GPR Mapping of the Adler Plot, Bonaventure Cemetery, Savannah, Georgia

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I. Introduction

This report presents the findings of a Ground Penetrating Radar (GPR) survey by the LAMAR Institute on Lots Q-396 and Q-397 in the Bonaventure Cemetery in Savannah, Georgia. The specific area under study is a small family enclosure identified at the entry as “Adler” (Figure 1). These graves lie within the Jewish section of Bonaventure Cemetery. The survey was requested by Sylvia Udinsky, one of the plot owners. The Udinskys desired to determine where precisely burials were located within the cemetery plot. Although seven 20th century grave markers are present within the enclosure, some uncertainty existed as to whether the two easternmost stones marked the head or foot areas of the deceased. GPR was seen as one solution to determining which areas within the enclosure contained burials and which areas were undisturbed.

Figures 2 and 3 show two views of the study area. Figure 2 is a view to the west on the south side of the enclosure. In Figure 2, two grave markers (Tombstones 1 and 2) are visible in the foreground and four (of five) are located in the rear. Figure 3 shows Tombstones 3-7 on the western side of the study area.
Figure 2. Southern Portion of Adler Enclosure, Facing West.

Figure 3 is a view to the southwest on the west side of the enclosure. Five graves are indicated on the surface in this section of the enclosure, marked by horizontal stone slabs and upright headstones (Tombstones 3-7).

Figure 3. West Portion of Adler Enclosure, Facing Southwest.

The seven marked graves in the Adler enclosure, which are keyed to the schematic diagram in Figure 4, include:

- Tombstone 1-Harry Adler, November 8, 1896-August 13, 1961
- Tombstone 2-Mose Adler, July 27, 1894-July 11, 1973
- Tombstone 3-Ramon Udinsky, July 2, 1920-May 7, 1960
- Tombstone 4- Faye G. Adler, March 15, 1906-July 18, 1976
- Tombstone 5- Sam Adler, July 4, 1895-January 19, 1978
- Tombstone 6- Sara Lynn Nathan, June 24, 1951-September 25, 1982
- Tombstone 7- Irving Stanley Nathan, April 23, 1918-April 24, 1996.

Figure 4. Burial Plan of Lots Q-396 and Q-397, Bonaventure Cemetery (North is to the top of this view).

Brief History of Bonaventure

Bonaventure was the plantation home of Josiah Tattnall in the colonial period. Josiah Tattnall, III sold the property to Peter Wiltberger in 1846 and in 1847 “The Evergreen Cemetery Company of Bonaventure” was incorporated. By 1853 the cemetery enclosed 70 acres but it contained relatively few graves. Bonaventure was purchased by the City of Savannah in 1907-1908. By 1915 about 300 perpetual care grave plots, each measuring 14 feet by 28 feet, had been established. A Jewish Cemetery section was established by 1919. By 1923 the cemetery encompassed 101 acres, 50 of which were developed ((De Bow 1854:247; American Jewish Committee 1919:359; Leland 1923:105; Bonaventure Historical Society 2010; Fleming 2001).
II. Research Methods

Ground Penetrating Radar, or GPR, is an important remote sensing tool used by archaeologists (Conyers and Goodman 1997; Conyers 2004). The technology uses high frequency electromagnetic waves (microwaves) 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 sample block in this study area was composed of a series of parallel radargrams (transects or traverses). Each radargram yielded two-dimensional cross-section or profile of the radar data. 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.

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.

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. Generally, Georgia’s coastal soils have moderately good properties for its application.

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.

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. 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). 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. The same equipment has been used successfully for GPR surveys on seven of Georgia’s barrier islands, including Cumberland, Jekyll, Ossabaw, Sapelo, St. Catherines, St. Simons, and Tybee islands (Elliott 2003a-c, 2004, 2005, 2006a-d, 2007, 2008a-b, 2009a-b; Elliott and Burns 2007).

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. Output from the survey was first viewed using *GroundVision*. This provided immediate feedback about the suitability of GPR survey in the area and the effective operation of the equipment.

The time window that was selected allowed data gathering to focus on the upper 2 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).

Upon arrival at the site, the RAMAC X3M Radar Unit was set up for the operation and calibrated. Several trial runs were made on parts of the site to test the machine’s effectiveness in the site’s soils. Machinery settings and other pertinent logistical attributes included the following:
Machine Settling
Time Window: 85 ns
Number of Stacks: 4
Number of Samples: 632
Sampling Frequency: 7,462 MHz
Antenna: 500 MHz shielded
Antenna Separation: 0.18 m
Trigger: 0.04 m
Radargram orientation: North to South
Radargram progress: East to West
Radargram Spacing: 50 cm
Total Radargrams: 18, total combined length 114.8 m
Dimensions: 9.5 m E-W by 7 m N-S

The GPR block consisted of 114.8 m of radar collection, which were collected along 18 radargrams. The grid arrangement of these radargrams is shown in Figure 5. Magnetic North is to the bottom of the page in this view. The block examined an area measuring 9.5 meters east-west by 7 meters north-south. This encompassed the entire Adler enclosure (Lots Q-396 and Q-397) as well as a 1 m swath along the unpaved cemetery road immediately east of the enclosure. The gaps in radargram coverage observable in Figure 5 are the result of obstacles including cemetery curbing tombstones and shrubbery. The site grid coordinates for the northeastern corner, expressed in UTM Zone 17 (NAD27) was approximately E 495336, N3544991.

GPR data from the survey was collected in the field and returned to the Elliott’s laboratory for post-processing. The GPR data from the present study was processed with GPR-Slice (Version 7.0). Goodman’s GPR-Slice program is recognized as the world leader in GPR imaging (Goodman 2006, 2010). Mapping in 3D 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 (ns). Time-depth can be roughly equated to depth below ground. This equivalency relationship can be calculated using a mathematical formula.
III. Results and Interpretation

Results

GPR survey of Lots Q-396 and Q-397 (the Adler Lot) in the Bonaventure Cemetery yielded successful results. Visual evidence of human burials was observed in side and plan views of the GPR data. Other soil anomalies, whose age and functions is undetermined, also were observed in the data but these do not likely represent historic graves.

Six representative radargrams collected during the project are shown in Figure 6. Strong radar reflections, visible as hyperbolas, are readily apparent in these views. These probably represent human burials associated with the Adler lot and possibly other earlier cultural features and/or natural disturbances.

Figure 6. Selected Radargrams.

The GPR survey results were examined in plan view at increasing time depths. Grid point 0, 0 is located in the northeastern corner of the sample block in these views. Dark blues represent strong radar reflections in this series of images.

Figure 7 shows a view of the GPR block from 4-7 ns. Figure 8 shows a view of the GPR block from 10-13 ns. Figure 9 shows a view of the GPR block from 15-19 ns. Figure 10 shows a view of the GPR block from 21-25 ns. Figure 11 shows a view of the GPR block from 27-
30 ns. At this depth radar reflections from several of the graves are still visible but other soil anomalies are apparent.
Figure 12 shows an Iso-3 dimensional view of the GPR data. This is a useful graphic for providing a sense of depth within the sample but this perspective is somewhat deceptive and not extremely useful in plotting the locations of graves.

Overlay analysis provides another useful way to view the GPR data in plan view. Using this method the results from several layers are combined to create a composite overlay map. One example is shown in Figure 13. While it is difficult to illustrate all of the likely grave GPR signatures in one plan view, this view approximates complete coverage of the two cemetery lots. The grave areas are well represented in this view, as are several small unrelated soil anomalies.

**Interpretations**

Figure 14 shows the aforementioned overlay GPR map superimposed on a portion of the Section Q cemetery plan map. The GPR plan view has been rotated to accurately match the orientation of the cemetery map. As may be observed, the eastern portion of the GPR survey block extends east of the cemetery lots. This area is presently a gravel lane. Again, dark blue areas in this view signify areas with strong radar reflections. These include human graves and other unrelated soil disturbances.
Figure 14. Overlay GPR Map on Section Q Cemetery Plan Map (North is up in this view).
IV. Summary

Bonaventure Cemetery is a municipal cemetery operated by the City of Savannah. The cemetery contains interments from the 19th-21st centuries. Portions of the cemetery are perpetual care lots, including the present study area. This GPR survey examined one small area of the cemetery. This GPR study represents the first employment of this remote sensing technology in Bonaventure Cemetery.

The LAMAR Institute’s GPR survey at Bonaventure Cemetery yielded favorable results. Figure 15 shows the projected grave locations superimposed on the overlay map. Areas shown in red on this map likely contain human grave remains. The remaining portions of Cemetery Lots Q-396 and Q-397 revealed no obvious grave signatures in the GPR survey data. This plan view shows that the northeastern quadrant of the cemetery plot, or the eastern 2/3 of Lot Q-397, is vacant. The balance of Lot Q-397 contains two graves. Lot Q-396 contains five graves. This lot may have area suitable for one additional grave on its southeastern corner. The area east and west of Tombstones 1 and 2 are likely insufficient for any additional interments.

Radar signatures for the seven marked graves within the Lots Q-396 and 397 generally correspond to the surface grave markers. No other historic graves are apparent from the GPR data within this study area.

The application of GPR technology is recommended for future studies where a non-intrusive means is desired to map the subsurface cemetery landscape. As a caveat, GPR is useful does it does not provide a complete understanding of the subsurface environment. Some extremely shallow interments or very small interments (such as infants or remains placed in small cremation urns) may not be recognized by this survey method. Also, the landform containing Bonaventure Cemetery may contain cultural features that predate the use of this area as a managed cemetery. Early historic (colonial or plantation era) or aboriginal features are expected to occur within the confines of the cemetery. Some of these features may contain human remains.

Grave excavation should proceed with great caution even though a reasonable effort was made to identify the graves buried within the lot. The interpretation of GPR data is an evolving science and some interments may not have been recognized.
Figure 7. Bonaventure Cemetery Lots Q-396 and Q-397 Showing Likely Grave Locations as Red Rectangles.
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