United States Department of Agriculture

NRCS

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Subject: MGT- Trip Report - Archaeology – Geophysical Assistance May 13, 2013

To: Vicky Drew
State Conservationist, NRCS
Colchester, Vermont

File Code: 330-20-7

Ken Sturm
Wildlife Refuge Manager
U.S. Fish and Wildlife Service
Missisquoi National Wildlife Refuge
Swanton, Vermont

Purpose:
The purpose of this investigation was to use ground-penetrating radar (GPR) to identify suspected buried Native American cultural features in an area that will be affected by a stream bank stabilization project near the confluence of Dead Creek and the Missisquoi River in the Missisquoi National Wildlife Refuge.

Principal Participants:
Joe Bertrand, Maintenance Mechanic, Missisquoi National Wildlife Refuge, Swanton, VT
Jim Doolittle, Research Soil Scientist, NSSC, NRCS, Newtown Square, PA
Steve Smith, Fish Biologist, U.S. Fish and Wildlife Service, Essex Junction, VT
Ken Sturm, Wildlife Refuge Manager, U.S. Fish and Wildlife Service, Missisquoi National Wildlife Refuge, Swanton, VT
Thomas Villars, Resource Soil Scientist, NRCS, White River Jctn., VT

Activities:
All activities were completed on February 26, 2013.

Summary:

1. Ground-penetrating radar has been widely used as a rapid, relatively inexpensive geophysical tool for identifying subsurface archaeological features. As GPR surveys are nondestructive, they are frequently used to obtain subsurface information at archaeological sites without disturbance.

2. Two small grids were set up across an area that is scheduled to be impacted by a stream bank restoration project in the Missisquoi National Wildlife Refuge near the confluence of Dead Creek and the Missisquoi River.

3. Ground-penetrating radar was methodically dragged by hand in a back and forth manner across the surface of the two gridded areas in order to scan the underlying soil for possible buried Native American cultural features. The subsurface reflection patterns on the resulting radar records were exceedingly complex with numerous linear and point anomalies. While a majority of the radar reflection patterns are considered characteristic of alluvial soil materials, some, however, suggest

possible buried cultural features. In the images that accompany this report, several locations within the two gridded areas have been identified and may, at the discretion of archaeologists, warrant more thorough examination.

4. It is very doubtful that small, isolated, buried cultural features such as projectile points, tools, pottery fragments, and chipping debris were detected in this soil environment using a 200 MHz antenna. In addition, larger buried cultural features such as post-holes, pits, hearths, and layers of occupation history should be detectable. Unfortunately, GPR detects but does not identify subsurface features. Without ground-truth borings to confirm or disprove interpretations, the identities of the detected subsurface anomalies remain uncertain. This will cause dilemmas for archaeologists involved in the preservation of artifacts.

5. On the radar records that accompany this report, several areas have been identified that appear to be different and suggest possible buried cultural features. At the discretion of the reviewing archaeologist, test pits may be excavated in these areas to confirm radar interpretations.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to be of assistance in this project.

Susan S Andrews

ACTING

DAVID R. HOOVER
Acting Director
National Soil Survey Center

Attachment (Technical Report)

cc:
David W. Smith, Director, Soil Science Division, NRCS, Washington, DC
Albert Averill, State Soil Scientist, NRCS, Amherst, MA
Timothy Binzen, Archaeologist, U.S. Fish and Wildlife Service, Region 5, Hadley, MA
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Technical Report on GPR Archaeological Investigations conducted within the Missisquoi National Wildlife Refuge on February 26, 2013.

Jim Doolittle

Background (From notes of Timothy Binzen, Archaeologist with US Fish and Wildlife Service, Northeast Regional Office):

The delta of the Missisquoi River contains several Native American settlement sites. These settlements were most numerous in this area from about 500 to 2,000 years ago. After the European contact, settlements were continued mostly by the ancestral Abenaki tribe. Soon after 1700, a Jesuit mission was established at the Abenaki town of Missisquoi, which stretched along the east side of the lower reaches of the Missisquoi River just west of Swanton, Vermont. Archaeological investigations at this site have documented a large number of projectile points, tools, pottery fragments, fire-cracked rock, chipping debris, and other evidence of an intense Native American settlement. The site is also known to contain buried cultural deposits and subsurface features such as pits and hearths.

During a flood event in the 1930s, Dead Creek carved a new channel into the Missisquoi River. This event divided the aforementioned Missisquoi archaeological complex into an upriver and a downriver section. The downriver section of this archaeological site (State of Vermont archaeological site number VT-FR-30) is located within Missisquoi National Wildlife Refuge.

In recent years, seasonal flooding at the confluence of Dead Creek and the Missisquoi River has eroded large sections of the stream bank. In a 2010 visit to this site, buried cultural features (charcoal-stained lenses) were observed at depths of 1.5 to 2 m along the eroding banks of Dead Creek. An erosion control project is planned for a section of the riverbank along Dead Creek. The proposed stabilization project will replace soil materials from a 12 x 80-foot area with rip rap stone. While these proposed erosion control measures will help to ensure the preservation of this important Native American cultural site, it is vital to know in advance the presence of any buried cultural features that will be impacted by soil removal and to take measures to protect them. This information can be used by the archaeological team monitoring the excavation work in the construction phase of this stabilization project.

The purpose of this brief study was to use ground-penetrating radar (GPR) to identify buried Native American cultural features in the impacted erosion control area.

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 higher frequency, 400 MHz antenna was initially deployed in this survey. However, the 400 MHz antenna lacked a suitable control handle and was difficult to maintain coupled to the ground surface in this terrain. As a consequence, a lower frequency, 200 MHz antenna was used in this investigation.

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

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

MNWR Study Site:
The study site (latitude 44.9463 ° N, longitude 73.1482 ° W) is located in a mostly open, partially wooded area next to the confluence of the Missisquoi River and Dead Creek. Figure 1 is a soil map of the study site from Web Soil Survey.[2] The study site is located in an area of Winooski silt loam (Wt). The very deep, moderately well drained Winooski soils formed in recent alluvial deposits of very fine sand and silt on nearly level flood plains. The Winooski soil series is a member of the coarse-silty, mixed, superactive, mesic Fluvaquentic Dystrudepts family. This soil is considered suitable for GPR soil investigations.

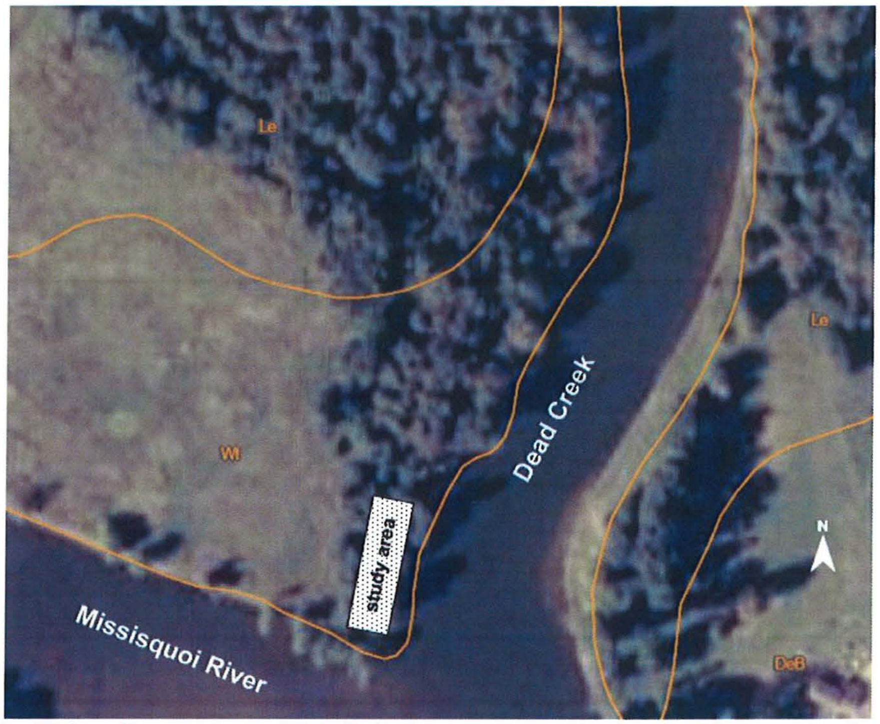

Figure 1. This soil map from Web Soil Survey shows the approximate location of the study site at the confluence of the Missisquoi River and Dead Creek.

Survey Procedures:
Two small rectangular survey grids were established across grassy, relatively non-wooded areas within the site, running parallel with the banks of Dead Creek. Grid A, which was closest to the junction of Dead Creek with the Missisquoi River, had approximate dimensions of 2.5 by 18 meters. Grid B, which was located to the north of Grid A, had approximate dimensions of 2.5 by 10 meters. Each grid was constructed using two parallel lines that were 2.5 m apart (trending essential east to west), which formed the opposing sides of each rectangular area. Along these parallel axes, survey flags were inserted into the ground at a uniform spacing of 50 cm (grid interval) (see Figure 2), and a distance-graduated guideline was stretched between matching survey flags on opposing sides of the grid a (see Figure 2). The GPR antenna was towed by hand on the soil surface along the graduated rope and, as it passed each 100-cm graduation, a mark was impressed on the radar record. Following data collection, the reference line was sequentially displaced 50 cm to the next pair of survey flags to repeat the process. For each grid, the

[2] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey, available online at http://websoilsurvey.nrcs.usda.gov/. Accessed 2/28/2013.

origin (X = 0, Y = 0) was located in the southeast corner and grid lines were numbered sequentially from one to six away from Dead Creek (located to the east).

Figure 2. Steve Smith, USFWS, repositions the distance-graduated guideline prior to Jim Doolittle, NRCS, conducting a ground-penetrating radar traverse across Grid Site B. The large orange box is the 200 MHz radar antenna.

Calibration of GPR:
Ground-penetrating radar is a time-scaled system. The system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., soil horizon, buried cultural feature) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (D), two-way pulse travel time (T), and velocity of propagation (v) are described in equation [1] (after Daniels, 2004):

$$v = 2D/T \qquad [1]$$

The velocity of propagation is principally affected by the relative dielectric permittivity (E_r) of the profiled material(s) according to equation [2] (after Daniels, 2004):

$$E_r = (C/v)^2 \qquad [2]$$

Where C is the velocity of light in a vacuum (0.3 m/ns). Typically, velocity is expressed in meters per nanosecond (ns). In soils, the amount and physical state (temperature dependent) of water have the greatest affect on the E_r and v. Dielectric permittivity ranges from 1 for air, to 78 to 88 for water (Cassidy, 2009). Small increments in soil moisture can result in substantial increases in the relative permittivity of soils (Daniels, 2004). Using a 100 MHz antenna, Daniels (2004) observed that the relative dielectric permittivity of most dry mineral soil materials is between 2 and 10, while for most wet mineral soil materials, it is between 10 and 30. At the time of this investigation, soils were moist and frozen in the upper part.

In order to convert radar data from a time-scale into a depth-scale for interpretations, an accurate estimate of the average subsurface velocity of propagation is required. This estimate can be obtained through direct ground-truthing, common midpoint survey (CMP), and or hyperbolic velocity analysis (Cassidy, 2009). The most simple and accurate method to determine the velocity of propagation is to identify reflections on radar records that are caused by known features at known depths (Conyers and Goodman, 1997). The velocity can be determined using the measured depth to a reflector, the two-way pulse travel time to the reflector (appearing on radar record), and equation [1]. Common mid-point method requires separate transmitting and receiving antennas. In CMP, the transmitting and receiving antennas are moved methodically outwards at equal distances from a common center point and changes in two-way travel time to a know reflector are measured. Hyperbola velocity analysis can be performed on radar records that contain reflection hyperbolas. Hyperbola velocity analysis involves matching an ideal form of a velocity-specified hyperbolic function to the form appearing on the radar record. Cassidy (2009) reported that hyperbolic matching methods produce estimated velocity values with error and variance of more than ±10%. In this study, no ground truth measurements were made to determine the depth to subsurface interfaces and CMP methods were not possible with the system used. As a consequence, the depth scale was approximated based on hyperbola velocity analysis. This resulted in an average E_r of 16.2 and a v of 0.75 m/ns.

Amplitude Slice Analysis:
In recent years, the use of advanced signal-processing software has enabled the enhancement of radar signals, which has improved pattern-recognition in some soils. Some of the signal processing methods used to improve the interpretability of subsurface archaeological features appearing on radar records are discussed by Sciotti et al. (2003) and Conyers and Goodman (1997). One advanced signal processing method that is commonly used in archaeological investigations is *amplitude slice analysis* (Conyers and Goodman, 1997). In this analysis, a three-dimensional (3D) pseudo-image of a small grid area is constructed from the computer analysis and synthesis of a series of closely-spaced, two-dimensional (2D) radar records. Amplitude differences within the 3D pseudo-image are analyzed in "*time-slices*" (or depth-slices) that examine changes within specific depth intervals in the ground (Conyers and Goodman, 1997). In this process, the reflected radar energy is averaged horizontally between adjacent, parallel 2D radar traverses and in a specified time (or depth) window to create a time-slice (or depth-slice) image. Each amplitude time-slice shows the spatial distribution of reflected wave amplitudes, which can indicate changes in soil properties or the presence of subsurface features. In many instances, *amplitude slice analysis* has been used to distinguish and identify buried cultural features and to reduce interpretation uncertainties.

Results:
Figure 3 contains three radar records that were collected across Grid A. Each grid line is orientated from south (left) to north (right) and are numbered from east (top traverse line) to west (bottom traverse line) away from Dead Creek. These lines are separated from one another by a distance of about 1 m. On these radar records, the depth and distance scales are expressed in meters. In general, the subsurface is characterized by a number of slightly undulating, segmented, planar reflections that vary in expression and signal amplitude. On each radar record, a group of segmented planar reflections can be seen stretching across the survey area at depth of about 1 and 2 m. These planar reflections represent major stratigraphic layers, which are characteristic of alluvial soil deposits. Low amplitudes (colored red and black on the radar records) reflections signify low contrast in dielectric properties between adjoining layers. High amplitude (colored white, grey, and blue on the radar records) planar reflections indicate adjoining stratigraphic layers that vary more substantially in dielectric properties. Differences in signal amplitude are attributed to contrast in soil textures, moisture contents, and/or densities. Buried, organic enriched cultural layers have been identified in some GPR studies by these reflection patterns and contrasts in signal amplitudes (often higher reflection amplitudes). Line 1 is closest to the streambank and has subsurface reflections that are noticeably higher in signal amplitudes than lines 3 and 5. As soils

that are closer to the cut bank slopes of Dead Creek drain more rapidly, the greater difference in signal amplitudes along Line 1 is attributed to greater contrasts in the soil moisture contents of the different strata.

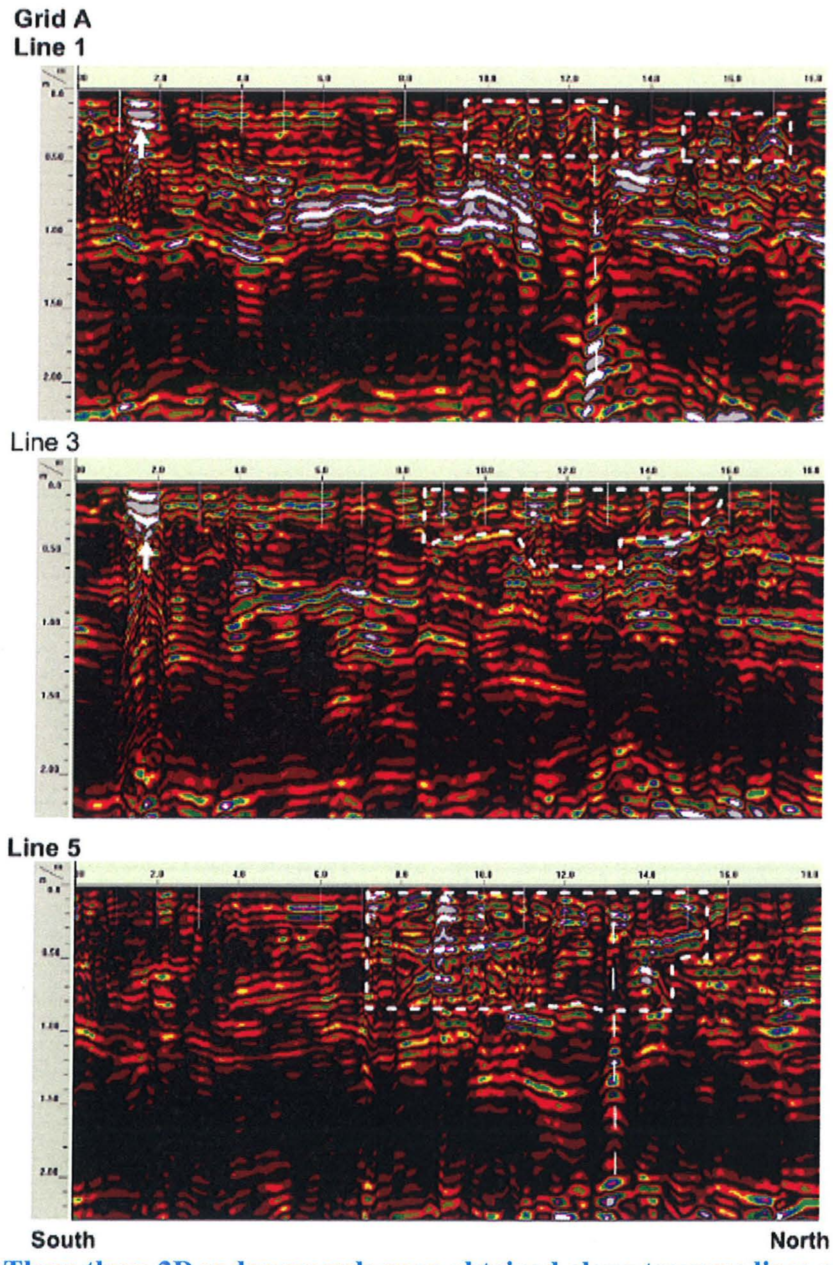

Figure 3. These three 2D radar records were obtained along traverse lines conducted across Grid A.

In Figure 3, a small white arrow near the 1.5 to 2.0 m distance marks on Lines 1 and 2 indicates a near-surface high-amplitude anomaly that may be worthy of closer inspection by an archaeologist. In each of the three radar records shown in Figure 3, white-colored dashed lines enclose polygonal areas in which the reflection patterns appear different from the adjoining sections. Reflection patterns within these highlighted areas appear more chaotically arranged, have higher-amplitude, and consists of both point and planar reflections. These patterns suggest areas of disturbance or dissimilar materials. However, these patterns do not necessarily signify buried cultural features. Tree roots, animal burrows and soil structural irregularities produce similar patterns.

In Figure 3, on the radar records for lines 1 and 5, a white-colored dashed vertical line between the 12.0 and 14.0 m distance marks has been used to identify a group of multiple reverberations that may indicate a buried metallic artifact. There are additional reflections and patterns appearing on the radar records shown in Figure 3 that suggest other anomalous features. Some of these features may represent buried cultural features. Unfortunately, GPR detects, but does not identify, buried anomalous features.

Figure 4 contains four time-sliced (or depth-sliced) pseudo-images from a three-dimensional (3D) cube that was constructed from the six radar traverses conducted across Grid A. These images represent views (looking down) from directly above the grid area. Separate horizontal time-slices of the 3D cube have been made at approximate depths of 0 (upper plot), 25, 50 and 75 cm (lower plot). In each plot, the time-slice is 0.15 cm thick. In each plot, clusters of higher amplitude reflections (colored red and yellow) suggest anomalous features, some possibly cultural. The anomalies occurring between the 8 and 12 meter distance marks (horizontal scale) are near a tree (located to the east; bottom of each plot) and may represent tree roots. However, the anomalies appearing near the 1 to 2 m distance marks on the 25 cm depth-sliced pseudo-image forms a linear pattern that is not associated with any nearby tree. This feature may be worthy of attention by an archaeologist. Care must be exercised in identifying any one of these anomalous reflections as buried cultural features, as they can also represent roots, rock fragments, burrow or inhomogeneities in the soil structure or fabric, which would produce similar reflections. A string of high amplitude, segmented reflections stretch across the lower boundary of the 25, 50, and especially the 75-cm depth slices. These features may reflect differences in soil hydrologic conditions along the cut bank to Dead Creek.

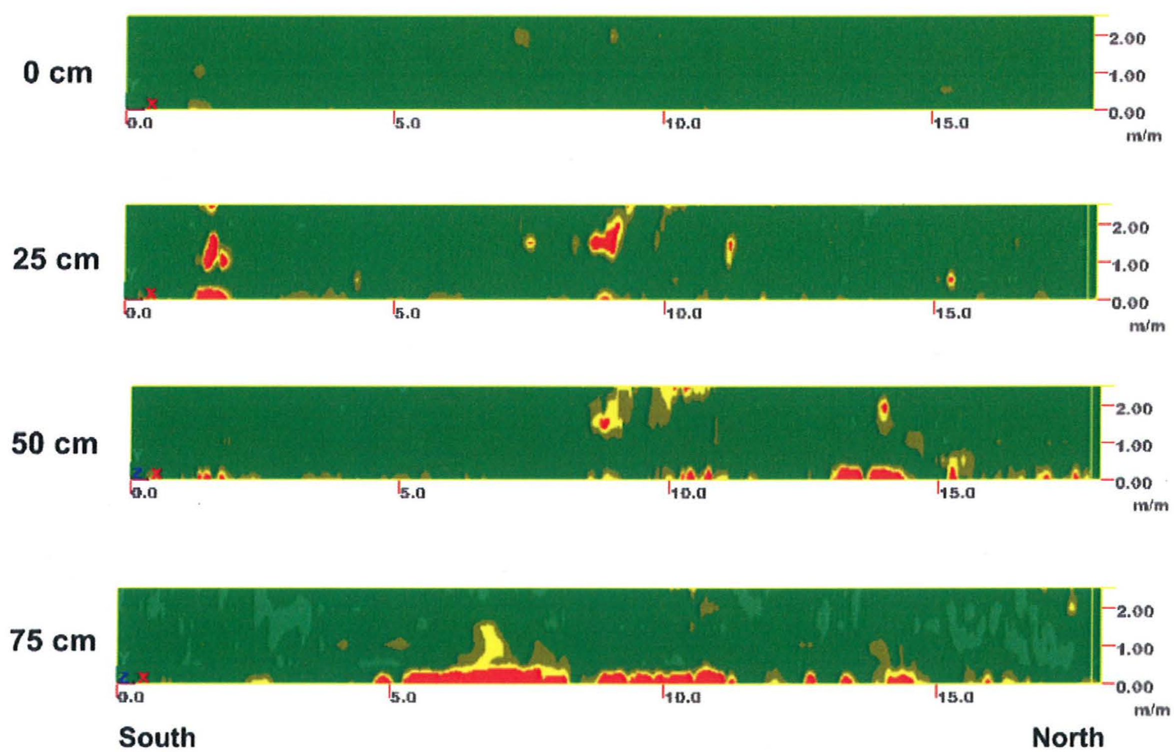

Figure 4. These four time- or depth-sliced pseudo-images are from Grid A. Several high amplitude reflections evident in the 25- and 50-cm depth-slices may be worthy of attention by an archaeologist.

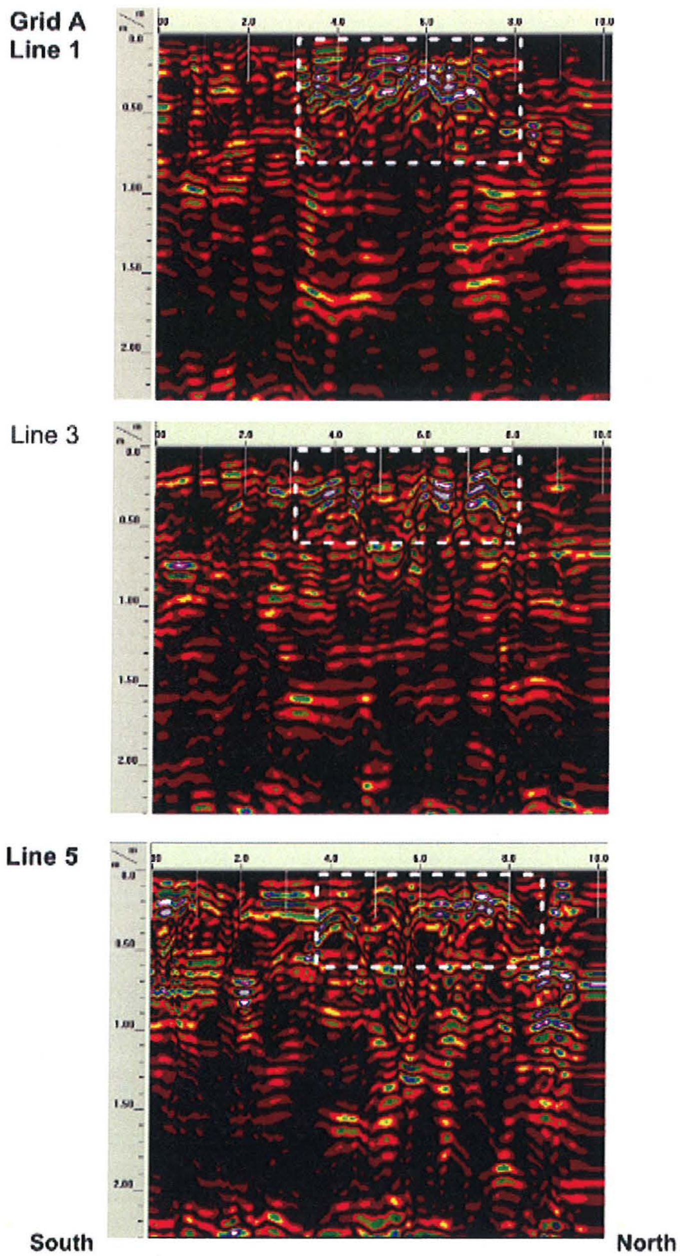

Figure 5. These three 2D radar records were obtained along traverse lines conducted across Grid B.

Figure 5 contains three radar records that were collected across Grid B. Each grid line is orientated from south (left) to north (right) and are numbered from east (top traverse line) to west (bottom traverse line) away from Dead Creek. These lines are separated from one another by a distance of about 1 m. On these radar records, the depth and distance scales are expressed in meters. On each radar record, an area with higher-amplitude, point and planar radar reflections has been identified and enclosed by white-colored dashed lines. The patterns within these delineated areas are strikingly different from adjoining sections and possibly suggest disturbance or anomalous features. These areas may be worthy of attention by an archaeologist.

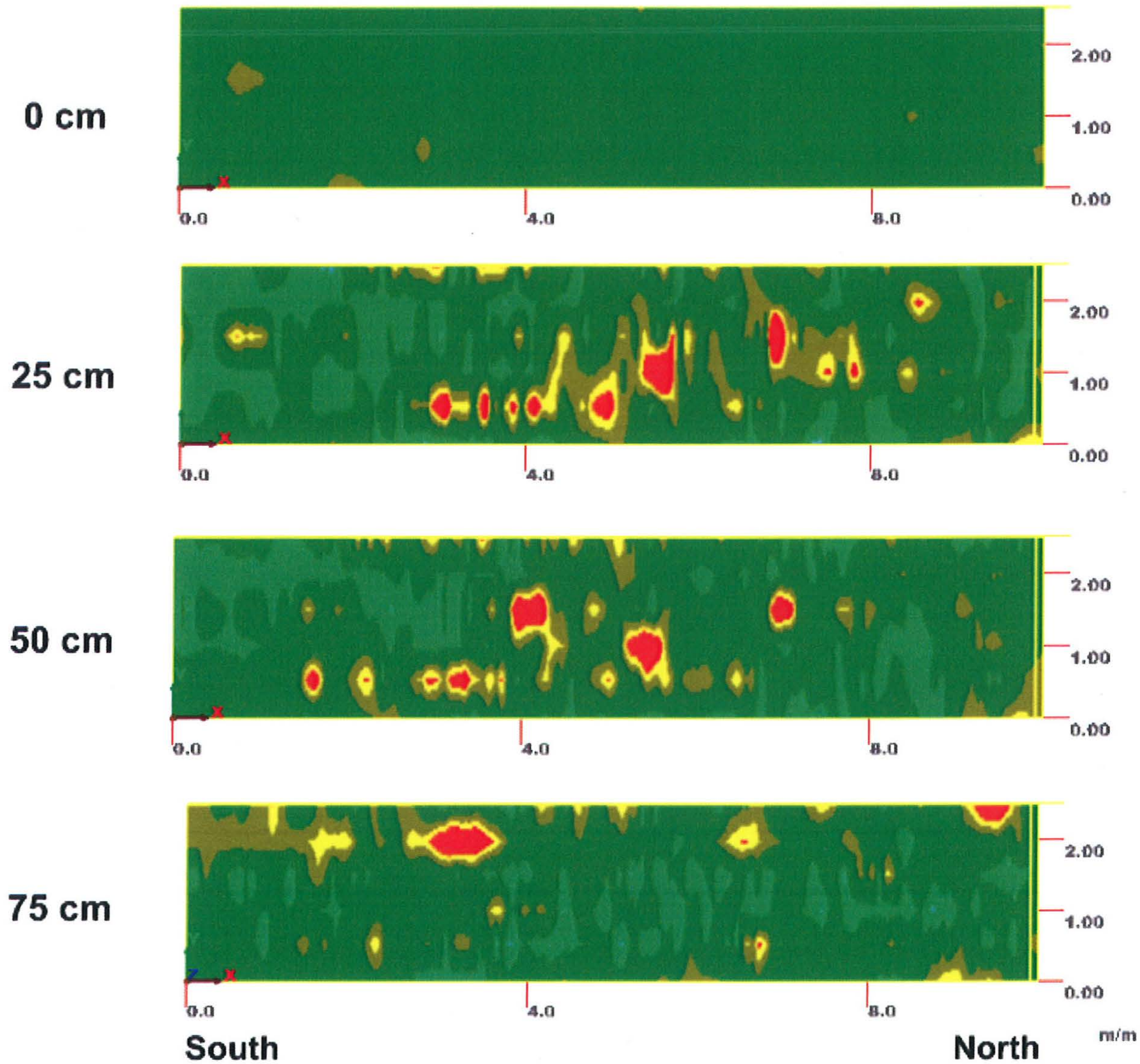

Figure 6. These four time- or depth-sliced images are from Grid B. The high-amplitude reflections (colored red and yellow) evident in lower depth-slices may be worthy of attention by an archaeologist.

Figure 6 contains four time-sliced pseudo-images from a three-dimensional (3D) cube that was constructed from the six radar traverses conducted across Grid B. These images represent views from directly above the grid area. Separate horizontal time-slices of the 3D cube have been made at depths of 0 (upper plot), 25, 50 and 75 (lower plot) cm. In each plot, the time-slice is 0.15 cm thick. In each plot, clusters of higher amplitude (colored red and yellow) reflections suggest anomalous features, some possibly cultural. A string of higher-amplitude point reflections appears to extend across the central portion of the 25 and 50 cm time-sliced images. The feature(s) that causes these conditions may be worthy of attention by an archaeologist. As stated previously, caution must be exercised in identifying any one of these anomalous reflections as buried cultural features without any ground-truth observations, as they can also represent roots, rock fragments, burrow or inhomogeneities in the soil structure or fabric, which would produce similar reflections.

References:

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