10United States Department of Agriculture | **Natural Resources Conservation Service** | **100 Campus Boulevard Suite 200 Newtown Square, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance

Date: 9 June 2006

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Purpose:
Ground-penetrating radar (GPR) surveys were conducted at the Huntington Cemetery, York Springs, Pennsylvania, in an attempt to locate unmarked graves.

Principal Participants:
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Mary Wolfe, Menallen Friends, York Springs, PA
Davis Worley, Menallen Friends, York Springs, PA

Activities:
All field activities were completed on 6 June 2006.

Summary:

1. While two of the most recent burials within the cemetery were identified with GPR, no evidence of pre-1900 burials was detected within the survey area.

2. The southern two-thirds of the grid area appear to be underlain by bedrock at depths ranging from 20 to greater than 40 inches. The relatively shallow depths to bedrock within this portion of the cemetery may have precluded its use for gravesites.

3. Confidence in identifying older graves is low in soils having large amounts of rock fragments and lacking well-expressed soil horizons and layers. With the passage of time, signs of burials (wooden coffins, grave shaft, disturbed soil materials, and human remains) are largely obliterated and reflections become too weak and difficult to discriminate with GPR.

It was my pleasure to work in Pennsylvania and to be of assistance to the Menallen Friends.

With kind regards,

James A. Doolittle
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cc:

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Background:
A cemetery adjacent to the Huntington Friends Meetinghouse in Huntington Township is the final resting ground for some of the early Quaker inhabitants of Adam County, Pennsylvania. The cemetery was used during the period of 1740 to 1920. Later overgrown with brush, the cemetery was cleared of debris and restored in the 1930s. At the time of this restoration, headstones and markers were placed in orderly rows, but did not mark known gravesites. The purpose of this investigation was to evaluate the potential of using ground-penetrating radar (GPR) to document graves in an area of Lehigh soil. If successful, this technology would provide information on the actual locations of graves within the cemetery. This information would be used to insure that future burials would not disturb existing graves. For its part in the Underground Railroad, the historic Huntington Friends Meetinghouse has been nominated for inclusion in the National Park Service's *National Network of Freedom*.

Ground-Penetrating Radar and Archaeological Investigations:
Ground-penetrating radar has been used extensively in support of archaeological, crime scene, and terrorism investigations. Ground-penetrating radar provides and expedient and tool for these investigations. In many soils, GPR has been successful in locating burials and identifying unmarked graves (Freeland et al., 2004; Miller et al., 2004; Gracia et al., 2000; King et al., 1993; Mellett, 1992; Bevan, 1991; and Vaughan, 1986).

Ground-penetrating radar often detects disturbances and the intrusion of foreign materials in soils. However, results vary with soils and soil properties. Soils with low clay, moisture, and soluble salt contents are considered well suited to GPR. Soils having high clay, soluble salt, and moisture contents rapidly attenuate the radar signal and limit the penetration depth and the effectiveness of GPR. Even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of unmarked graves is never assured with GPR. The detection of unmarked graves is affected by (1) the electromagnetic gradient existing between the burial and the soil, (2) the size, depth, and shape of the buried feature, and (3) the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna by a buried object is dependent upon contrasts in the dielectric properties between the object and the surrounding soil. The greater and more abrupt the difference in dielectric properties, the greater the amount of energy that is reflected back to an antenna, and the more intense will be the amplitude of the reflected signals on the radar record. The *reflective coefficient* is a measure of the differences in dielectric properties of two adjoining materials. The *reflection coefficient* is dependent upon differences in the relative *dielectric permittivity* (E_r) of the two adjoining materials. The E_r of a material is strongly dependent upon its moisture content. As a consequence, the amount of energy reflected back from a boundary or interface is dependent on the abruptness and difference in moisture contents between the two materials.

For burials, the rate of decay or weathering varies with the materials used to contain the corpse. Corpses may be buried in sacks, body bags, wooden caskets, or in fiberglass, composite, or metal coffins. If a casket or coffin is partially intact, an air-filled void may exist, which is often detectable with GPR. Prior to 1850, most corpses were buried in sacks or wooden caskets, which rapidly decayed in soils and left little to be discerned with GPR. Coffins were not patent until the 1840s. At first, many buried objects will contrast with the surrounding soil matrix. However, with the passage of time, buried objects decay or weather and become less electrically contrasting with the soil. Body fluids, salts, and gases in decomposing tissue are electrically conductive and will absorb the radiated radar energy resulting in a "whiteout" area (zone of no signal return) beneath recently buried corpse (Miller et al., 2004; Mellett, 1992). In highly acid soils, human skeletal remains and evidence of burials will not persist (Mellett, 1992).

On radar records, the depth, shape, size, and location of subsurface features may be used as clues to infer burials. The size and depth of a buried feature affect detection. Large objects reflect more energy and are easier to detect than small objects. The reflective power of a buried feature decreases with the fourth power of the distance to the feature (Bevan and Kenyon, 1975). Small objects, which are detectable with GPR at shallow depths, are unnoticeable at deeper depths. Most bones are too small to be distinguished with GPR (Bevan, 1991; Killam, 1990). Bevan (1991) noted that it is more likely that GPR will detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials that directly surrounds a burial rather than the bones themselves. However, in soils that lack contrasting soil horizons or geologic strata, the detection of soil disturbances or grave shafts is more difficult. In addition, with the passage of time, natural soil-forming processes will erase the signs of disturbances.

Burials are difficult to distinguish in soils having rock fragments, tree roots, animal burrows, modern cultural features, or segmented horizons and layers. These scattering bodies produce undesired subsurface reflections that complicate radar records. Under these adverse conditions, burials may be indistinguishable from the background clutter. In soils having numerous scattering bodies, GPR often provide little meaningful information to supplement traditional sampling methods (Bruzewicz et al., 1986). The identification of buried cultural features was complicated by scattering bodies in radar surveys conducted by Bevan (1991), Doolittle (1988), Vaughan (1986), and Dolphin and Yetter (1985).

In the past, subsurface reflections were identified and correlated on two-dimensional (2D) radar records alone. Today, three-dimensional (3D) imaging techniques can be used to help reconstruct the geometry of subsurface features, distinguish and identify potential targets, and reduce interpretation uncertainties (Pipan et al., 1999). Three-dimensional interpretations of GPR data have been used to identify burials, middens, and other cultural features (Goodman et al., 2004; Whiting et. al, 2000; and Conyers and Goodman, 1997).

The use of digital signals and sophisticated signal-processing software, have enabled signal enhancement and improved pattern-recognition on some radar records. In recent years, a sophisticated type of GPR data manipulation, known as *amplitude slice-map analysis*, has been used in archaeological investigations (Conyers and Goodman, 1997). For this analysis, a 3D image of a site is derived from a series of closely-spaced, 2D radar records (Conyers and Goodman, 1997). In the time-sliced data, reflection amplitudes are averaged horizontally between each adjoining sets of parallel radar records in specified time windows to create a time-sliced image of grid areas. Each time-sliced image shows the spatial distribution of reflection amplitudes, which may provide clues as to changes in soil properties or the presence of buried cultural features.

Survey Area:
The survey area is located in a cemetery adjacent to the Huntington Friends Meetinghouse at 300 Quaker Church Road, York Springs, Pennsylvania. The cemetery is located on a ridge top and in an area of Lehigh channery silt loam, 0 to 3 percent slopes (LhA) (see Figure 1). The deep, moderately well drained Lehigh soil forms in residuum weathered from metamorphosed sandstone and shale. In areas of Lehigh soil the depth to bedrock typically ranges from 40 to 60 inches. Lehigh is a member of the fine-loamy, mixed, superactive, mesic Aquic Hapludalfs family. The clay fraction contains large amounts of kaolinite and moderate amounts of illite and chlorite clay minerals. The clay content of Lehigh soil is moderate ranging from 10 to 20 % in the surface layers and from 17 to 32 % in the subsoil (http://soildatamart.nrcs.usda.gov). Because of its moderate clay content, Lehigh soil is considered moderately suited to profiling with GPR

Figure 1. Soil Map showing the location (enclosed square) of the GPR survey site near the Huntington Friends Meetinghouse. The GPR survey was conducted in an area of Lehigh channery silt loam, 0 to 3 % slopes (LhA).

Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000, manufactured by Geophysical Survey Systems, Inc. (Salem, New Hampshire).[1] The SIR System-3000 weighs about 9 lbs and is backpack portable. With an antenna, this system requires two people to operate. A relatively high frequency 400 MHz antenna was used in this

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

investigation. In this area of Leigh soil, the 400 MHz antenna provided a satisfactory balance of penetration depth and resolution, and was deemed suitable for this investigation.

Radar records contained in this report were processed with the RADAN for Windows (version 5.0) software program (Geophysical Survey Systems, Inc).[2] Each radar record was submitted to the following processing procedures: setting the initial pulse to time zero, color transformation, marker editing, and distance normalization. The processed radar records were combined into a 3D image using the 3D QuickDraw for RADAN Windows NT software (Geophysical Survey Systems, Inc).[2] Once the radar records were combined, the resulting file was filtered (horizontal high-pass filtration), migrated, and the gain adjusted for display purposes. Once processed, arbitrary cross sections and time slices were viewed and selected images attached to this report.

Interpretations:
Based on hyperbola-matching techniques (the shape of a hyperbole is dependent on signal velocity), the relative dielectric permittivity (E_r) in the upper part of the Lehigh was estimated to be 7.6. This E_r results in a propagation velocity of 0.108 m/ns (meter/nanosecond). In this study, using this velocity of propagation and a scanning time of 50 ns, the maximum depth of penetration was about 2.7 m. However, the velocity of propagation is spatial variable and decreased with increasing depth. Therefore all depths provided in this report must be considered as close approximations.

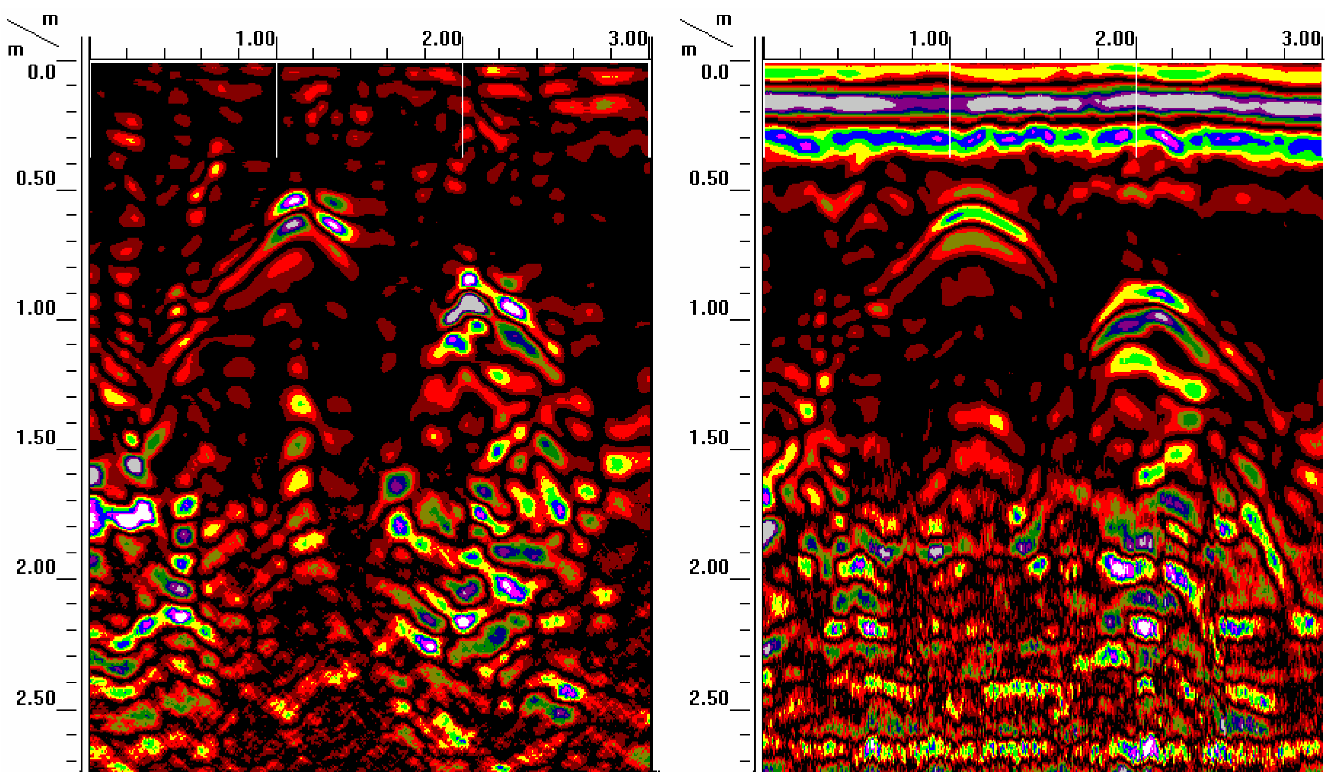

Figure 2. These two images are from the same radar record and show the effects of processing. The radar record on the left has been migrated and filtered through the infinite impulse response filter.

Figure 2 shows the effects of migration and filtration on a radar record that was collected over the two most recent burials at the Huntington Cemetery. In each record, all scales are in meters. The depth scale is based on an assumed velocity of propagation of 0.108 m/ns. Both radar images are from the same radar record. On both radar records, the initial pulse has been adjusted to time zero, colors have been transforms, marker have been edited, and the distance normalized.

In Figure 2, the two burials are identifiable by their high-amplitude hyperbolic reflections. One burial is at a depth of about 50 cm at the 1 m distance mark; the other burial is at a depth of about 80 cm at the 2 m distance mark. Below a depth of about 140 to 150 cm, the radar imagery suggests contrasting materials, which, in areas of Lehigh soil, are assumed to be

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highly fractured bedrock.

In Figure 2, the radar record on the left has been migrated and filtered through the infinite impulse response filter. Migration attempts to remove diffractions, distortion, dip displacement and out-of-line reflections (Neal, 2004). To reduce background noise and improve interpretations, the radar image on the left has also been processed through a horizontal high-pass filter. This filter altered the radar image by removing and smoothing data greater than a specified number of scans (76 scans) in length. The file of radar records used to construct the 3D images shown in this report was processed similar to the left-hand radar record shown in Figure 2.

Survey Procedures:
A 30 by 30 meter grid was establish across a portion of the cemetery using two, 30 m long, survey lines. These survey lines were arranged parallel to one another and spaced 30 m apart. These two survey lines formed the opposing sides of the square. The two parallel survey lines were orientated in essentially an east-west direction. Along each of these two lines, survey flags were inserted in the ground at intervals of 50 cm. For positional accuracy, GPR traverses were completed along a reference line, which was stretched and sequentially moved between corresponding flags on the two parallel survey lines. Pulling the 400 MHz antenna along the reference line completed a GPR traverse. Along the reference line, marks were spaced at intervals of 1 m. As the antenna was towed passed each reference point, a vertical mark was impressed on the radar record. Walking, in a back and forth manner, along the reference line, which was moved sequentially between similarly numbered flags on the two parallel survey lines, completed a GPR survey.

<u>Results</u>
Figure 3 is a 3D cube display of the 30 by 30 m (98 by 98 ft) grid area. The direction of the north arrow has been approximated. The origin of the grid is located in its southeast corner. Grid lines are superimposed on this cube at horizontal distances of 5 m (about 16 ft) and depth intervals of 50 cm (20 inches). For display purposes, a 16 by 19 m section has been cutout of the cube to a depth of about 120 cm.

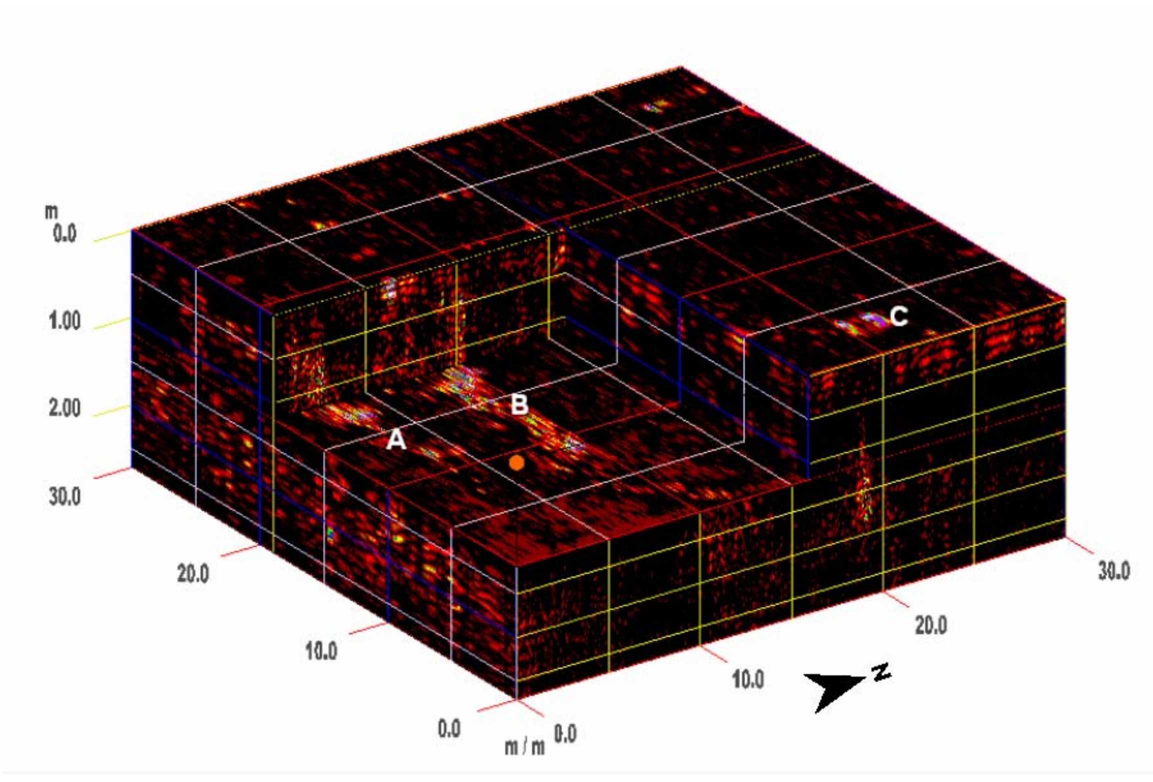
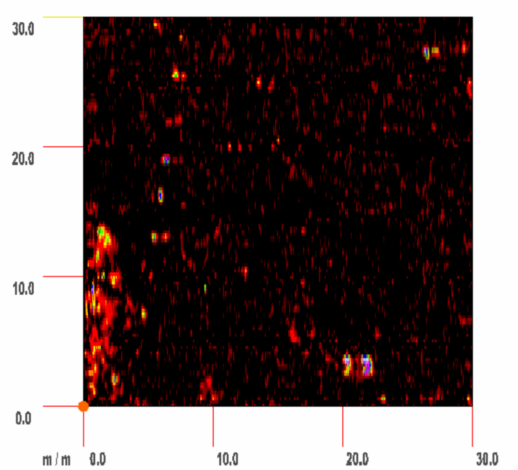


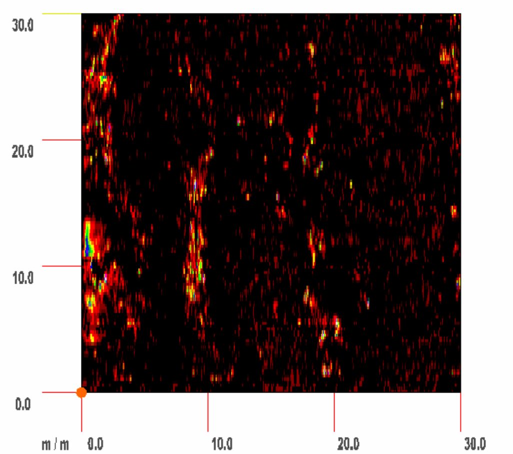
Figure 3. A three-dimensional cube display of the grid area with a 16 by 19 m inset removed to a depth of about 120 cm.

In Figure 3, two high amplitude, linear reflectors (labeled “A” and “B”) are evident in the southern third of the grid area. These linear reflectors closely parallel one another and extend in an east to west across the grid area. On one exposed side of the cutout cube (Y axis = 19 m), these linear reflectors appear as complex vertical arrangements of point reflectors.

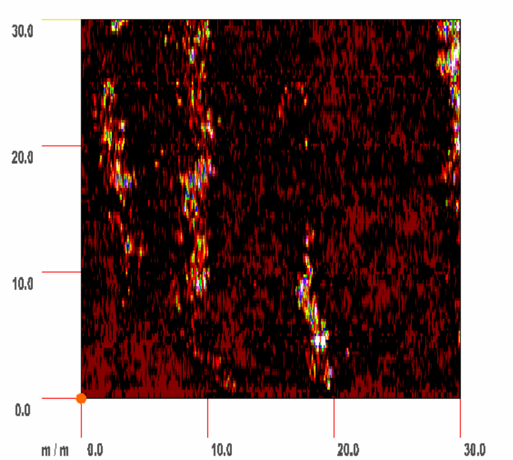
These vertical columns approach to within 50 cm of the soil surface. The spatial patterns and characteristics of these reflectors are too broad and segmented to represent buried utility or drainage lines. Their appearance suggests irregular and fractured pinnacles of parent rock.



0 cm



60 cm



120 cm

Figure 4. Overhead views of three amplitude time-sliced images of the grid area. Time or depth slices have been made at approximate depths of 0, 60, and 120 cm.

In Figure 3, the feature producing the high-amplitude surface reflections near "C" is the concrete base of two headstones. The base was either passed over or included within the radiation pattern of the antenna. Other reflectors are evident in the 3D cube image, but the identifications of these features are uncertain and would require extensive ground truth observations and excavations.

Figure 4 provides three time-sliced images of the grid area. Each image of the grid area is viewed from directly overhead. These horizontal slices across the grid area occur at the noted soil depths with the imagery from the overlying soil removed. The origin is located in the lower left-hand corner (southeast corner of the grid area) of each time- (or depth-) sliced image. The three horizontal time-slices represent depths of about 60, 120, and 180 cm. These depth estimates are based on an averaged propagation velocity of 0.108 m/ns through the soil.

In Figure 4, the shallowest (60 cm) slice shows a zone of high-amplitude (white, blue, green, and yellow colors) reflections in the southeast corner of the grid area. These reflections indicate an area of contrasting soil materials, possibly indicating the presence of compacted surface layers or an area with greater amounts of rock fragments. Additional high-amplitude point reflectors are scattered across the grid area. Some appear orientated in an east to west direction, while others appear randomly arranged. `Some of these reflectors could represent headstones, cultural debris, or rock fragments that were crossed over with the radar antenna. Other than these features, the 0 cm time-sliced image is nondescript and consists of mostly low (black to dull red colored) amplitude reflections that do not form any noteworthy or identifiable spatial pattern.

In the 60 and 120 cm slices, four separate linear features can be identified extending across the grid area in an east to west direction. These linear features are fairly broad, irregular in depth and width, and variable in signal amplitudes. These characteristics do not suggest graves or artifacts buried in the soil. These linear features are believed to represent pinnacles of parent rock. If these features represent pinnacles of parent rock, their close spacing and shallow depths in the southern two-thirds of the cemetery would preclude the likelihood of burials in this section.

Other than the lithologic features described in this report, no significant subsurface features were identifiable on radar records. On both 2D radar records and the 3D radar file, no feature could be unambiguously identified as a burial within the survey area.

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