GPR Mapping of Lot K-207, Bonaventure Cemetery, Savannah, Georgia

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Submitted to: 
First City Capital Management, Inc. 
P.O. Box 8374 
Savannah, Georgia

By Daniel T. Elliott

The LAMAR Institute 
P.O. Box 2992 
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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Methods</td>
<td>5</td>
</tr>
<tr>
<td>Results</td>
<td>9</td>
</tr>
<tr>
<td>Summary</td>
<td>20</td>
</tr>
<tr>
<td>References Cited</td>
<td>21</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1. Project Location Lot K-207, Bonaventure Cemetery, Savannah, Georgia (Google Maps 2010) 3
Figure 2. Bonaventure Cemetery Lot K-207 with GPR Image Overlay Superimposed (Bonaventure Cemetery 2010) 3
Figure 3. Aerial View of Bonaventure Cemetery Lot K with GPR Overlay Superimposed (Google Earth 2010) 3
Figure 4. Lot K-207, Bonaventure Cemetery. 4
Figure 5. Radargram Plan Map (Radargram 1 began at 0, 0 m in the southwestern corner of Lot K-207) 8
Figure 6. Radargrams 1-10, Lot K-207, Bonaventure Cemetery 9
Figure 7. Radargram 3, Bonaventure Lot K-207. Grave 3 is seen in this view as strong radar reflections from 5-7 m on radargram. 11
Figure 8. Radargram 5, Bonaventure Lot K-207 (Location of Tombstone 1 at surface indicated by small white triangle) 12
Figure 9. Radargram 7, Bonaventure Lot K-207 (Location of Tombstone 2 at surface indicated by triangle on left and azalea bush obstruction at plot margin indicated by triangle on right 13
Figure 10. GPR Plan of Lot K-207 at 6-9 ns Time Depth (North is Up) 14
Figure 11. GPR Plan of Lot K-207 at 10-13 ns Time Depth 14
Figure 12. GPR Plan of Lot K-207 at 14-17 ns Time Depth 15
Figure 13. GPR Plan of Lot K-207 at 17-21 ns Time Depth 15
Figure 14. GPR Overlay Plan Map of Bonaventure Lot K-207 with Graves 1-3 Indicated by Stars and Possible Graves 4 and 5 Indicated by Triangles (North is Up). 16
Figure 15. Suspected Graves 1, 2 and 3 Shown in Red and Possible Graves 4 and 5 Shown in Magenta on Bonaventure Cemetery, Lot K-207 GPR Map (North is Up) 16
Figure 16. GPR Overlay Map Superimposed on a Portion of Bonaventure Cemetery, Section K Map (North is Up) 18
Figure 17. Bonaventure Lot K-207 with Suitable Burial Plots (in Green) (North is Up) 19
Introduction

This report presents the findings of a Ground Penetrating Radar (GPR) survey by the LAMAR Institute on Lot K-207 of the Bonaventure Cemetery in Savannah, Georgia (Figures 1-3). This 28 foot by 14 foot lot is owned by the Estate of Jan Callen. The LAMAR Institute was retained by First City Capital Management, Inc. to map the cemetery lot using GPR technology.

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. By 1923 the cemetery encompassed 101 acres, 50 of which were developed (De Bow 1854:247; Leland 1923:105; Bonaventure Historical Society 2010; Fleming 2001).

Lot K-207 is a rectangular cemetery plot containing two 20th century grave markers within the enclosure. Its location within Section K of Bonaventure Cemetery is indicated in Figures 2 and 3. The approximate center point of Lot K-207 is at Latitude 32.045064 degrees, Longitude -81.045492 degrees.

Extant grave markers are small granite tombstones for Leonard Parker Lipsey, Sr. (Tombstone 1 on left) and Eva Harrison Lipsey (Tombstone 2) (Figure 4). This photograph shows a north-facing view of Lot K-207. Tombstones 1 and 2 (from left to right) are visible near the center of the lot. Tombstone 1 states, “Leonard Parker Lipsey Sr. US Army World War I 1893 1936” and Tombstone 2 is inscribed, “Eva Harrison Lipsey 1893 1973”. These markers are centered on the lot on its east-west axis, but are offset to the south and their center points are approximately 3.5 meters north of the southern lot boundary. Although the grave plot is identified on its southern boundary as “Lipsey-McGill”, no marked graves for members of the McGill family exist.

In addition to two tombstones within the grave lot, two other burials were reported to exist within the lot. Their locations were unknown. GPR was seen as one solution to determining which areas within the enclosure contained burials and which areas were undisturbed.
Figure 1. Project Location Lot K-207, Bonaventure Cemetery, Savannah, Georgia (Google Maps 2010).
Figure 2.  Bonaventure Cemetery Lot K-207 with GPR Image Overlay Superimposed (Bonaventure Cemetery 2010).

Figure 3.  Aerial View of Bonaventure Cemetery Lot K with GPR Overlay Superimposed (Google Earth 2010).
Figure 4. Lot K-207, Bonaventure Cemetery.
Methods

Ground Penetrating Radar, or GPR, is an important remote sensing tool used by archaeologists. This study by the LAMAR Institute represents only the second application of this technology in Bonaventure Cemetery. An earlier investigation by the LAMAR Institute examined grave lots in Section Q, southwest of the present study (Elliott 2010). 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 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 (6.56 feet) 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 Setttings**
- Time Window: 87.5 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: South to North
- Radargram progress: West to East
- Radargram Spacing: 50 cm
- Total Radargrams: 10, or 84 m total length
- Dimensions: 8.5 m N-S by 4.5 m E-W

The GPR block consisted of ten radargrams, which covered a total of 84 (linear) meters. The grid arrangement of these radargrams is shown in Figure 5. Magnetic North is to the top of the page in this view. The only hindrance to complete coverage was a small azalea bush located at the northern end of Radargram 7, which shows as a 1.5 meter gap.

GPR data from the survey was collected in the field and returned to 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 had 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.
Figure 5. Radargram Plan Map (Radargram 1 began at 0, 0 m in the southwestern corner of Lot K-207).
Results

GPR survey of Lot K-207 in Bonaventure Cemetery was successfully accomplished. The data collection was done on October 14, 2010 and post-processing and reporting were completed from October 14-21, 2010. Ten radargrams were collected and profile views of these are shown in Figure 6. Three examples are shown in more detail in Figures 7-9. The distance in meters is shown at the top and bottom of each of these radargrams with 0 m located at the south end of Lot K-207. Depth is displayed in two ways. On the left is the actual time depth in nanoseconds (ns) and on the right side is shown the approximate depth in meters below ground (1 meter=3.28 feet). Each of these three radargrams displays substantial radar reflections. Most of this ground disturbance is likely related to burials in the cemetery lot.

Top Row (l to r): Radargrams 1-4; Middle Row 5-8; Bottom Row 9-10.

Plan maps of the Lot K-207 GPR data are useful in imaging historic graves. The GPR data collected from Lot K-207 was imaged using GPR-Slice software. Examples of the output are shown in Figures 10-13. Shades of blue represent strong radar reflections in these views.
Overlay Analysis is another useful method for imaging GPR radar data. This consists of creating composite overlay maps from selected time slice layers of GPR data to create a composite view. Figure 14 shows one example where this was done. In this view three likely grave reflections are recognized. The lower two graves (Graves 1 and 2) correspond to Tombstones 1 and 2 and the third (Grave 3) is an unknown person with no surface marker.

Other strong radar reflections also are apparent in this view. These include two anomalies, one immediately west of Grave 3, which was designated Grave 4, and one along the southern edge of the burial lot, designated Grave 5. Both Graves 4 and 5 are not indisputable grave GPR signatures. Ground-truthing excavations would be necessary to eliminate either as a non-grave.

Some of the other radar reflections along the lot margins resulted from technical issues of the survey where the GPR machinery was used along the granite curbing. This was done in an attempt to have complete coverage of the Lot K-207. It introduced some extraneous radar reflections, however, in the process.

Figure 15 shows the general locations of the suspected graves as red rectangles overlain on the GPR map. GPR survey of Lot K-207 indicates three likely interments in the cemetery lot. These include the two graves marked by granite markers, a third probable interment in the northwestern section of the lot, and two other radar reflections that may represent portions of human burials along the cemetery lot margin. Figure 16 shows the GPR Overlay map superimposed on a portion of the Bonaventure Cemetery, Section K plan map.

Figure 17 shows the areas of suspected graves (shown in red) and areas suitable for future interments (shown in green) on Lot K-207. The standard sized perpetual care burial lots in Section K at Bonaventure cemetery measure 14 feet by 28 feet. Each lot is intended to accommodate 12 burials. From this standardized arrangement and the findings from the GPR mapping, Lot K-207 has space remaining for approximately seven or eight burials.
Figure 7. Radargram 3, Bonaventure Lot K-207. Grave 3 is seen in this view as strong radar reflections from 5-7 m on radargram.
Figure 8. Radargram 5, Bonaventure Lot K-207 (Location of Tombstone 1 at surface indicated by small white triangle).
Figure 9. Radargram 7, Bonaventure Lot K-207 (Location of Tombstone 2 at surface indicated by triangle on left and azalea bush obstruction at plot margin indicated by triangle on right.)
Figure 10. GPR Plan of Lot K-207 at 6-9 ns Time Depth (North is Up).

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Figure 12. GPR Plan of Lot K-207 at 14-17 ns Time Depth.

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Figure 15. Suspected Graves 1, 2 and 3 Shown in Red and Possible Graves 4 and 5 Shown in Magenta on Bonaventure Cemetery, Lot K-207 GPR Map (North is Up).
Figure 16. GPR Overlay Map Superimposed on a Portion of Bonaventure Cemetery, Section K Map (North is Up).
Figure 17. Bonaventure Lot K-207 with Suitable Burial Plots (in Green) (North is Up).
Summary

The LAMAR Institute completed GPR Survey of Lot K-207 at Bonaventure Cemetery in October 2010. This mapping effort was done at the request of First City Capital Management, Inc., Savannah, Georgia. The cemetery plot is presently owned by the Estate of Jan Callen. The Executors of the estate wished to know the disposition of any human remains within Lot K-207. GPR mapping was seen as a reasonable means to accomplish this goal. The GPR survey was completed without complications and profile and plan maps of the GPR data suggest that the lot contains three interments (designated Graves 1-3) and portions of two possible interments (designated Graves 4 and 5). Graves 1 and 2 correspond to granite tomb markers, while Grave 3, located in the northwestern corner of the lot, is unmarked. The two partial, possible burials (Graves 4 and 5) are located near the edge of Lot K-207. Survey along the edge of the grave plot was hampered by the granite curbing, which introduced other extraneous radar reflections. Figure 17 shows the portions of Lot K-207 that likely contain graves and the areas of the lot that appear suitable for future burials.

As a caveat, GPR does not provide a complete understanding of the subsurface environment. The interpretation of GPR data is an advancing science and some subtle interments may not have been recognized. 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.

Grave excavation should proceed with caution even though a reasonable effort was made to identify the graves buried within the lot. Despite these disclaimers, GPR mapping in Lot K-207 proved to be a very useful tool that will provide guidance for future responsible use of this cemetery plot. The application of GPR technology is recommended for future studies at Bonaventure Cemetery and elsewhere where a non-intrusive means is desired to map subsurface cemetery landscapes.
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