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2013

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Rodgers, Michael D. and Richards, Paul L., "Use of Ground Penetrating Radar to identify the presence and orientation of Graves in St. Brigitts Cemetery, Bergen New York" (2013). *Geotechnical Survey Reports*. 2.

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# **Use of Ground Penetrating Radar to identify the presence and orientation of Graves in St. Brigitts Cemetery, Bergen New York**

By

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## **INTRODUCTION**

The Diocese of St. Brigitts Church in Leroy and Bergen New York are planning to make improvements to St. Brigitts cemetery located at the intersection of Munger Rd and Rte 33 in Bergen, New York. These improvements include the refurbishment of existing head stones, the replacement of headstones where none currently exists, and the identification of land areas where new graves may be located. Like many nineteenth century cemeteries in the area, St. Brigitt cemetery has a long history of burial, and internment procedures have not been consistent over time. Originally, caskets were oriented facing the top of the hill, which is the focal point of the cemetery and the location of a beautiful crucifix. Since then, some caskets have been buried in the opposite direction, thus there is some uncertainty as to where each casket is actually buried. The cemetery is laid out as a series of rectangular and trapezoidal plots around a hill (Figure 1). These plots range in size from 150 to 615 square feet and are located west of the top of the hill. Families and their relatives are often housed within their own plots. As these plots are not completely filled, there is a need to know exactly where the caskets are buried so that descendants may elect to be buried next to their ancestors. The purpose of this study is to determine the location of all caskets buried at the site and their approximate orientation relative to the headstone. This orientation can be either East of the headstone, in which the casket faces the top of the hill, or West of the headstone in which the casket is facing away from the top of the hill.

## **METHODOLOGY**

Ground Penetrating Radar (GPR) was employed to conduct this study because it has been successfully used for identifying unmarked graves in several previous studies (Conyers, 2006; Fiedler et al, 2009; Ruffell et al, 2009; Doolittle and Bellantoni, 2010). GPR is a non-invasive geophysical technique where pulses of electromagnetic radiation in the microwave band are beamed into the ground. When this radiation reaches a dielectric boundary, any interface where the dielectric characteristics of the materials change appreciably, some of this energy will be reflected. A receiver in the instrument then determines the distance to the boundary based on the time elapsed. By evaluating the spatial distribution of these boundaries, it is possible to identify the location of buried objects, voids and the stratigraphic structure of soil and bedrock. In this application here, we

are using it to confirm whether or not a buried casket is present. Interpretation was carried out at the site when the data was collected so that supporting field information, such as microtopography, the location of the headstone, the direction the headstone engraving is facing, and the engraving text could be incorporated in the analysis. All anomalies likely to be caskets were marked in the field once they were located.

The GPR profiler used in this investigation was a SIR-3000 manufactured by GSSI Inc. A 400 megahertz antenna was used to collect all data. This antenna has a 16 bit resolution and is capable of profiling 3 meters under ideal conditions. A dielectric constant of 8 was assumed to estimate depth from signal response time. This value was determined by iterative estimation in order to reproduce the average depth of the top of a known casket. According to the cemetery caretaker, three feet is the average depth of the top of a casket. Longitudinal distance was evaluated with a survey wheel calibrated to a tape measure. Profiles were conducted in transects East and West of each headstone. Figures 2-8 presents the location of all transects conducted in this study. Interpretations were made by examining the response profile in the field and considering the location, orientation and text on each headstone. Select data was brought back to the lab and processed using RADAN Data Analyzer for Windows version 7.0.2.5. Time zero was adjusted to remove data above the air ground interface. Background signal was eliminated using a mathematical filter. A variety of gains were employed to extract the profile most conducive to interpretation. This was conducted to confirm the interpretation already made in the field.

A typical casket is a box made up of wood, metal or concrete. As the box contains air, the sides, top and bottom of the casket reflect RADAR signals strongly. This is because the dielectric contrast between the air and soil are much different (16 versus 1). The casket building material may also play a role in the susceptibility for a signal return. As the antenna is dragged over the site, signals will be returned at different angles creating an upside down U shaped feature in the GPR profile. These features are commonly called “Halos” in the literature. Soil containing no casket will likely contain signal returns that create a “layer-cake profile”, which is caused by radar being reflected from soil and clay horizons. Rocks and roots may also be present as small halos in these profiles.

## **RESULTS**

A typical profile of soil containing caskets is presented in Figure 9. The colors in the profile represent the intensity of the returning radar signal, and vary from low to high in order of the following colors: Dark grey, grey, light grey, green, red and white. Layers of high return intensity (green, red, white) represent changes in dielectric constant, wet or highly conductive layers. Caskets appear as large halos located 0.7 to 1.7 meters depth. Sometimes multiple halos were observed. Older grave sites did not always have large halos associated with them. These however did contain large signal responses at the same depth where halos are located in. Figures 10-12 present responses from soil that does not contain caskets. The profile in Figure 11 was taken next to a tree which had large roots exposed at the surface. Note the small halos at the top of the profile caused by the roots.

Figure 12 was taken through the unpaved road located in the middle of the cemetery. Note the bright, horizontal signal located at the top of the profile. We interpret this to be due to compaction at the top of the profile. This changed the bulk density of the soil enough to cause a dielectric contrast at the top of the profile. Foot and vehicular traffic clearly has an impact on the response of the signal.

## **DISCUSSION**

The differences in the GPR response between soil containing caskets and soil not containing caskets was pronounced. Large halos are almost always associated in close proximity to headstones. This made it easy to distinguish whether a casket was present. In most cases, associated field information (presence of a shallow depression, and or the orientation of text on the headstone), confirmed the side with which the casket was buried. For example if the text was located on the east side of the headstone, the anomaly (and casket) was buried to the west. There were profiles with large halos located in places where headstones are not present. As they occur in the same corridor as rows with headstones we interpret these to be unmarked graves. These appear to be sites where headstones were moved or removed historically. There also appeared to be a few headstones that have no GPR evidence for a buried casket. At the top of the hill, two of the headstones had caskets that were buried to the south of the headstone, in contrast to all other headstones in the cemetery. This finding makes sense because the people buried there are facing the Crucifix at the top of the hill. The orientation of text on the monument confirms this. Based on the work conducted, there are 432 anomalies that are likely to contain buried caskets. Whether these are single, double or two caskets buried close together are not always possible to determine, because of the variety of radar responses that can be returned. However, profiles with multiple large halos tended to be associated with headstones that indicate two people are buried there.

## **CONCLUSIONS**

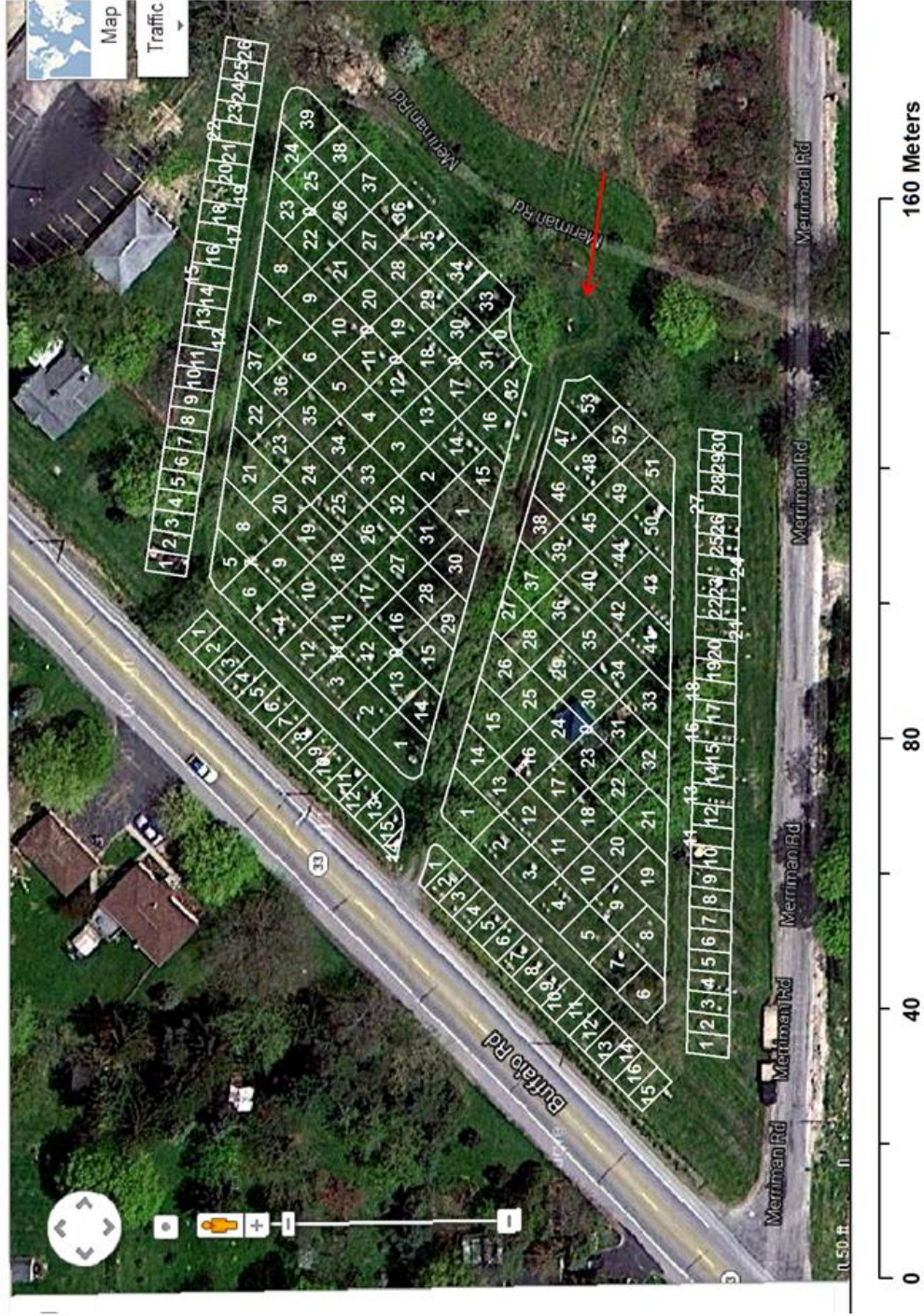
Based on this geophysical survey, there are 432 sites in the cemetery where caskets are buried. These sites have all been marked for the Diocese. There are occurrences of graves without headstones and headstones without graves. Quite a few of the plots still have room for future internments.

## **REFERENCES CITED**

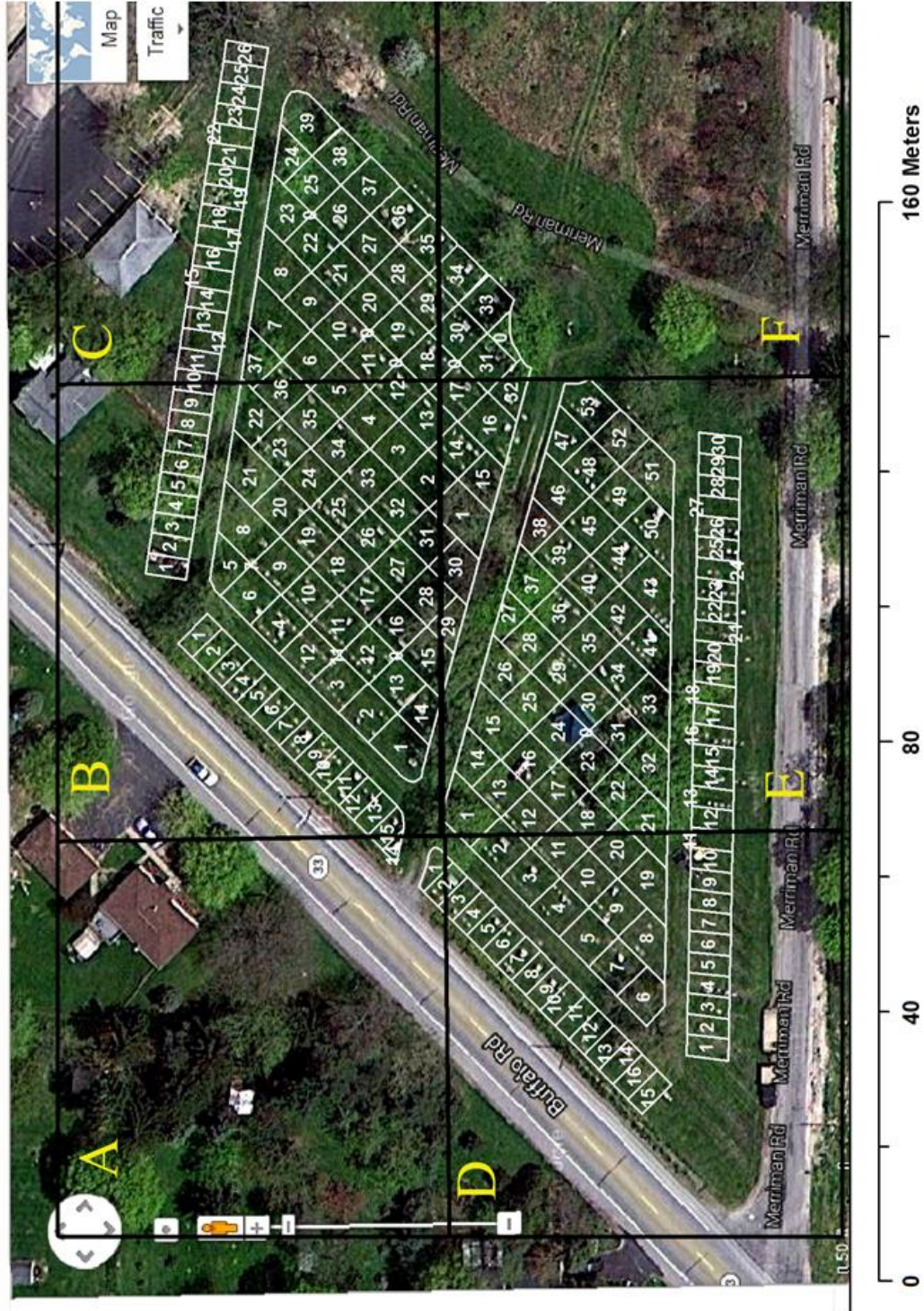
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**Figure 1** Map of burial plots at cemetery. The red arrow is the crucifix at the hilltop.

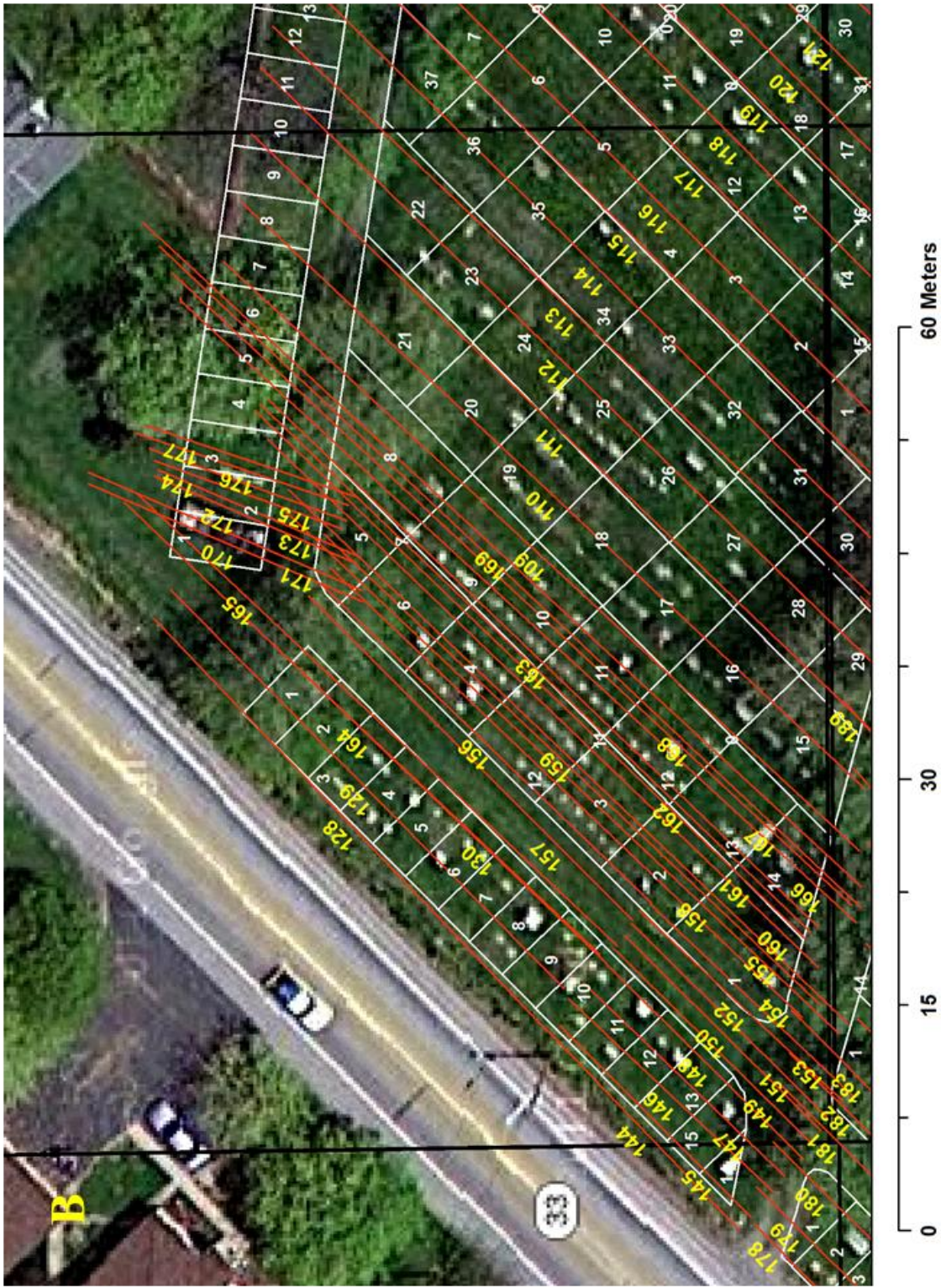


**Figure 2** Location of quadrant maps (A-G) that contain the location of GPR transects. A transect was conducted East and West of each row of headstones to determine the direction of the casket



**Figure 3** Map of GPR transects (red lines, yellow ID numbers) in quadrant A.





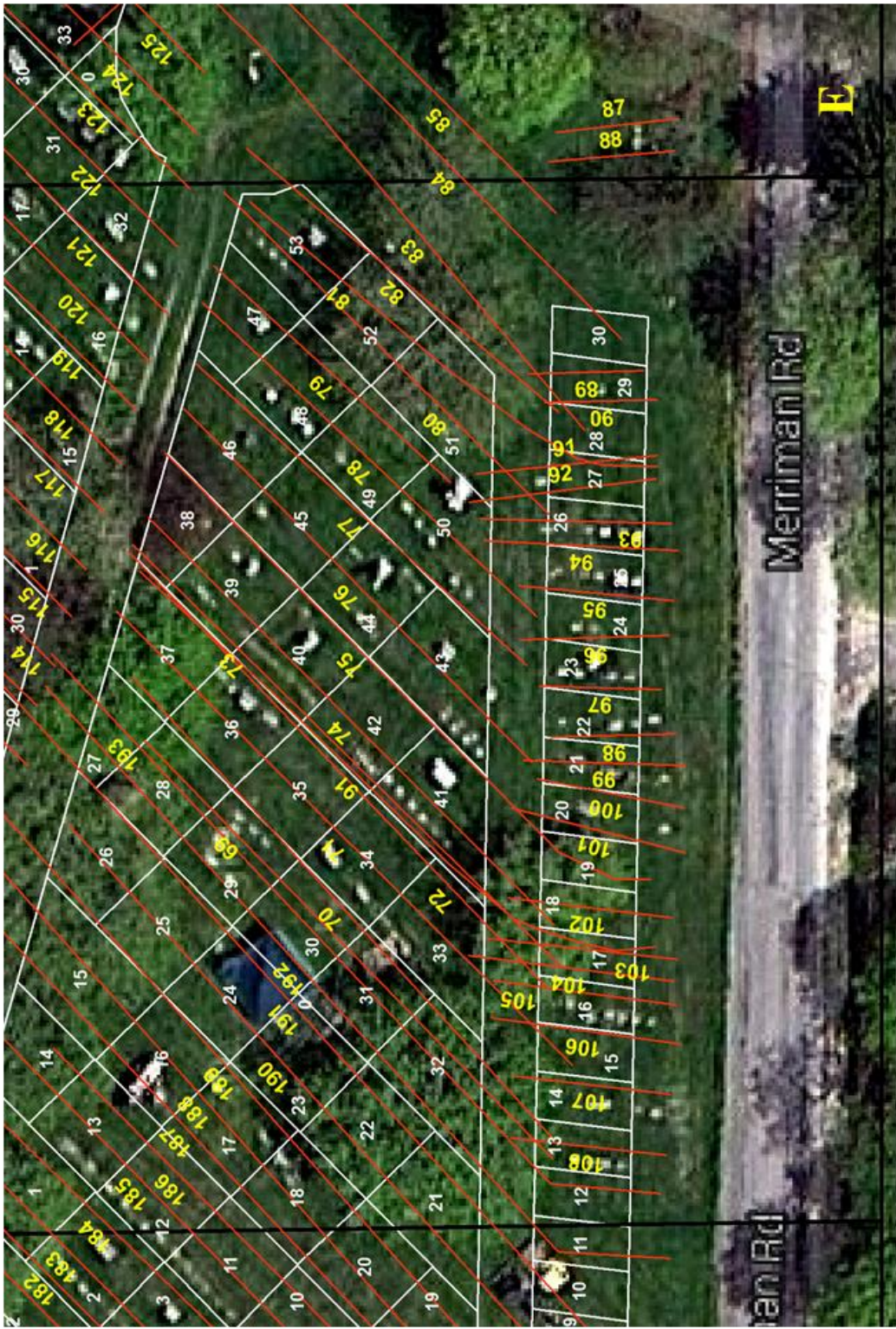
**Figure 4** Map of GPR transects (red lines, yellow ID numbers) in quadrant B.



**Figure 5** Map of GPR transects (red lines, yellow ID numbers) in quadrant C.



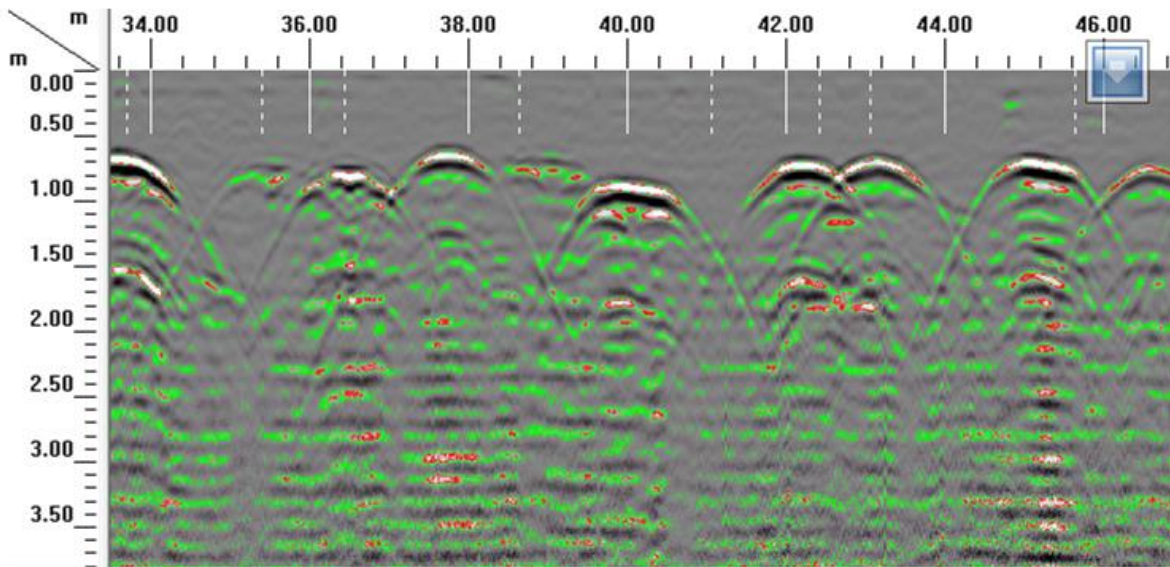
**Figure 6** Map of GPR transects (red lines, yellow ID numbers) in quadrant D.



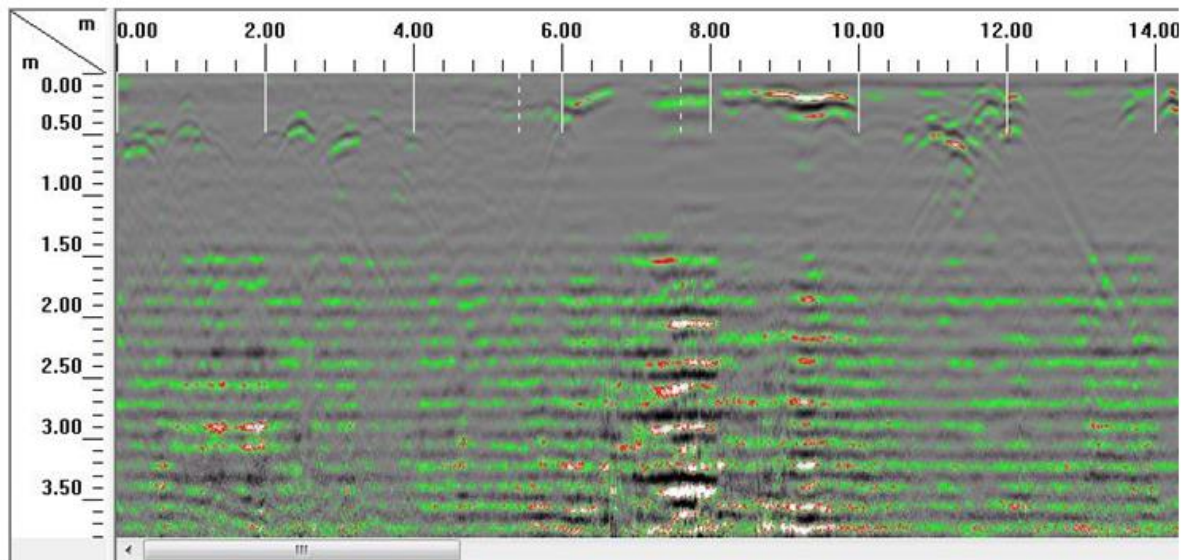
**Figure 7** Map of GPR transects (red lines, yellow ID numbers) in quadrant E.



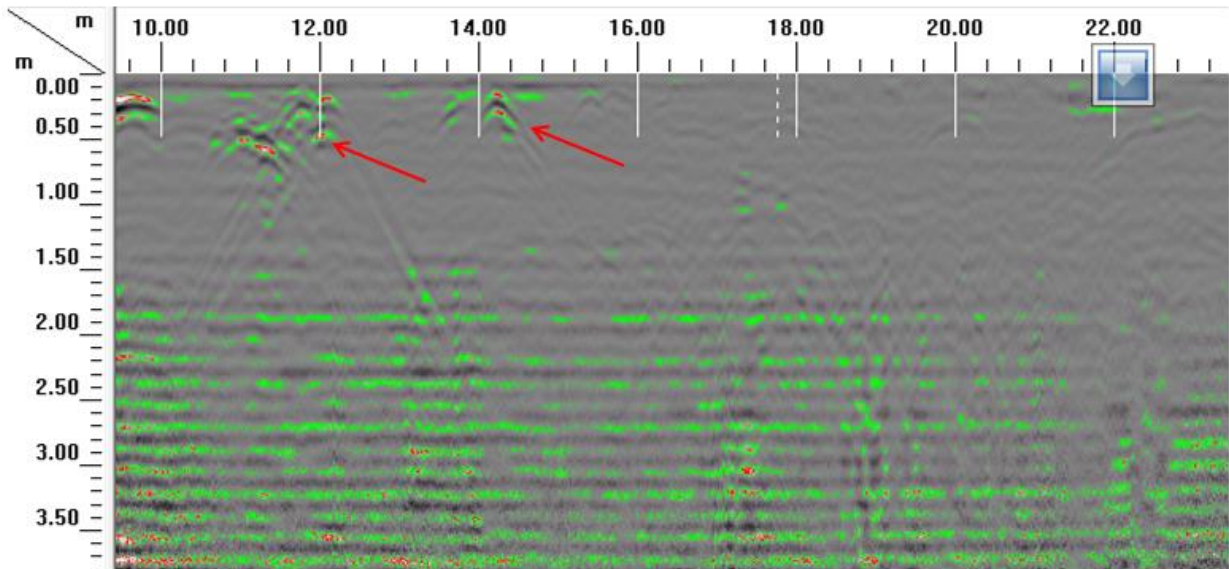
**Figure 8** Map of GPR transects (red lines, yellow ID numbers) in quadrant F.



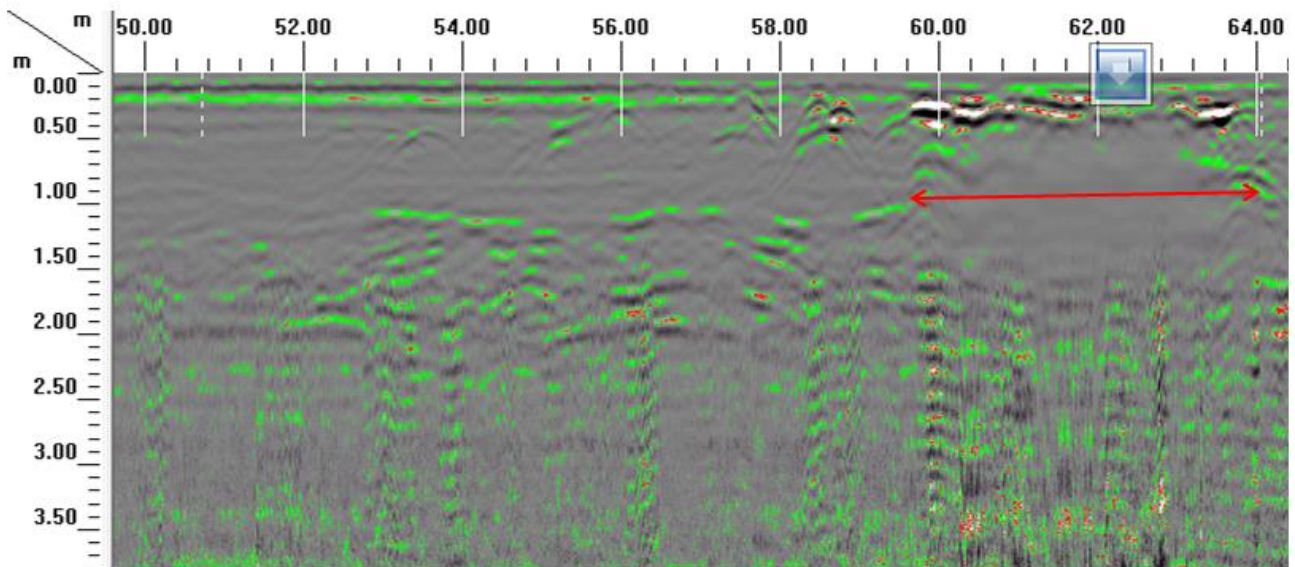
**Figure 9** GPR profile of a transect containing halos interpreted to be caskets. The white vertical dotted lines are headstones. Note how the apex of many of the halos coincides with a headstone.



**Figure 10** GPR profile of a transect containing no graves. Smaller halos are evident near the top of the profile. These are interpreted to be rocks.



**Figure 11** GPR profile of a transect containing small halos interpreted as roots (red arrows).



**Figure 12** GPR profile of a transect containing the driveway leading to the top of the hill (red arrow).