**United States Department of Agriculture**

**Natural Resources Conservation Service**

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**Subject:** Archaeology -- Geophysical Assistance **Date:** 22 October 2004

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**Purpose:**
Ground-penetrating radar (GPR) was used to help students investigate the subsurface beneath Pioneer Park in Lewiston, Idaho. The objective of this survey was to ascertain whether any evidence exists that would suggest the presence of unmarked graves within the park's boundaries.

**Participants:**
Steve Branting, Consultant, Gifted & Innovative Programs, Lewiston, ID
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**Activities:**
All field activities were completed on October 9, 2004.

**Findings:**

1. Ground-penetrating radar permitted a rapid, nondestructive investigation of portions of Pioneer Park without the need for extensive and expensive excavations. Interpretations contained in this report are considered preliminary estimates of site conditions. The results of this investigation are interpretive and do not substitute for direct ground-truth observations by qualified archaeologists. The use of ground-penetrating radar can reduce the number of coring observations, direct their placement, and supplement their interpretations.

2. Detail radar surveys were completed in five areas of Pioneer Park. Time-sliced images of radar data were constructed and used to interpret each site. Radar surveys did confirm disturbances and the placement of multiple utility, drainage, and/or irrigation lines across the park. Two of the five grid areas were underlain by these lines. One grid was setup in a children's playground. However, extensive areas do remain

seemingly void of subsurface anomalies.

3. Grid 5, which was located in the extreme southeastern part of the park, provided the greatest indication of possible unmarked grave-sites. Multiple reflectors that varied in length from one to two meters and aligned in essentially and east to west orientation were discerned on a time-sliced image of the grid area. While the identity of these reflectors remains tentative, their form and depth suggest possible grave-sites.

It was my pleasure to work with Tom Burnham and to assist Steve Branting and his students at Lewiston High School in this project.

With kind regards,

James A. Doolittle
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**Background:**
The *5th Street Cemetery* was used by the residents of Lewiston from about 1862 until December 1888. In 1889, faced with expansion, the city of Lewiston exhumed the burials at the *5th Street Cemetery* and supposedly re-buried the remains in a new cemetery located about 12 blocks south on the edge of town, the *Normal Hill Cemetery*. Steve Branting's group of high school students has learned that, in 1889, the residents had only a brief period of time to remove the buried relatives. After this short period of time, the city removed any remaining interments and charged the costs to the surviving family members. It is known that the city contractor worked in the old *5th Street Cemetery* for only a short time and could therefore only exhume an estimated 20 graves. City official may have decided that some remains, especially those with no local relatives, should be left undisturbed. It is quite possible therefore that more headstones than graves were moved. Today, the site of the *5th Street Cemetery* is known as Pioneer Park. Ground-penetrating radar (GPR) surveys were carried out in an attempt to resolve weather some burials of the former *5th Street Cemetery* remain in Pioneer Park.

**Equipment:**
The use and operation of GPR are discussed by Daniels (2004). The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-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 System-3000 weighs about 9 lbs and is backpack portable. With an antenna, this system requires two people to operate. A 400 MHz antenna was used in this investigation.

The RADAN for Windows (version 5.0) software developed by Geophysical Survey Systems, Inc, was used to process the radar records.[1] Processing included setting the initial pulse to time zero, color transformation, marker editing, distance normalization, signal stacking, background removal, migration, and range gain adjustments. Radar records were processed into three-dimensional images using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc.[1] Once processed, arbitrary cross sections and time slices were viewed and selected images attached to this report.

**Survey Procedures:**
Prior to field work, Pioneer Park was walked and reviewed, and the most desirable area(s) selected by Steve Branting. To expedite field work, two equal length and parallel lines were established at each selected site. These two parallel lines defined a rectangular grid area. Survey flags were inserted in the ground at equal intervals (50 cm) along each of these two lines. For positional accuracy, surveys were completed by stretching and sequentially moving a reference line between similarly numbered flags on the two parallel grid lines.

Pulling the 400 MHz antenna along a reference line that was stretched between similarly numbered flags on the two parallel survey lines completed a GPR traverse. Along the reference line, marks were spaced at 1-m intervals. 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 the GPR survey.

Five survey grids were setup within Pioneer Park. Grids were restricted to open areas, which were generally free of trees, and varied in size. The coordinates of each grid were measured with a survey-grade GPS unit, which was operated by Ron Perkins of the Idaho Department of Transportation. Grid #1 was the northern-most grid established within the park. The dimensions of this grid were 30- x 15-m. Grid #2 was established in the south-central portion of the park in a grassy area to the immediate west of a children's playground. The dimensions of the Grid #2 were 8- x 15-m. Grid #3 bordered the western side of Grid #2. The dimensions of this grid were 4- x 4-m. Grid #4 was established in an open area within the children's playground. The dimensions of Grid #4 were 4- x 4-

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

m.  Grid #5 was established on a grassy area near the southeast corner of the park.  The dimensions of the Grid #5 were 20 x 10-m.

*Figure 1.  Tom Burnham instructs students on how to layout a survey grid in the field.*

**Use of GPR for Archaeological Investigations:**
A favorable feature of GPR is its ability to detect soil disturbances and the intrusion of foreign materials.  GPR is therefore a useful tool for locating burials (Bevan, 1991; Davenport, 2001; Gracia et al., 2000; King et al., 1993; and Vaughan, 1986).  Ground-penetrating radar has been used to locate unmarked graves (Bevan, 1991; Davis et al., 2000; Dittmer, 2004; Mellett, 1992; Miller, 1996, Nobes, 1999 and 2000; Unterberger, 1992).  However, results vary with soil conditions.  In some soils, rates of signal attenuation are so severe that GPR cannot profile to the required depths.  Even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never guaranteed with GPR.  The detection of burials is affected by the electromagnetic gradient existing between the feature and the soil; the size, depth, and shape of the buried feature; and the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna from a burial is a function of the contrast in dielectric properties that exists between a buried feature and the soil.  The greater and more abrupt the difference in electromagnetic properties between the buried feature and the soil, the greater the amount of energy that is reflected back to the antenna, and the more intense will be the amplitude of the reflection recorded on the radar record.  The contrast between many buried objects and the soil materials is small resulting in lower chances of detection.

Remains may be buried in sacks, body bags, or in wooden, fiberglass, composite, or metal caskets.  Metallic or lead coffins and burial vaults provided large and contrasting interfaces that produce strong, recognizable radar reflections.  If a coffin is intact, an air-filled void exists, which can be detected with GPR.  Bevan (1991) used GPR to detected intact coffins, but was not successful in detecting collapsed or soil-filled coffin, or bones alone.

At many sites, the most distinctive feature of a grave is the disturbed soil materials that fill and cover the grave shaft (Bevan, 1991).  Bevan (1991) noted that it is more likely for GPR to detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials, which directly surrounds a burial rather than the bones themselves.  Refilled excavations contain disturbed soil materials that can have electrical properties that contrast with the surrounding, undisturbed soils (Bevan, 1991; Miller, 1996).  Often, GPR operators rely on the presence of soil disturbance to identify burials.   However, in soils that lack contrasting horizons or geologic strata, the detection of disturbances or grave shafts is improbable. In addition, with the passage of time, the signs of disturbances are erased by natural soil-forming processes.

The depth and size of a burial affect detection. Burials may range in depth from shallow (<50 cm) to very deep (>150 cm). Large, electrically contrasting features reflect more energy and are easier to detect than small, less contrasting features. Small, deeply buried features are more difficult to discern on radar records. Bones are generally too small to be distinguished with GPR (Killam, 1990; Bevan, 1991).

The shape and orientation of a subsurface anomaly may suggest its identity. Subsurface anomalies that are narrow and linear may suggest burials. Burials may be uniformly spaced or aligned in a particular direction. Bartel (1982) observed burials aligned with the orientation of the solar traverses. Multiple, elongated subsurface anomalies occurring at a common depth suggest burials.

In some soils, burials are difficult to distinguish because of the presence of clutter such as stratified or segmented soil layers, rock fragments, tree roots, and animal burrows. Vaughan (1986) and Bevan (1991) found the detection of graves complicated by rock fragments, which introduced unwanted clutter and complicate the interpretation of radar records.

In the search for burials with GPR, success is never guaranteed. Even under ideal site and soil conditions, burials will be missed with GPR. The usefulness of GPR for site assessment purposes depends on the amount of uncertainty or omission that is acceptable.

**Calibration of GPR:**
Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., bedrock, soil horizon, stratigraphic layer) 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 the following equation (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 the equation:

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

Where C is the velocity of propagation in a vacuum (0.2998 m/nanosecond). Velocity is expressed in meters per nanosecond (ns). A nanosecond is one billionth of a second. The amount and physical state of water (temperature dependent) have the greatest effect on the $E_r$ of earthen materials.

The velocity of propagation is temporally and spatially variable. The soils within Pioneer Park were very dry at the time of this investigation. Based on hyperbola-matching processing techniques (the shape of a hyperbole is dependent on signal velocity), the velocity of propagation decreased with increasing depth, but over the scanned depth averaged about 0.16 m/ns ($E_r$ of 3.3). With a scanning time of 40 ns, the maximum penetration depth was about 3.3 m.

**Radar Interpretations:**
Figure 2 is a radar record that was collected in front of several (four) headstones within *Normal Hill Cemetery*. The graves date from 1881 to 1915. Other than the first and last lines, the white vertical lines at the top of the radar record were impressed as the antenna pasted in front of each of the four headstones. The distances between these marks (headstones) were variable, but on this radar record they have been normalized (equal interval).

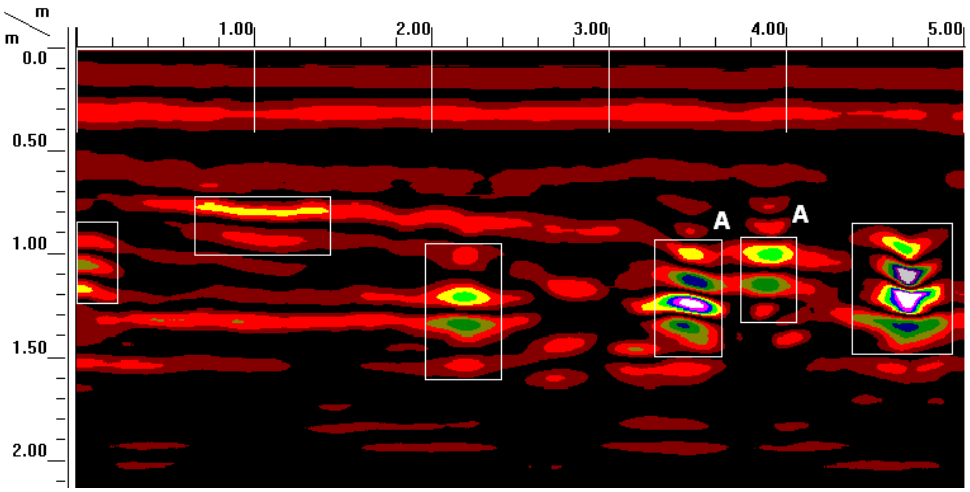


*Figure 2. High-amplitude subsurface reflectors may indicate burials with the Normal Hill Cemetery.*

The radar record (Figure 2) provides a continuous record of subsurface features in front of four headstones. On this radar record, the approximate locations of high-amplitude subsurface reflections have been enclosed in boxes. Six high-amplitude subsurface anomalies have been identified. If these anomalies represent burial, they occur at depths ranging from about 70 to 90 cm and are generally offset from the center of the headstones. The high amplitude anomaly in front of the first headstone (below the 1-m mark) is too linear and is therefore suspected to be a soil horizon. In Figure 2, the letter “A” has been used to identify (to the immediate left of letter) possible backfilled materials overlying two possible burials. The backfilled materials contain mixed materials that contrast with the surrounding soil. Contrast in grain size distributions and moisture contents provide reflective surfaces that are displayed on the radar record. The backfilled soil materials provide reflections whose patterns contrast with the bounding undisturbed soil materials.

Survey results from other headstone groupings within *Normal Hill Cemetery* revealed that many interments are offset or on either side of headstones. This does not seem extraordinary if headstones were procured an erected several years after the interment. Though cemetery caretakers insist that burials were in front of headstones, subsurface anomalies and indications of soil disturbances were observed on radar records obtained from either side of some headstones.

**Results:**

**3D Time-sliced image:**

On radar records, the depth, shape, size, and location of subsurface features may be used as clues to infer burials. In the past, reflections could only be identified and correlated on two-dimensional radar records. The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern-recognition on radar records. Today, three-dimensional (3D) imaging techniques are commonly used to distinguish coherent noise components, reduce interpretation uncertainties, and aid identification of potential targets on radar records (Pipan et al., 1999). Three-dimensional interpretations of GPR data have been used to identify burials, middens, and other cultural features (Conyers and Goodman, 1997; Whiting et. al, 2000; Goodman et al., 2004).

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). A 3D image of a site is derived from the computer analysis of a series of closely-spaced, two-dimensional radar records (Conyers and Goodman, 1997). Amplitude differences within the 3-D image are analyzed in "*time-slices*" that examine only changes within specific depth intervals in the ground (Conyers and Goodman, 1997). Time-slice data are created using spatially averaged amplitudes of return reflections. The reflected energy is averaged horizontally between each set of parallel radar records and in specified time windows to create a time-slice. Each amplitude time-slice shows the spatial distribution of reflected wave amplitudes, which are indicative of changes in soil properties or the presence of buried features.

Three-dimensional images were prepared for each grid and radar data were interpreted using *amplitude slice-map analysis*. Figures 3 thru 7 contain 3D time-sliced diagrams of grids 1 thru 5, respectively. In each figure, all units are expressed in meters. The origin of each grid is located in the southeast corner of the grid. Horizontal "time-slices" were made across a 3D cube of the grid area at the depths specified in each figure. These depths are based on an assumed signal propagation velocity of 0.016 m/ns through the soil. The width of each time-slice is about 30 cm

Grid 1:

Grid 1 was the largest, most northern and distant grid surveyed within Pioneer Park. It was located on a slight grassy slope that contained only one, very small, recently planted tree. Four horizontal time-sliced images of the grid area are shown in Figure 3. At all depth intervals, the grid area was characterized by generally indistinct reflections of low amplitudes. This attribute, subsurface reflections of low amplitudes, suggests similar soil properties and a general lack of contrasting subsurface features. In the 0 cm time-slice image of Grid 1 (see upper image in Figure 3), reflections are of very low amplitudes and indistinct. No distinct pattern is evident in this slice. The absence of moderate to high amplitude signals in this slice indicates very similar soil properties (moisture, density, texture) at very shallow depths. In the 60 cm slice, two moderate to high amplitude, linear features punctuate the otherwise pervasively low amplitudes of reflected signals within the grid area. Both linear anomalies appear to extend away from the southeast corner (origin) of the grid. One linear feature extends in a north-northwesterly direction, while the other (less distinct) extends in a westerly direction. These linear features are probably buried utility, irrigation, and/or drainage lines. In the 120 cm slice, two additional, moderate to high amplitude linear features are evident. These features parallel one another and extend in a general east to west direction across the grid area. Also evident in the 120 cm slice are reverberated signals from the two linear features seen in the 60 cm slice.

A clustering of short (1- to 2-m) linear reflectors is evident in the northeast corner of the 120 cm slice. These reflectors are variable in amplitude, appear randomly distributed, and have a common east to west orientation. The identity of these features is unknown. No trees (possible reflections from roots) presently occur in this portion of the grid area. This area of the grid may be worthy of exploratory excavations by archaeologists.

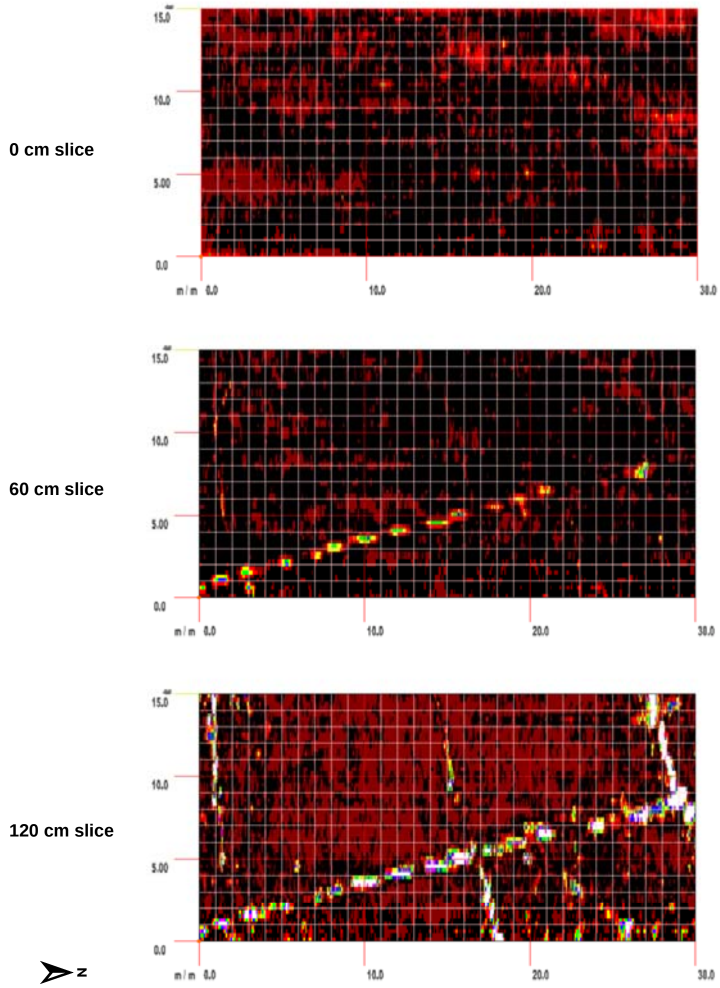


*Figure 3. Amplitude anomalies are evident in these three-dimensional time-slices of Grid 1. Horizontal time-slices made at depths of 0, 60, and 120 cm.*

<u>Grid 2:</u>

Figure 4 contains 3D time-sliced images of Grid 2. This grid was located in the south-central portion of Pioneer Park to the immediate west of the children's playground area. With one minor exception, no moderate to high amplitude subsurface reflector is evident in the upper 60 cm of the soils within Grid 2. The cluster of high amplitude reflections in the southwest corner of the 0-cm slice may indicate roots from a nearby tree.

In the 120-cm slice shown in Figure 4, several intersecting or parallel, high-amplitude, linear features are apparent. Being linear, these features are inferred to be cultural. These features appear segmented and may represent former utility or drainage lines that have been disrupted or disturbed. The presence of these features indicates a highly disturbed area.

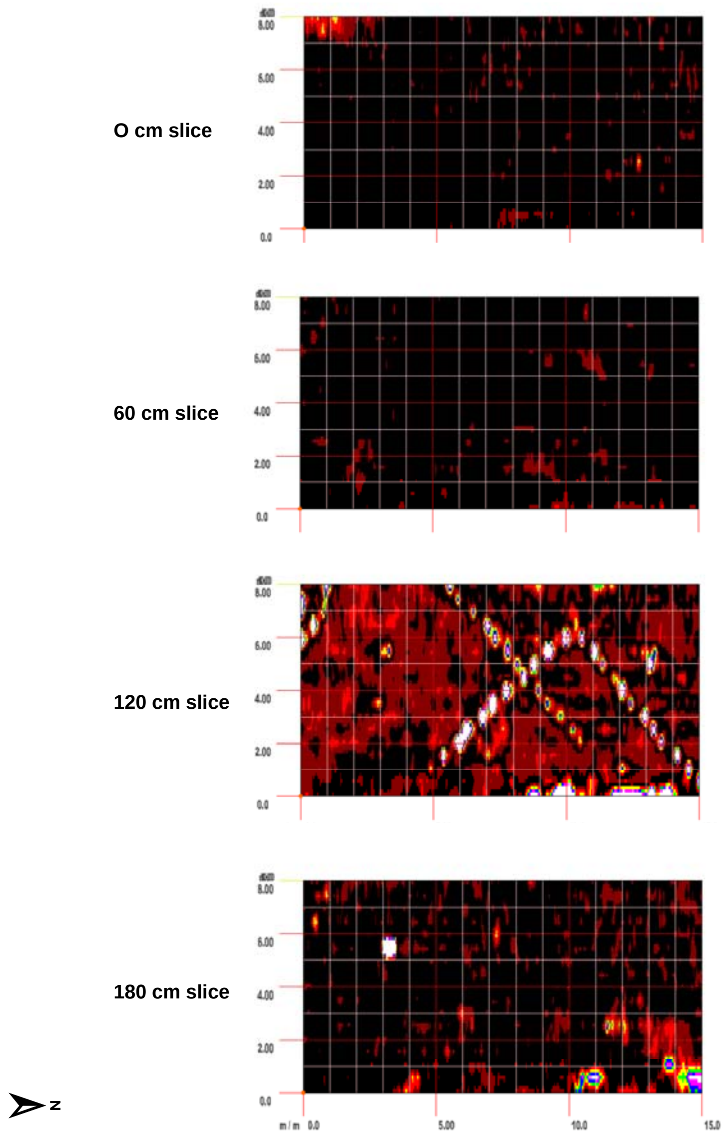


*Figure 4. Amplitude anomalies are evident in these three-dimensional time-slices of Grid 2. Horizontal time-slices made at depths of 0, 60, 120, and 180 cm.*

In the lower two time slices (120 and 180 cm), several moderate to high amplitude anomalies are evident. Reverberations from a very high-amplitude anomaly, which is believed to be metallic feature, can be seen in each slice at position X = 3, Y = 5 to 6. In the 120-cm slice, several moderate amplitude subsurface features are evident at X = 3, Y = 3.5; X = 12, Y = 1; and X =13, Y = 5 to 6 in the 120 cm time slice. In the 120-cm slice, the high amplitude reflections along the extreme northeastern border of the grid area (right-hand portion of lower boundary) are attributed to a retaining wall for the children's playground. Many of the higher amplitude reflections in the lower right hand (northeast) corner of the 180 cm slice appear in the general vicinity of the linear features shown in the 120 cm slice. However, some of these anomalies appear offset from these linear features and may be worthy of exploratory excavations by archaeologists.

<u>Grid 3:</u>

Figure 5 contains 3D time-sliced images of Grid 3. This small grid was located to the immediate west of Grid 2 in the south-central portion of Pioneer Park. A large tree bordered the northwest boundary of this grid area. As within the other grid areas, no moderate to high amplitude subsurface reflector is evident in the upper 60 cm of the soils. However, in the 120 cm slice, amplitudes increase and higher amplitude reflections form a sweeping arch in the northeast portion of the grid area. In general, these higher amplitude features appear to lack linearity and are believed to reflect natural soil features. In the 180 cm slice several moderate amplitude reflections are evident at about X = 1, Y = 0; X = 2, Y = 0.5; X = 3.5, Y = 2. However, there depths appear to be too great to suggest burials.

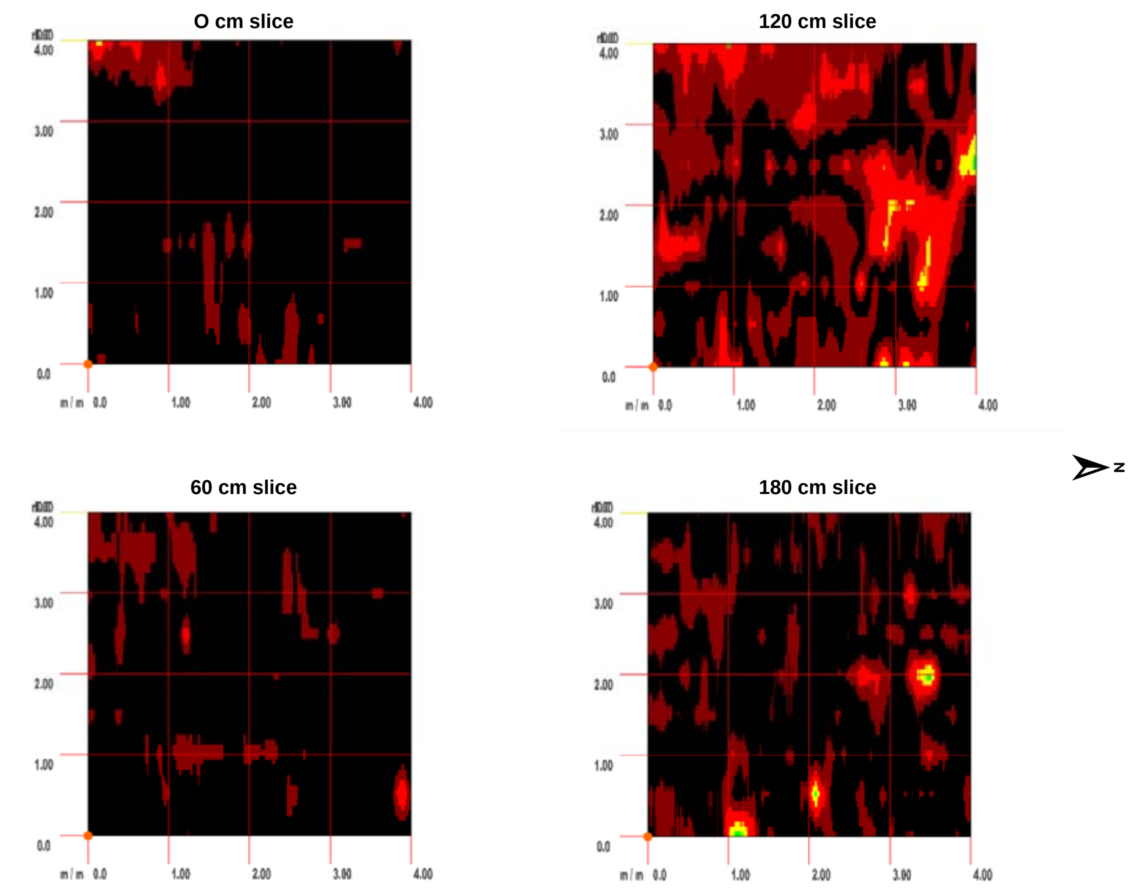


*Figure 5. Amplitude anomalies are evident in these three-dimensional time-slices of Grid 3. Horizontal time-slices made at depths of 0, 60, 120, and 180 cm.*

<u>Grid 4:</u>

Figure 6 contains 3D time-sliced images of Grid 4. This grid was located in an open area within the children's playground. No moderate to high amplitude subsurface reflectors are evident in the upper 60 cm of the soils within the playground area. However, at a depth of about 120 cm, several high amplitude reflectors are apparent. Two closely spaced anomalies occur between X = 2.5 and 3, and Y = 1.5 and 2.75. Being highly contrasting with the encompassing soils, these features are suspected to be cultural. There depth and dimensions portends possible burials. These features may warrant further exploratory investigations by a qualified archaeologist.

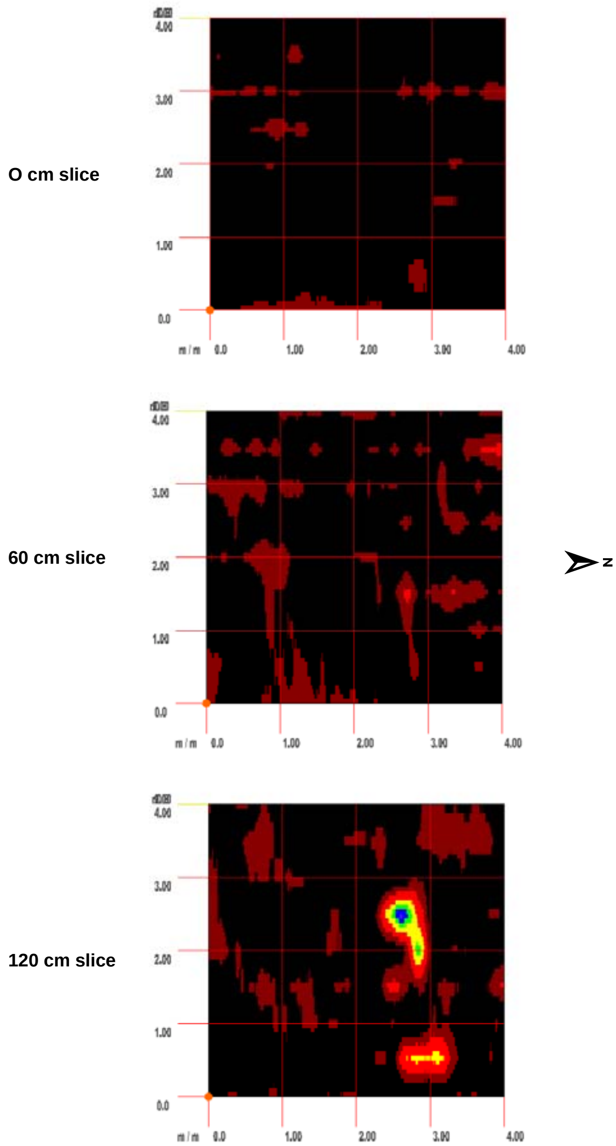


*Figure 6. Amplitude anomalies are evident in these three-dimensional time-slices of Grid 4. Horizontal time-slices made at depths of 0, 60 and 120 cm.*

<u>Grid 5:</u>
Figure 7 contains time-sliced images of Grid 5. This grid was located near the extreme southeastern corner of Pioneer Park. This area of the Park is relatively higher-lying and located near a former access road to the *5$^{th}$ Street Cemetery*. This area represents a highly likely location for former grave-sites. Spatial patterns in the 0 and 50 cm slices are dispersed, non-linear and random. They are believed to principally represent variations in soils and soil properties. Several clusters of high amplitude reflections are evident in the 50-cm slice. Most noteworthy are the high amplitude reflectors located at X = 2.5, Y = 1, and the two between X = 18 to 19, Y = 5 to 7. Each of these reflectors was detected on two or more passes of the antenna in similar locations and at similar depths.

The 100-cm slice of Grid 5 is most intriguing. Multiple, narrow, high-amplitude linear reflectors are evident in this slice. These reflectors vary in length from one to two meters and are all orientated in essentially and east to west orientation. While the identity of these reflectors remains speculative, their form and depth do suggest possible grave-sites. The cluster of high amplitude (white-colored) reflections evident in the extreme lower left-hand (southeast) corner of the 100 and 150-cm slices are also believed to be artificial. There intensity, density, and arrangement suggest possible remnants from a former structural feature or possible burials.

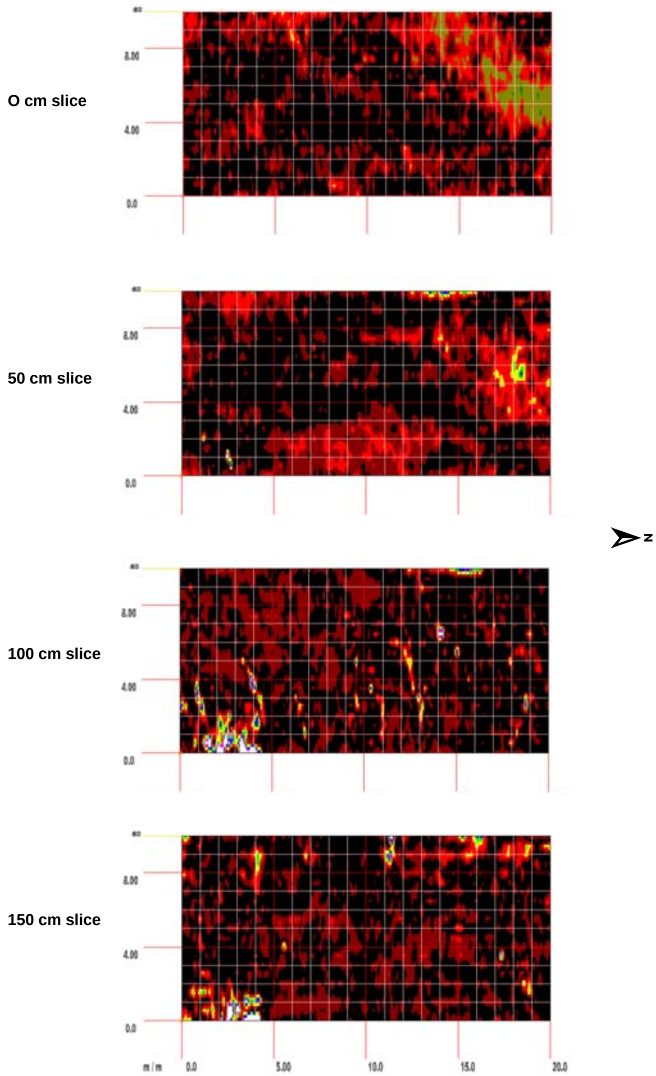


*Figure 7. Amplitude anomalies are evident in these three-dimensional time-slices of Grid 5. Horizontal time-slices made at depths of 0, 50, 100, and 150 cm.*

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