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Natural Resources Conservation Service

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Subject: Soils – Geophysical Investigations **Date:** 2 April 2015

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Purpose:
The purpose of this visit was to use ground-penetrating radar (GPR) to detect burials at Belmont Manor in Elkridge, Maryland.

Activities:
All activities were completed on 22 March 2014.

Principal Participants:
Meg Boyd, Executive Director, Howard County Conservancy
Michael Calkins, Soil Conservation Planner, Howard County Soil Conservation District
Dean Cowherd, Assistant State Soil Scientist, USDA-NRCS
Jim Doolittle, Research Soil Scientist, USDA-NRCS
Fred Dorsey, Belmont Historian
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Ashley Jarvis, Education Manager, Howard County Conservancy
Jules Richa, Volunteer, Howard County Conservancy
Crystal McCormick, Engineering Specialist, Howard County Soil Conservation District

Summary:
1. Based on radar imagery, a probable location of Billy Barton's grave has been identified. However, no clear reflection patterns suggesting the presence of Jay Jay's grave was evident on the radar data.

2. A detailed GPR survey of an open area within the cemetery located near Belmont Manor revealed the occurrence of several elongated (in essentially an east to west direction) reflectors at relatively shallow depths. These patterns are clustered within a specific section of the cemetery that has no gravestones and seem unnatural, or at least atypical for an area of Chillum soils. These reflectors are considered significant and worthy of further investigations by qualified archaeologists. These reflectors may represent the remnants of historical burials and unmarked graves. The shallow depths of these features is perplexing and causes some concern over the interpretations provided. However, as no ground-truth verification was possible to confirm the velocity of signal propagation, the

velocity may be greater than estimated and the depth scale (based on hyperbola matching procedures) used may be in error.

It was my pleasure to work with you on this project.

James A. Doolittle
Research Soil Scientist
National Soil Survey Center

Background:

Belmont Manor, though having different owners, has remained a working farm since the early 1700s. One of its owner, Howard Bruce raised thoroughbred horses and was the owner of Billy Barton (1918-1951), who ran in several races including England's Grand National Handicaps. He won the Maryland Grand National twice, the Maryland Hunt Cup, the New Jersey Hunt Cup, the Pennsylvania Hunt Cup, and the Virginia Gold Cup. In 1951, Billy Barton was buried with full tack, in an upright position near a barn located at Belmont Manor. Another horse, Jay Jay (1933-1963) is buried alongside Billy Barton. Though two headstones have been erected at the burial site on Belmont Manor, ground-penetrating radar was used to locate and confirm the actual interment sites.

Figure 1. Billy Barton on the cover of the March 18, 1929, Time Magazine.[1]

Ground-Penetrating Radar (GPR):

Ground-penetrating radar is a non-invasive, high-resolution geophysical tool that is used extensively in soil and archaeological explorations. Ground-penetrating radars transmit short pulses of high to ultra-high frequency (center frequencies from 12.5 MHz to 2.6 GHz) electromagnetic energy into the ground to detect subsurface interfaces. A time-scaled system, GPR measures the time that it takes pulses of electromagnetic energy to travel from an antenna to a subsurface interface and back. Whenever a pulse contacts an interface separating layers with different dielectric permittivity (E_r), a portion of the energy is reflected back to a receiving antenna. The more abrupt and contrasting the E_r on opposing sides of an interface, the greater the amount of energy that is reflected back to the antenna and the greater the amplitude of the recorded signal. To convert the travel time into a depth scale, the velocity of pulse propagation or the depth to a reflector must be known.

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[1] Courtesy of content.time.com – "Jockey Billy Barton riding steeplechase".

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR-3000), manufactured by Geophysical Survey Systems, Inc. (GSSI; Salem, NH).[2] The SIR-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR-3000 weighs about 4.1 kg (9 lbs.) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Jol (2009) and Daniels (2004) discuss the use and operation of GPR. Operating procedures for the SIR-3000 are described by Geophysical Survey Systems, Inc. (2004). Antenna with center frequencies of 270 and 400 MHz were used in this study. However, because of a better balance of exploration depth and resolution, interpretation were more straightforward with the 270 MHz antenna. As a consequence, the 270 MHz antenna was used in both detailed grid surveys at Belmont Manor.

The RADAN for Windows (version 7.0) software program (developed by GSSI) was used to process the radar records.[2] Processing procedures used included: header editing, setting the initial pulse to time zero, color table and transformation selection, FIR filtration (signal stacking, horizontal high pass filtration), migration, and range gain adjustments. These processing techniques were used to improve pattern recognition.

Three-dimensional (3D) GPR was used to assist the identification and improve the interpretation of subsurface features. Beres *et al*. (1999) observed that 3D GPR improves the definition of subsurface structures and can result in more complete and less ambiguous interpretations than traditional 2D GPR records.

GPR and the Search for Burials:
The detection of burials with GPR is never guaranteed, as results are highly site-specific. Soils having high electrical conductivity rapidly attenuate radar energy, restrict penetration depths, and limit the effectiveness of GPR for the detection of burials. The electrical conductivity of soils increases with increases in water, clay, and soluble salt contents. Excessively drained and well drained, sandy soils are considered well-suited to high resolution, deep profiling with GPR and the detection of unmarked graves. Conversely, poorly drained and very poorly drained, clayey soils are considered poorly-suited to GPR.

The amount of energy that is reflected back to a GPR antenna is dependent on the contrast in dielectric permittivity that exists across subsurface boundaries or interfaces. The greater and more abrupt the contrast in dielectric permittivity between the buried corpse or coffin and the surrounding soil, the greater the amount of energy reflected back to the antenna, and the more intense and conspicuous will be the amplitude of the reflected signal. Burials that have dielectric properties similar to the surrounding soil matrix are poor reflectors of electromagnetic energy and are difficult to image and detect on radar records (Bevan, 1991; Vaughan, 1986). Because of more substantial contrasts in dielectric properties, GPR is often very effective in detecting recently interred than older remains (Usti, 2013; Schultz, 2008). Grave shafts, coffins, and corpses can produce conspicuous reflections. However, with the passage of time, buried corpse or wood coffin decompose and become less contrasting with the surrounding soil matrix, therefore reducing the potential for detection with GPR. Bevan (1991) and Conyers (2006) noted that grave shafts are often the most noticeable and distinctive features observed on radar records of older graves. Grave shafts cause the truncation of soil horizons and stratigraphic layers, and are backfilled with mixed, soil materials, which can contrast with the adjoining undisturbed soil materials. However, the detection of grave shafts with GPR requires the presence of contrasting soil horizons and layers, which does not always occur.

The detection of burials with GPR often depends upon the material(s) used to contain the corpse or are buried with the corpse. This partially explains differences that have been observed in the state

[2] Manufacturer's names are provided for specific information; use does not constitute endorsement.

preservations and detection of burial with GPR in the same cemetery. Within a given cemetery, bodies may be interred in shrouds, coffins, and/or burial vaults (Owsley and Compton, 1997). Early settlers often buried their dead wrapped in shrouds and placed in coffins made of wood (Owsley and Compton, 1997). Wood coffins were the most commonly used burial receptacle until the mid-to-late 19th century (Haberstein and Lamers, 1981). Preservation of these early burials and their identification with GPR depends on soil conditions, but is generally poor (Owsley and Compton, 1997).

Shallow burials are more likely to be detected with GPR than deep burials, especially in conductive soils that have high rates of signal attenuation. In general, the greater the depth of burial the lower the rate of decomposition and greater the state of preservation (Tibbet and Carter, 2008). Mann *et al*. (1990) reported that bodies buried at shallow depths (0.3 or 0.6 m) may skeletonize within a few months, while those buried at deeper depths (0.9 or 1.2 m) take many years to decompose.

In soils, large contrasting features reflect greater amounts of energy and are easier to detect with GPR than small less contrasting features. Bones are generally too small or lack sufficient contrast with the surrounding soil matrix to produce noticeable radar reflections (Usti, 2013; Solla *et al*., 2012; Doolittle and Bellantoni, 2010; Conyers, 2006; Watters and Hunter, 2004; Bevan, 1991; Killam, 1990). In addition, any reflections from bones will be indistinguishable from rock fragments (Davis *et al*., 2000), tree roots (Hansen *et al*., 2014; Miller, 1996), and animal burrows (Hansen *et al.*, 2014; Watters and Hunter, 2004).

The shape and orientation of burials often provides clues as to their identity. On radar records, abrupt, vertical breaks in the continuity of reflections from soil horizons or stratigraphic layers are considered unnatural and an indication of human disturbance. On two-dimensional (2D) radar records, subsurface features such as coffins, crypts, or corpses produce hyperbolic-shaped reflections when crossed orthogonally to their long axis, and plane reflections when crossed parallel to their long axis. On 3D-GPR pseudo images, reflection patterns that are rectangular shaped, aligned in an east-west direction, and occur at a common depth provide strong indications of burials. Typically, on three-dimensional GPR (3D-GPR) images, burials appear as high-amplitude, oblong (about 65 cm wide and 200 cm long) features.

The contrast in the dielectric permittivity between burials and the surrounding soil matrix will diminish over time making it more difficult to image and identify older burials. The preservation of burials and their identification with GPR depends on different, interacting, and highly variable soil properties (Owsley and Compton, 1997). Factor that influence the preservation of burials include soil water content, soil reaction (pH), soil temperature, along with the vulnerability to faunal destruction and disturbance, and human activity (Surabian, 2012a; Henderson, 1987; Gill-King, 1997). Surabian (2012b) discusses soil properties that influence decomposition and evaluates the potential of burial and bone preservation for the soil map units found in Connecticut.

Survey Area:
Belmont Manor (39.2258 N latitude, 76.7452 W longitude) is located on Belmont Woods Road in Elkridge, Maryland. Figure 2 is a map of Belmont Manor and Historic Park that was prepared by the Howard County Conservancy. On this map, the approximate locations of the cemetery and Billy Barton's gravesite are shown. The cemetery is enclosed by the red-colored rectangle in the upper left and Billy Barton's gravesite is enclosed by the red-colored rectangle in the center right portion of the Belmont Manor Conservancy.

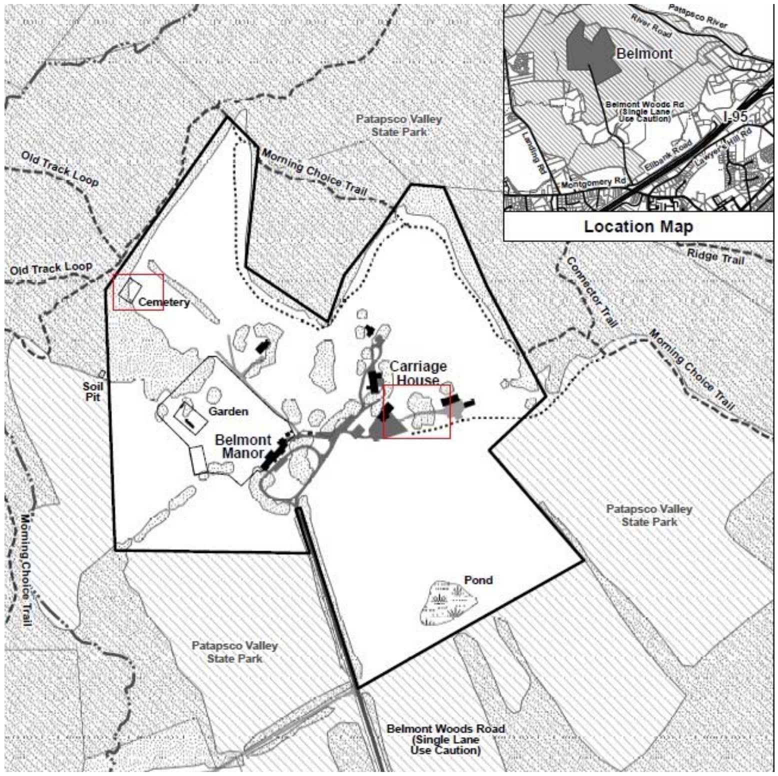

Figure 2. On this map of Belmont Manor, the general locations of Billy Barton's grave and the Family cemetery plots are shown.

Figure 3. This soil map of Belmont Manor is from the Web Soil Survey. The locations of Billy Barton's gravestone (red point symbol) and family cemetery (red dashed lines) are shown.

Figure 3 is a soil map from the Web Soil Survey. Billy Barton's gravesite (red-colored point symbol) is located in an area mapped as Chillum loam, 5 to 10 percent slopes (CeC). The family cemetery (enclosed by red-colored lines) is located in an area mapped as Chillum loam, 2 to 5 percent slopes (CeB). The very deep, well drained Chillum soils formed in a silty eolian mantle underlain by loamy fluviomarine sediments. The Chillum soil series is a member of the fine-silty, mixed, semiactive, mesic Typic Hapludults taxonomic family. The silty eolian mantle is 20 to 40 inches thick. Typically, the solum is loam, silt loam or silty clay loam. The loamy fluviomarine sediments are typically gravelly. Unless limes, the soil is extremely acid to strongly acid. The depth to bedrock is greater than 60 inches. Chillum soils are considered to have moderate potential for deep profiling and the use of GPR.

Survey procedures:
Ground-penetrating radar surveys were conducted in two areas: the site of Billy Barton's grave and an open area within a family cemetery. An 8 (X axis) by 6 (Y axis) meter survey grid was established directly in front of the headstones for Billy Barton and Jay (Figure 4). To facilitate the construction of this grid, two parallel, 6-m survey lines were laid out (spaced 8 m apart) and served as grid axis lines (Y axis). Along these two parallel axis lines, survey flags were inserted into the ground at a 50 cm interval. A line was stretched between matching survey flags on the two opposing axis lines. The 270 and 400 MHz antennas were towed along this line. Following data collection, the line was sequentially displaced 50 cm to the next pair of survey flags to repeat the process. A distance-calibrated survey wheel with encoder was bolted onto the antennas to provided control over signal pulse transmission and data collection. Each radar traverse was stored as a separate file.

Figure 4. A detailed GPR grid survey being conducted at the site of Billy Barton's grave.

A 15 (X axis) by 13 (Y axis) meter survey grid was established across an open area within the family cemetery site. Two parallel, 13-m survey lines were laid out (spaced 15 m apart) and served as grid axis lines (Y axis). Along these two parallel axis lines, survey flags were inserted into the ground at a spacing of 50 cm. A line was stretched between matching survey flags on the two opposing axis lines and a GPR survey was conducted in a similar fashion to the one that was conducted at the Billy Barton site with the 270 MHz antenna.

Digging is prohibited at Belmont Manor. As a consequence, the depth scales were interpreted based on hyperbolic-matching techniques. This can result in depth errors of more than 10 %.

Results:

Billy Barton's Gravesite:

Figure 5 contains two, two-dimensional (2D) radar record from line X = 1 m of the grid. These radar records were collected one meter away and parallel with the long axis of the headstones for Billy Barton and Jay Jay. The red lines at the top of these records identify the relative locations of the headstones (which are at a distance of 1 m away from this traverse line). The records were collected using the 270 (left) and 400 (right) MHz antenna.

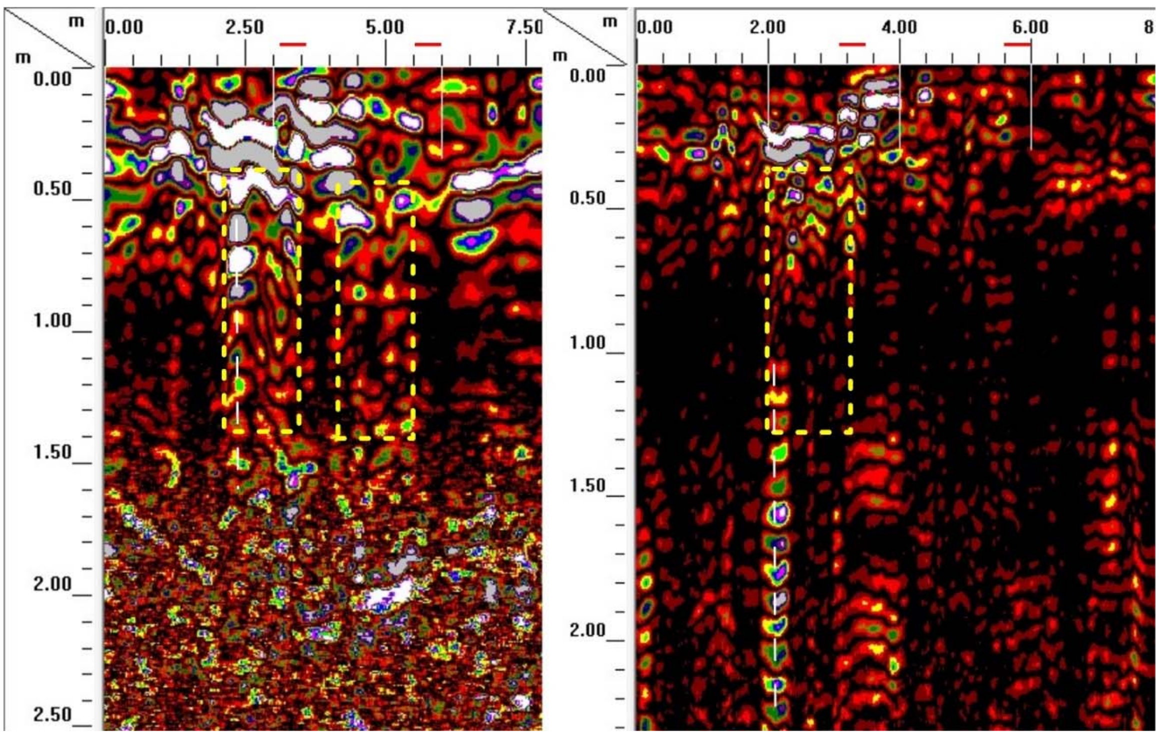

Figure 5. These radar records were collected at the Billy Barton Gravesite. The record on the left was collected using a 270 MHz antenna, the record on the right was collected with the 400 MHz antenna. All scales are expressed in meters.

On each radar record shown in Figure 5, rectangles formed by yellow-colored, segmented lines have been used to identify anomalous subsurface reflection patterns that have abrupt vertical boundaries. These patterns suggest soil disturbances and contrasting features and properties that may represent the disturbed soil within refilled burial trenches. Two sets of anomalous reflection patterns have been identified on the radar record collected with the 270 MHz antenna (record on left). Only one set can be identified on the 400 MHz radar record (right). On both radar records, along the left hand side of the left identified feature, a white-colored, dashed, vertical line has been used to identify a column of reverberated radar reflections. Such responses are created when the radar's signal interacts with an object in such a way that the signal repeatedly bounces around within an object. Often, reverberations are caused by buried metal objects. In this case, it is mentioned that Billy Barton was buried in an upright position in full tack; perhaps this represents a stirrup or halter bit.

A 3D pseudo-image of the grid site was constructed from a set of 13, closely spaced (50 cm) traverse lines that were aligned parallel with the x-axis. Each traverse line was approximately 8 m long. This procedure produced an 8 by 6 m (48 m^2) grid area. The relatively dense set of traverse lines is necessary to resolve the geometry and size of different subsurface features and to prevent spatially aliasing the data (Grasmueck and Green, 1996). Once the radar data were processed into a 3D pseudo-image of the grid site, arbitrary time slices were extracted from the 3D data set. Time or amplitude slice analysis (Conyers, 2004) was used to examine differences in signal amplitudes within the 3D pseudo-image in "time-slices" (or depth-slices). In each depth-sliced image, the reflected radar energy is averaged horizontally between adjacent, parallel radar traverses and in specified time (or depth) windows. In many instances, amplitude depth-slice images have been used to distinguish and identify artifacts and to reduce interpretation uncertainties.

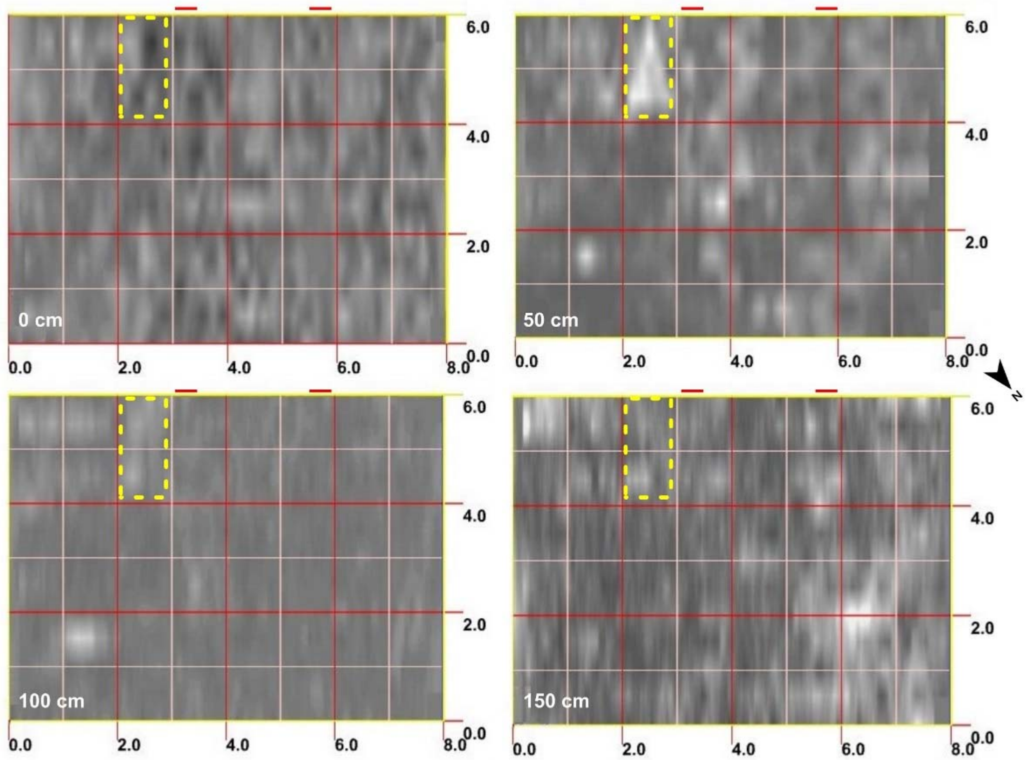

Figure 6. A 3D solid-cube pseudo-image of the grid located near the silo (remnants of the silo are off this grid in the near foreground). All scales are expressed in meters.

Figure 6 contains four depth-sliced images (depths of 0, 50, 100, and 150 cm), that show the distribution of reflected signal amplitudes. Each depth-slice is about 15 cm thick. These depth-sliced images are viewed from directly overhead looking downward into the soil. In Figure 6, red lines at the top of each depth-sliced image have been used to identify the approximate locations of the two headstones. Patterns suggesting the presence of the two graves are generally weak and indistinguishable. On the 50-cm depth sliced image, however, a relatively high-amplitude (colored white), rectangular reflection pattern that is orientated with its long axis in a general east-to-west direction has been identified. The yellow-colored segmented lines used to identify the anomalous pattern on the 50-cm depth-sliced image have been reproduced in the other three depth-sliced images as well. Based on radar imagery, this location is interpreted as being the site of Billy Barton's grave. No clear reflection patterns suggesting the presence of Jay Jay's grave is evident on the depth-sliced images.

<u>Family Cemetery:</u>
A 15 by 13 m (195 m^2) grid was constructed in a relatively open area of the family cemetery in an attempt to ascertain the presence of any unmarked graves. A detailed GPR survey was completed across this grid

area using a 270 MHz antenna (see Figure 7). A total of 27, closely-spaced (50 cm) traverse lines, which were aligned parallel with the x-axis, were surveyed in a back and forth manner across the grid area. Each traverse line was approximately 15 m long.

Figure 7. A GPR survey being conducted across the Belmont cemetery site using a 270 MHz antenna.

Figure 8 shows an un-migrated and migrated radar record from grid line Y = 10 m. Migration reverses the effect of the unfocused nature of the antenna bean in the collected data. Migration is used to focus the diffracted energy by removing diffraction tails from hyperbolas and to more correctly position steeply-dipping reflectors. Several prominent hyperbolas from subsurface objects have been identified by red-colored arrows on the un-migrated radar record (on left). On the migrated record (on right), diffractions, distortion, dip-displacement and out-of-line reflections have been removed resulting in a less noisy presentation. On this migrated record, the presumed contact between the eolian silt mantle and the underlying fluviomarine sediments of Chillum soils provides an irregular boundary that varies in expression and signal amplitudes between depths of about 75 to 120 cm. This interface is rather unclear and difficult to trace laterally on radar records. However, the uniformity and lack of reflectors within the silt mantle contrasts with the high-amplitude reflections and stratified patterns of the underlying materials. Noteworthy is a zone of relatively weaker reflections that is highlighted by yellow-colored segmented lines on the migrated record in Figure 8. Within this anomalous zone a more prominent reflector has been highlighted by an ellipse.

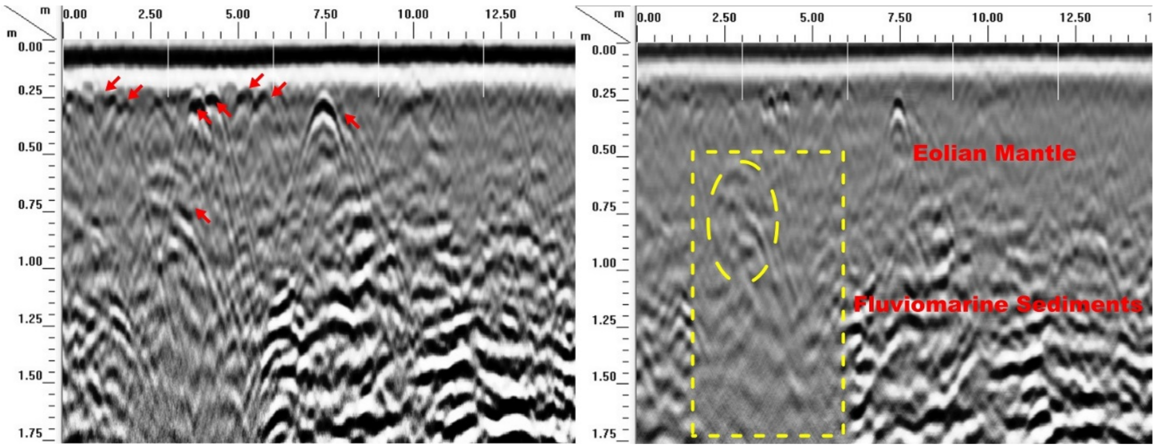

Figure 8. An un-migrated (left) and migrated (right) radar record from line Y =10m of the cemetery grid site provide evidence of subsurface point reflectors that may represent unmarked burials. All scales are expressed in meters.

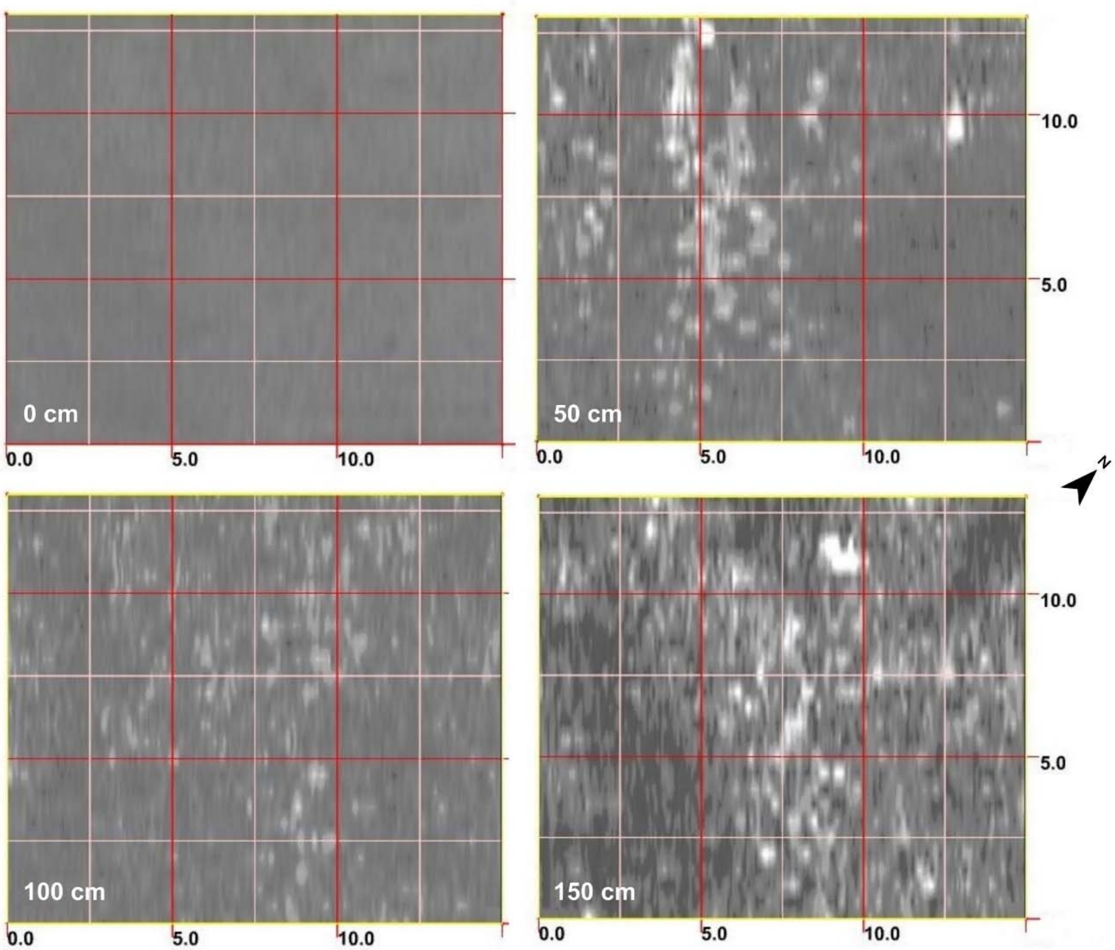

Figure 9. These four depth-sliced images show reflected signal amplitudes at different soil depths. All scales are expressed in meters.

Figure 9 contains four depth-sliced images (depths of 0, 50, 100, and 150 cm), which show the distribution of reflected signal amplitudes. In each of image, the survey area is viewed from directly overhead. Each depth-slice is about 15 cm thick. The image of the surface (0 cm depth-sliced image) is uniform and virtually free of high-amplitude reflections. A noticeable spatial pattern of high amplitude reflectors are apparent of the 50 cm depth-sliced image. Many of the reflectors evident on the 50-cm depth-sliced image are elongated and appear to be aligned in an approximate east-west orientation. A majority of these reflectors are located between X = 4 and 7 m. Many of these reflectors were identified and flagged as the radar survey progressed. On the 100-cm depth sliced image, the number and amplitude of reflectors decrease. Many of the reflectors evident on this and the 150-cm depth-slice image are believed to represents the contact with and inhomogeneities within the underlying fluviomarine sediments.

Results are interpretive. Unmistakable radar evidence supporting the presence of unmarked graves is lacking. However, the occurrence of several elongated (in east to west direction) reflectors at uniform and relatively shallow depths in an explicit section of the cemetery's open area is significant and worthy of further investigations by qualified archaeologists. The clustering of these reflectors seems unnatural and artificial. These reflectors may represent the remnants of historical burials and unmarked graves. However, the shallow depths of these features is perplexing (errors may exist in the depth scales used, but features are still relatively shallow).

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