spaced, however, the grave radar “signature” is less clear-cut. By slicing the radar data at various depths along the hyperbola, the aerial perspective can be refined for optimal viewing and recognition. Since not all graves were dug to the same depth, 3-D slices at different depths can often yield very different views of graves in plan by varying the slice only a few centimeters. The GPR signature for aboriginal features on the Georgia coast has not been fully established. The current work is an important attempt towards characterizing aboriginal features with GPR technology.

Using the same RAMAC X3M GPR system as that used in the present study, Elliott has conducted several GPR studies of 18th and 19th century archaeological sites in coastal Georgia. The first study was at the New Ebenezer town site in Effingham County, Georgia (Elliott 2003a). The results of the GPR work at New Ebenezer were quite exciting and included the delineation of a large portion of a British redoubt palisade ditch and the discovery of several dozen previously unidentified human graves (both within and beyond the known limits of the Jerusalem Lutheran Church cemetery). More recently, GPR survey was conducted by Elliott and his colleagues, at Fort Morris and Sunbury Cemetery (Liberty County), Sansavilla Bluff (Wayne County), Woodbine Plantation cemetery (Camden County), and Garden Homes [Waldburg Street, Savannah] (Chatham County), the Gould-Bethel Cemetery (Chatham County), Bullhead Bluff Cemetery (Camden County), Fort Saint Andrews (Camden County) and numerous other sites with satisfactory results (Elliott 2003b; 2004; 2006).

The equipment used for this study consisted of a RAMAC/X3M Integrated Radar Control Unit, mounted on a wheeled-cart and linked to a RAMAC XV11 Monitor (Firmware, Version 3.2.36). A 500 megahertz (MHz) shielded antenna was used for the data gathering. MALÅ GeoScience’s Ground Vision (Version 1.4.5) software was used to acquire and record the radar data (MALÅ GeoScience USA 2006a). The radar information was displayed as a series of radargrams. Easy 3D software (Version 1.3.3),
which was developed by MALÅ GeoScience (2006b), was used in post-processing the radar data and 3-D imaging. This entailed merging the data from the series of radargrams for each block. Once this was accomplished, horizontal slices of the data were examined for important anomalies and patterns of anomalies, which were likely of cultural relevance. These data were displayed as aerial plan maps of the sample areas at varying depths below ground surface. These horizontal views, or time-slices, display the radar information at a set time depth in nanoseconds. Time-depth can be roughly equated to depth below ground. This equivalency relationship can be calculated using a mathematical formula.

Output from the survey was viewed using the GroundVision, which provided preliminary information about the suitability of GPR survey in the area and the effective operation of the equipment. The GPR data from the present study was further processed with more robust imaging software, which was developed by Dean Goodman and called GPR-Slice (Version 5.0). Goodman’s GPR-Slice program is recognized as the world leader in GPR imaging (Goodman 2006). The output from his software, which is superior to that generated by Easy 3D, forms the results presented in this report.

Upon arrival at the site, the RAMAC X3M Radar Unit was set up for the operation and calibrated. Figures 2 and 3 show the GPR survey in progress. Several trial runs were made on parts of the site to test the machine’s effectiveness in the site’s soils. The only significant obstacle for the survey was the preexisting archaeological excavations, which were left open, and the adjacent backdirt piles. A large cast iron object was inserted the base of one of these open test units and the soil velocity was determined using this buried object. Various adjustments to the GPR equipment were made in the field during the data collection phase. The time window that was selected allowed data gathering to focus on the upper 1.5 meters of soil, which was the zone most likely to yield archaeological deposits. Additional filters were used to refine the radar information during post-processing. These include adjustments to the gain. These alterations to the data are reversible, however, and do not affect the original data that was collected. This same combination of GPR equipment and radar imaging software was used previously in coastal Georgia with very satisfactory results (Elliott 2003a, 2003b; Rita Elliott et al. 2002). Machinery settings and other pertinent logistical attributes included the following:

**Machine Settlings**
- Time Window: 97 ns
- Number of Stacks: 4
- Number of Samples: 512
- Antenna: 500 MHz shielded
- Antenna Separation: 0.18 m
- Trigger: 0.02 m
- Radargram orientation: West-East
- Radargram progress: South-North
- Radargram Spacing: 50 cm
- Total Radargrams: 73 radargrams, comprising 61 transects
- Dimensions: 30 m North-South by 60 m (or less) East-West
Grid North for the GPR block was True North. The Southwest corner of GPR Block A block was located at 620 North, 750 East on the IAS site grid.

Figure 2. Archaeologist Katie Epps Gathering GPR Radargram, Theus Plantation.

Figure 3. Challenging Obstacles for the GPR Survey Team.
Results and Interpretation

One sample block of GPR data, designated Block A, was collected by the survey team at the Theus plantation site. This block measured 60 m East-West by 30 m North-South. Figure 4 shows a GPR plan map (time slice) of Block A at a shallow depth (5-11 ns). The linear plow rows are visible in this view. This view demonstrates how the GPR survey collection was oriented across the plow rows. This view does not contain any significant information about the subsurface features, although it represents a novel way to display modern agricultural furrows on an archaeological site.

Figure 4. Aerial View of Block A at 5-11 ns Time Depth.

Figure 5 shows a timeslice of Block A at 10-16 ns. Several strong radar reflections are apparent in this view. Two large, parallel radar anomalies are visible in the southwestern portion of the block. These anomalies are approximately 14 m apart Northwest-Southeast and extend for approximately 14 m Northeast-Southwest. IAS archaeologists previously excavated three test excavation units near these GPR anomalies. One of these intersected the northern anomaly near its northeastern end, while the other two test unit locations were located just east of the anomalies.
Figure 5. Aerial View of Block A at 10-16 ns Time Depth.

An alignment of four circular radar reflections is visible in this plan view. These anomalies are nearly evenly-spaced (about 13-15 m apart) and they are oriented East-West. IAS archaeologists excavated a 2 m by 2 m test unit on one of these anomalies and a very large feature was revealed and it is shown in plan view at the base of the plowzone in Figure 6).

Four evenly-spaced, parallel, narrow lines, which are oriented Northwest-Southeast are apparent in this view. These correspond to the irrigation ditches that are visible on the surface and are marked by PVC spigots. These irrigation ditches are modern and of no research value, other than to serve as a check for the GPR mapping capability.

Figure 7 shows a timeslice of Block A at 66-72 ns. In this view a cluster of strong radar reflections are evident on the eastern side of the survey block. If these anomalies are cultural, then they are very deeply buried. Judging from their orientation and patterning, they may represent natural features of an ancient geological shoreline, rather than some human-related phenomena. Their location on the eastern edge of the GPR block, which is nearest to the present-day salt marsh, further supports this natural shoreline interpretation.
Figure 6. Large Feature Exposed at Theus Plantation Following GPR Survey.

Figure 7. Aerial View of Block A at 66-72 ns Time Depth.
Summary

Ground Penetrating Radar (GPR) was employed by the LAMAR Institute team at the Theus plantation site on the Palmetto Bluff development in Beaufort County, South Carolina. Results of the GPR survey were used by IAS archaeologists to locate Phase III excavation units. The results of the Phase III data recovery are presently being compiled by their research team.
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