GPR Detection and Geophysical Characteristics of Burials in an 19th Century Cemetery

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Abstract

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We conducted a GPR (Ground Penetrating Radar) survey as part of a forensic investigation of the Second Site Cemetery (Rice Cemetery, Hartt Cemetery) in Mecklenburg County, North Carolina. The oldest marked grave at Second Site is 1797, although it is likely that unmarked graves date back to 1780. The most recent marked grave is dated 1848, but forensic evidence suggest that Second Site was in active use until at least the 1880s.

The Second Site cemetery contains a "members" section and a "servants" section. The servants section contains graves of slaves, former slaves, and possibly other individuals. Our objectives were to determine the locations of unmarked graves in the servants cemetery, and to define the GPR characteristics that might help distinguish between burials in simple (or no) enclosures and those involving ornamented caskets with hardware.

We selected a 15 m by 15 m section of the servants cemetery (Section A) and a second 5 m by 5 m section (Section Z) to conduct GPR surveys, and excavated one grave in each section. Our GPR surveys were done with a GSSI SIR 3000 and a 400 MHz antenna in distance mode.

The Section A GPR survey comprised parallel north-south profiles at 0.2 m intervals, and a set of cross lines at 0.5 m spacing. The Section Z profiles were north-south but at a spacing of 0.4 m.

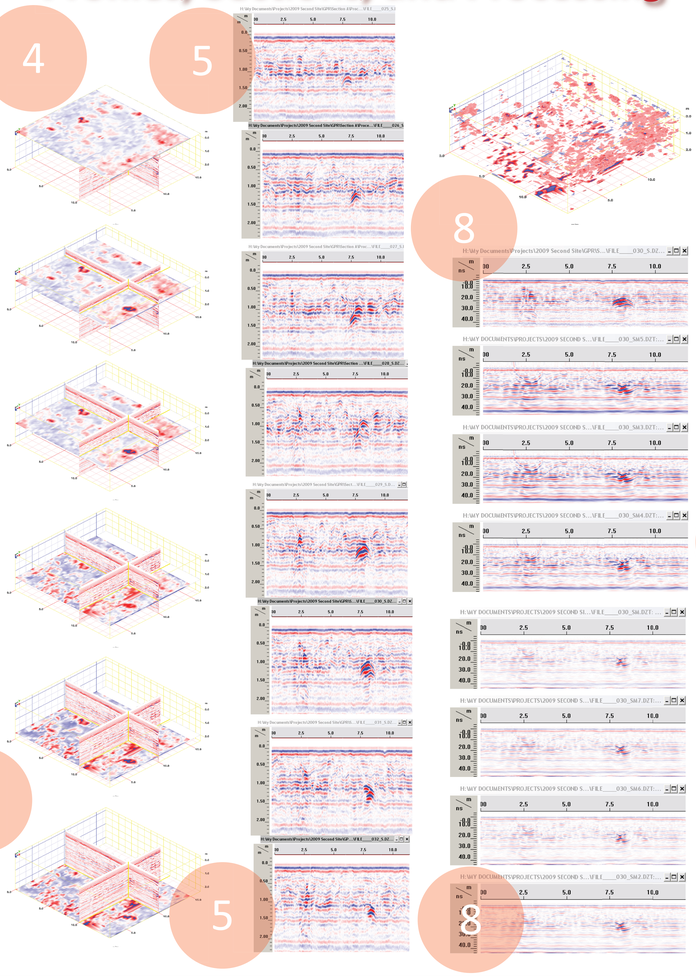
Soils in the cemetery are CeB2: Cecil sandy clay loam, clay, clay loam, and sandy loam derived from saprolitized metagranite. We established that a relative permittivity of 3 was suitable for this site at average depths of about 1.5 m, the nominal depth of burial.

GPR profiles in both sections revealed some common geophysical characteristics. Most graves are longitudinally oriented east-west. Our north-south profiles therefore define grave lengths. Graves in non-migrated GPR sections are parabolic reflections with lower frequency responses than background. The size, shape, and spectral qualities of these reflections distinguish them from other sources (debris, stones, roots). We found a horizontal reflective horizon about 0.5 m thick at depths of 1.0-1.5 m that coincides with a hard clay soil layer exposed in excavations. Most grave shafts terminate within this horizon. This clay layer may be a normal part of the soil profile and not an accumulation zone at the bottom of grave shafts, but this is still to be verified by soil profiles.

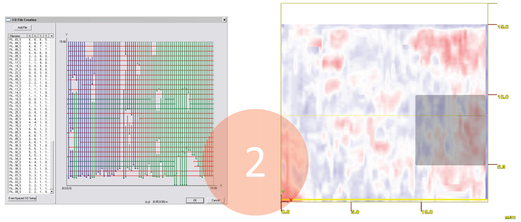
The grave in Section A contained iron nails, metal thumb screws, in situ swing bail handles, some still attached to carbonized casket wood, ceramic buttons, and very poorly preserved human remains. An worn eye coin from this grave was dated 1876, the maximum date of interment. The excavated, undated grave in Section Z, which unexpectedly contained a double burial, produced sparse small, iron wood nails and minimal human remains.

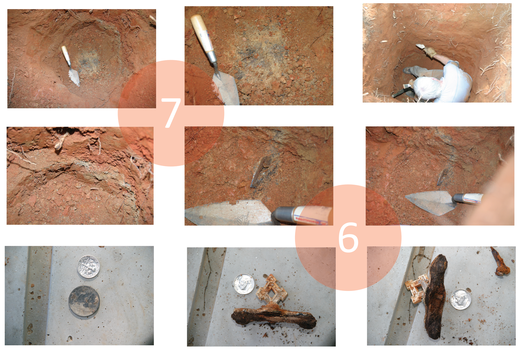
The Section A grave showed a well-defined GPR reflection with which we can correlate other graves in the servants cemetery. In contrast, the Section Z grave produced a much weaker reflection probably because of the general absence of hardware. We believe it is possible to begin to map burial practices on the basis of the GPR characteristics of each grave.

Profiles, Sections, and Processing



Maps and Excavations





Discussion

The study site (1) was cleared of debris by a group of local citizens, who also located many graves by using manual probes and looking for unadorned head- and foot-stones. It is likely that for many decades the Second Site cemetery lie adjacent to fields, probably cotton, but it had never been developed since the church that occupied this land moved.

We completed a dense orthgonal grid of GPR profiles over a 15 m by 15 m section at the southwest corner of the servants' cemetery. Profiles were spaced 0.2 m along north-south lines and 0.5 m along east-west lines (2). We used GSSI's RADAN software to compile and interpret the 107 profiles as a 3D volume. Subsequent to the GPR survey, we conducted forensic excavations of two graves on opposite sides of the cemetery. The excavation targets were determined from the radar data, and from careful evaluation of the land surface looking for markers and depressions.

The results of our GPR work are shown in areas 2, 3, 4, and 5 on this display. All of these data were collected with a 400 MHz antenna and data logger set to distance mode on a cart (3). The surface slice of our data cube displayed distinctive patterns in the radargram (2) that coincided in part with graves marked by other criteria. We found through data analysis and excavation that this site is characterized by soils with a permittivity of 3-8 because of the heavy clay fraction. In profiles, fence diagrams, and 3D anayses, some graves are associated with strong, lower frequency reflections but surprisingly some graves clearly delineated by markers appeared relatively transparent to the GPR. This is likely due to differing burial practices.

Serial slices through the data volume (4) revealed that most graves are at a depth of about 1.5 m. Both of the excavations, only one of which is displayed here, contained human artifacts and remains at between 1.5 and less than 2 m. Graves with better radar signatures are usually somewhat elongate in plan views (4). Although some tree roots were found at burial depths, most of the root volume is at less than 0.5 m depth. The excavations were remarkably clear of unnatural debris, perhaps indicating little disturbance over time.

The column of profiles (5) is a series of north-south lines run 0.2 m apart. Our line orientations were chosen to go normal to the predicted longitudinal directions of graves, but tracking the stronger reflection in this series (that is one of our excavated graves) suggests some slight skewing in the expected orientations. Many of the weaker reflections above 1 m are roots, and some are pseudo-reflections caused by the antenna bouncing. It appears, however, the what initally showed as a strong, single reflection of a grave actually contains multiple targets (5, middle profiles). We now suspect that such composite reflections may be caused by artifacts such as casket hardware embedded in the graves. Our first excavation revealed several swing bale casket handles, still vertical in the soil and sediment grave infilling, and ornatmental thumbscrews. Some of this hardware is still attached to black, carbonized wood with nails or screws (6). We believe, however, that the original wooden casket is now reduced to a black, organic thin fibrous residue (6). A second excavation in a different, possibly older part of the cemetery, did not reveal metallic artifacts more than a few small, highly rusted nails.

In our excavation, we found the base of the grave shaft to be filled with a yellow-gray, granular, loamy soil often separated from orange -red natural soil and infill by the thin black zone noted above. It is within the former material that all artifacts and human remains were found, so we believe that this horizon, generally no more than a few cm think is the collapsed coffin. Also, in both excavations, we discovered a very dense, hard, brick-red clay horizon both above and beneath the yellow-gray soils. We do not know if this clay is an alluvial deposit within the grave shafts or a pre-existing natural part of the soil horizon. We will be doing soil core sampling in undisturbed areas around the cemetery to determine the extent of the horizon. Interestingly, there is a weak, horizontal radar reflector at about the corresponding depth of the excavations visible across the entire surveyed site, and most of the stronger grave reflections appear to lie within that zone.

Finally, we attempted migration in RADAN of some of the GPR profiles (8) that show the reflection associated with this excavation. The results are (velocity in m/ns followed by dielectric constant): 0.0881, 11.605 (Kirchoff); 0.0983, 9.31323 (Kirchoff); 0.0957, 9.81792 (hyperbolic); 0.0804, 13.9285 (hyperbolic); 0.0957, 9.81792 (hyberbolic); 0.0855, 12.3103 (Kirchoff); and 0.0983, 9.31323 (Kirchoff). Some of this variation is due to selection of suitable hyperbolae, but it's also possible that there are multiple objects creating composite reflections in some graves.