# Ground-Penetrating Radar Survey at the Elk Landing Site (18CE60), Elkton, MD

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## Introduction

Two grids (50m x 50m and 25m x 25m) of ground-penetrating radar data were collected in the open field south of the Hollingsworth House at the Elk Landing site in Elkton, MD on March 19th and 10th 2012. The purpose of this study was to search for a War of 1812 era earthwork and other associated subsurface features. This location was chosen based on historical records and oral accounts. Members of the Northern Chesapeake Chapter of the Archaeological Society of Maryland, Inc., along with archaeologist Dr. James Gibb and soil scientist Bill Stephens, assisted in the survey. Ground-penetrating radar was selected for use at this site because this geophysical method can potentially map buried features of interest to about two meters in depth. GPR allows for the quick collection of data in a non-invasive way.

The ground-penetrating radar survey was preceded by a magnetometer survey in August 2011. The results of that survey are detailed in a final report. A brief description of that survey and its connection to the GPR survey is discussed further below. The GPR grids were set up over the same area of the magnetometer survey (Figure 1).

A GSSI SIR-3000 GPR system was used for all collection with 400 MHz dipole antennas and a survey wheel for distance calibration (Figure 2). The reflection profiles were collected using a 40 nanosecond time window (equal to about 1.5 – 2 meters or 5 – 7 feet in the ground). Velocity analysis was done to measure depth in meters rather than time. One nanosecond in time depth equals to 5cm of actual depth. Forty reflection traces were collected per meter along transects of 50 and 25 meters in each grid. Profiles were spaced 50cm apart for greater subsurface reflection. Reflection data were processed to yield amplitude slice-maps and linear profiles. These images were used to delineate buried features of interest. Analysis of vertical profiles aids in identifying stratigraphy and the structure of possible buried features in vertical slices. A spatial analysis in planview can be made using the amplitude slice-maps.

## The GPR Method

Ground-penetrating radar data are acquired by transmitting waves of radar energy into the ground from a surface antenna, reflecting the energy off buried objects, features, or sediments and soils and then detecting the reflected waves back at the ground surface with a receiving antenna. The radar antennas are moved across the ground in predetermined spaced transects to collect data. These transects are usually collected within grids of a survey area with subsurface reflections collected along each transect.

As radar energy moves through various materials, the velocity of the waves will change depending on the physical and chemical properties of the material through which they are traveling (Conyers 2004). The amplitude of reflected waves is greater with stronger reflected signals. The stronger signals are a result of the greater contrast in electrical and magnetic properties between two materials at the interface (Conyers 2004). The travel time of the energy waves are measured in nanoseconds. Depth can be measured with the known velocities of the energy pulses and the travel time. Velocity changes with the interaction of the wave with different material composition and water saturation of the soils.

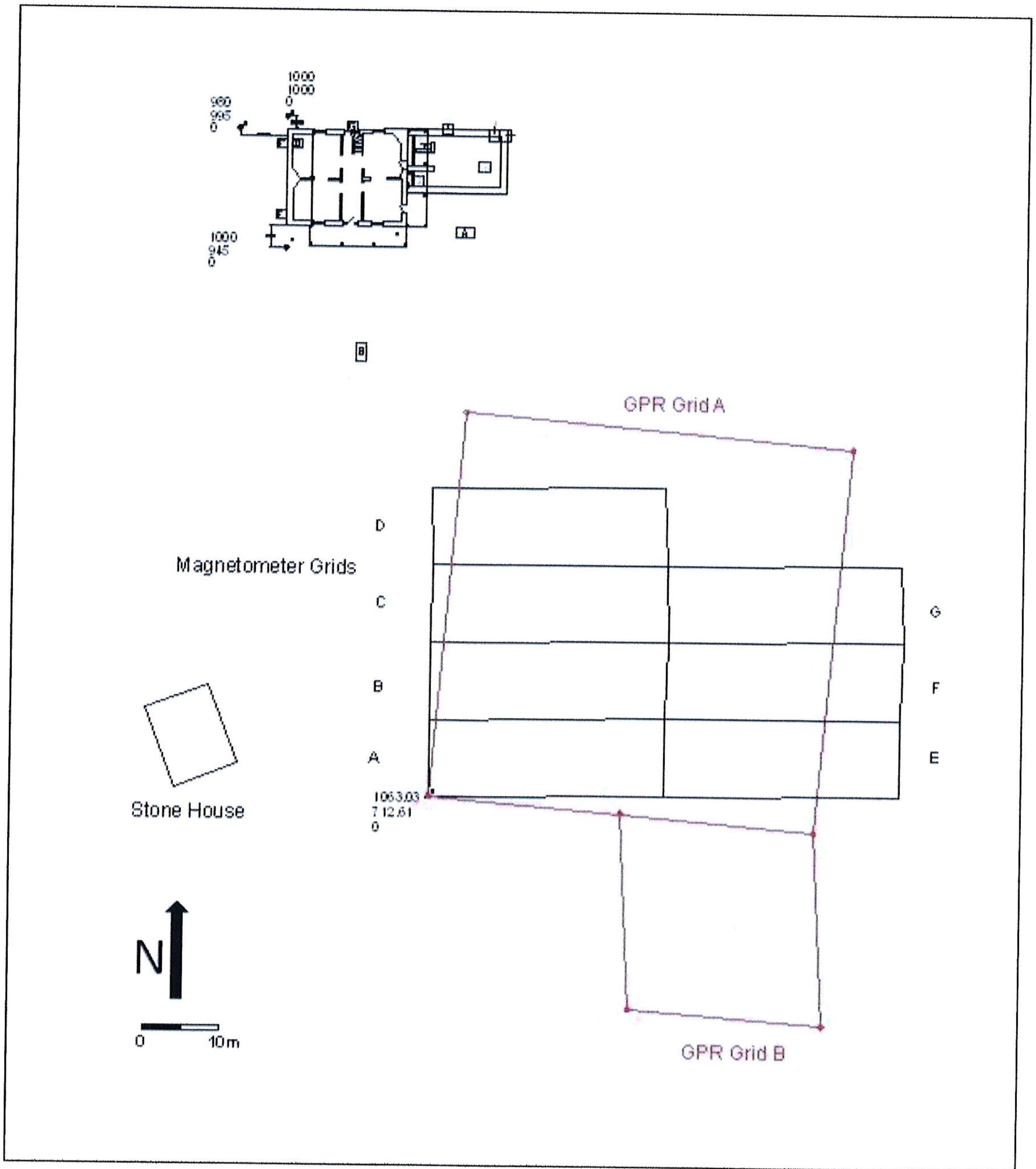


Figure 1. Location of Hollingsworth House and Stone House and the magnetometer and GPR grids. Magnetometer grids are in black and the GPR grids are in red.

The frequency of the radar energy transmitted into the ground controls the depths of penetration and amount of resolution of the radar energy. GPR antennas have varying frequency from 10 megahertz (MHz) to 1000 MHz: the lower the frequency, the deeper the radar penetration, depending on soil conditions. In this survey, a 400 MHz antenna was used, which produced readable data to approximately 25 centimeters (less than a foot). The soils and sediments of a site are a large component of the success of GPR surveys in archaeology. The best conditions for energy propagation are dry sediments and soils without an abundance of clay (Conyers 2004). Soils at the Elk Landing site were relatively well suited for a ground-penetrating radar survey.

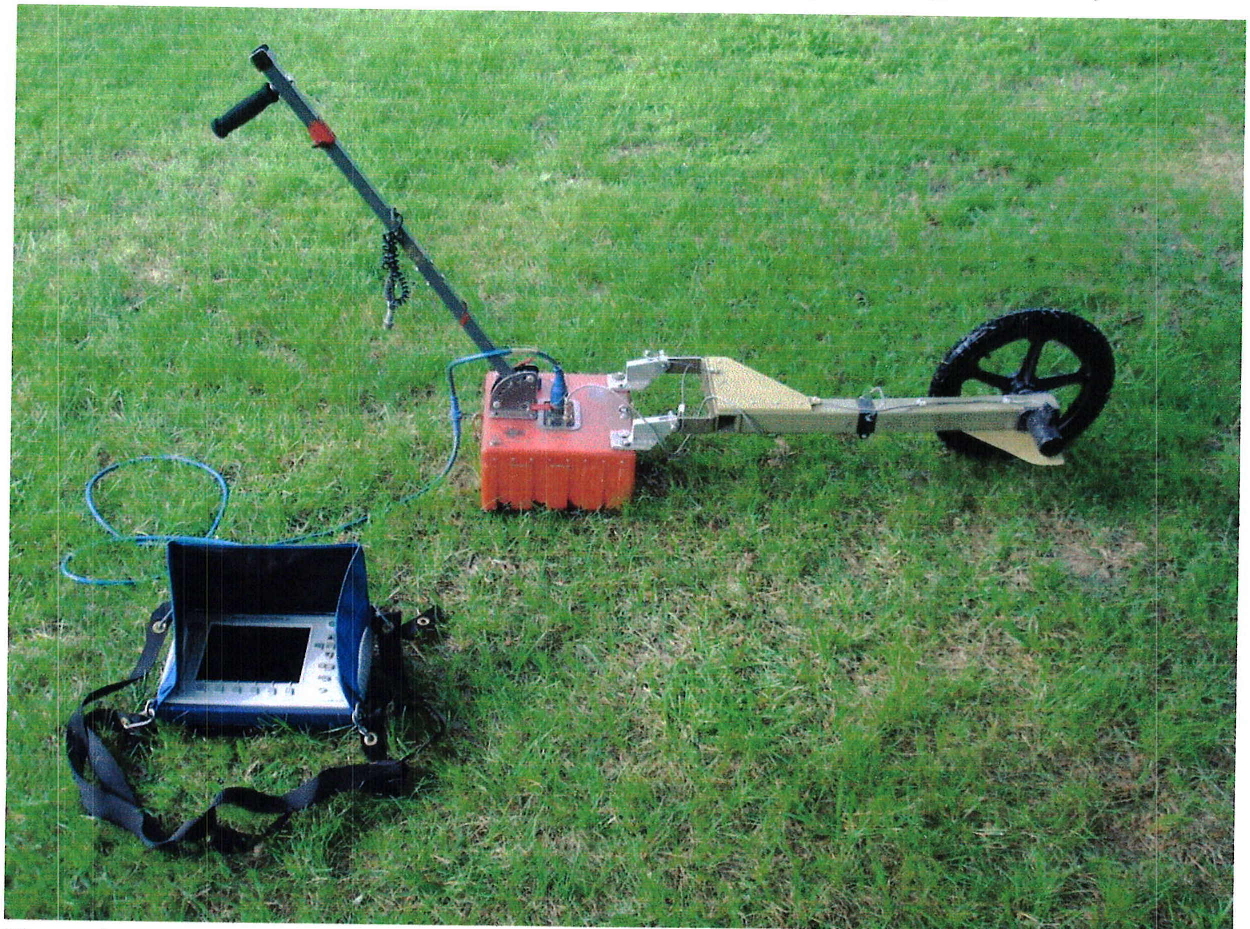

Figure 2. GSSI SIR-3000 GPR system with 400 MHz antennas and a survey wheel for distance calibration.

The velocity of the radar energy wave changes as it moves through the ground and interacts with different materials. The physical and chemical properties that the radar wave encounters also change the velocity (Conyers 2004). The distance of buried objects in the ground can be determined when the travel times of the radar energy is measured. This ability of GPR allows it to be a powerful tool in archaeological applications. When the contrast is greater in the properties of two subsurface materials, the reflected signal becomes stronger. This results in greater amplitude of reflected radar energy waves (Conyers 2004).

The data from a ground-penetrating radar survey are collected along closely spaced transects within a grid (Conyers 2004:11). Each transect consists of thousands of radar waves that reflect off of subsurface interfaces. These waves are then stacked together to create a trace creating a two-dimensional vertical profile of the transect along which the radar antenna was moved. Further two and three-dimensional images can then be created by putting these traces together.

## Data Processing Procedures

The initial data processing involved the generation of amplitude slice-maps (Conyers 2004). Amplitude slice-maps allow for the viewing of the differences in the reflected amplitudes across the grid at certain depths. These amplitudes measure the degree of physical and chemical differences in the subsurface materials. Denser buried materials, such as metal, produce strong or high amplitude reflections. These maps are created by comparing the reflected amplitudes of different raw vertical profiles. The amplitudes of all traces are compared to all the other nearby traces along a profile. This data set can then be "sliced" horizontally and displayed to show the variation of reflection amplitudes at specified depths. This allows for images that show both the amplitudes in a plan view but also does so with depths. The subsequent slice-maps allow features to become visible to the human eye.

Data are collected while moving up and back along transects, usually within a grid. The data of every other profile must then be reversed in order to have all the data processed together. After this step, we create .xyz files, creating a Cartesian coordinate grid where the data will eventually be placed. The last step is to generate the amplitude slice-maps using the Surfer 9 mapping program. These maps are a series of the x, y, and z values with x and y being the location on the surface within a grid and the z value as the reflected amplitudes at different depths in the subsurface (Conyers 2004).

The two-dimensional vertical reflection profiles are used to match the validity of any features that were seen in the amplitude slice-maps. The reflection profiles show whether radar energy is reflecting from a flat layer or material versus a single point source object. Flat layer or material is seen as a distinct horizontal band on the profile while single objects are represented as a hyperbola. These profiles can be used to confirm buried features of interest seen in the amplitude slice-maps.

## Results

### Grid A

The first grid (A) was 50m x 50m just south of the Hollingsworth House in a relatively flat and open field. Transects were spaced 50cm apart. A time window of 40ns was used and all gains were adjusted for the present soils. Within this grid there are several very interesting and distinctive features that I will address. Amplitude slice-maps were created in both 5 and 10ns slices. Only the 10ns slices will be discussed here as they show the features in better resolution. Vertical profiles were used to help identify buried features of interest and match them with those found in the amplitude slice-maps. All of the buried features of interest can be seen in two slice-maps, the 10-20ns (50-100cm) slice-map and the 20-30ns (100-150cm) slice map.

A clear linear feature, running from the SE to the NE, with two "cut-outs" can be seen in the 10-20ns and 20-30ns slice-maps (Figure 3). There may be a third "cut-out" at the edge of the NE corner but if there is a continuation of the high amplitude linear feature, it is outside the survey area. These "cut-outs" may represent an area at the edge of the earthwork where gun emplacements were located.

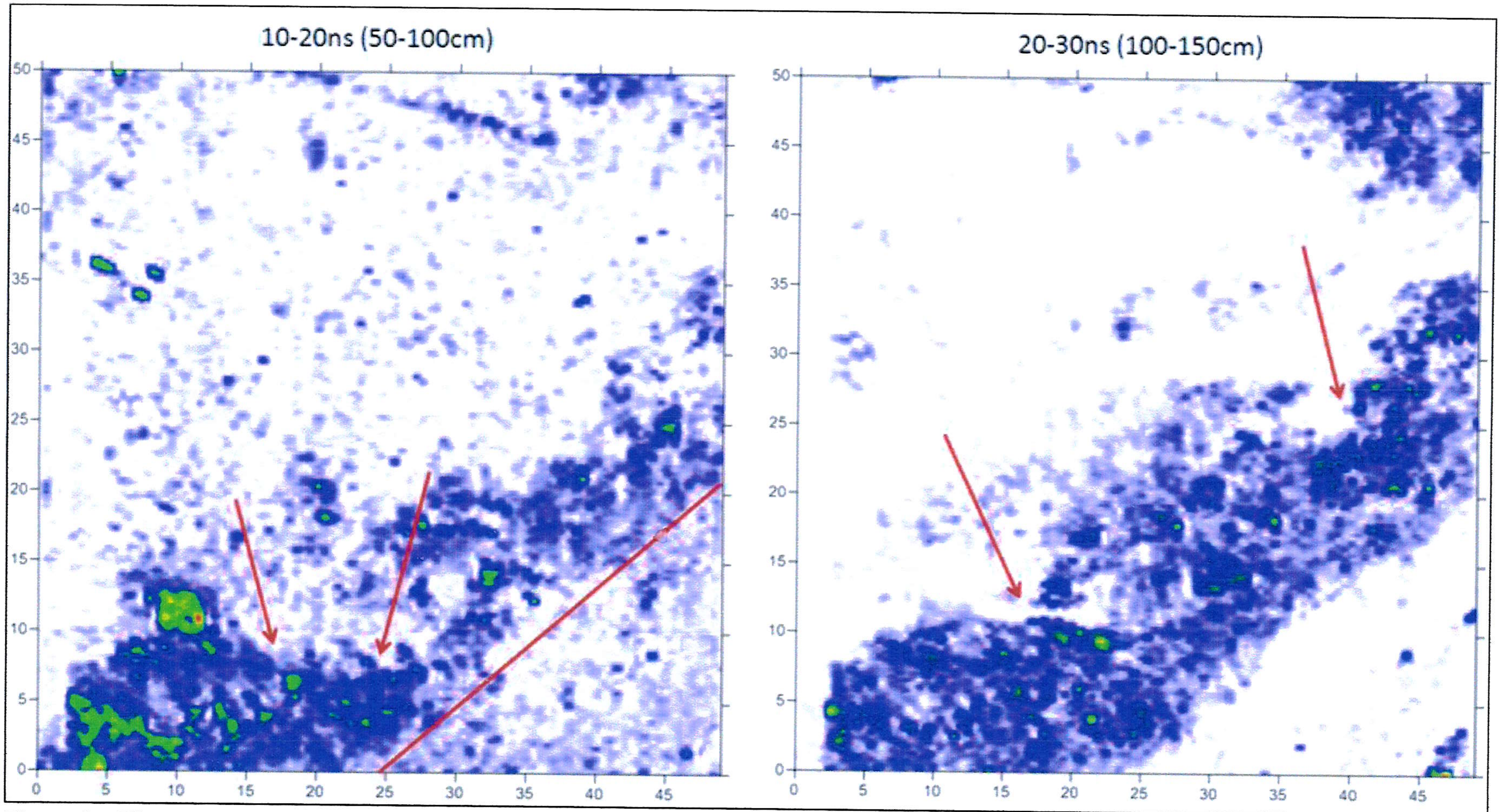


Figure 3. Slice-maps from Grid A showing the outline of the edge of the possible earthwork. Red arrows point to the areas where the embankment was cut-out. The red line in the 10-20ns slice delineates the edge of the feature.

The vertical profiles show what can't be seen in the amplitude slice-maps. In these profiles, a ditch can be seen near the north end of the grid running east/west and also what appears to be a two-tiered area of disturbed materials, most likely representing the earthwork embankment outer edge (Figure 4). The vertical profile was collected from the south to the north in the grid. This corresponds to A and B in figure 4. The ditch is of such low amplitude that it does not show up on the amplitude slice-maps, which is why it is important to look at the vertical profiles as well to get a complete picture. The ditch in the profile seems to be quite far from the earthwork (10m) and that is due to the way the data were collected as it cuts diagonally across the feature, making the ditch seem further away than it is from the earthwork. The vertical profile showing the ditch and earthwork runs through the grid at the 25.5 meter mark (Figure 5). While this is just a sample showing the ditch in one profile, it does show up in other profiles.

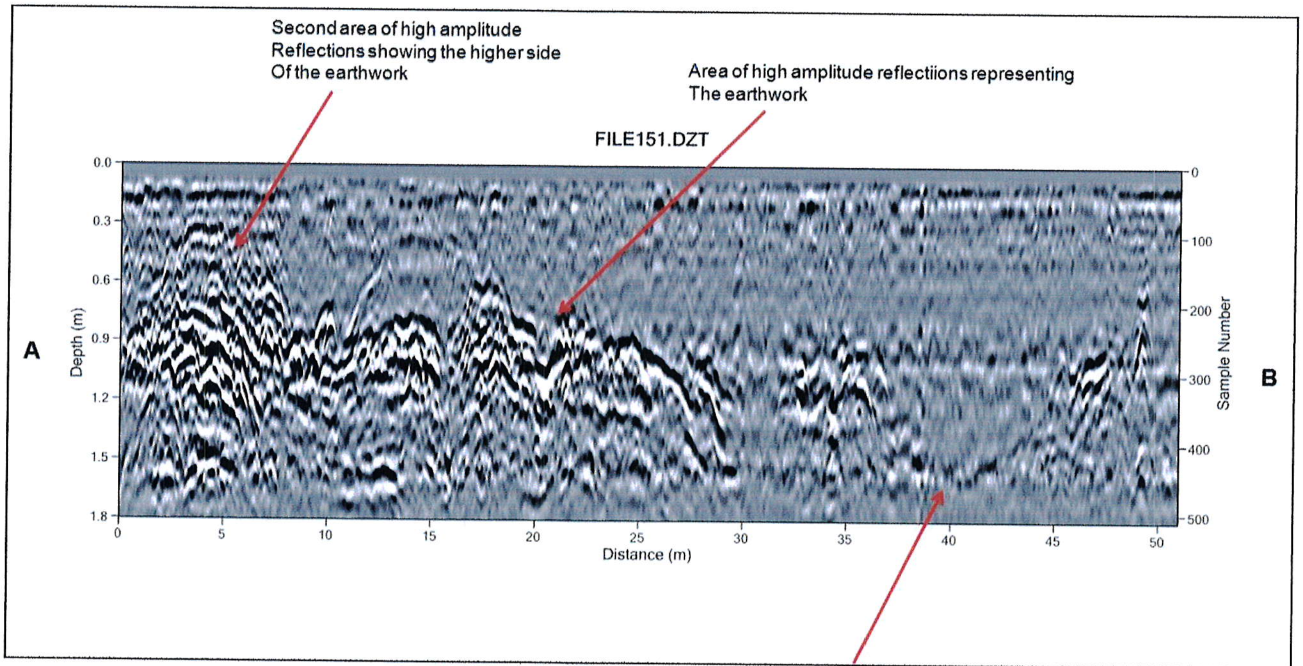


Figure 4. Vertical profile showing the three features of the possible earthwork.

In the 10-20ns slice-map and a vertical profile, there is a high amplitude square feature that is roughly 2.5m x 2.5m (Figure 6 and 7). This feature is highly reflective and can only be seen in this one slice-map, which means it is not very thick. It may be geological or anthropogenic; a large slab of stone would account for this type of amplitude reflection as would a hard packed surface created by use-wear. What this feature is and determining whether or not this is related to the earthwork or not is not possible without ground-truthing.

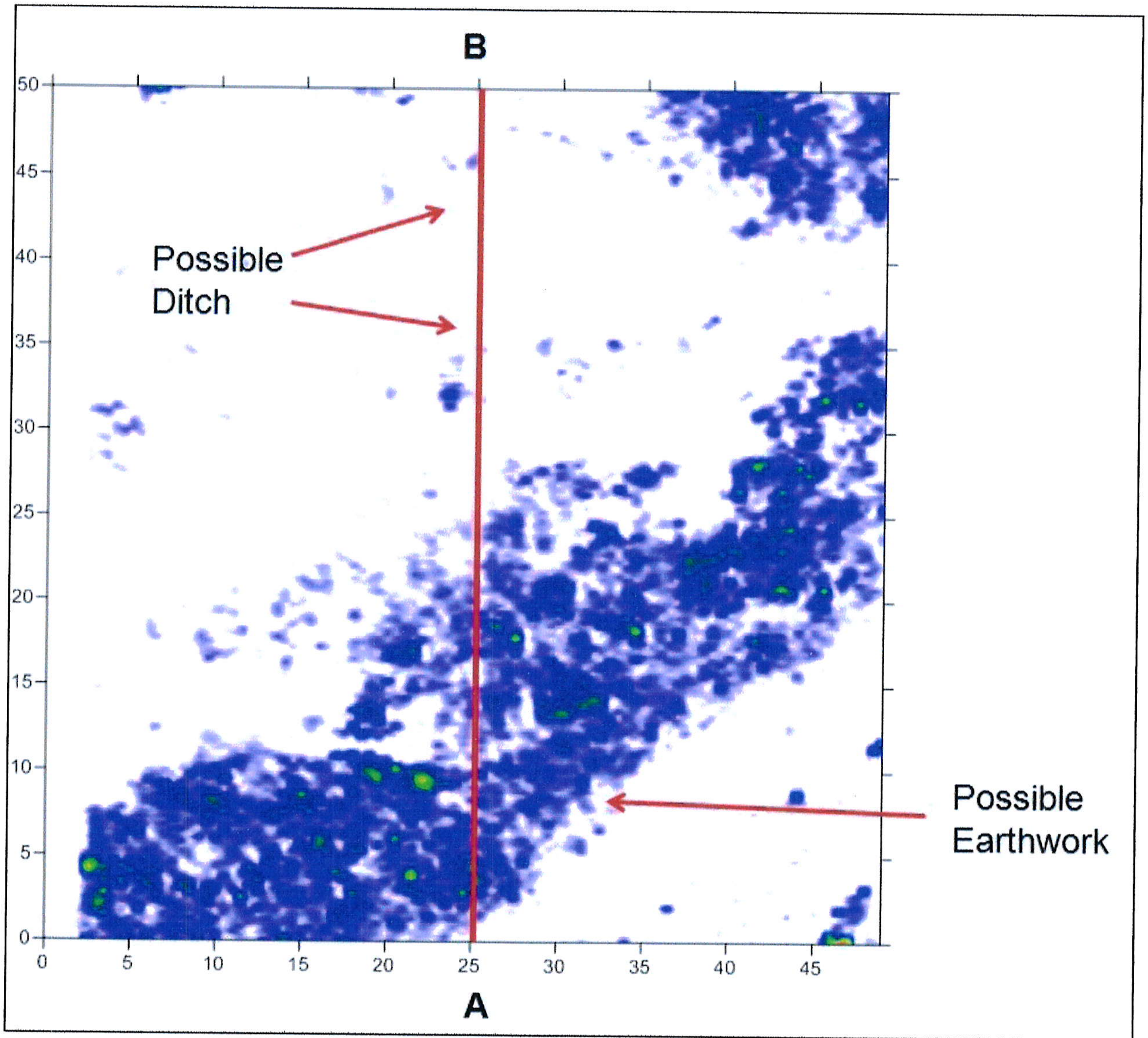


Figure 5. 20-30ns (100-150cm) slice-map showing location of possible ditch and earthwork. Red line indicates vertical profile 151 (Figure 3) where the ditch and tiered earthwork shows up best.

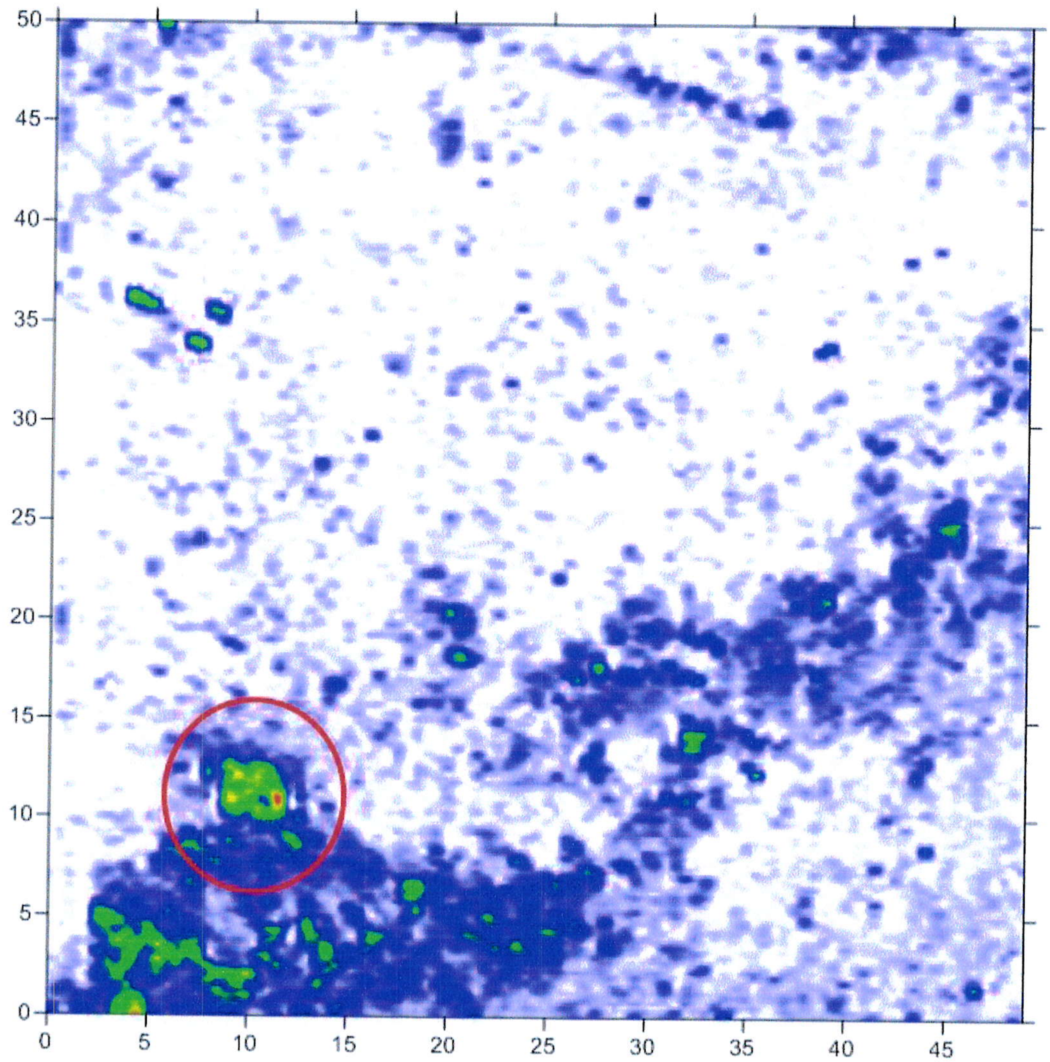


Figure 6. 10-20ns slice-map with square feature circled in red.

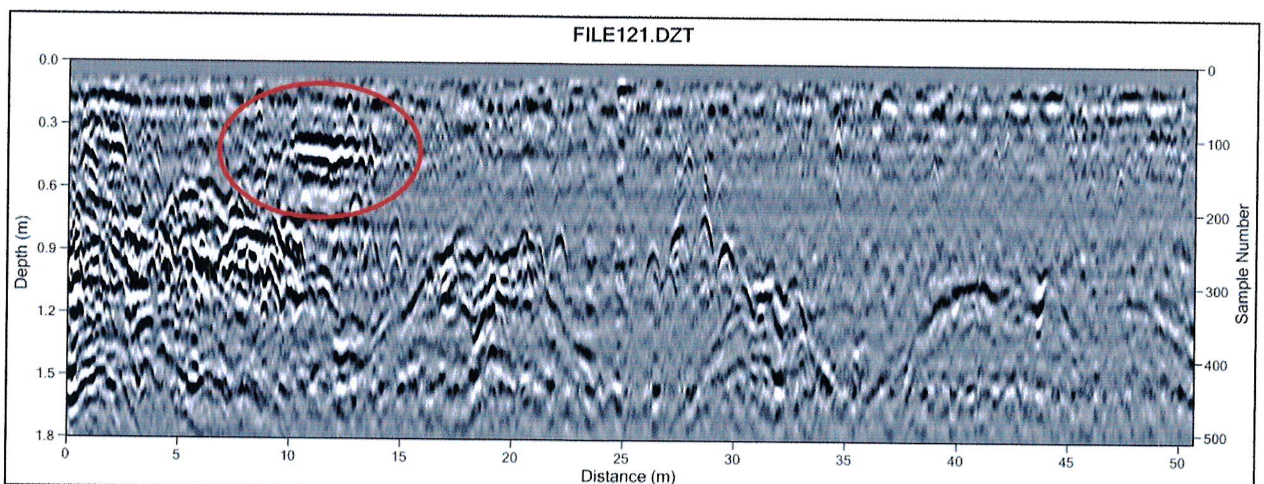


Figure 7. Vertical profile showing same feature as figure 4 circled in red.

## Grid B

The second grid (B) was 25m x 25m running south from the SE corner of grid A. Transects again were 50cm apart with a time window of 40ns. This grid was targeted for survey as a secondary location farther south and closer to the water in the search for the earthwork. While this grid did show some areas of high amplitude reflections that may or may not be related to each other or with the earthwork, it did not show any characteristics of the possible earthwork found in grid A. In the 20-30ns and 30-40ns amplitude slice-maps there are a cluster of high amplitude reflections, the causes of which remain to be determined (Figure 8). The nature of these reflections is most likely a combination of the geological aspects of the subsurface with some high amplitude reflections caused by metal objects. This grid did not show any signs of the proposed earthwork.

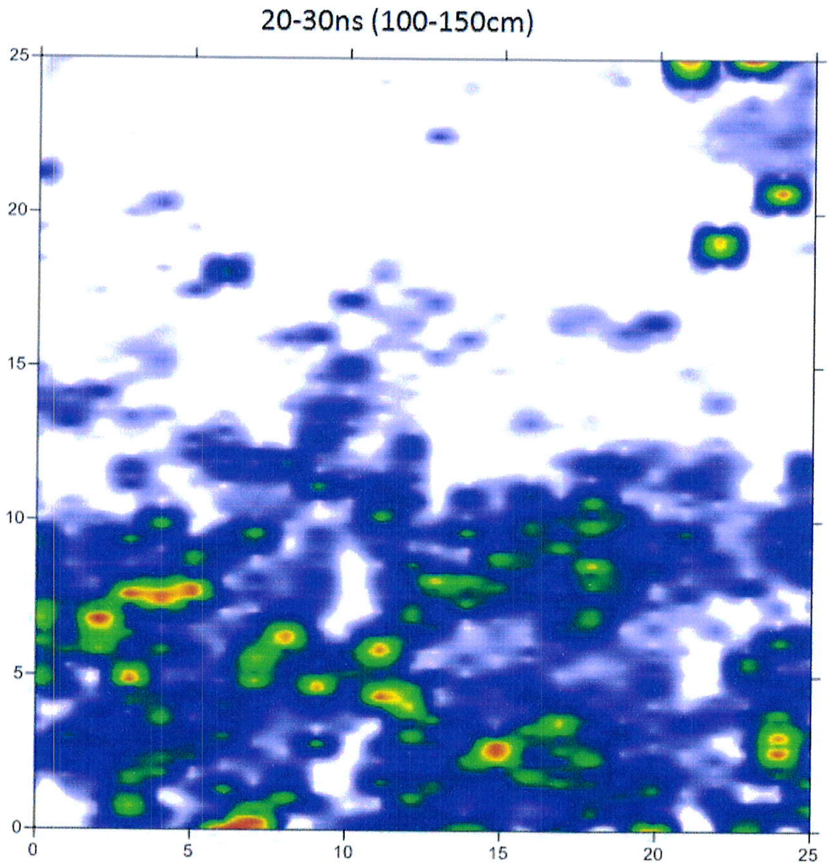


Figure 8. Amplitude slice-map showing an area of high amplitude reflections south of the earthwork feature in grid A.

**Magnetometer Results Confirmation**

The magnetometer survey conducted in August 2011 showed two linear features that may be anthropogenic (Figure 9).

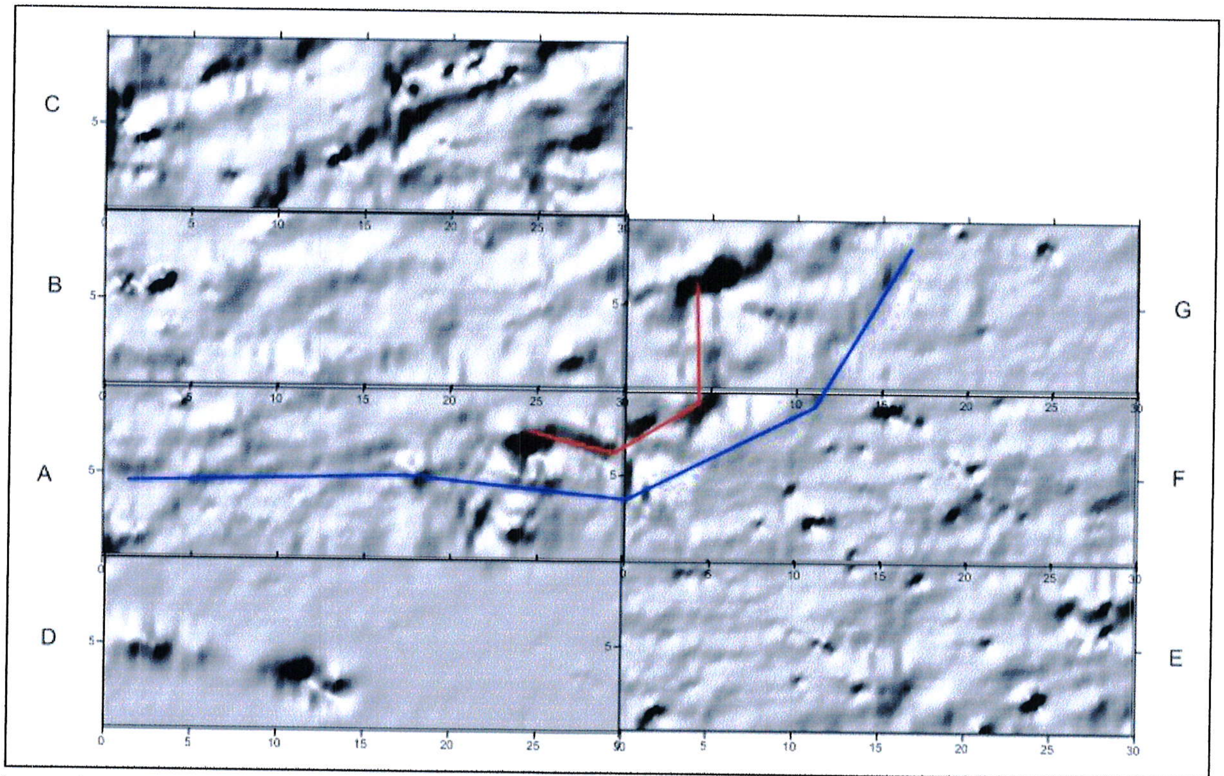

Figure 9. Magnetometer results from August 2011 showing two linear features in blue and red.

Those results are confirmed by the ground-penetrating radar survey. The GPR grid A was placed using the same datum of the magnetometer survey. Although the GPR grid is slightly skewed east of north, a clear connection can be seen between the location of the anomalies from the magnetometer survey and that of the GPR survey. The linear feature in red corresponds to the "cut-out" seen in the GPR survey (see Figure 2). The blue line corresponds to the possible embankment and the edge of the features seen in the GPR surveys.

**Conclusion**

This preliminary ground-penetrating radar survey was done as a discovery project, searching for the possible location of a War of 1812 earthwork. This survey was done ahead of the 2012 ASM Annual Archaeological Field Session.

Analysis of both reflection profiles and the three-dimensional amplitude slice-maps were used to make all interpretations. The reflection profiles proved to be valuable for identifying the shape and depth of reflections related to the possible earthwork. It is important to remember that while the reflection features support the above interpretations, they should be confirmed with some type of excavation. The years of farming and leveling of the ground most likely cut through and removed parts of the feature but some areas do remain. An additional ground-penetrating radar survey to the east and west of this grid would also help in delineating its limits.

**References**


Clark, A.

1990 *Seeing Beneath the Soil: Prospecting Methods in Archaeology.* B.T Batsford Ltd., London.

Conyers, Larry

2004 *Ground-Penetrating Radar for Archaeology.* Alta Mira Press, New York.

Conyers, Lawrence and Lucius, Jeffrey

1996 Velocity analysis in archaeological ground-penetrating radar studies. *Archaeological Prospection V (3):* 25-38.

Gaffney, C. & J. Gater

2003 *Revealing the Buried Past: Geophysics for Archaeologists.* Tempus Publishing Ltd. Gloucestershire.

Johnson, Jay K.

2006 *Remote Sensing in Archaeology.* The University of Alabama Press, Tuscaloosa.

Kvamme, Kenneth

2003 Geophysical Surveys as Landscape Archaeology. *American Antiquity* 68 (3):435-457.

Quantock, Peter C.

2011 A Partial Geophysical Survey of the Elk Landing Site (18CE60), Elkton, MD. Archaeological Society of the Northern Chesapeake, Archeological Society of Maryland.