United States Department of Agriculture

NRCS

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Subject: Soils – Geophysical Investigations **Date:** 29 September 2010

To: Juan Hernandez
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Purpose:
At the request of Dr Gary Schaffer, a ground-penetrating radar (GPR) survey was conducted over a portion of an abandoned and neglected cemetery in Ripley, Maine. The purpose of this survey was to determine the extent of the cemetery and the locations of unmarked gravesites.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Greg Granger, Soil Resource Specialist, USDA-NRCS, Dover-Foxcroft, ME
Gary Shaffer, Archaeologist/Cultural Resources Specialist, USDA-NRCS, Bangor, ME

Activities:
All field activities were completed on 16 September 2010.

Summary:

1. Ground-penetrating radar provided little information concerning the cemetery's boundaries or the locations of unmarked gravesites. While GPR provide sufficient penetration depths and resolution of subsurface features, the state of preservation of the burials is considered poor. As a consequence, burials provide only faint and indistinguishable radar reflections. The soils consist of unsorted, heterogeneous sediments (glacial till) and contain large numbers of rock fragments. On radar records, these materials are characterized by chaotic reflection patterns. The lack of well expressed soil horizons and the mixed, heterogeneous fabric of till further obscured the recognition of burials on radar records.

2. A detailed GPR grid survey did revealed two, high-amplitude subsurface reflection patterns. One is considered a potential unmarked grave site. The other is noteworthy because of its anomalous expression. These two features, which are evident and spatially located on the 50-cm time-slice image of the site, may be deemed worthy of further examination by an archaeologist.

3. Gray Shafter shovel scraped two additional anomalies that were identified on radar records. Although these excavations were limited to very shallow depths of only 10 to 15 cm, no cultural features were found. Deeper excavations are needed to confirm the nature of the apparent disturbances and/or recognized anomalous features.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to work with and be of assistance to your fine staff in this investigation.

JONATHAN W. HEMPEL
Director
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cc:
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Technical Report on a Ground-Penetrating Radar Archaeological investigation that was conducted at the Fush Hill Cemetery, Ripley, Maine.

Jim Doolittle

Background:
The NRCS is involved in the construction of a manure storage facility on the Rufus Cooley farm in Ripley, Somerset County, Maine. During an earlier site investigation, Gary Scheffer, noticed a neglected cemetery that is located in a loafing area about hundred feet away from the construction site. The cemetery is greatly disturbed as loafing cows have toppled many of the gravestones. Gary has initiated conservation efforts to restore the cemetery and reduce the amount of downslope erosion caused by the removal of surface cover by loafing animals.

The name of the cemetery is the Fush Hill Cemetery. Dates of interment range from the 1850s to the 1880s. The cemetery is located on the boundary of a Thorndike very rocky silt loam on 3 to 15 percent slopes (TkC), and a Thorndike-Bangor silt loams on 0 to 8 percent slopes (TtB) map unit. The shallow, somewhat excessively drained Thorndike and the very deep, well drained Bangor soils formed in glacial till on uplands. Depths to bedrock are less than 50 cm and greater than 150 cm for Thorndike and Bangor soils, respectively. .Thorndike is a member of the loamy-skeletal, isotic, frigid Lithic Haplorthods family. Bangor is a member of the coarse-loamy, isotic, frigid Typic Haplorthods family. Because of their low clay contents, both soils are considered well suited to deep penetration with GPR. However, the large amounts of rock fragments in these soils create unwanted background noise, which mask and produce reflections that are similar to burials, thus confusing interpretations.

Equipment:
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).[1] 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. A 400 MHz antenna was used in this study.

The RADAN for Windows (version 6.6) software program developed by GSSI was used to process radar records.[1] Processing included: header editing, setting the initial pulse to time zero, color table and transformation selection, migration, and range gain adjustments (refer to Jol (2009) and Daniels (2004) for discussions of these techniques).

In recent years, an advanced type of GPR data manipulation, known as *amplitude slice-map analysis,* has been used in archaeological investigations (Conyers and Goodman, 1997). In this analysis method, a three-dimensional (3D) pseudo-image of a small grid area is constructed from a computer analysis and synthesis of multiple, closely-spaced, two-dimensional (2D) radar records. Amplitude differences within the 3D pseudo-image are analyzed in "*time-slices*" that examine changes within specific depth intervals in the ground (Conyers and Goodman, 1997). In the *time-slice* process, reflected radar energy is averaged horizontally between adjacent, parallel radar traverse lines and in specified time (or depth) windows to create a *time-slice* (or *depth-slice*) image. Each amplitude *time-slice* shows the spatial distribution of reflected wave amplitudes, which may indicate changes in soil properties or the presence of subsurface features. In many instances, 3D-GPR imaging techniques have been used to distinguish and identify potential targets and to reduce interpretation uncertainties.

[1] Trade names are used for specific references and do not constitute endorsement.

Survey Procedures:
To collect the data required for the construction of a 3D-GPR pseudo-image, a small survey grid was established across the western portion of the cemetery. In order to construct the survey grid, two parallel lines were established across the grid site. These lines were spaced 23 meters apart. Along each of these parallel lines, survey flags were inserted into the ground at a spacing of 50 cm. A reference line was extended between matching survey flags on opposing sides of the grid using a distance-graduated rope. GPR traverses were conducted along this distance-graduated rope. A 400 MHz antenna was towed along the graduated rope, and as it passed each 100-cm increment, a mark was impressed on the radar record. Following data collection, the reference line was sequentially moved to the next pair of survey flags to repeat the process. In this manner, a series of closely-spaced, parallel GPR traverse lines were collected for the construction of a 3D pseudo image.

The grid's dimensions were 7 by 23 m grid. The origin (0, 0 m) of the grid is located in the northwest corner of the site. Using the 400 MHz antenna, 15 parallel radar traverses were conducted across the grid area in essentially a south-north direction. Each traverse line was 23-m long. The distance between each traverse line was 50 cm.

Results:
Figure 1 is a representative radar record from the survey area. This record was collected along the fourth radar traverse across the site, which corresponds to line Y = 150 cm. In Figure 1, all measurements are expressed in meters. The depth scale has been approximated using a dielectric permittivity of 9.8. The large number of chaotically arranged radar reflections is typical of glacial till. In Figure 1, a very prominent, high-amplitude (colored white and grey) anomaly is identified to the left of "A". This feature suggests a possible coffin. It could also, however, represent a large stone or boulder. A shallowly buried horizontal feature has been indentified at "B". This feature appears anomalous and attracted my attention. Both features may be deemed worthy of further examination by an archaeologist.

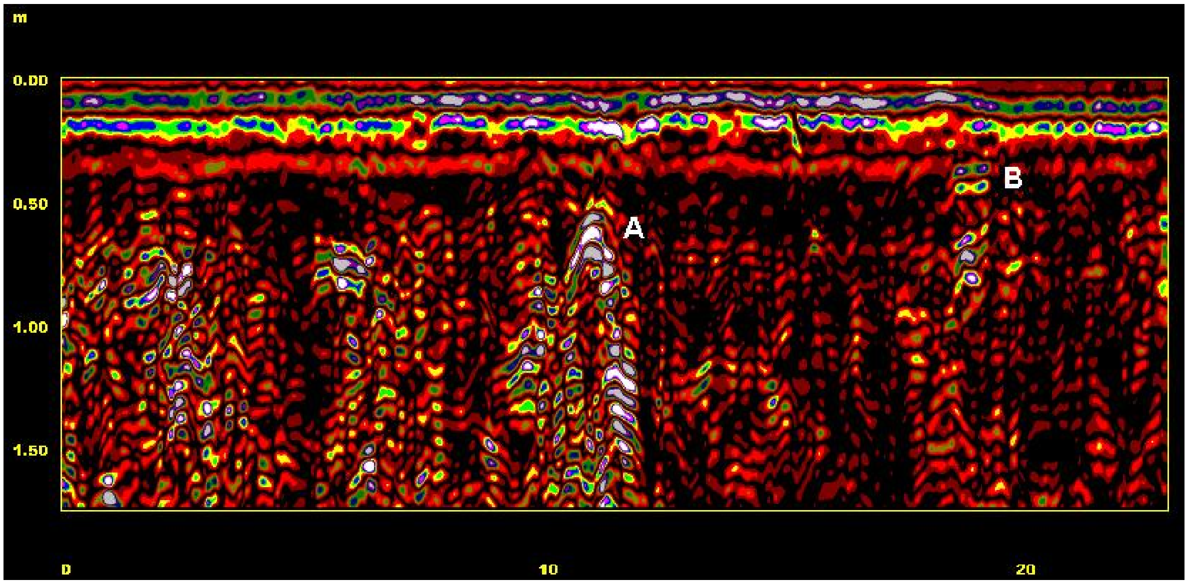

Figure 1. In this 2D radar record of line Y = 150 cm, high-amplitude hyperbolic and planar reflections respectively suggest a possible burial (A) and a peculiar, shallowly buried object (B).

Figure 2 is the radar record that was collected along Y = 650 cm. In Figure 2, all measurements are expressed in meters. The depth scale has been approximated using a dielectric permittivity of 9.8. Compared with Fig. 1, a lower display gain setting was used in Fig. 2. While the chaotic imagery is again characteristic of till, the radar record is by and large nondescript with the exception of two high amplitude reflections and their reverberations (to the left of both "A"). These feature represent dislodge headstone, which were lying on the soil surface and were passed directly over by the radar antenna. It is noteworthy that subsurface reflections (colored dull red) are generally absent within the 40 to 60 cm depth interval with the exception of the area surrounding these two dislodge headstones. The weak reflections in the area of the dislodge headstones suggest soil disturbances.

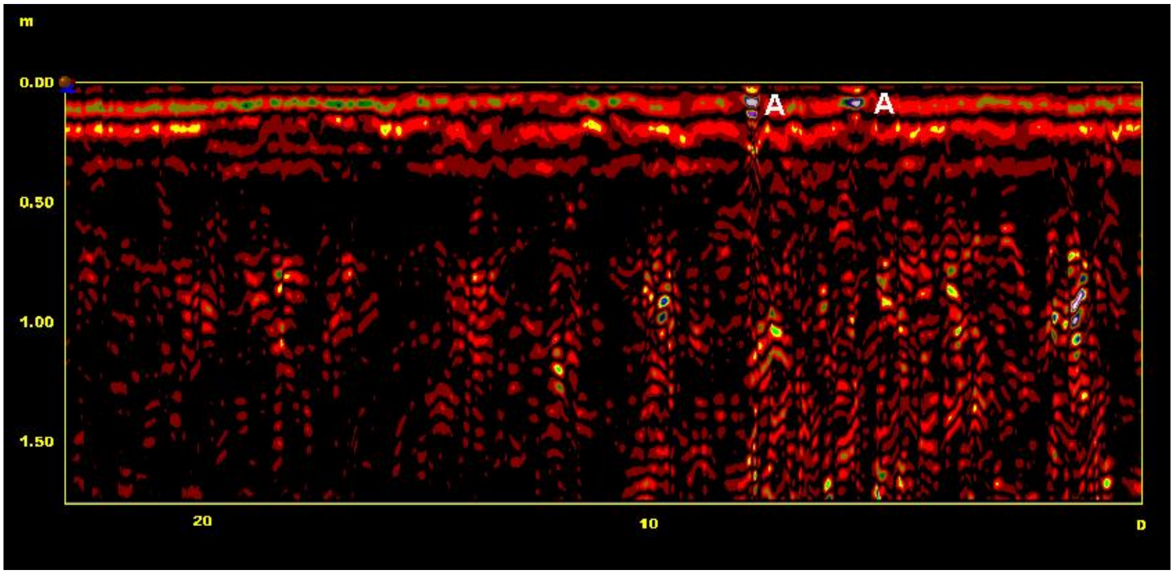

Figure 2. In this 2D radar record of line Y = 650 cm, two high-amplitude reflections and reverberated signals (to the left of both "A") indicate the passage of the antenna over two dislodge headstones.

Figure 3 contains a 3D pseudo-image and four, horizontal *time-sliced* images of the grid site. These horizontal *time-* or *depth-sliced* images were extracted from the 3D pseudo-image of the grid site at depths of 0, 50, 100, and 150 cm. In the 0-cm *depth-sliced* image (surface), variations in signal amplitude are attributed mainly to differences in soil moisture and/or soil compaction. The loafing area for cows can be identified by the uniform signal amplitudes (A) in the right-hand portion of the slice. Also in the 0-cm *depth-sliced* image, reflections from the two dislodged headstones that were passed over by the antenna are identified at "B". In the reminder of the *depth-slice images*, spatial patterns appear normal for till. These patterns are nonaligned and random. In the 50- cm depth-sliced image, two conspicuous, high-amplitude (colored white) reflections suggest anomalous features and possibly burials. While these reflections attract our attention, their identities are unknown. However, their size, depths and orientations may provide clues to their identities. Multiple, similarly aligned, elongated subsurface anomalies that occur at a common depth on radar records can identify burials.

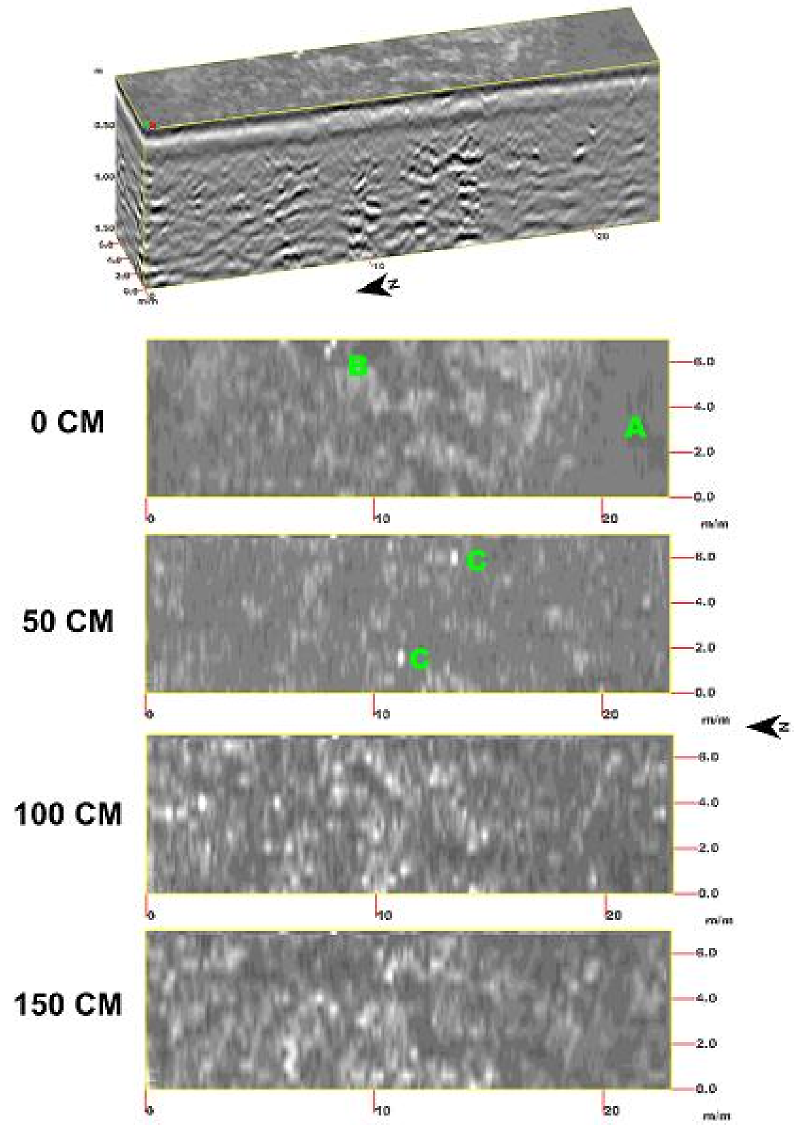

Figure 3. A 3D pseudo image and four horizontal time- or depth sliced images of the Ripley survey area.

References:

Conyers, L.B., and D. Goodman, 1997. *Ground-penetrating Radar; an Introduction for Archaeologists*. Alta Mira Press, Walnut Creek, California, USA.

Daniels, D.J., 2004. Ground Penetrating Radar; 2nd Edition. The Institute of Electrical Engineers, London, United Kingdom.

Jol, H., 2009. Ground Penetrating Radar: Theory and Applications. Elsevier Science, Amsterdam, The Netherlands.