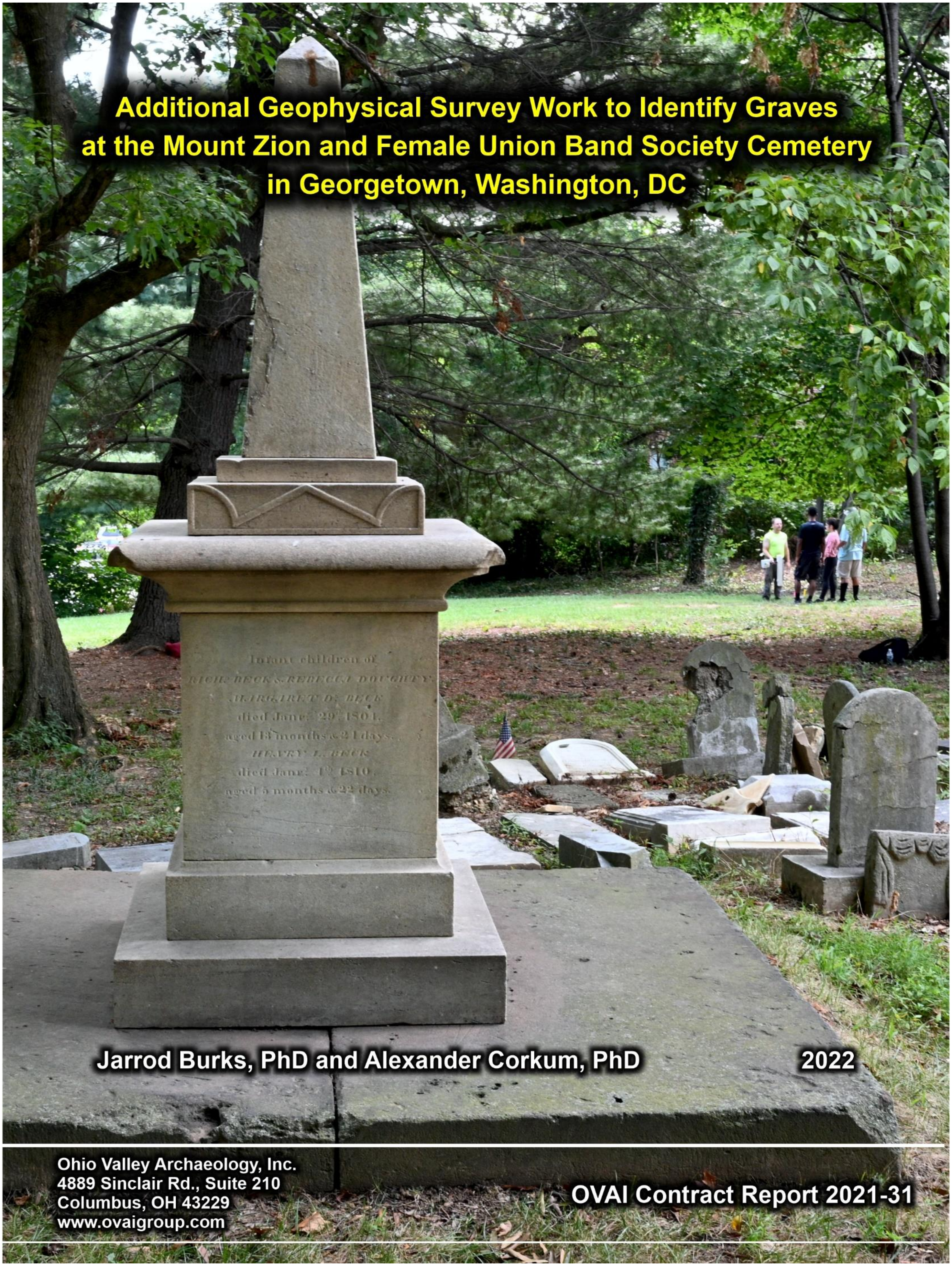
Additional Geophysical Survey Work to Identify Graves at the Mount Zion and Female Union Band Society Cemetery in Georgetown, Washington, DC



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2022

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OVAI Contract Report 2021-31

On the cover: A view of the Mount Zion Cemetery with magnetometer survey instruction in background, August 2021. (photo credit: Alexander Corkum)

OVAI Contract Report #2021-31

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Executive Summary

In mid-August of 2021, Ohio Valley Archaeology, Inc. conducted additional geophysical survey at the Mount Zion-Female Union Band Cemetery in the neighborhood of Georgetown, Washington, D.C. This new survey represents an expansion of both scope and methodology over work conducted in 2018. The new work was completed on behalf of the Mount Zion-Female Union Band Society, along with the National Trust for Historic Preservation, as part of a community outreach program to engage local college students in the heritage of the cemetery and the methods used to document it.

The geophysical survey work included magnetometry, ground penetrating radar, and electromagnetic conductivity covering an area of 1.2 acres of the cemetery. The magnetic and radar surveys extended the boundaries of the original area surveyed in 2018, while the conductivity survey is a new technique that focused on the flatter, previously surveyed ground of the cemetery. Additionally, the team conducted photogrammetry work to produce three-dimensional models of 10 headstones standing or laying in the cemetery.

This new survey work identified an additional 24 graves over the 116 which had been previously detected. Furthermore, clear evidence of rows of graves was found in the eastern half of the cemetery, and these indications appear to extend down the slope at the cemetery's northern edge. Finally, a real time kinematic global navigation satellite system (RTK GNSS) was used to more accurately tie the existing local grid system into a geographic coordinate system. The new mapping results have been integrated into a geographic information system (GIS) including all the results and cemetery features mapped to date.

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Acknowledgements

This trip to Georgetown to work on the Mount Zion and Female Union Band Cemetery was funded by a joint venture between the Mount Zion and Female Union Band Society and the National Trust for Historic Preservation's Hope Crew initiative. Many thanks to Lisa Fager, Executive Director of the Mount Zion and Female Union Band Society, for the work of her team in preserving, protecting, and promoting the cemetery as a sacred and historic place. We appreciate all the great historical information Lisa provided while we were on site!

The Ohio Valley Archaeology, Inc. field crew included Jarrod Burks and Alex Corkum. Jarrod ran the magnetic and radar surveys while Alex conducted the electromagnetic conductivity survey. The OVAI team was joined in the field by students participating in the Hope Crew program with the National Trust. They bravely worked through some high heat and humidity conditions during the week of field work. Many thanks to Molly Baker and Milan Jordan of the National Trust Hope Crew team for their efforts to save important historic sites all across the United States!

Introduction

Cemeteries serve a utilitarian function for a community, but they are also places of remembrance, touchstones for families to reconnect with those they have lost. The relationship a community has with its cemeteries is shaped by a variety of both internal and external factors. As communities grow and change, the services a cemetery provides may no longer align with the community surrounding it and the cemetery can become marginalized and forgotten. If left too long without care, cemeteries become overgrown, their monuments displaced or destroyed, and eventually the locations of graves that were once marked become "lost." Older cemeteries are also important historical resources, representing a tangible link to a community's story (see e.g., Baugher and Veit 2014; Sloane 1991).

The Mount Zion/ Female Union Band Cemetery has had a storied past, representing two distinct communities in the heart of Georgetown (Figures 1 and 2). With the vast majority of the grave markers missing or displaced, archaeological geophysics provides a valuable method to restore some of the spatial context of this historic cemetery in a non-invasive manner.

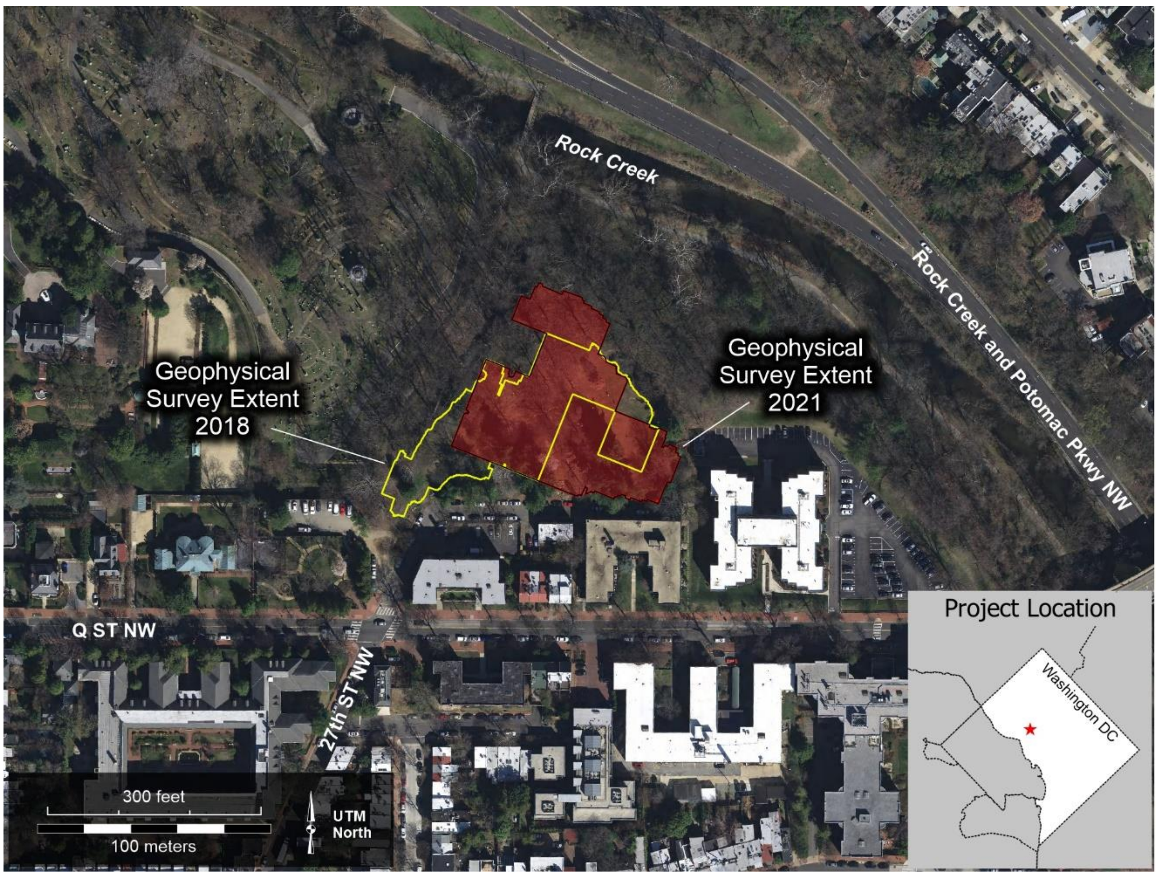


Figure 1. Project area location map on a 2018 aerial photograph.

In mid-August of 2021, Ohio Valley Archaeology, Inc. (OVAI) conducted additional geophysical survey work at the Mount Zion/Female Union Band Society Cemetery. This survey expanded upon the previous geophysical survey conducted in August of 2018 (Burks and Corkum 2019). These surveys are part of a larger effort to help determine the positions of unmarked graves below ground. The work was performed on behalf of the Mount Zion/Female Union Band Society, as part of their efforts to clean up and restore the cemetery. Additional funding came through the National Trust for Historic Preservation's Hope Crew program, which provided a small number of local college students an opportunity to learn about geophysics and photogrammetry as they are applied in cemetery settings. The group started out with some classroom time at the beginning of the week. Then the team (OVAI+Hope Crew) moved out to the cemetery where the Hope Crew students participated in all aspects of the geophysical survey data collection and photogrammetry work.

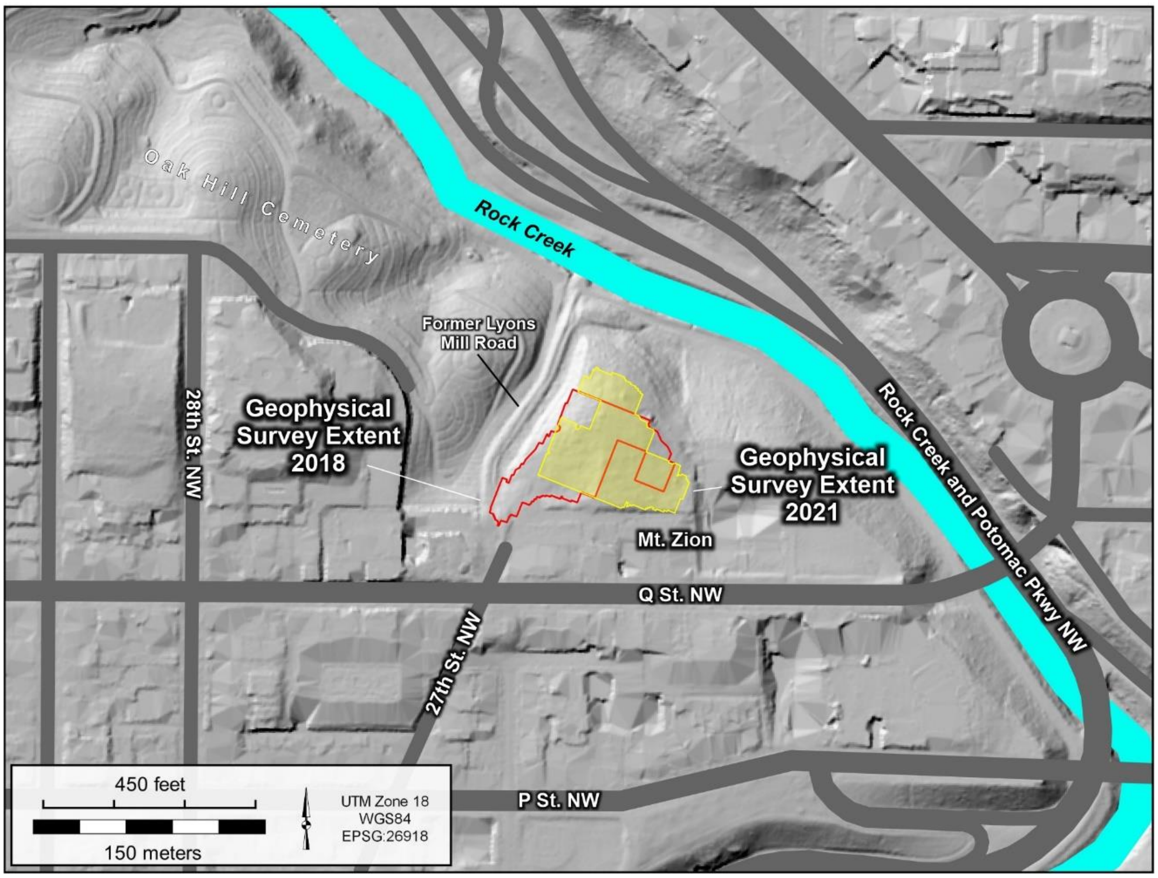


Figure 2. Geophysical survey area on a digital surface model of the area (surface model based on the 2018 LiDAR data available at http://opendata.dc.gov).

The new geophysical survey work included magnetometry, ground penetrating radar, and electromagnetic conductivity surveys covering an area of 1.2 acres within the cemetery (Figure 3). This new survey work identified an additional 24 graves over the 116 previously detected by Burks and Corkum in 2018 (see Burks and Corkum 2019). These new results represent an expansion of both scope and methodology over the work conducted in 2018. The original survey work focused on an area of the cemetery covering about 1.1 acres, including the central mowed portion, as well as some ground toward the back (north side) of the cemetery where brush was cleared to allow for the survey work. The new survey work extends the limits of the survey to the north and east, covers an area with clusters of monuments lying on the ground, and adds new electromagnetic data to the central mowed areas overlapping with the original survey (Figures 1 and 3).

The following report is organized in several sections. It begins with this brief introduction and a description of previous survey results. Next, a methods section discusses geophysical survey instruments, specifically focusing on the new technique employed on this visit—electromagnetic conductivity. This is followed by a presentation of the new geophysical survey results, highlighting the geophysical anomalies of interest that were detected. A final summary and recommendation section pulls together the findings and provides suggestions for next steps. Additional maps of the data and data interpretations are provided in the appendices at the end of this report. Results of the photogrammetry work also appear in the appendices.

Figure 3. Project area location map showing the new geophysical survey extents in relation to the 2018 survey.

Previous Geophysical Survey Work: A Summary

The geophysical survey work conducted in August of 2021 builds upon the previous geophysical surveys conducted in 2018. During that survey, a total of 1.08 acres of magnetic data and 0.95 acres of GPR data were collected (Figure 4). This work focused on areas that were clear of obstructions and most likely to yield the best quality data. This was important for the ground penetrating radar technique since it requires close contact with the ground and is therefore particularly susceptible to thick ground cover and obstructions.

Figure 4. Map of the survey area from 2018 and the site grid on an April 2015 aerial photograph from Google Earth.

In the 2018 work, a total of 116 possible graves were detected in the magnetic and radar data collected across about 1.1 acres of the cemetery (Figure 5). In the radar data, most of the detected graves (60) were identified as very subtle features in the approximately 1000 radar profiles examined from the site. Another 29 possible/probable graves were spotted in the radar amplitude slice maps (horizontal plan maps created using the radar profiles). It is not uncommon for graves to be visible in profile but not in plan view. Finding so few graves in the slice maps often happens in environments with numerous trees, where the tree roots can look very similar to the radar signatures of graves. Variation in soils and soil moisture—especially increased moisture from recent rains—also affect grave detectability in radar data.

One very notable discovery in the radar slice maps (and the magnetic data) was a large iron object, perhaps a metallic container containing a coffin, that is buried just a foot beneath the surface. While this is quite shallow for a coffin, the tops of containers such as vaults often are not buried that deeply. Furthermore, grading in the mid-late 1970s could have removed surface soils in this area, creating a new ground surface that is much closer to the tops of the burials in this area. If the coffin handle found during the 2018 survey was brought to the surface by this grading, it is possible that the grading in the 1970s did extensive damage to at least portions of the cemetery.

Fewer graves were found in the 2018 magnetic data, but those that were detected created large, distinctive anomalies. In some cases, the magnetometer detected iron within the grave shaft—perhaps an iron casket or a larger burial container/vault. Also, at least 31 magnetic anomalies appear to correspond to the subsurface remains of iron posts that likely are associated with burial plot boundary markers (i.e., rails) or fences. Many occur in clusters that show us the locations of the burial plots and the approximate alignments of the rows that the plots are located within.

Rows of anomalies were detected in several areas of the cemetery, and these can be used to more extensively estimate the locations of rows in areas of the cemetery lacking anomalies or surface markers. The map in Figure 5 is the geophysical interpretation map with two areas of projected rows. The green projected rows are located in the Female Union Band portion of the cemetery. Their alignment is based on the existing graves and plot markers located in this area—especially the bases of iron pipes that once supported the rails surrounding burial plots that were detected in the magnetic survey. The purple rows show a notably different alignment on the east side of the cemetery, though this interpretation was somewhat tenuous in 2018 and based primarily on subtle radar features. As we show below, the new electromagnetic conductivity data clearly support this difference in alignment between the east and west sides of the cemetery.

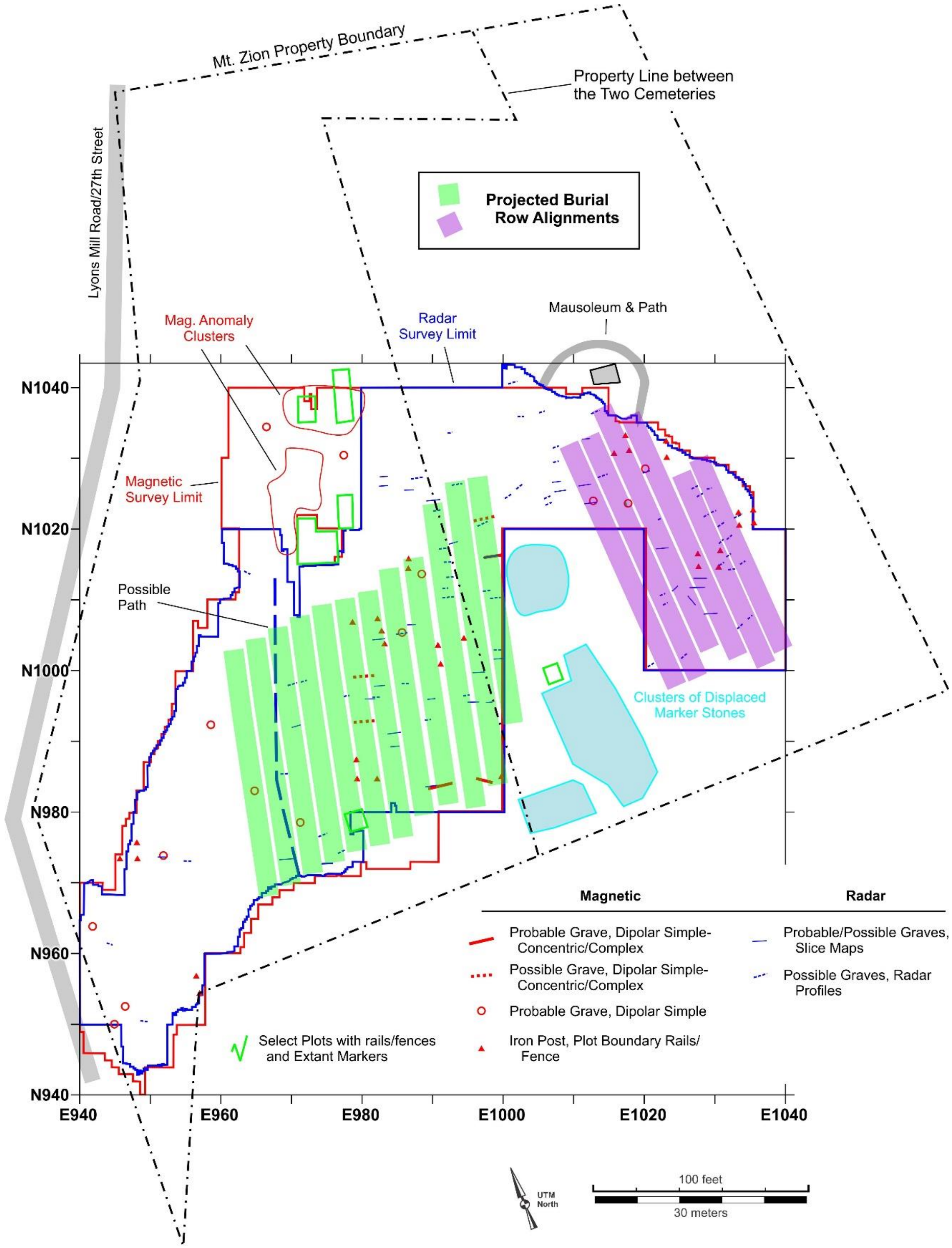


Figure 5. Geophysical survey results from 2018 survey with projected burial row alignments.

Methods

Geophysical survey instruments are commonly used around the world by archaeologists to find buried features, such as graves. Most things of archaeological interest are no more than a few feet below the surface. At these depths, the instruments detect archaeological features and graves by measuring subtle changes caused by differences in the soil, including for example changes in its electrical conductivity, electrical resistance, and magnetism (e.g., Aspinall et al. 2008; Bevan 1998; Clark 2000; Conyers 2004, 2012; Gaffney and Gater 2003; Heimmer and DeVore 1995; Lowrie 2007; Weymouth 1986). Certain types of *objects* can also be detected with regularity.

Each instrument is designed to measure a different property of the ground, and some of these properties, like magnetism and electrical resistance, vary in ways almost totally independent of one another. This means that when looking for buried things that are subtle and difficult to detect, such as graves, it is worth using multiple instruments when possible. It can be difficult to anticipate which instrument will work the best, and often each instrument detects a different aspect of the target feature. Combining the results of multi-instrument surveys in cemeteries almost always yields a richer interpretive map than a single instrument survey.

Ground penetrating radar, electromagnetic conductivity, and magnetometry were used for the Mount Zion Cemetery survey (Figures 6 and 7). Geophysical surveys are typically conducted by using the instruments to collect a series of readings along parallel lines (a.k.a. transects) in a rectilinear block (a.k.a. grid square). Data points are recorded at timed intervals, or based on distance, as the instruments are moved along the transects in each block. When possible, it is better to survey an area that is considerably larger than the target feature to provide a context within which to see that feature. So, for example, if one is looking for a single grave, it is important to survey well beyond the edges of the grave to locate other possible nearby graves or the remains of a fence that might have surrounded the burial area. It also is important to collect high-density data when possible, especially when looking for graves or other small features. Higher density data provide a clearer image of what lies underground.

Generally, the data collected by geophysical survey instruments during cemetery surveys must be transferred to a computer where special software is used to process the data and make maps of the survey results. In these maps the data values are assigned a range of colors related to their strength. In areas with little change in the readings, the colors are all similar—think of these areas as the typical background signature of the site. Areas in the data with unusual values that differ from the background are referred to as *anomalies*, and the goal is for graves to appear as anomalies in the data. Of course, the real challenge is knowing which anomalies are important and which are caused by tree roots, animal burrows, and other things not significant to the goals of the project.

Figure 6. Two of the geophysical survey instruments used in the Mount Zion Cemetery survey.

For some brief background information on using geophysical survey in cemeteries, see Burks and Corkum (2019). The ground penetrating radar and magnetometry methods also are further introduced there. Electromagnetic conductivity, the new technique tried at the Mount Zion Cemetery in 2021, is briefly explained below.

Electromagnetic Conductivity

Electromagnetic conductivity meters, or EM meters, can measure two geophysical properties of interest to archaeological and cemetery surveys—electrical "apparent" conductivity (the "quadrature" component of the EM signal) and something very similar to magnetic susceptibility (the "In-phase" component of the EM signal). Conductivity meters have been in use in American archaeological and cemetery work for decades (Bevan 1983, 1991; Clay 2006; Dalan 2006). Though conductivity meters overlap somewhat with other instrument types (e.g., radar and magnetometry) in the kinds of things they can detect, they go about making their measurements in a much different way (Witten 2006).

Conductivity meters are active geophysical instruments—they emit a signal and measure the response to it. Figure 7 provides a visual representation of a conductivity meter in action—in this case, a GF Instrument's CMD MiniExplorer, which was used for the Mount Zion Cemetery survey. All conductivity systems have a transmitter loop (also referred to as a coil), marked Tx in Figure 7, and at least one receiver loop (Rx). The CMD MiniExplorer has three receivers, each of which samples a slightly different volume/depth of soil. When the transmitter fires, it creates a fluctuating magnetic field (the red lines in Figure 7) that causes electricity—eddy currents (green in Figure 7)—to flow in nearby conductive materials. As the eddy currents flow, they create a secondary magnetic field (blue dashed lines) with a strength that is proportional to the conductivity of the material they are flowing through. The receivers in the conductivity meter detect the secondary magnetic field, which causes electricity to flow through the conductive material within the receivers. The more conductive the ground, the stronger the secondary magnetic field will be. Note the different spacings between the transmitter and receivers in the instrument in Figure 7. Increases in the spacing equals increases in depth/distance of detection. The CMD MiniExplorer produces data for three depth measurements: 50 cm, 100 cm, and 180 cm. The shallow data often detects numerous metallic objects near surface, while the deeper data picks up on what is in the bottom of the grave shaft.

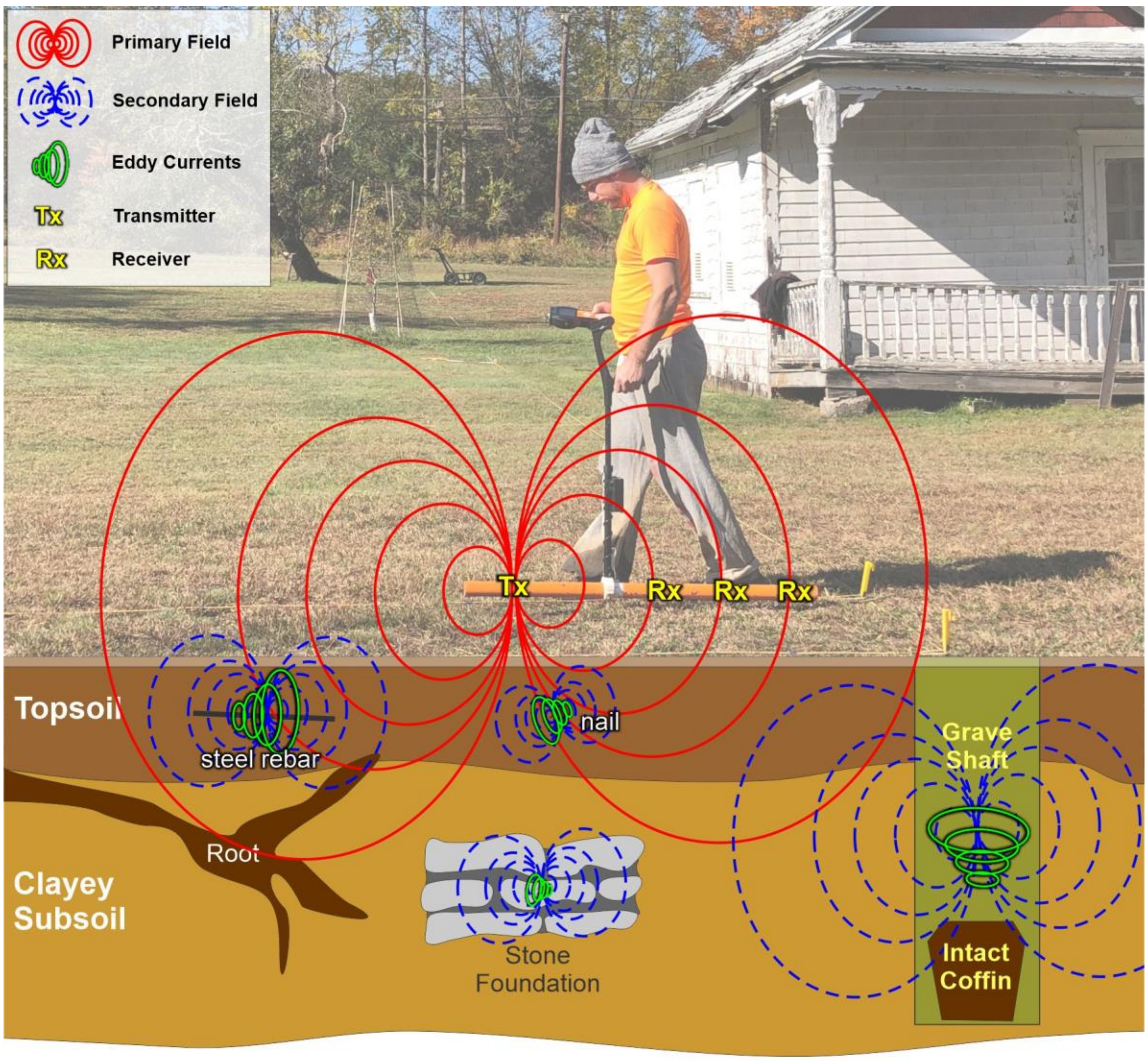


Figure 7. Basics of an electromagnetic conductivity survey, showing locations of the instrument transmitter and receivers (in this case, the operator is walking in the survey “reverse” direction).

In practice, conductivity meters can detect a wide range of subsurface objects and features. Because the instrument induces the flow of eddy currents, it can detect objects made from all types of metals (not just iron, like the magnetometer). On the electrical conductivity side of detectability, the instrument is good at detecting major changes in soil moisture or ion content. More moisture and ions mean better current flow and thus stronger conductivity readings and stronger responses in the receivers. Pit type features such as graves, storage pits, and refuse pits often hold water better than the ground around them and therefore create higher conductivity readings. Drier features, such as roadways and building foundations, produce lower conductivity values because the eddy currents cannot flow through them as well, if at all.

The magnetic susceptibility component (In-phase) of conductivity meter survey results is very similar to the types of things that magnetometers can detect. Topsoil generally is higher in susceptibility than clayey subsoil, so pits filled with a large percentage of topsoil (especially down at the subsoil level) may be detected. Conversely, subsoil deposited in the features, especially if it is near surface, also may be detectable as lower readings against the background susceptibility of the site. Thus, graves can appear as higher (more topsoil) or lower (more clay) readings. Archaeological midden (refuse) and burned soil often produce notably higher susceptibility values, and pits filled with these materials can be detected, as well as burned surfaces such as the dirt floors of houses that have burned down.

In the example in Figure 8, a conductivity meter was used to survey a 20x40 meter area of a nineteenth century cemetery in the hilly portions of eastern Ohio. This area of Ohio has sandstone bedrock and loamy soils with clayey subsoil. In the Figure 8 image, the conductivity and magnetic susceptibility components of the survey results are presented side by side and sorted by receiver/depth, with shallow results toward the top and deeper toward the bottom. All datasets show at least some indications of graves, but the clearest and most distinctive comes from receiver two, which detected at least 15 probable graves in both components of the data. These graves likely contain brick rubble in their fill, which may have been added when the grave shafts subsided and the fill was brought in to level them off. The large brick church on the property underwent several periods of construction and maintenance and the brick rubble from this work may have been used as fill.

For the Mount Zion Cemetery project, the CMD MinExplorer shown in Figure 7 was used to collect 10 readings per meter along transects spaced 50 cm apart. The data were collected in a parallel survey pattern—that is, all data collection transects ran in one direction (grid north). The data were downloaded and interpolated (resampled to 10 samples per meter) using the CMD Data Transfer software provided by GF Instruments. Once exported from this software, the results were gridded into six files per 20x20 meter grid square (C1, C2, C3, I1, I2, I3) using the Surfer software package. These grids were then assembled into a composite block and further processed in the TerraSurveyor software, where they were despiked and clipped. Once complete, the resulting processed data were exported as a Surfer grid file, low pass filtered in Surfer, and then pulled into QGIS.

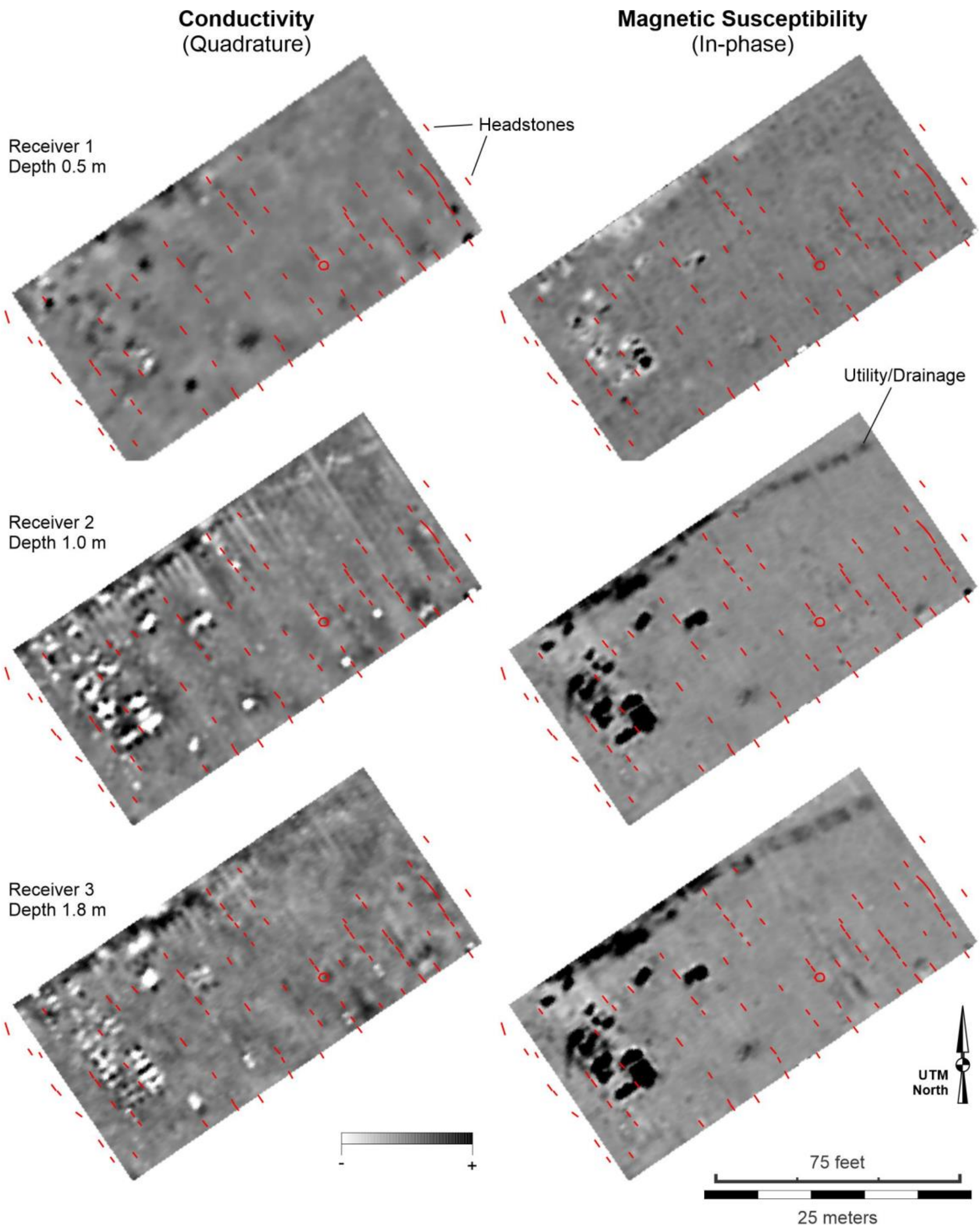


Figure 8. Examples of graves detected in electromagnetic conductivity data.

Results of the Field Work

Reestablishing the Site Grid

The geophysical survey conducted in 2018 established a local survey grid which needed to be expanded to accommodate the new geophysical survey in 2021. An additional step was taken after the survey grid was extended; it was registered with a highly accurate and precise Real Time Kinematic (RTK) Global Navigation Satellite System (GNSS) with paired base and rover units. This provided more accuracy for georeferencing the data (and tying it into a GIS with aerial photos and other mapping data) over the previous method, which involved a handheld GNSS. A surveyor with an equally precise RTK system could reestablish the survey grid utilizing only a single datum and the coordinates provided in Table 1, or a total station laser transit can be used along with two of the datums—one to set up on and another to backsight to.

Geophysical survey data tend to be collected in grid squares/blocks of set sizes. At Mount Zion Cemetery, we used a grid of 20x20 meter blocks, with partial blocks located along the edges of the survey area or in places where obstacles limited the survey. The map in Figure 9 shows the arrangement of the site survey grid on a shaded relief map made using high resolution LiDAR data. The grid was aligned to match the cemetery's main axes, as determined by existing rows of marker stones and the main axes of extant burial plot enclosures. The coordinates at the edges of the grid in Figure 9 are in meters. The red (2021) and blue (2018) lines indicate the limits of the geophysical surveys. The new survey (2021) area indicated in red in Figure 9 overlaps the 2018 survey indicated in blue and was extended north down the slope toward Rock Creek, as well as to the east into the clusters of headstones and newly cleared areas at the southeast corner of the cemetery.

A Leica TC405 laser transit total station, set up at N1000, E1000, was used to set out the 2018 survey grid stakes at 20-meter intervals, along with fiberglass tape measures for setting in stakes in partial blocks. All grids added for the 2021 survey were laid in using fiberglass tapes and mapped using the laser transit. Reference points were established on Mill Road NW where there was limited tree canopy, and these points were mapped with both the laser transit and the RTK GNSS system. This allowed the local grid system to be translated (moved and rotated with a fixed internal geometry) to the UTM geographic coordinate system in a GIS environment. Once properly georeferenced, the geophysical data and survey grid could be accurately placed relative to modern aerial imagery, LiDAR data, historic imagery, and historic maps in a new GIS created for the project.

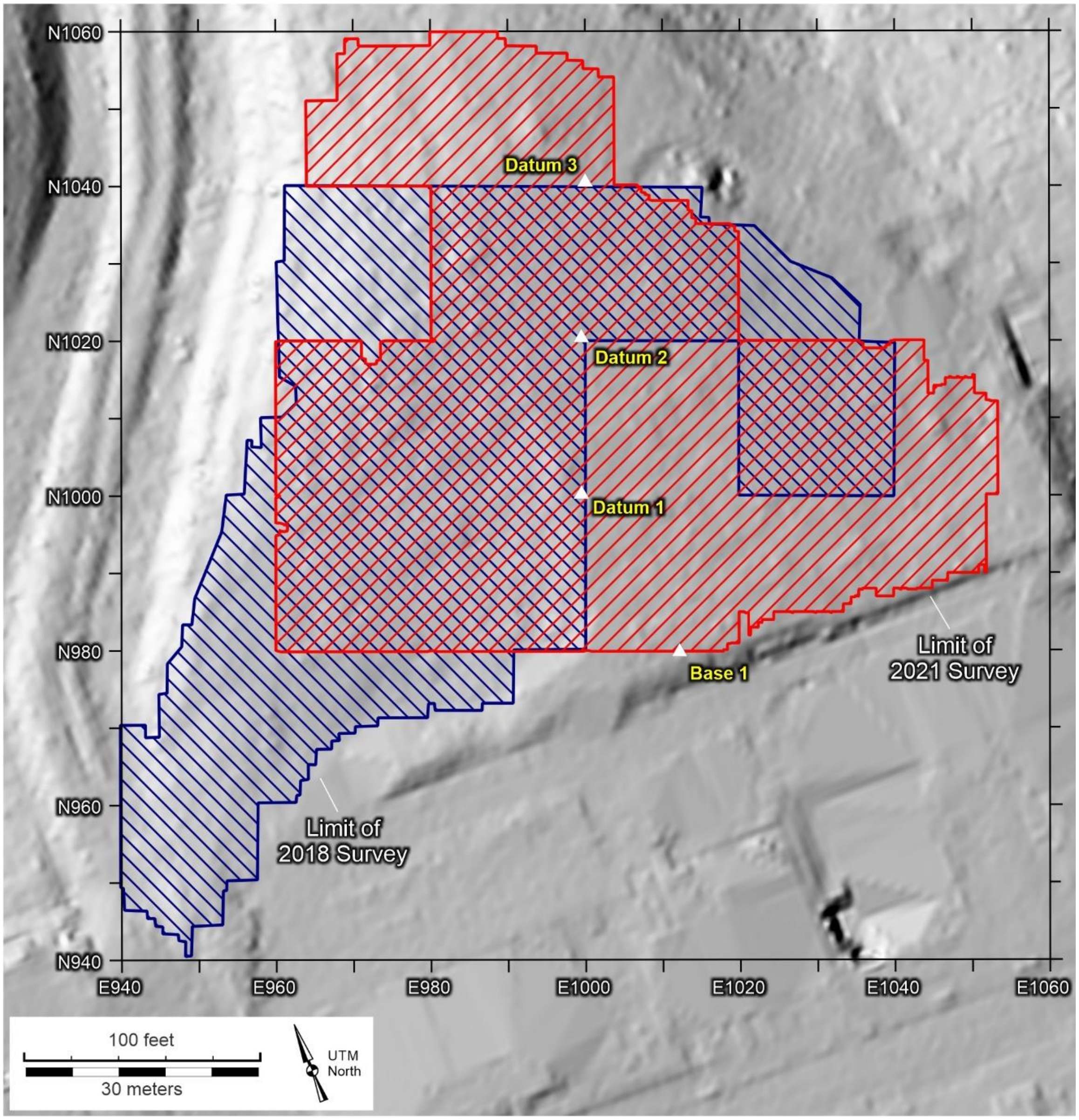


Figure 9. Map of the survey areas and the site grid on LiDAR data from 2018.

Table 1. Survey grid datum coordinates from the RTK GNSS.

	Site Grid Local Coordinates		Geographic Coordinates			
Datum	**Northing**	**Easting**	**UTM Northing**	**UTM Easting**	**Latitude**	**Longitude**
1	1000	1000	4308942.97	321902.25	38º54’40.800831”	-77º03’14.748151”
2	1020	1000	4308961.74	321909.76	38º54’41.414687”	-77º03’14.454173”
3	1040	1000	4308980.22	321917.72	38º54’42.019713”	-77º03’14.140986”
Base Station			4308919.32	321906.42	38º54’40.037244”	-77º03’14.552919”

*UTM Zone 18 north, Datum=WGS84. Primary GNSS data were collected with a Stone X S10 RTK global navigation satellite system (GNSS). GNSS data and transit data were tied together in a GIS using common points recorded with both systems.

A base station datum was added to the existing three mapping datums (semi-permanent mapping points) to help re-establish the survey grid in the future (Base 1 in Figure 9). Table 1 contains the survey grid and UTM coordinates for the datums, which are 10-inch galvanized nails pounded down to just below ground surface (i.e., they are not visible to the casual cemetery visitor). With these coordinates, a good GPS/GNSS, and a metal detector, it should be relatively easy to relocate the datums and re-establish the survey grid to locate features detected in the geophysical data. As a cautionary note, the geographic coordinates of the survey grid may be within 25 centimeters (the maximum accuracy of the base station GNSS) of the provided coordinates, but the entire grid is accurate to itself within 2 centimeters, which one should bear in mind when attempting to relocate the datums.

Geophysical Survey Results

The 2021 geophysical survey work had two primary goals: (1) extend the survey data into the more difficult to access areas along the cemetery margins and (2) test whether a third technique—electromagnetic conductivity—could produce useful results. Extending the geophysical survey into newly cleared regions of the cemetery posed unique challenges, including steep slopes to the north, piles of monuments to the south, and unusually shaped survey boundaries to the southeast.

Figure 10 shows the results of the new magnetic survey, which occurred in the southeastern corner of the cemetery and on the steep slope to the north. White areas in the data are less magnetic and darker areas are more magnetic. Recall that graves were detected in two ways in the magnetic data collected in 2018—as individual dipolar anomalies (a strong black/white anomaly) associated with an iron burial container and as rectilinear clusters of smaller dipolar anomalies created by the buried iron pipes associated with iron rails used to surround burial plots. We can see indications of both in the new magnetic data. At least two iron burial containers and a rectilinear cluster associated with a burial plot surround were detected on the north slope (where no headstones are present), while at least two iron burial containers were detected in the southeastern area. This area also appears to have many scattered iron objects (smaller dipolar anomalies), which is perhaps not a surprise since it appears to be an area where displaced monuments, burial plot surrounds, and other mobile debris has been deposited. The piles of headstones surrounding an earlier iteration of the cemetery entrance have also created clusters of magnetic anomalies. Some of these anomalies are associated with the markers themselves (some are concrete with iron wire inside of them); offerings placed beside some of the markers within the clusters of stones also created magnetic anomalies. Figure 11 shows all the magnetic data collected to date, and the large dipolar anomalies associated with iron burial containers (marked by yellow arrows) stand out markedly now that the size of the survey area is large enough to see the general trends in the data.

The new ground penetrating radar data also detected some of these iron burial containers, as well as other possible graves. Figure 12 is a detailed view of the new radar data from the southeastern corner of the cemetery. Red indicates areas of strong radar reflections, while blue areas produced weak reflections. A possible grave or metallic burial container is indicated by the yellow arrow. Tree roots, fill, or near-surface rock are visible at the northeastern edge of this survey area. Additional possible graves are visible at various depths in the sequence of slice maps presented in Figure 13.

The radar work on the north slope was considerably more challenging. The data had to be collected with one person slowly walking the radar downhill and two people carrying it back up (Figure 14). Though no grave markers are visible in this area, possible graves were detected in the radar data. Figure 15 is a detailed view of a radar slice map from 80-95 cm below surface showing a possible grave. Others may be present, as well. A look at a sequence of slice maps in Figure 16 shows a distinctive edge in the data—a divide between the many reflections to the west and the relatively quiet area in the data to the east. Additional north-south linear bands in the data visible in the 70-85 cm below surface slice hint at the presence of a row of graves (indicated by the yellow arrow). This row is much more visible in the electromagnetic conductivity data, as are others.

The conductivity survey was performed as an experiment to see how this technique might work in Mount Zion Cemetery. The conductivity technique has been used to good effect in cemetery surveys, but its use is relatively infrequent compared to techniques like ground penetrating radar. Conductivity surveys can detect all types of metal, but they also are good at detecting relatively subtle differences in soil moisture and magnetism that are detected by the magnetometer or the radar. Furthermore, the conductivity meter produces data at multiple depths and is much more mobile than the radar. For example, while the radar could not be used to survey over the piles of headstones, the conductivity meter had no problems surveying in this area (Figure 17).

Figure 18 shows a detailed view of the deepest "In-phase" component (apparent magnetic susceptibility) of the electromagnetic conductivity data. White areas in the data are less conductive and dark areas are more conductive. There are many anomalies in these data. The small black and white anomalies are metal objects. Many of the larger anomalies are metallic burial containers—indicated by the blue arrows in Figure 18. The yellow arrows indicate the locations of rows of graves, which run in a north-south direction. It appears that the intact soils (i.e., unexpected) at the edges of the grave shafts occur as areas of lower apparent magnetic susceptibility (the linear white features) while the spaces between them sometimes contain a peak in the readings, suggesting the presence of a grave or burial container. The rows detected in these data match up in orientation to the indications of rows in the radar data from the slope to the north. They also roughly match the projected row alignments for this part of the cemetery noted in the 2018 work (see Figure 5). A look at all six of the conductivity datasets (apparent conductivity and apparent magnetic susceptibility, each at three depths) in Figure 19 shows a few more possible graves and highlights the fact that the two different datasets produced by conductivity surveys actually detect different types of features/properties. Specifically, we can see in this figure that the rows of graves that are so obvious in the magnetic susceptibility data are essentially invisible in the conductivity data.

Together, these new results have identified an additional 24 graves over the 116 which had been previously identified. These new graves, along with those detected in 2018, are indicated on the new interpretation map presented in Figure 20. While we still have not detected all graves present within the cemetery, the increased numbers of detected graves help confirm the overall layout originally detected in the 2018 work—the rows of graves have two slightly different alignments. Table 2 provides a summary of which instrument detected the various grave types.

Table 2. Summary of geophysical interpretations.

Anomaly Type	Number	Possible Grave	Probable Grave
Magnetic			
Post/Pipe of Plot Surround	31	11 enclosures	
Dipolar Simple			14
Dipolar Simple-Concentric/Complex		3	3
Radar			
From Slice Maps			29
From Radar Profiles		60	
Electromagnetic			
From Conductivity		-	-
From Magnetic-Susceptibility			25
Total Minimum # of Graves in Data Interpretation	**140**		

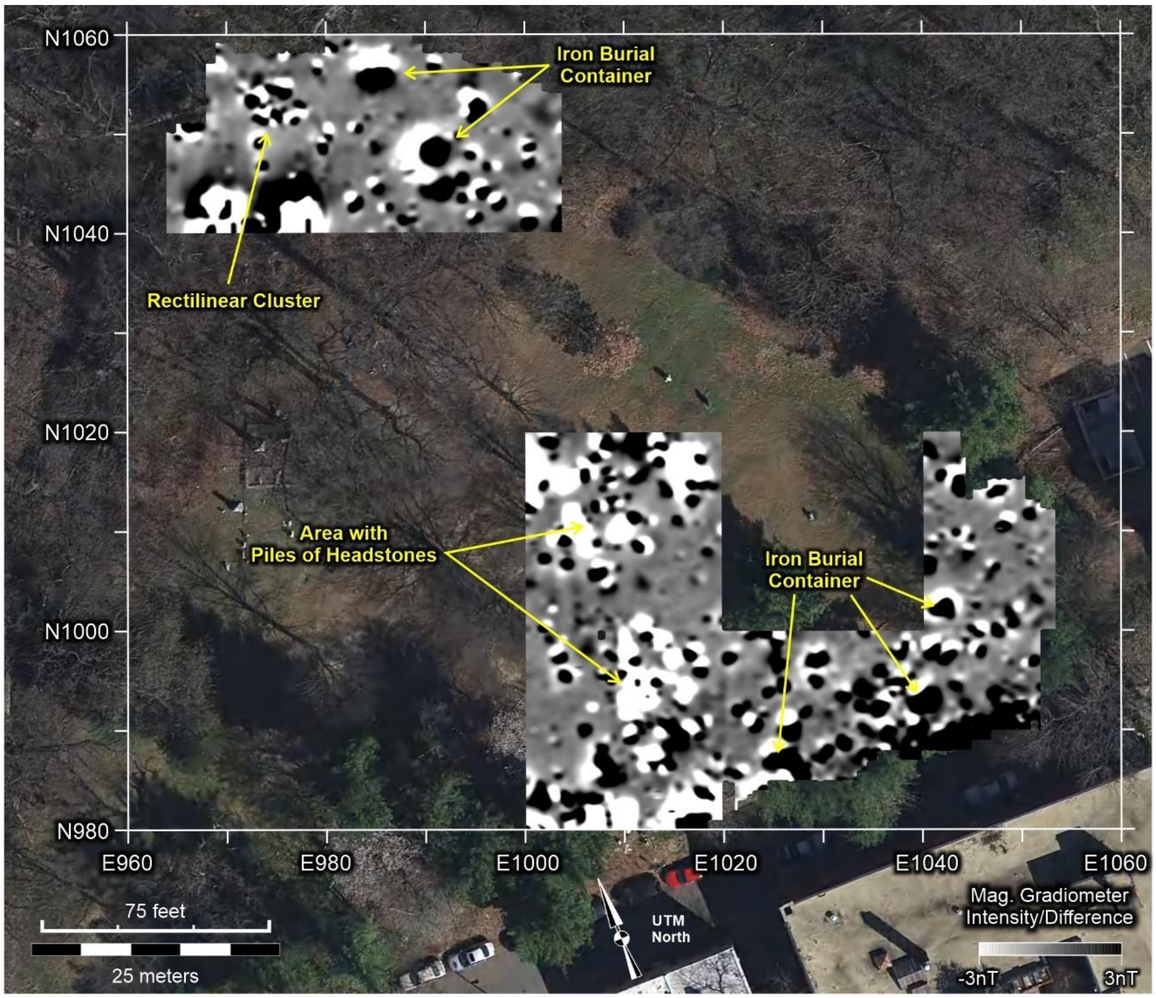


Figure 10. Newly collected magnetic data on a 2018 aerial image.

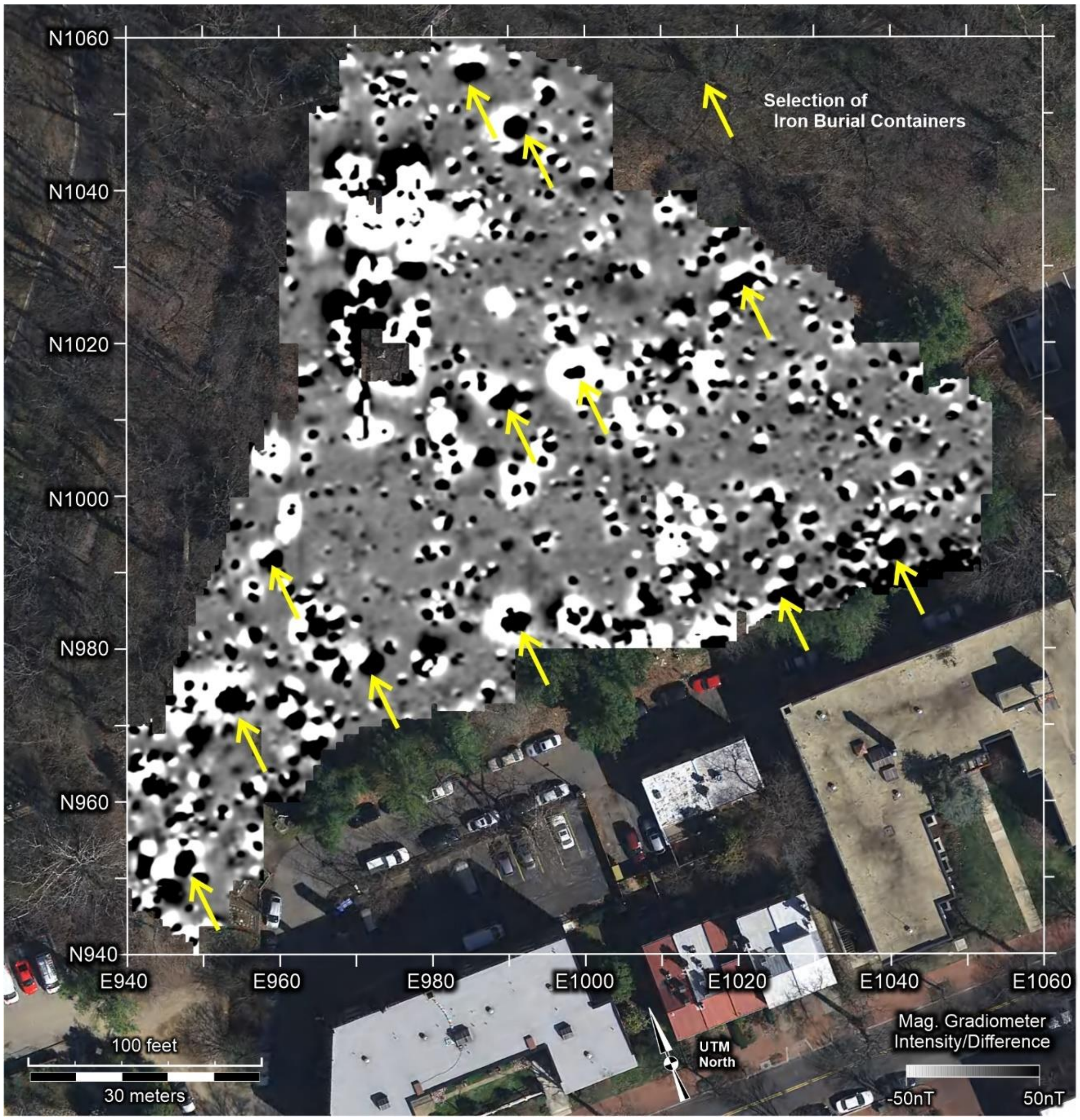


Figure 11. Combined magnetic data from 2018 and 2021 surveys.

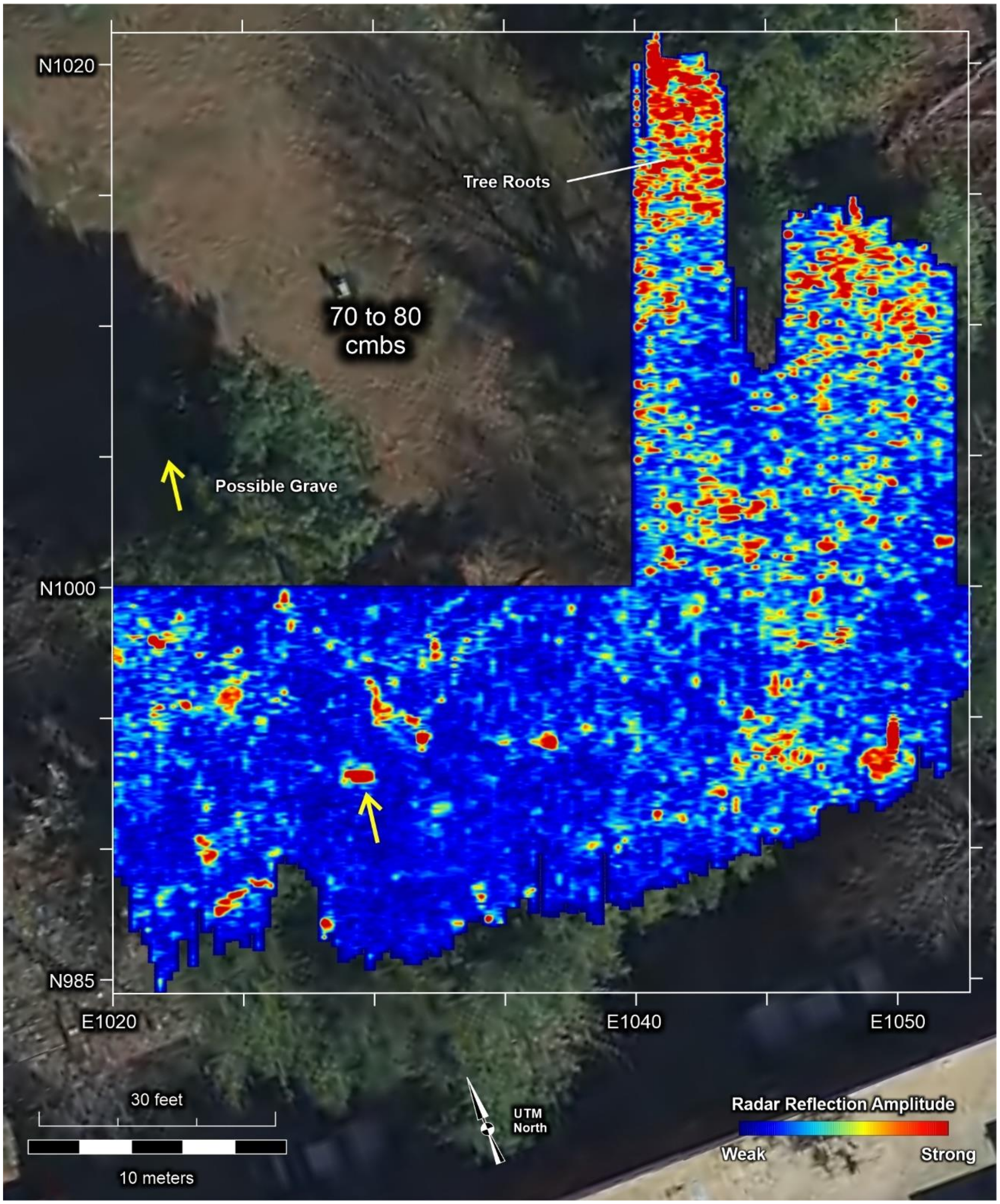


Figure 12. Detail view of radar amplitude slice map at 70-80 cm below surface, southeast of previous survey.

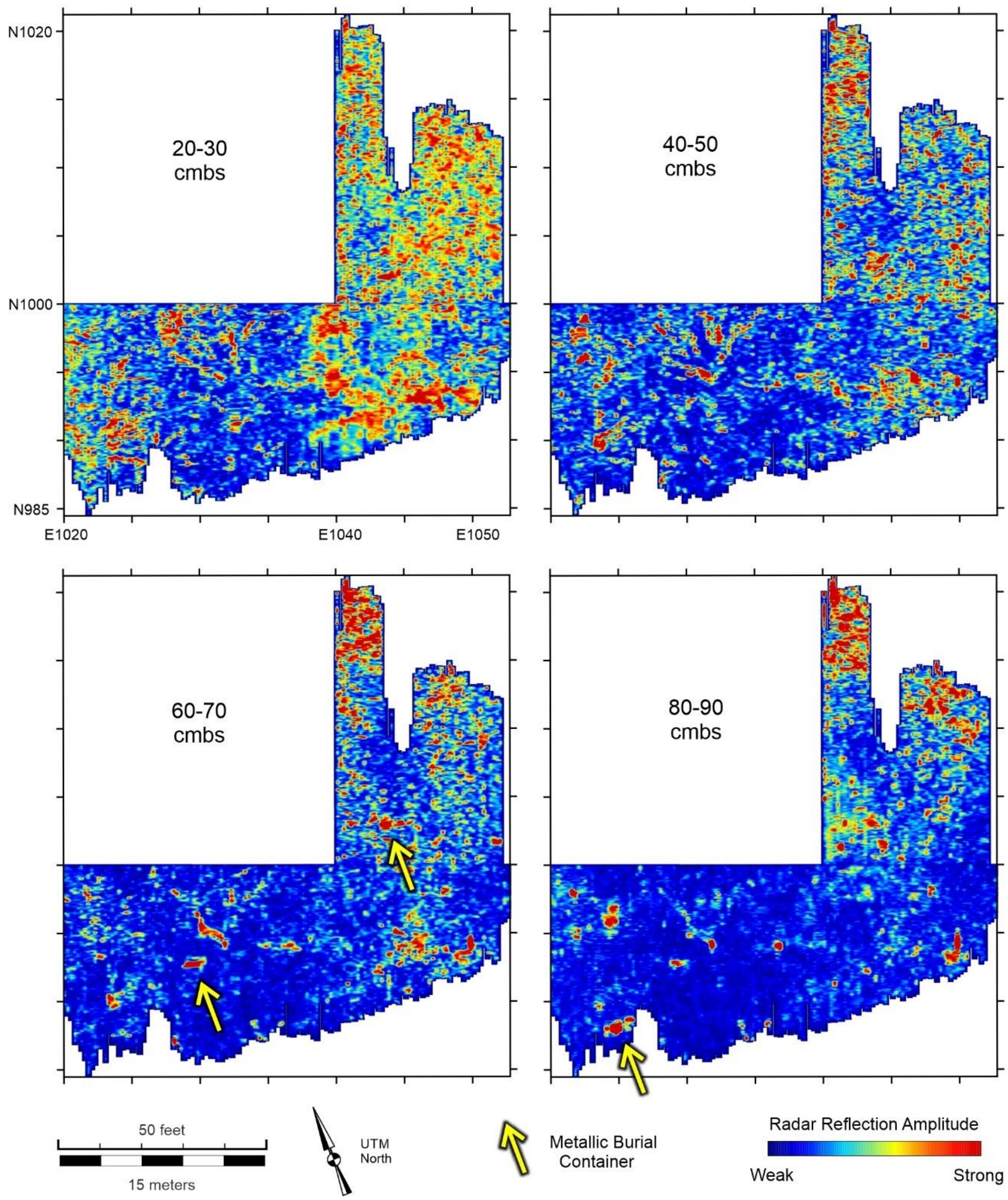


Figure 13. Sequence of radar amplitude slice maps at select depths in Area 1, the southeastern survey area.

Figure 14. Images of collecting radar on the north slope of the cemetery, after the vegetation was cleaned off by the Hope Crew (National Trust for Historic Preservation).

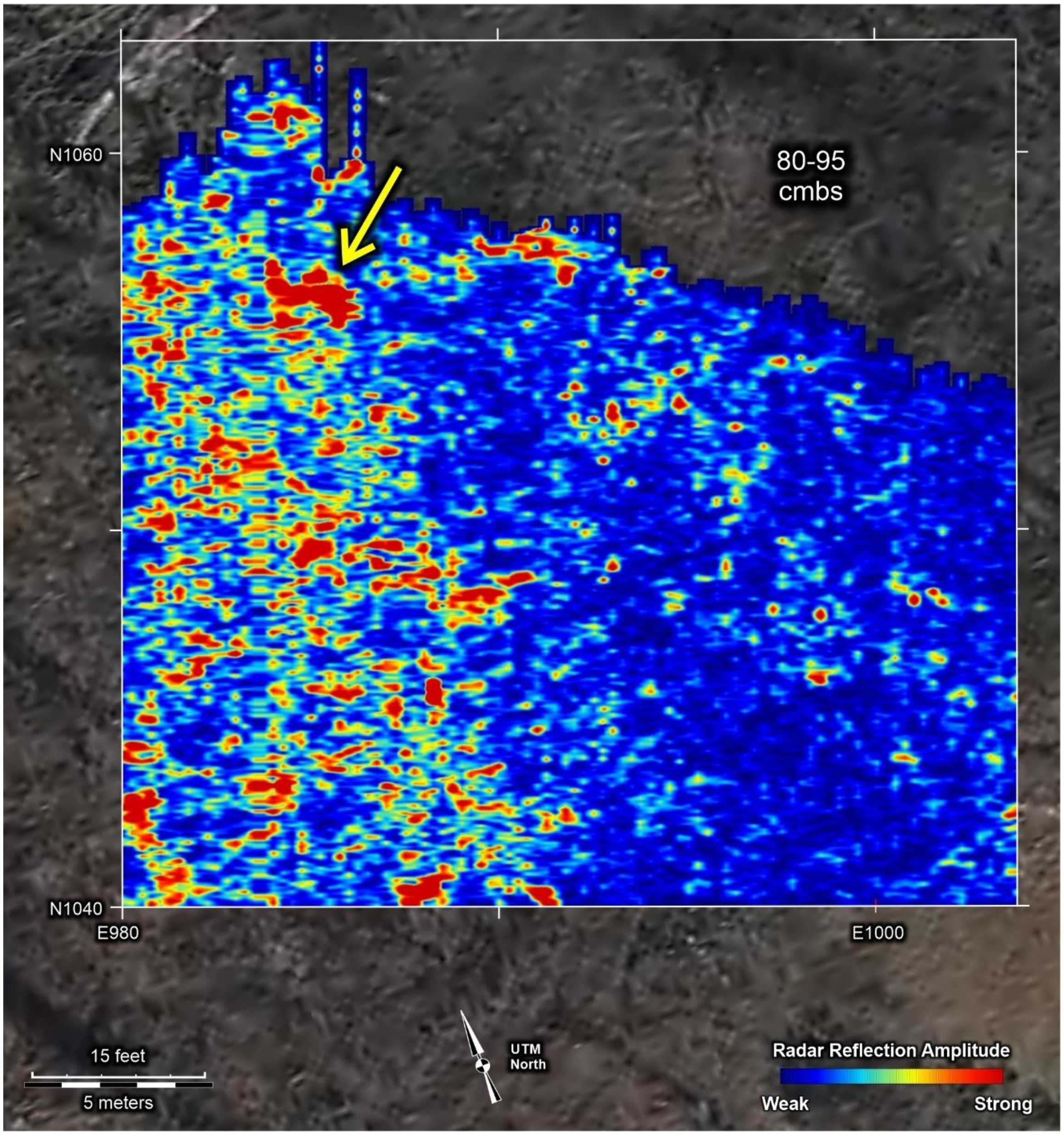


Figure 15. Detail view of radar amplitude slice map in Area 2 at 80-95 cm below surface, north of previous survey.

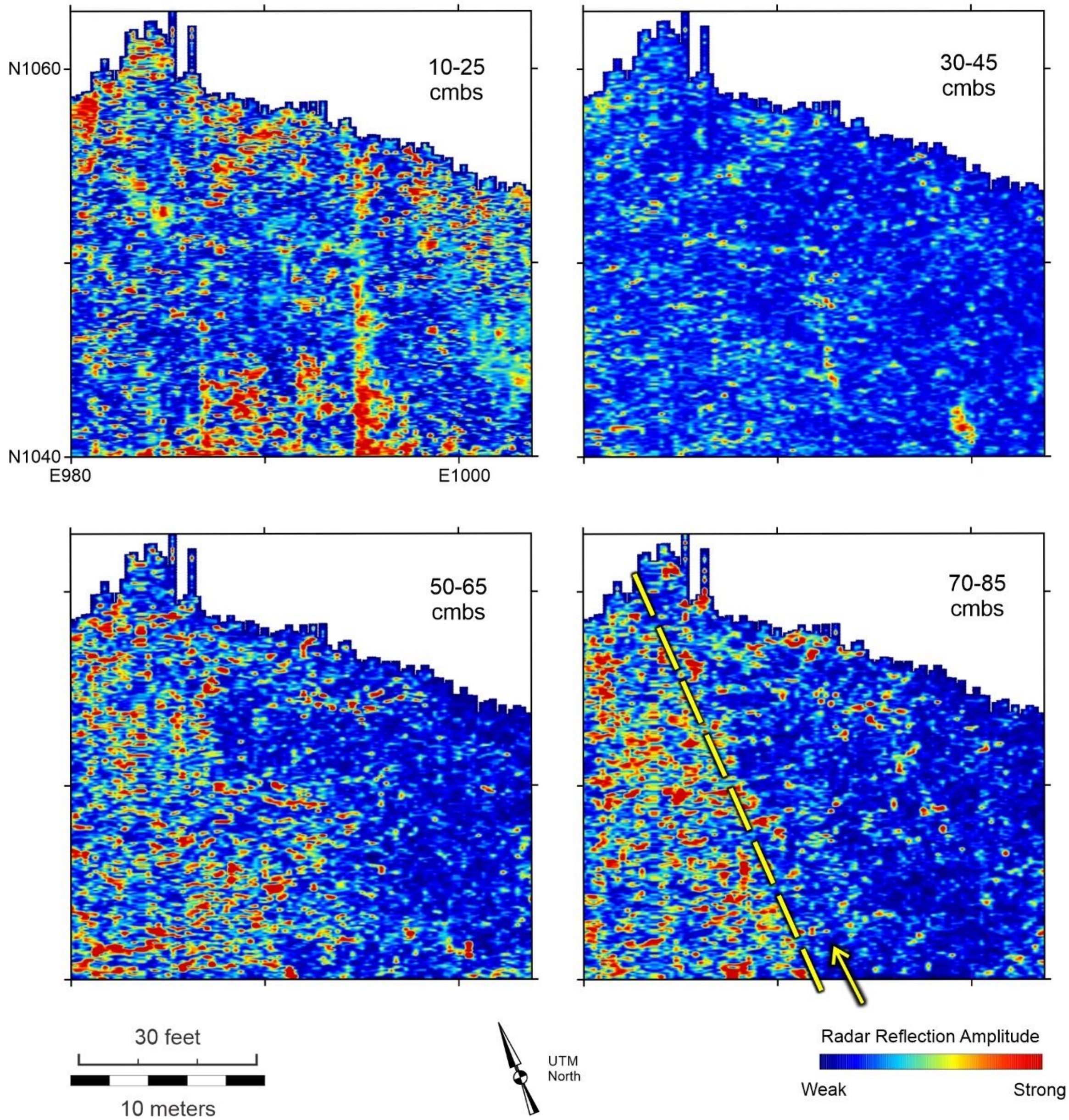


Figure 16. Sequence of radar amplitude slice maps at select depths in the northern survey area—dashed yellow line marks distinctive edge in data, while yellow arrow indicates probable row of graves.

Figure 17. Images of the conductivity meter in action (top) at the edge of what appears to have been a central entrance to the cemeteries, and (bottom) within one of the headstone clusters/piles.

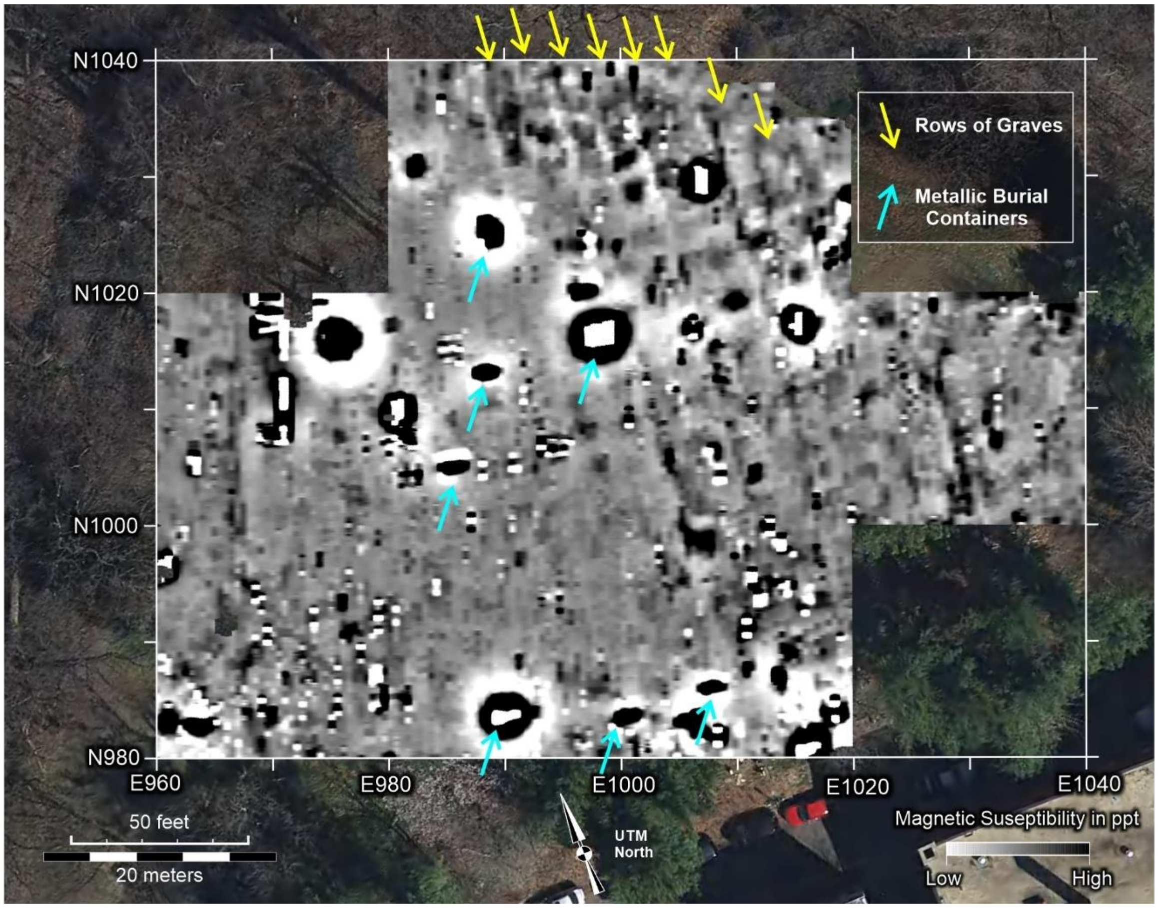


Figure 18. Magnetic Susceptibility dataset (In-phase component of Conductivity data) reading down to 1.8 meters below surface, on 2018 Google aerial imagery.

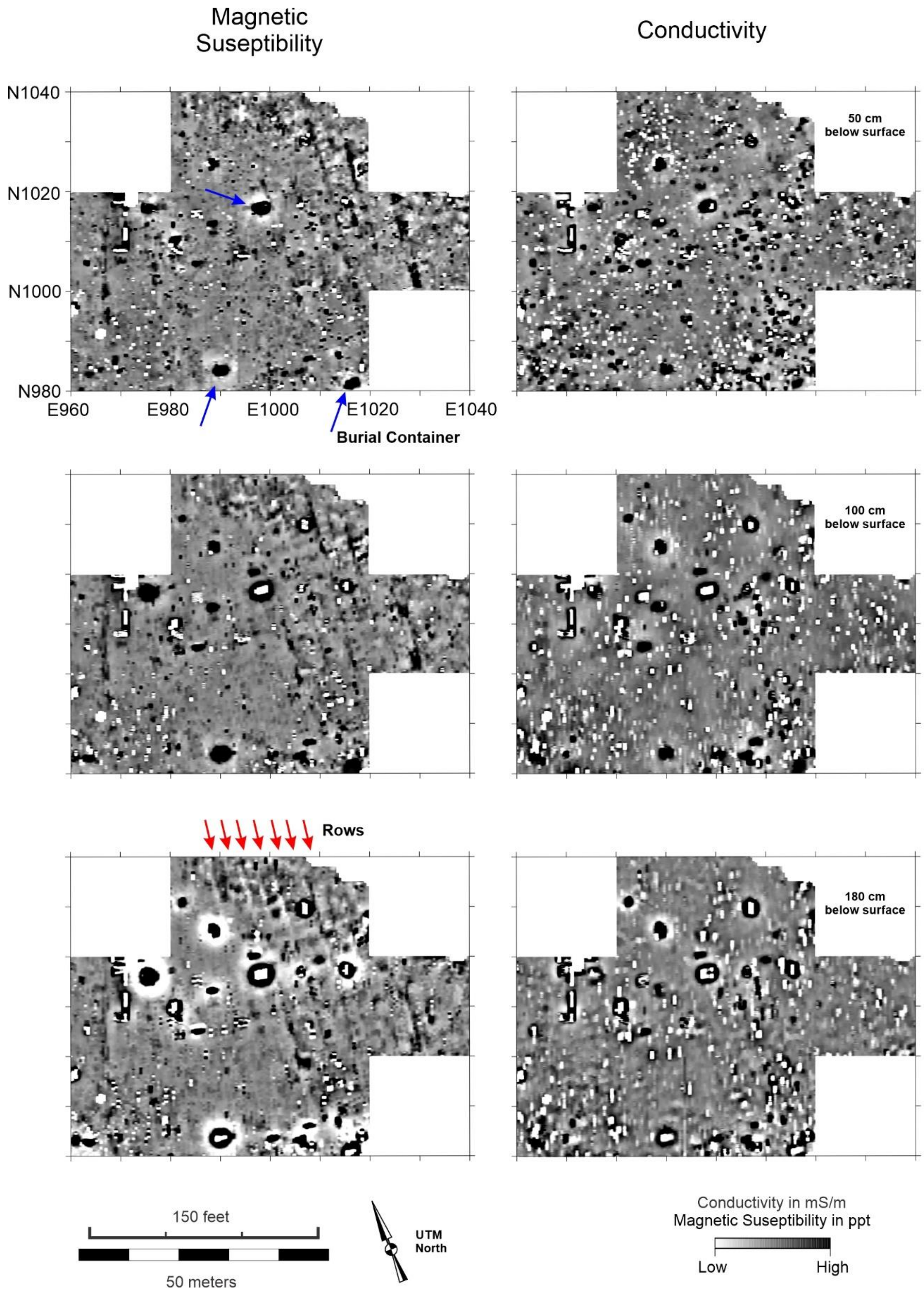


Figure 19. Display of the "Conductivity" and "Magnetic Susceptibility" datasets from the CMD MiniExplorer at three depths.

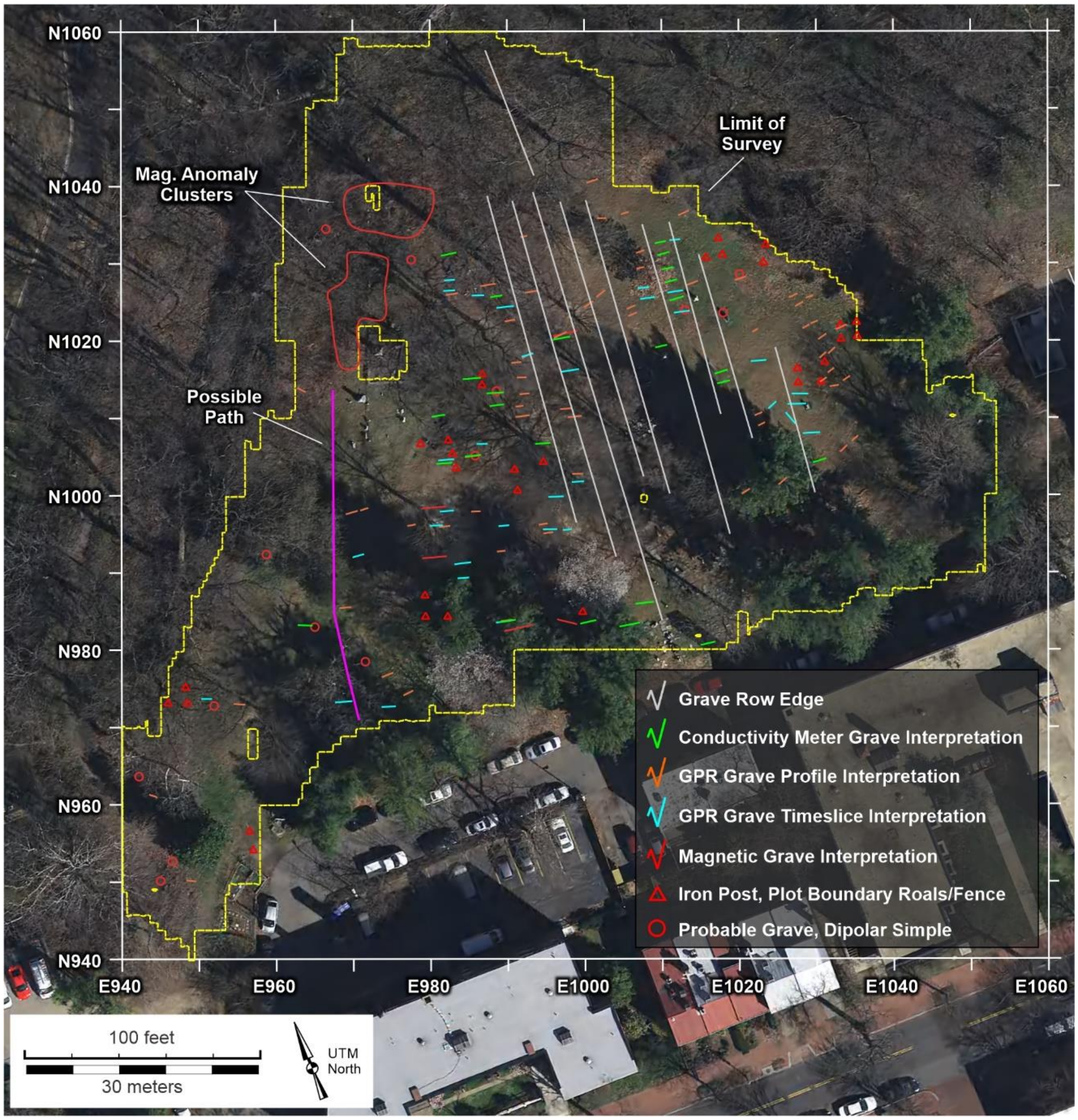


Figure 20. Geophysical survey results with projected burial row alignments.

Summary and Recommendations

In August of 2021, OVAI and a team of student internees working with the Hope Crew program at the National Trust for Historic Preservation spent several days in the Mount Zion Cemetery pushing the extent of the magnetic and radar surveys into previously unsurveyed areas of the cemetery. The team also tested a new technique—electromagnetic conductivity—in the flatter portions of the cemetery.

The new survey results, when combined with the previous geophysical survey conducted in 2018, bring the total number of detected graves to 140. These new graves were detected by all three instruments, and the electromagnetic conductivity technique was found to be quite useful in the Mount Zion Cemetery. While 140 is clearly just a small number of the graves present within the cemetery, enough graves and indications of rows of graves have been detected to show the overall structure of the cemetery. In particular, graves are arranged in long north-south rows within the surveyed portions of the cemetery. Row alignment changes slightly at about the midpoint of the cemetery—the former boundary between the Mount Zion Cemetery and the Female Union Band Society Cemetery. Importantly, the new survey data show that the north-south row alignment extends north onto the slope leading down to Rock Creek—at least in the sloped portion of the cemetery that was surveyed in 2021.

Several next steps are recommended, following the successful execution of this multifaceted geophysical survey, some of which are carried over from the suggestions made in the survey report for the 2018 survey (Burks and Corkum 2019) and are still considered worthwhile for future possible work.

(1) Collect detailed location data on all surface features visible within the cemetery. While the Bohler map contains many useful features that were precisely mapped (see Burks and Corkum 2019: Figure 27), it does not include all visible surface features related to burial plot boundaries and marker stones. For example, during the Stage 1 geophysical survey work, many subtle features, including what appeared to be footstones, were observed on the surface in the northwest corner of the cemetery where the vegetation had recently been thoroughly cleared. If the vegetation in the more overgrown parts of the cemetery can be thoroughly cleared away, then a systematic walk over of the area should locate many components of the cemetery that are subtle but visible at the surface. Mapping these will help in determining the locations of additional graves, and it will further clarify the structure of the cemetery.

(2) Conduct geophysical surveys in the ditch along Lyons Mill Road. At least three headstones are present in this old ditch, suggesting that more graves could be located here. This area would need significant brush and debris clearing to make it accessible for magnetic and radar survey. Furthermore, it will be extremely difficult to georeference the data in this area of the cemetery. However, the new work with the RTK GNSS should allow one to use a transit and the established site datums to measure in any survey areas along the old Lyons Mill Road.

(3) Conduct additional electromagnetic conductivity survey. Given the demonstrated utility of this technique for detecting metallic burial containers

and the edges of rows at Mount Zion, the expansion of this survey technique into other portions of the cemetery will surely yield more identified graves.

(4) Take a closer look at the north slope for evidence of intact graves. This area is still covered in brush and is very steep. This slope could preclude geophysical survey. However, it might be possible to collect magnetic and conductivity data on the slope. Further, the bases of monuments likely occur at the surface on the slope, and they could be mapped using a laser transit, if the vegetation is well cleared. A major lingering question about this area is how the graves are laid out on the most extreme part of the slope. Do they follow the north-south row alignments identified in the flatter portions of the cemetery, or are the long axes of graves on the slope turned to follow the contour lines of the slope?

References Cited

Aspinall, Arnold, Chris Gaffney, and Armin Schmidt
2008 *Magnetometry for Archaeologists*. Altamira Press, New York.

Baugher, Sherene, and Richard F. Veit
2014 *The Archaeology of American Cemeteries and Gravemarkers*. The University of Florida Press, Gainesville.

Bevan, Bruce
1983 Electromagnetics for Mapping Buried Earth Features. *Journal of Field Archaeology* 10:1, 47-54, DOI: 10.1179/009346983791504354
1991 The Search for Graves. *Geophysics* 56:1310-1319.
1998 *Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration*. Special Report No. 1. Midwest Archeological Center, Lincoln, Nebraska.

Burks, Jarrod, and Alex Corkum
2019 The Search for Graves at Mt. Zion/Female Union Band Cemetery in the Georgetown Neighborhood of Washington, D.C.: Observations from the Results of a Geophysical Survey. Contract Report 2018-66. Ohio Valley Archaeology, Inc. Columbus, Ohio.

Clark, Anthony
2000 *Seeing Beneath the Soil: Prospecting Methods in Archaeology*. Revised Edition. Routledge, New York.

Clay, Berle
2006 Conductivity Survey: A Survival Manual. *Remote Sensing in Archaeology*. Tuscaloosa, Alabama.

Conyers, Lawrence B.
2004 *Ground-Penetrating Radar for Archaeologists*. Altamira Press, Walnut Creek, California.
2012 *Interpreting Ground-penetrating Radar for Archaeology*. Left Coast Press, Inc. Walnut Creek, California.

Dalan, Rinita
2006 Magnetic Susceptibility. *Remote Sensing in Archaeology.* Tuscaloosa, Alabama.

Gaffney, Chis, and John Gater
2003 *Revealing the Buried Past: Geophysics for Archaeologists*. Tempus, Stroud, England.

Heimmer, Don H., and Steven L. DeVore
1995 *Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations*. National Park Service, Rocky Mountain Region, Denver.

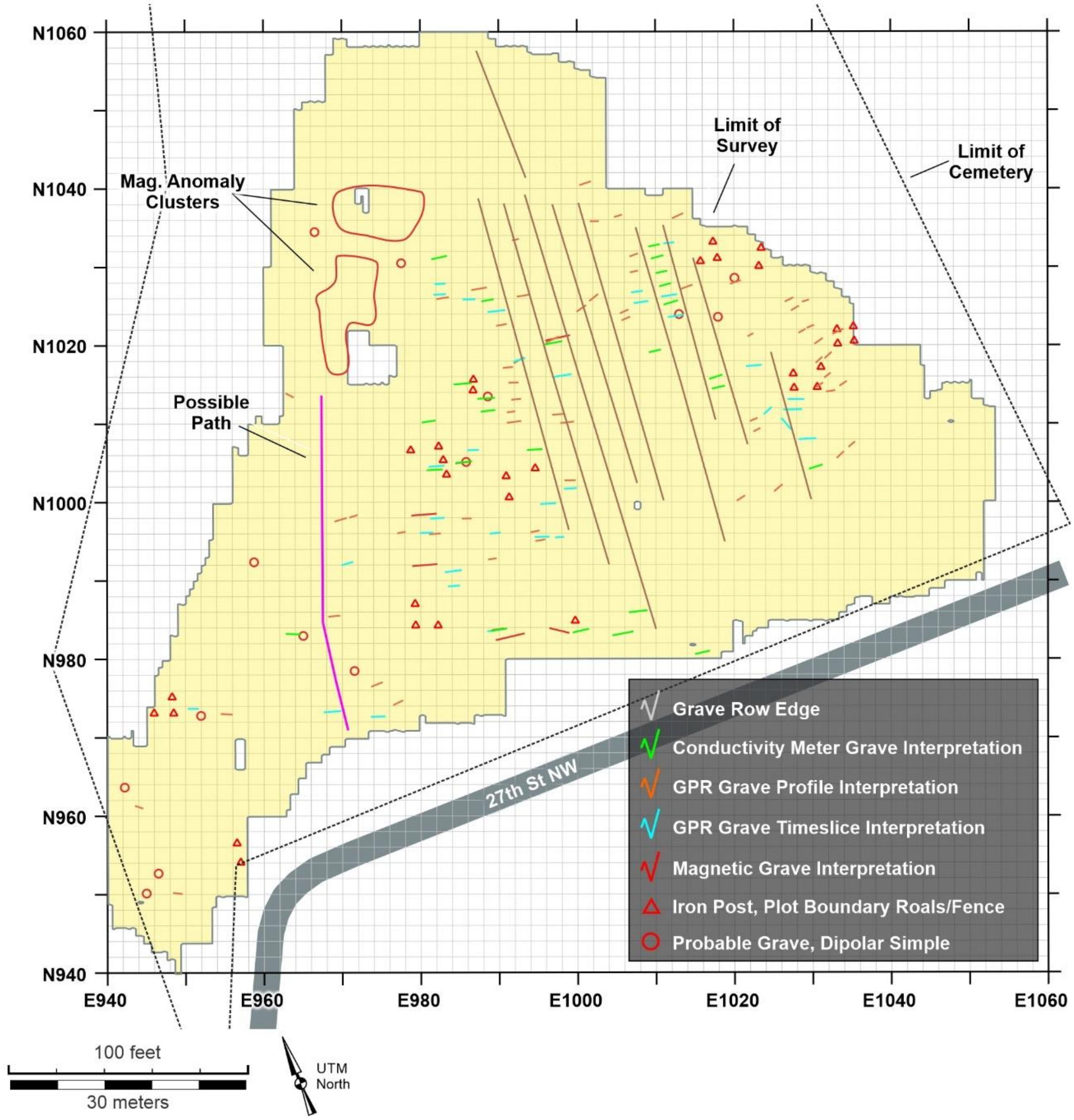
Lowrie, William
2007 *Fundamentals of Geophysics, second edition*. Cambridge University Press, Cambridge, Great Britain.

Sloane, David Charles
1991 *The Last Great Necessity: Cemeteries in American History*. The John Hopkins University Press, Baltimore.

Weymouth, John W.
1986 Geophysical Methods of Archaeological Site Surveying. *Advances in Archaeological Method and Theory* 9:311-395.

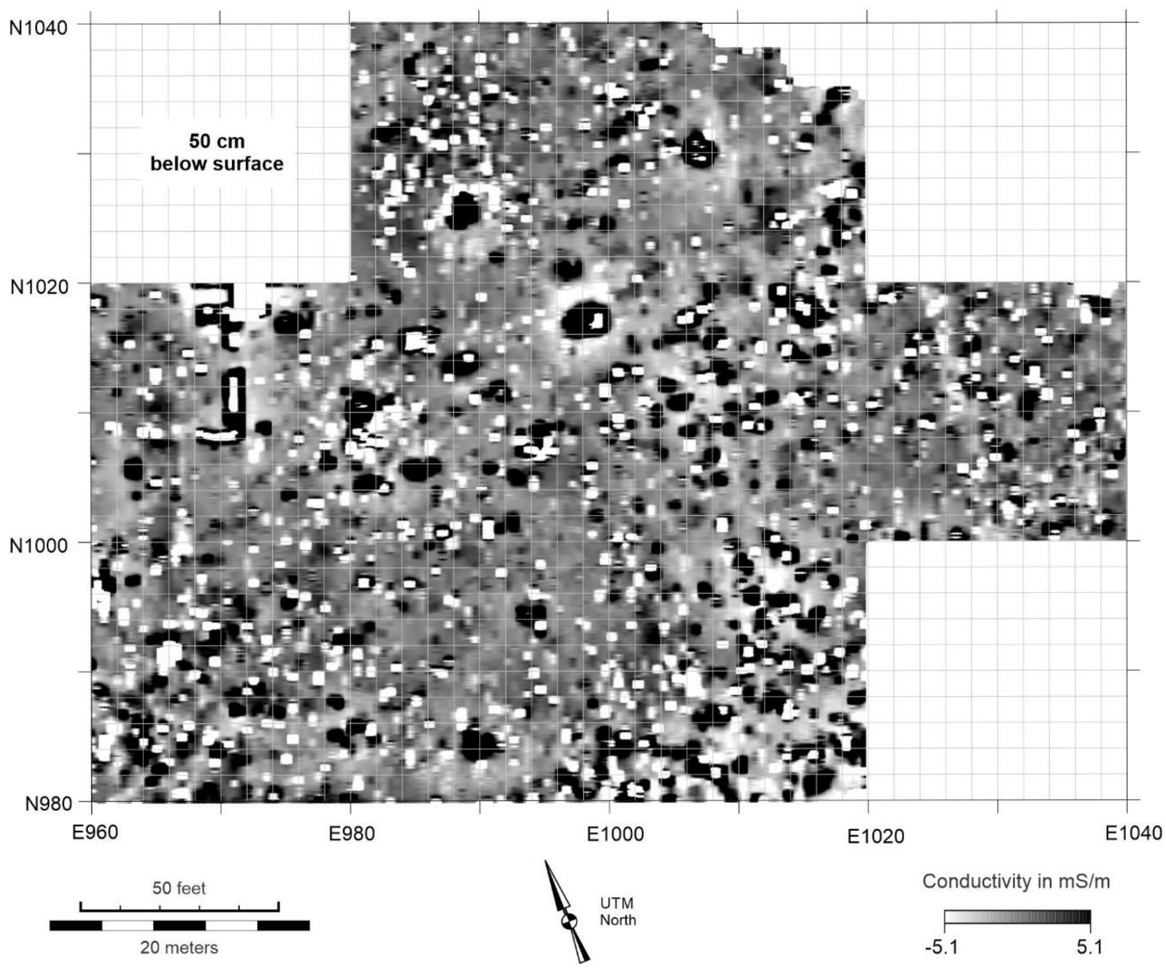
Witten, Alan J.
2006 *Handbook of Geophysics and Archaeology*. Equinox Publishing, London.

Appendix A. Interpretation Map

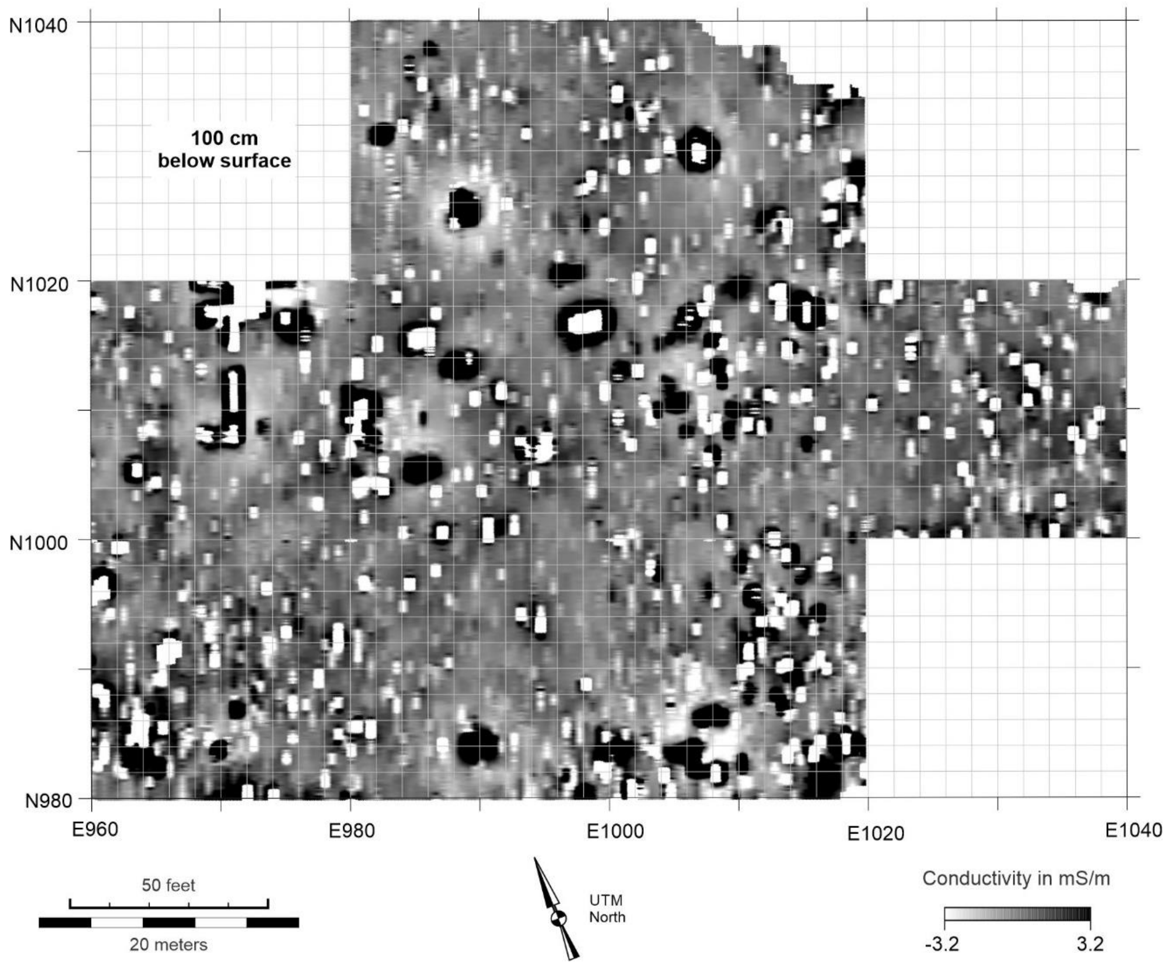


Appendix B. Electromagnetic conductivity data maps.

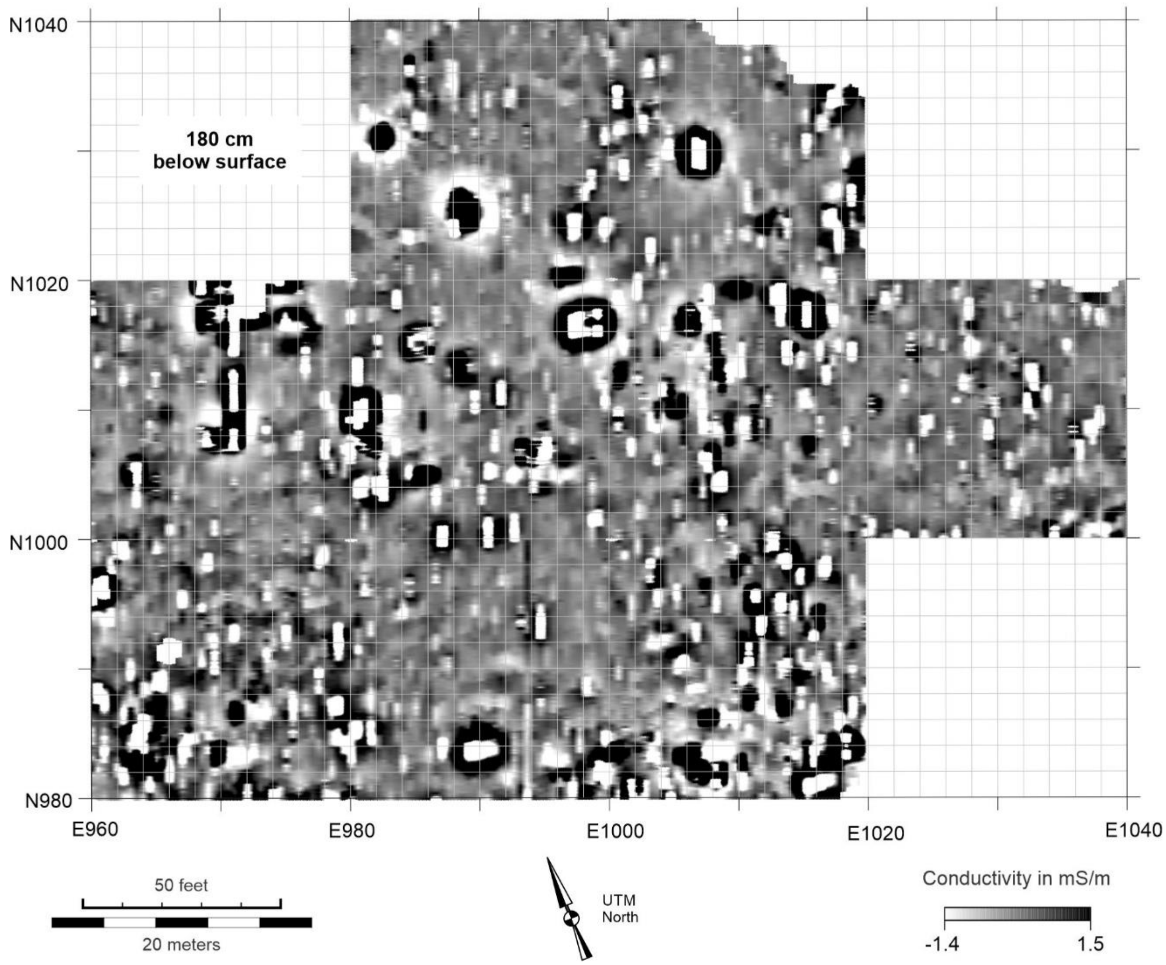
Apparent Conductivity



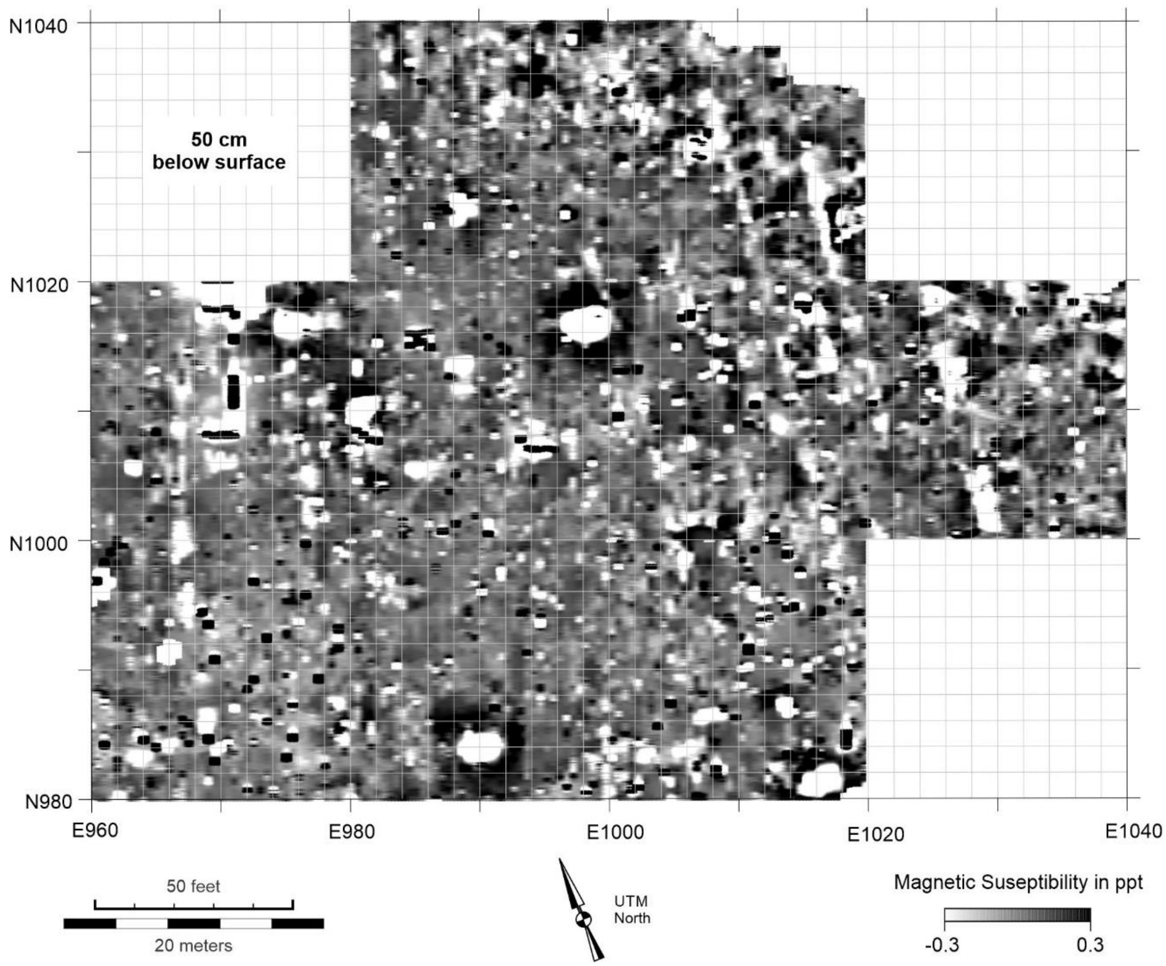
Apparent Conductivity



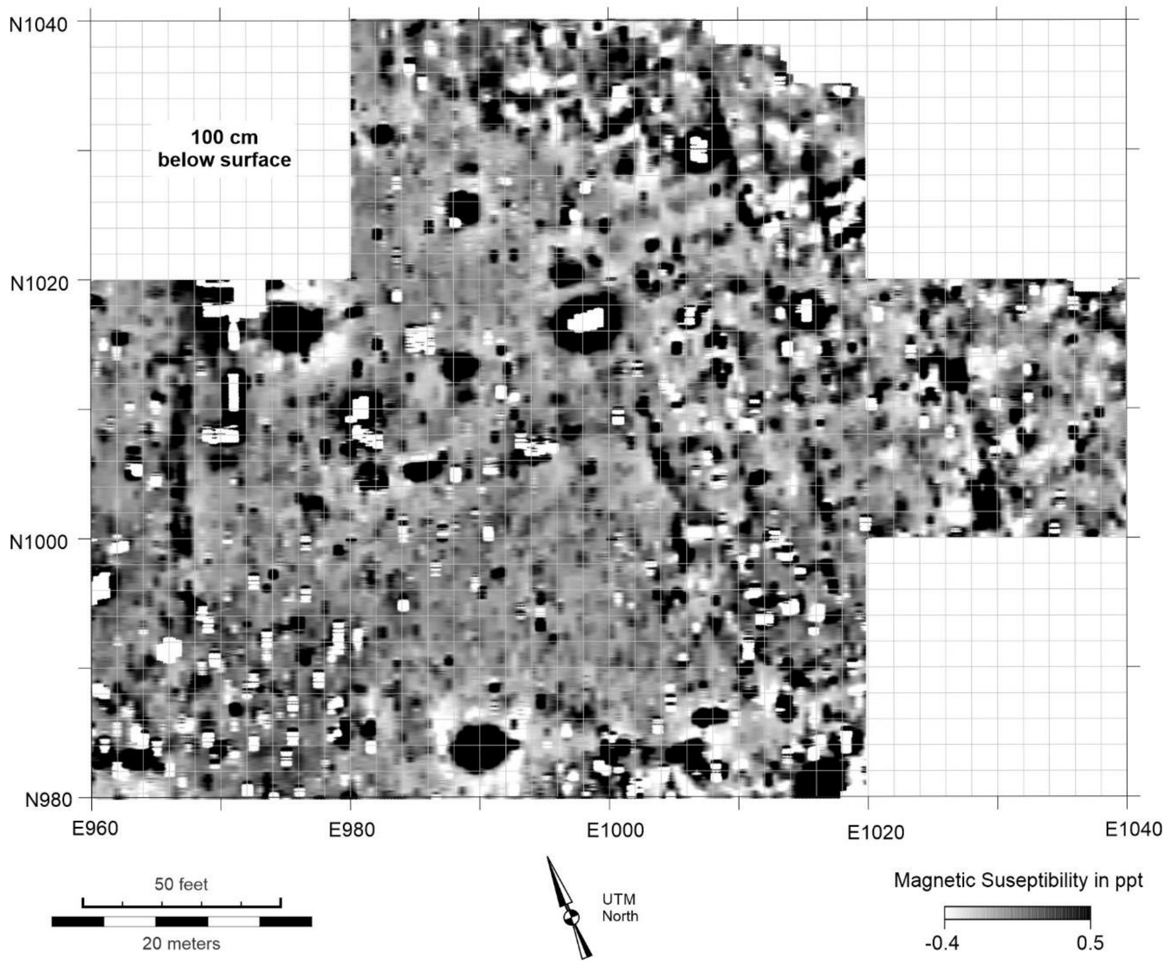
Apparent Conductivity



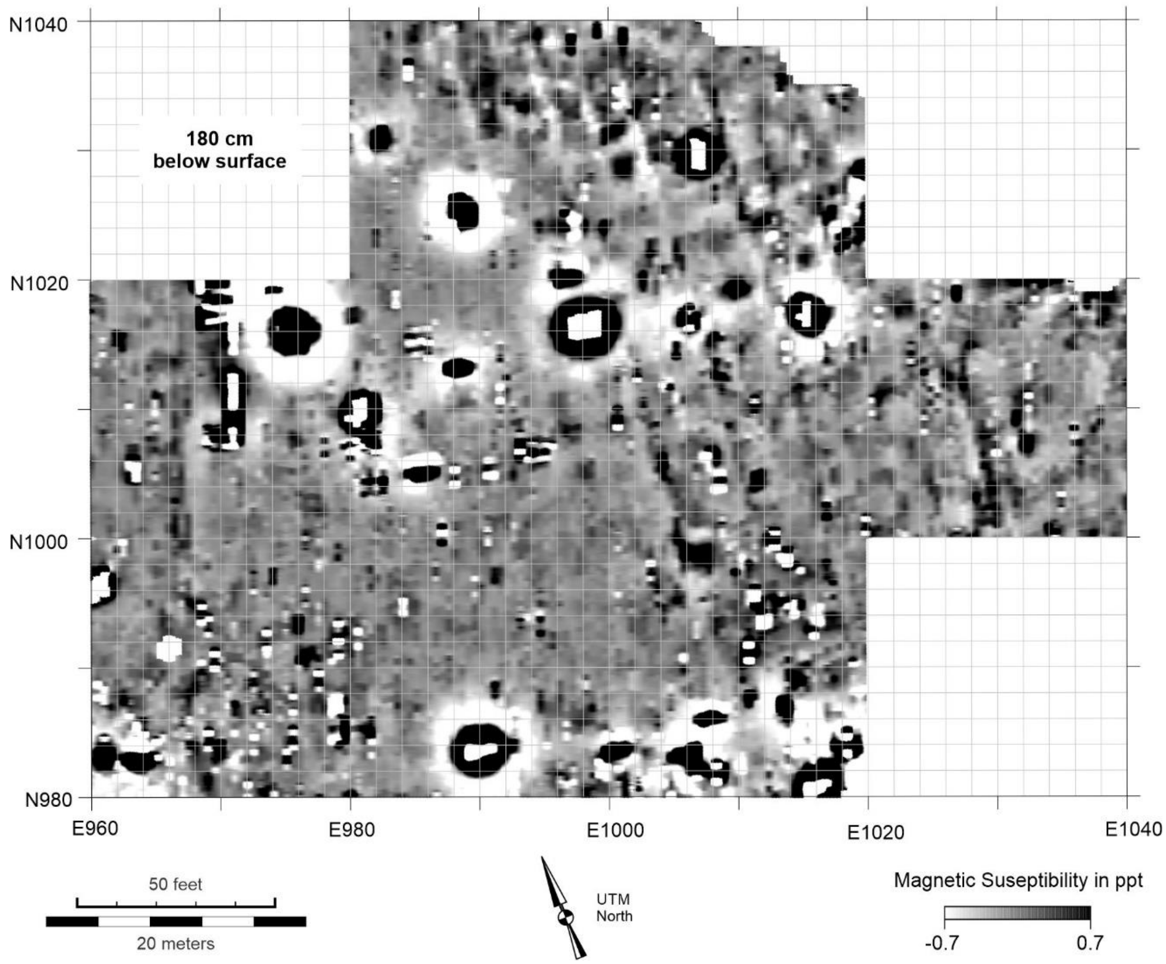
Apparent Magnetic Susceptibility



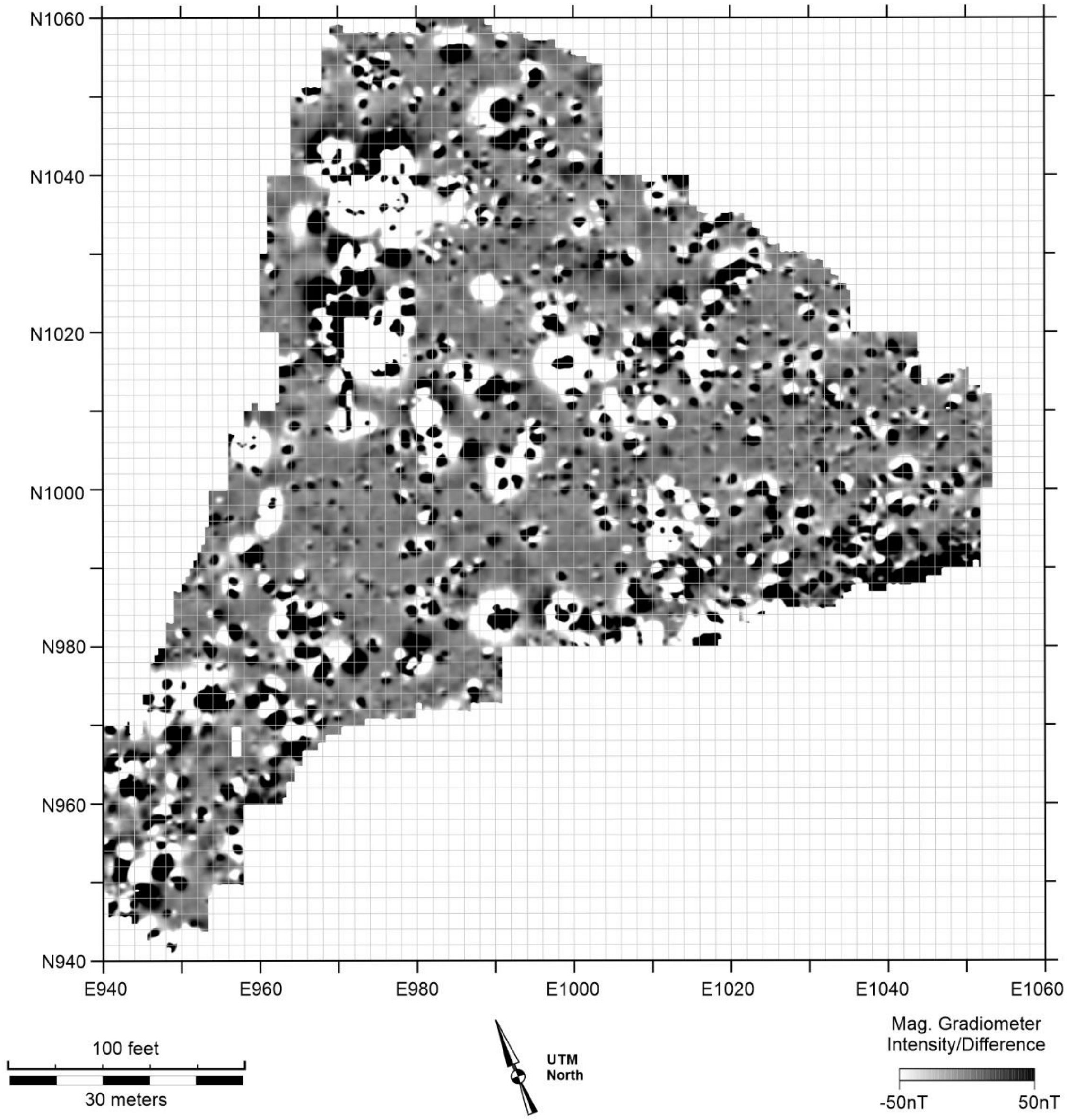
Apparent Magnetic Susceptibility



Apparent Magnetic Susceptibility

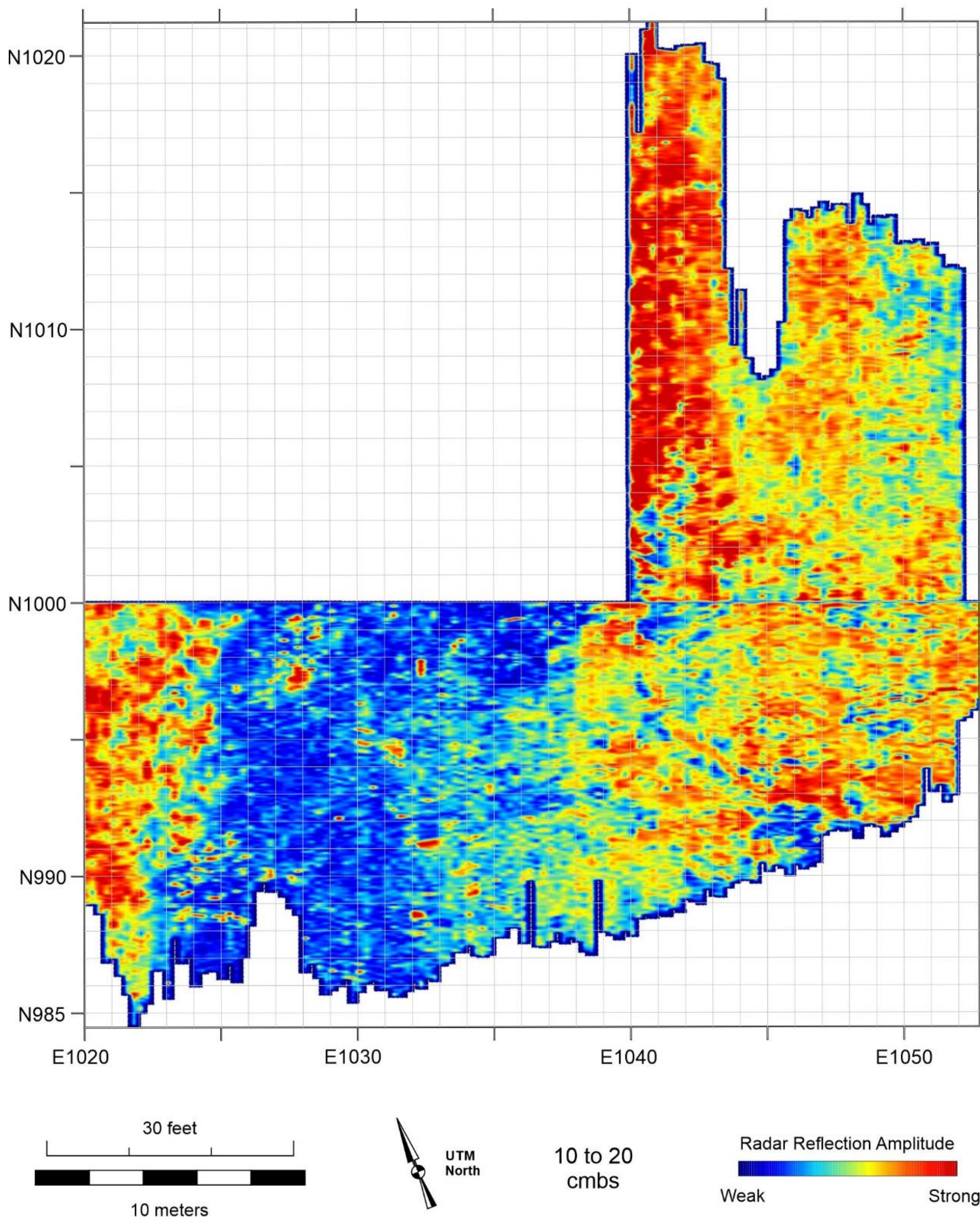


Appendix C. Magnetic data map.

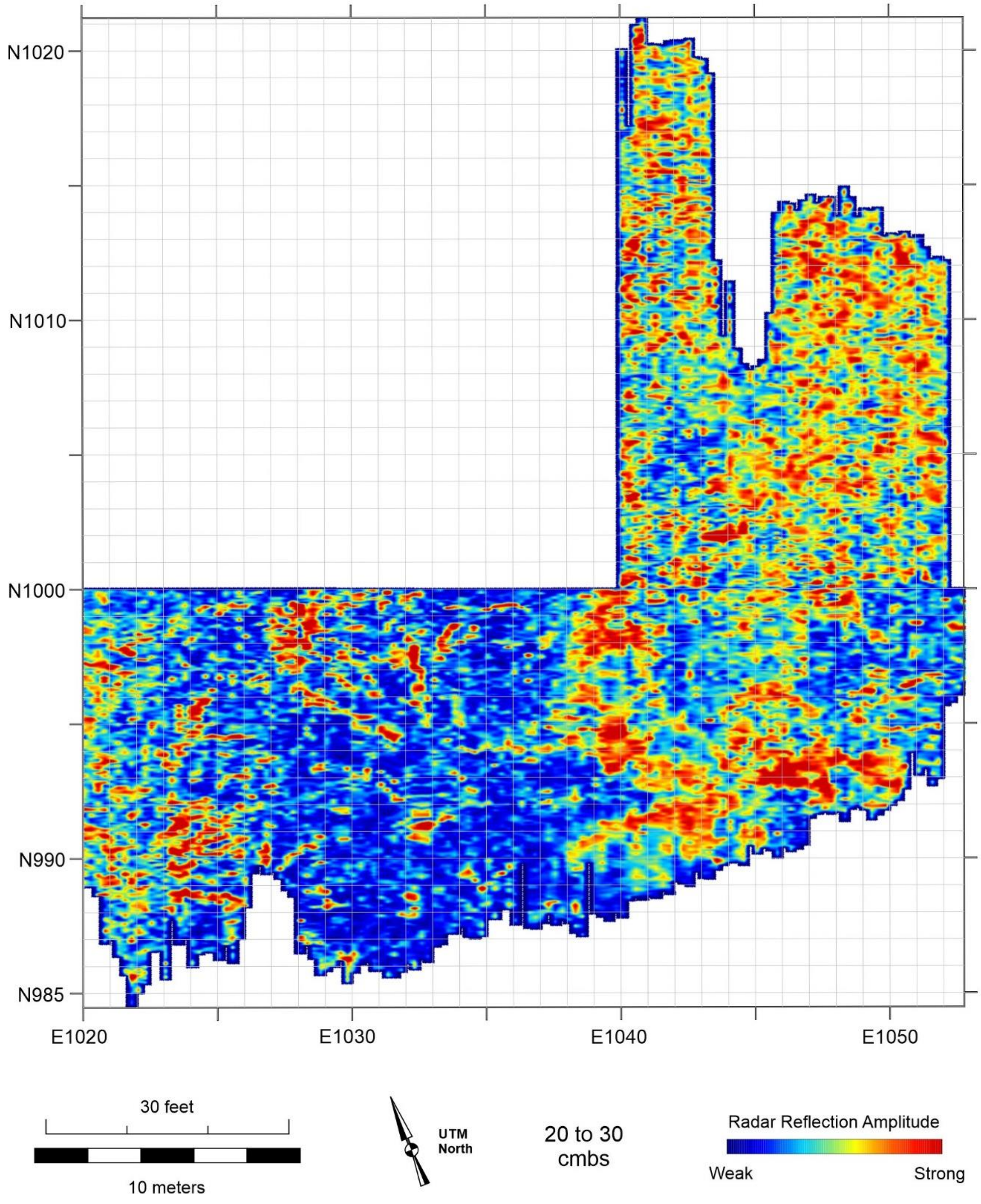


Appendix D. Ground penetrating radar data maps.

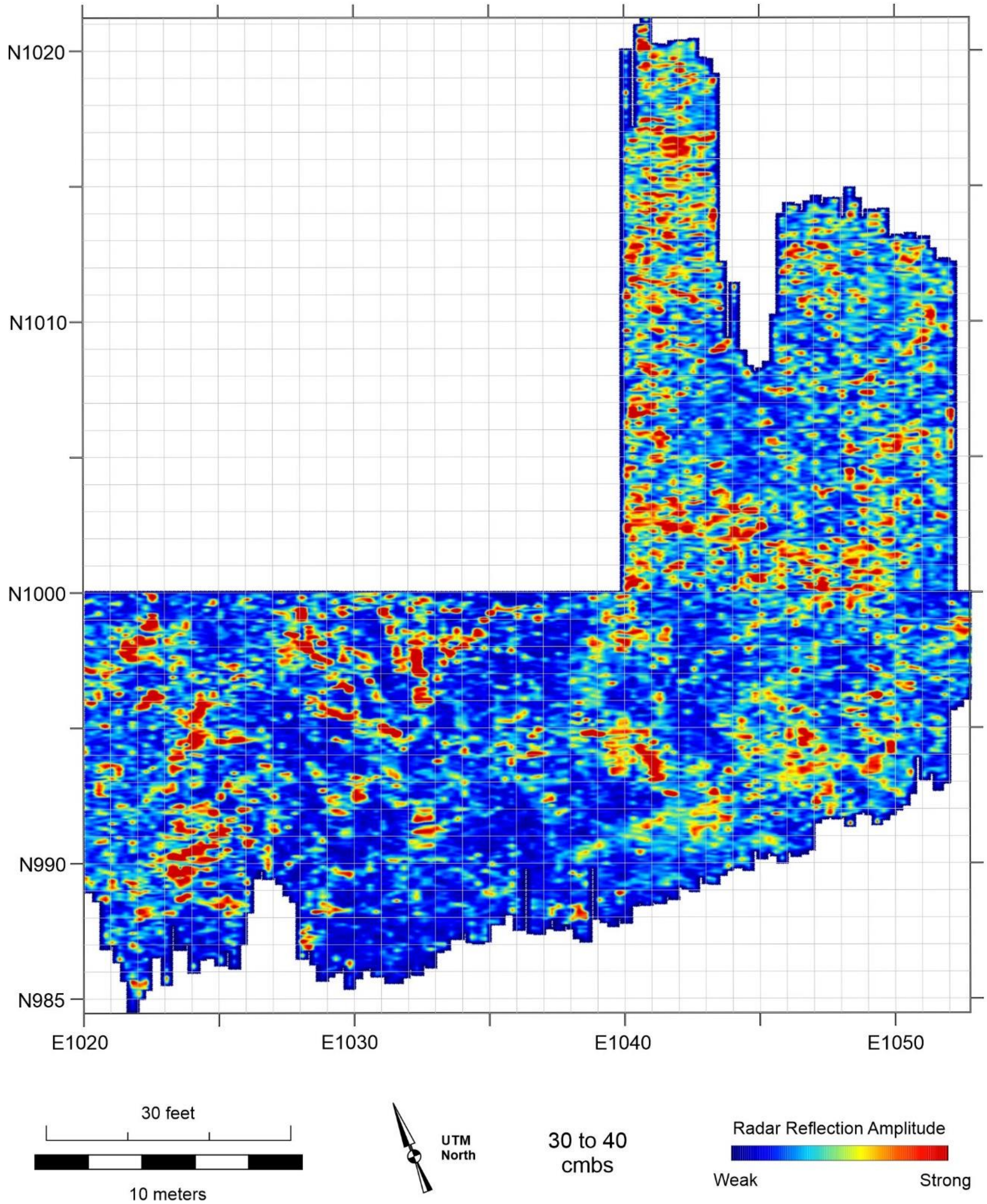
Area 1 GPR time slice at 10-20 cm below surface



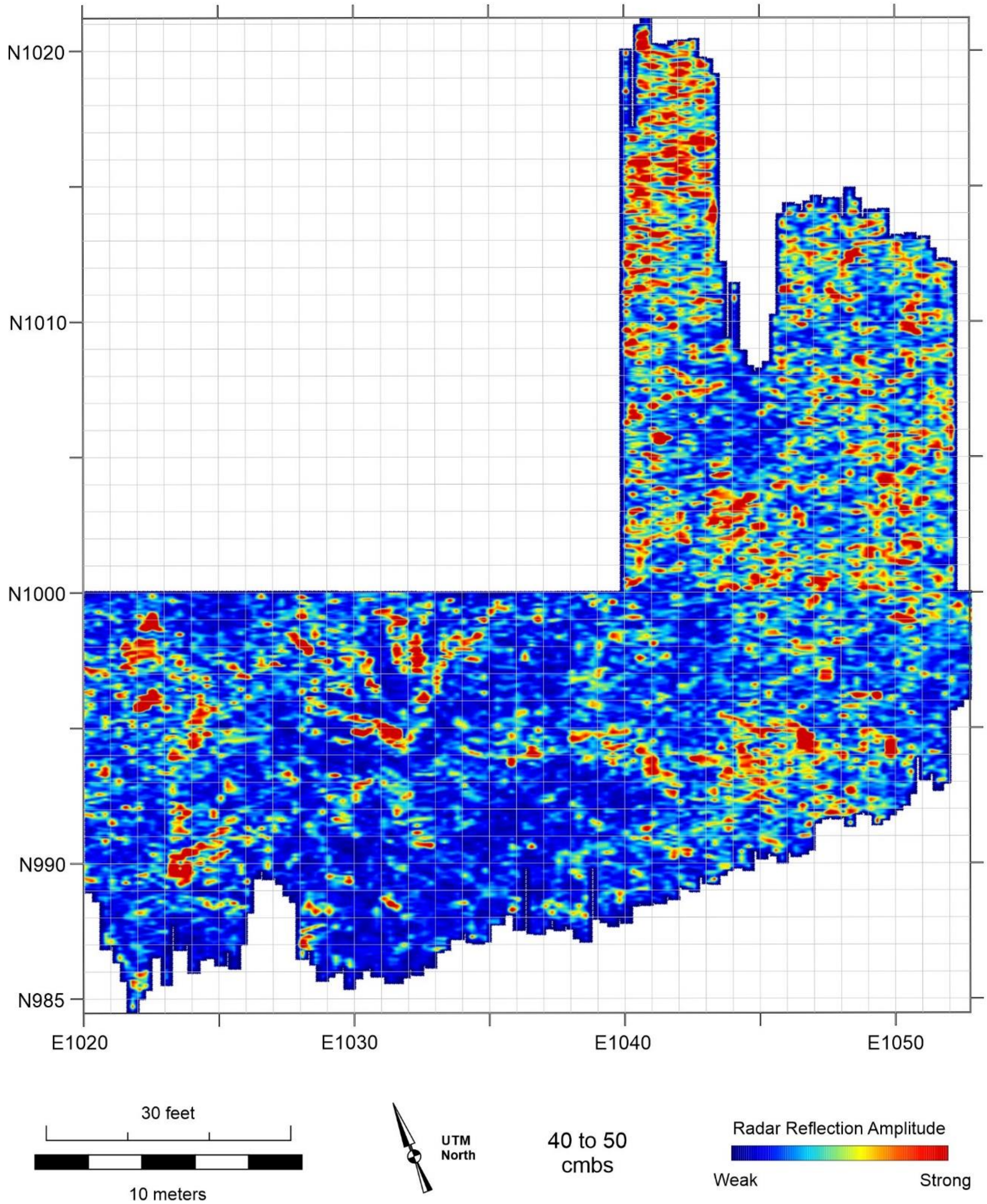
Area 1 GPR time slice at 20-30 cm below surface



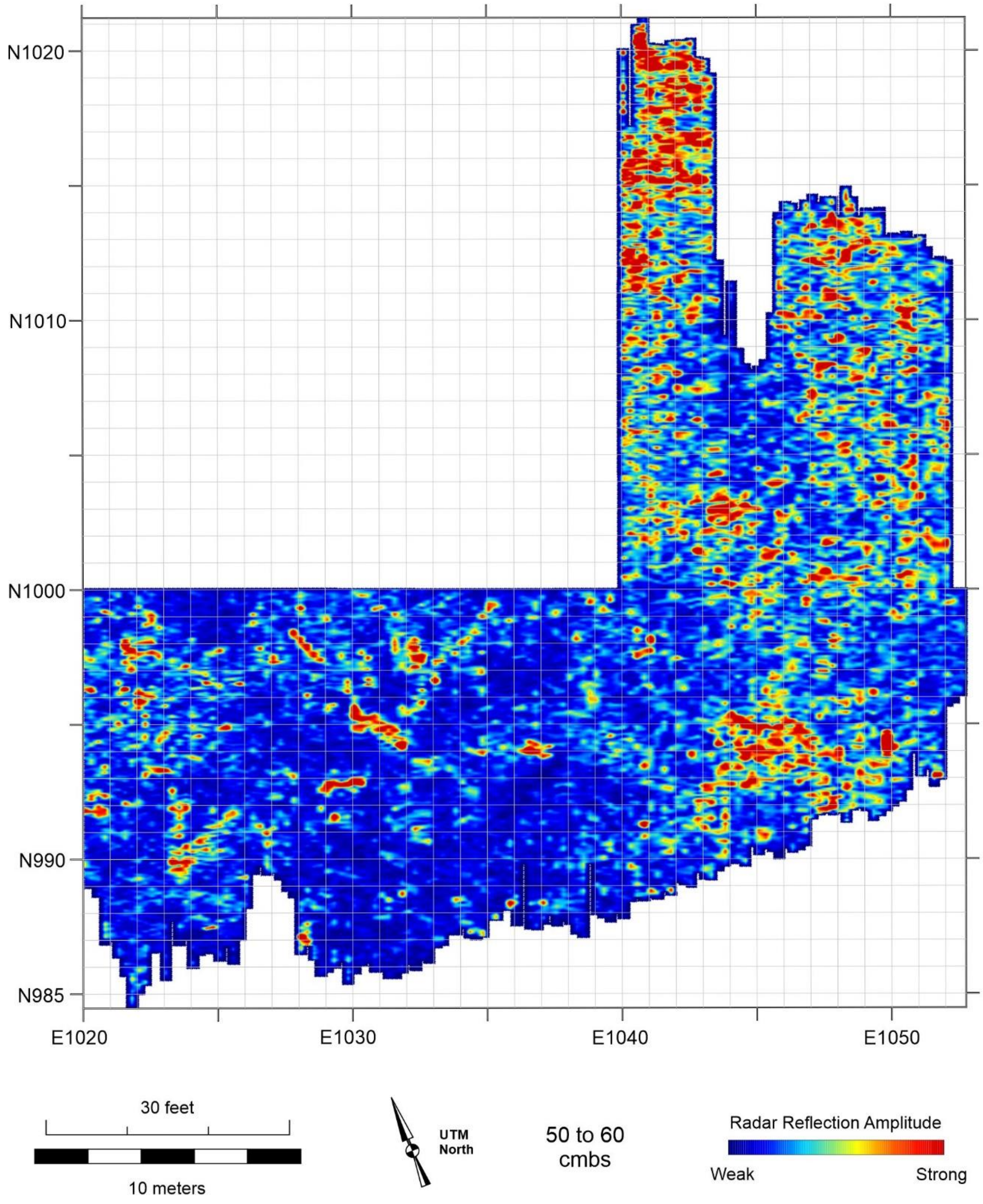
Area 1 GPR time slice at 30-40 cm below surface



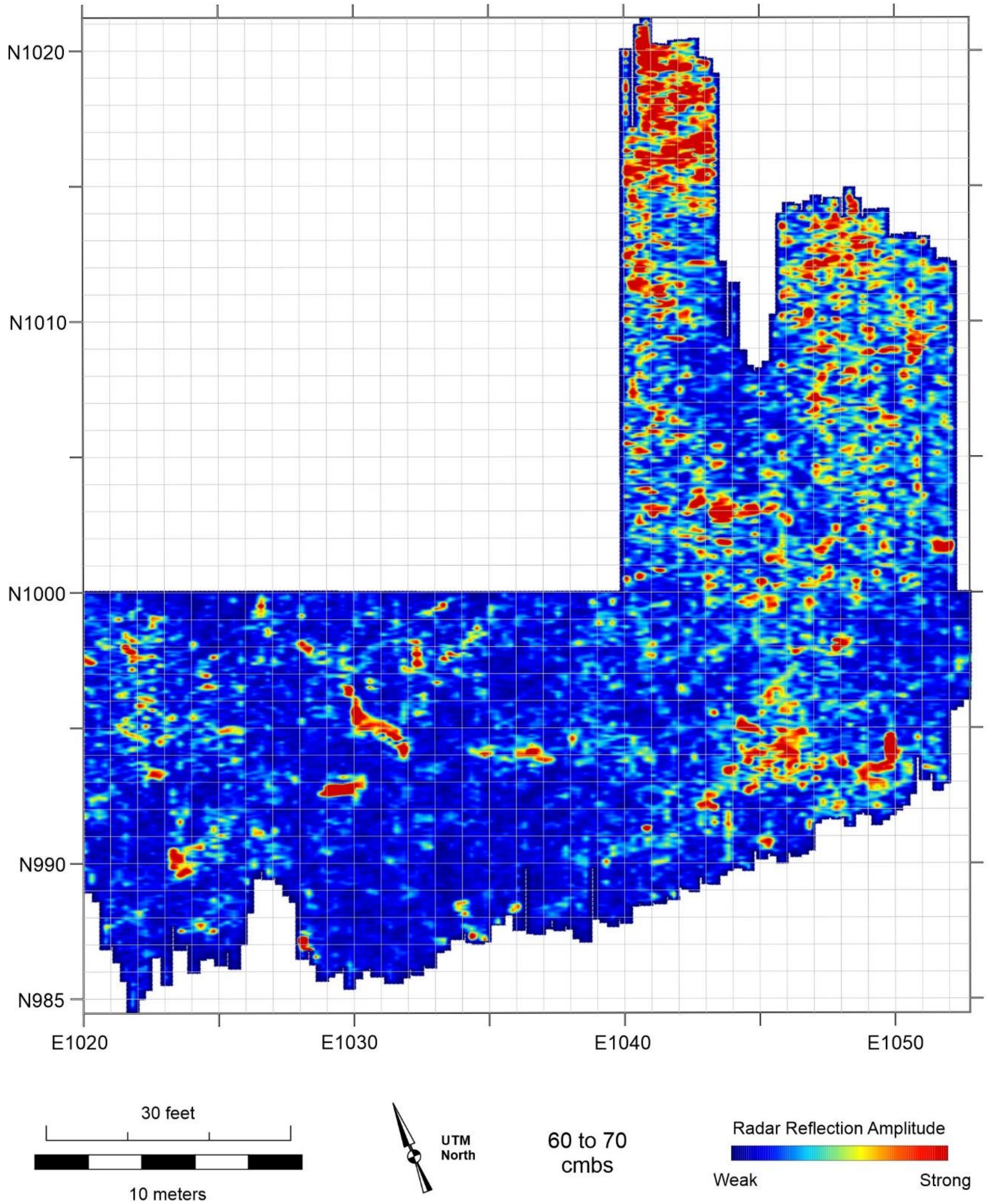
Area 1 GPR time slice at 40-50 cm below surface



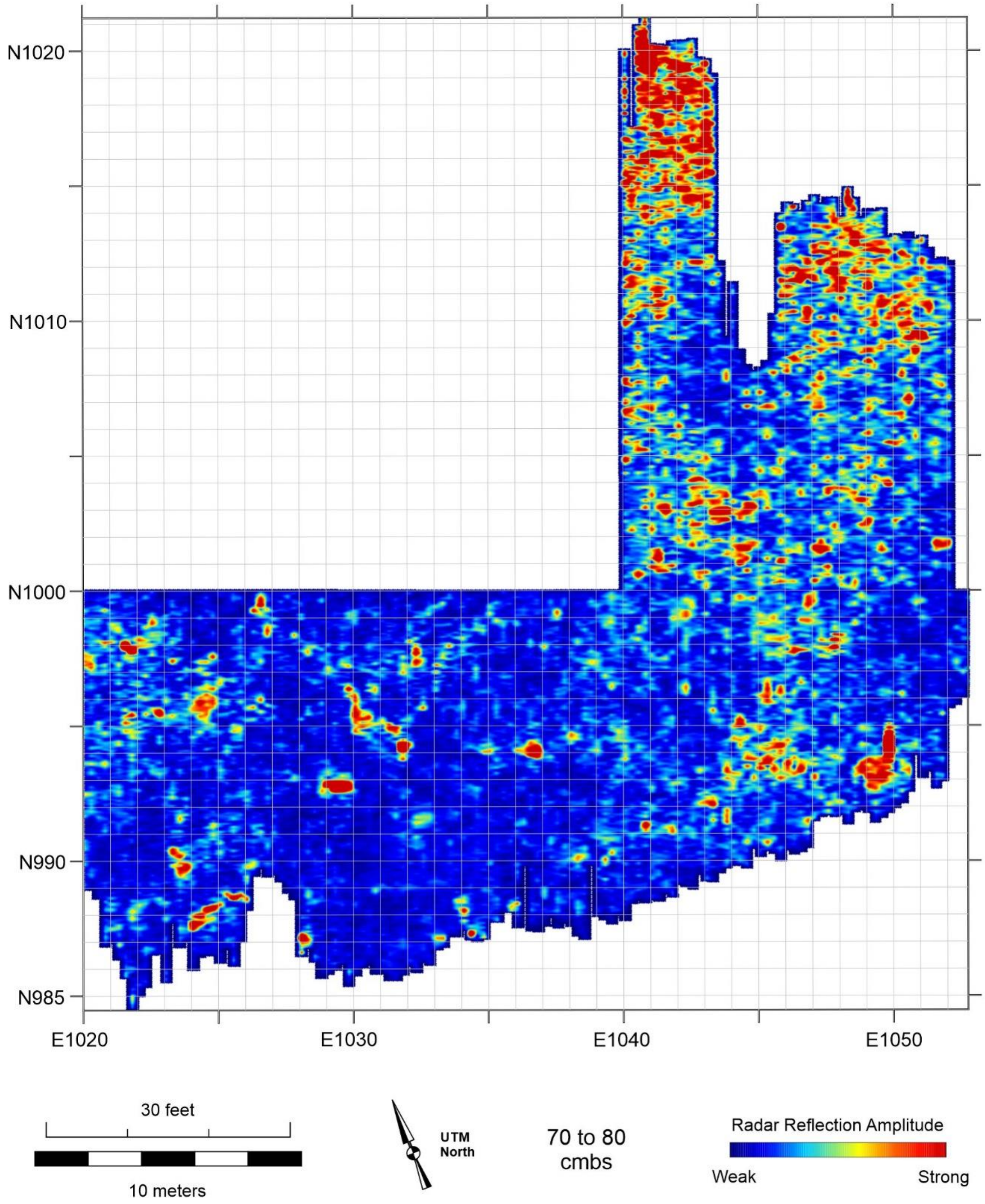
Area 1 GPR time slice at 50-60 cm below surface



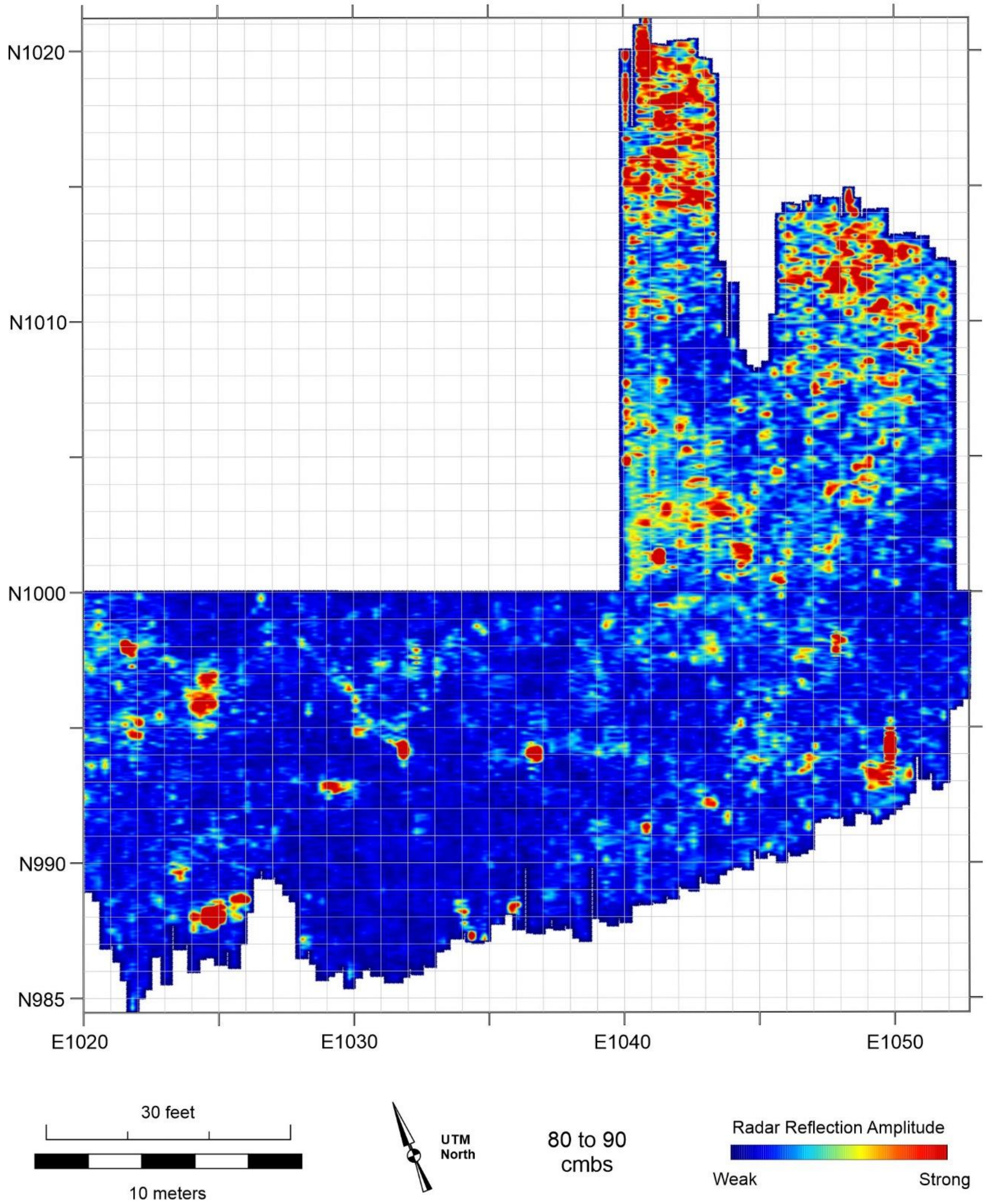
Area 1 GPR time slice at 60-70 cm below surface



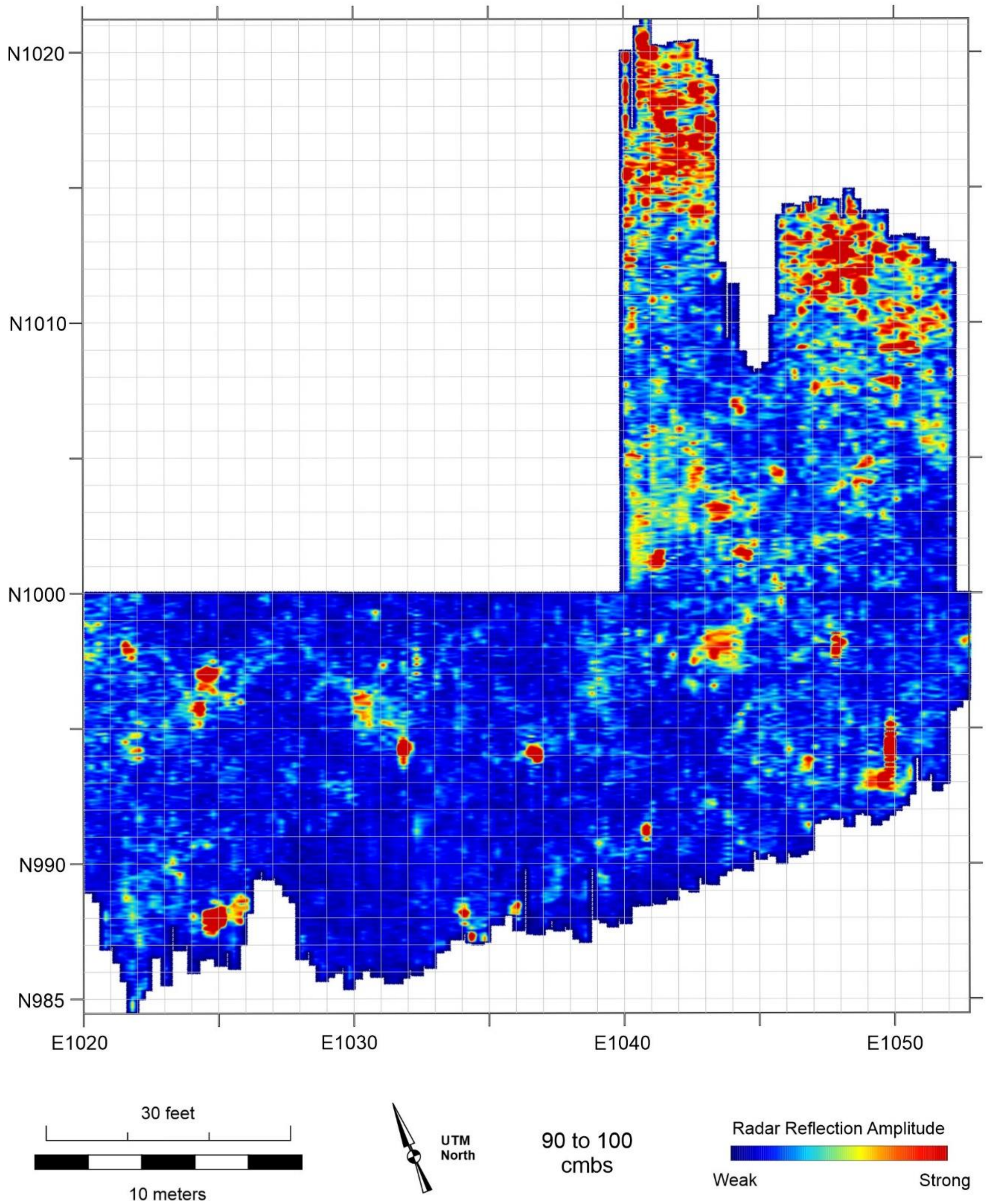
Area 1 GPR time slice at 70-80 cm below surface



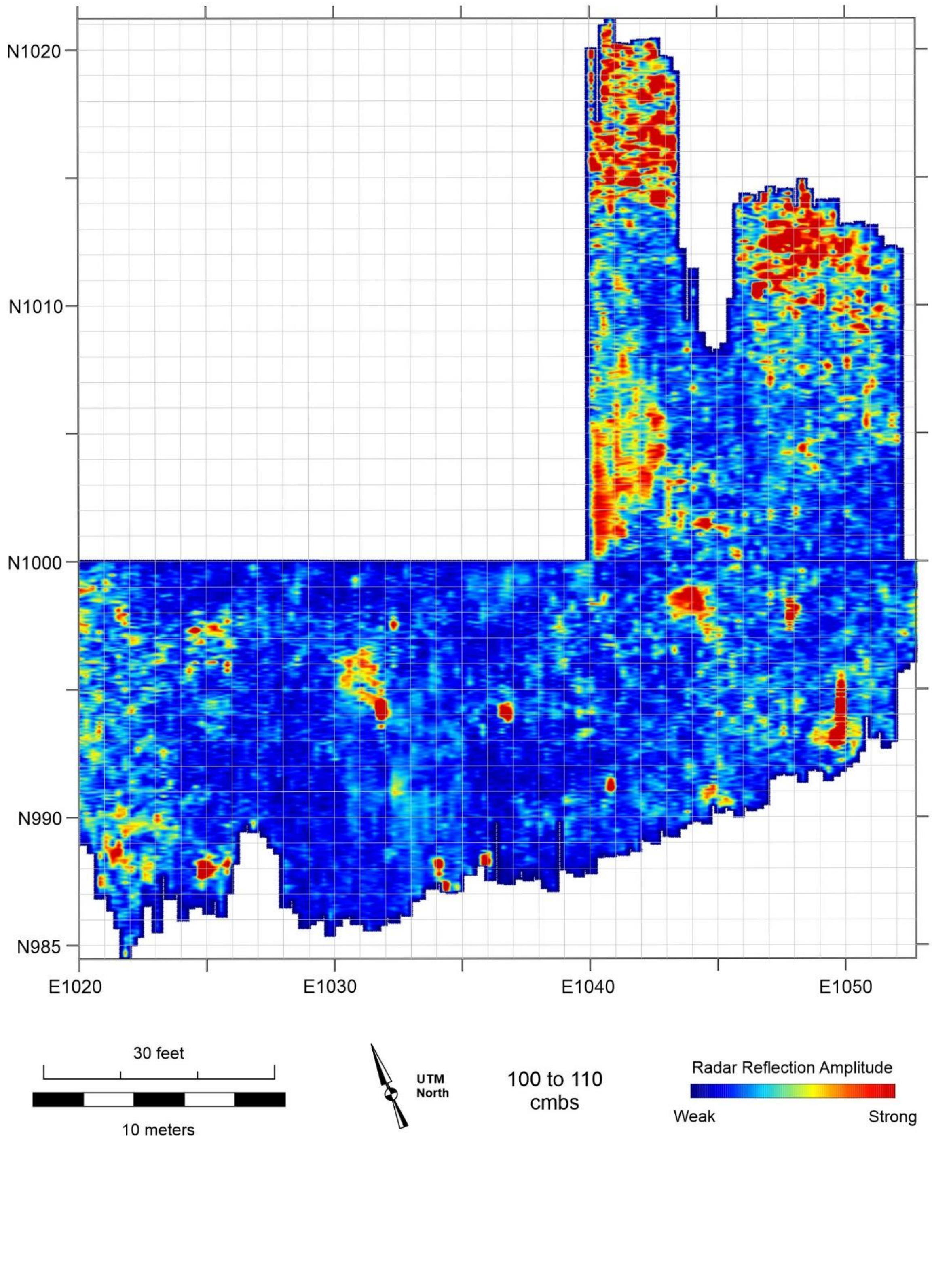
Area 1 GPR time slice at 80-90 cm below surface



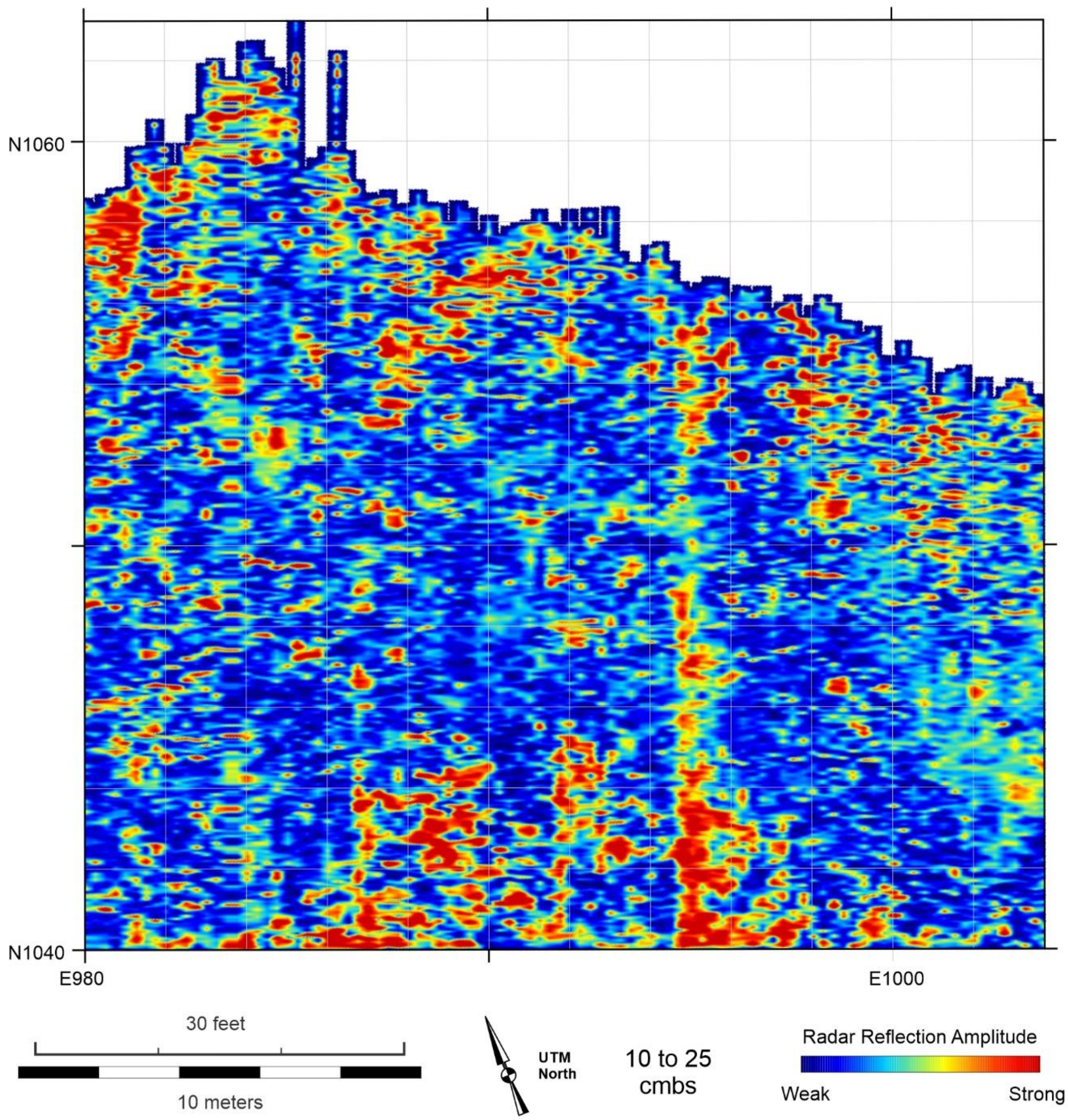
Area 1 GPR time slice at 90-100 cm below surface



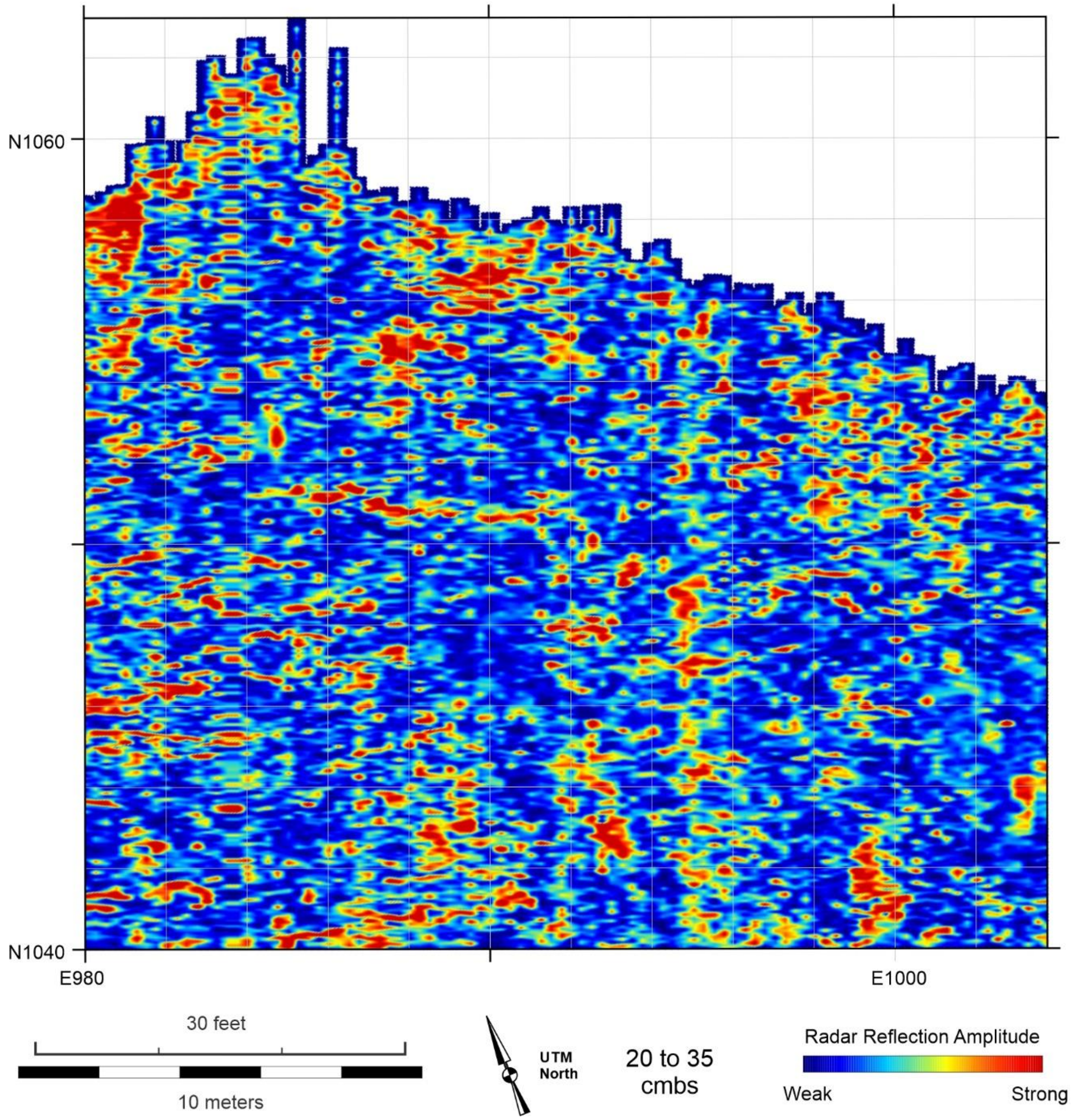
Area 1 GPR time slice at 100-110 cm below surface



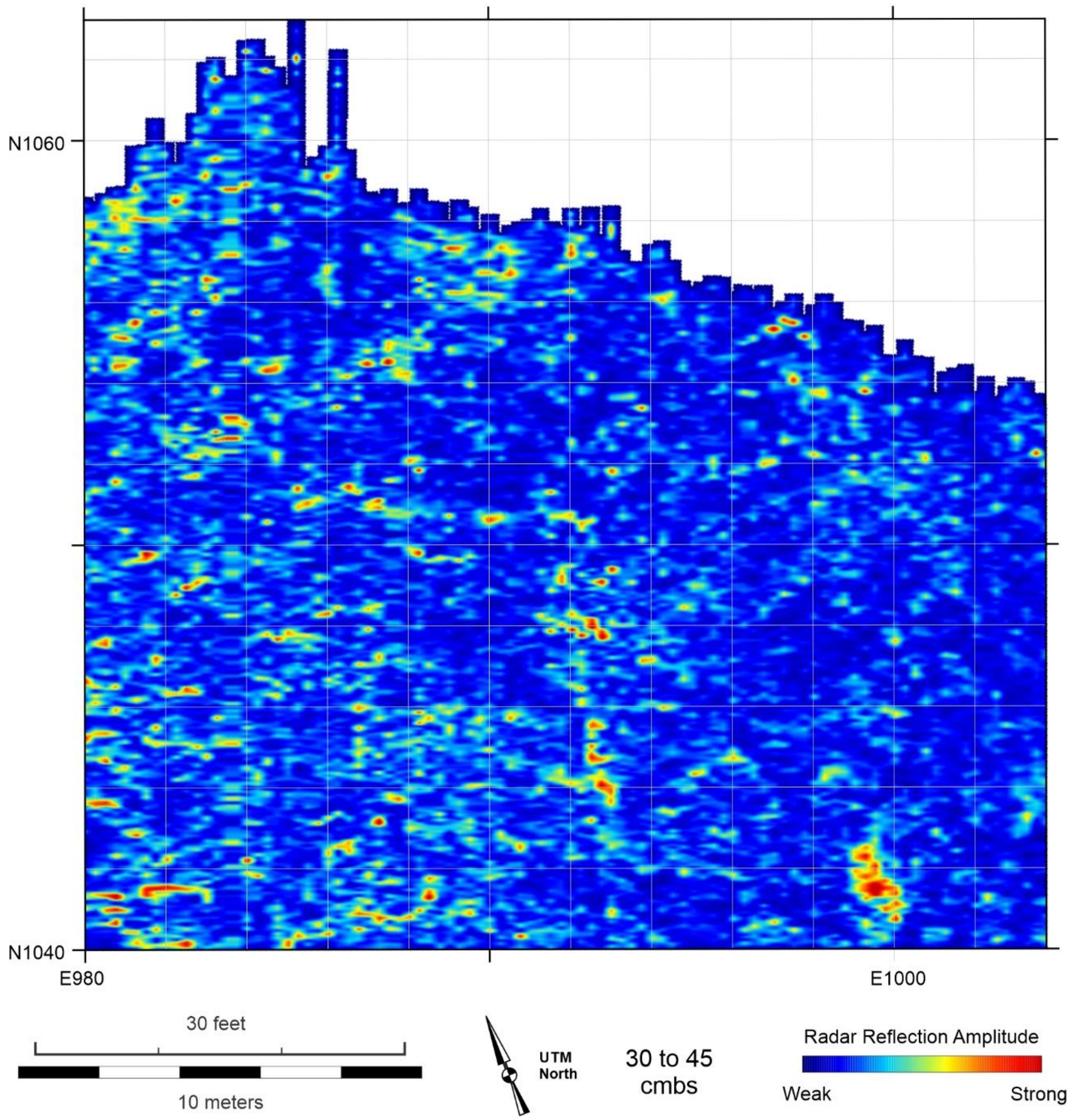
Area 2 GPR time slice at 10-25 cm below surface



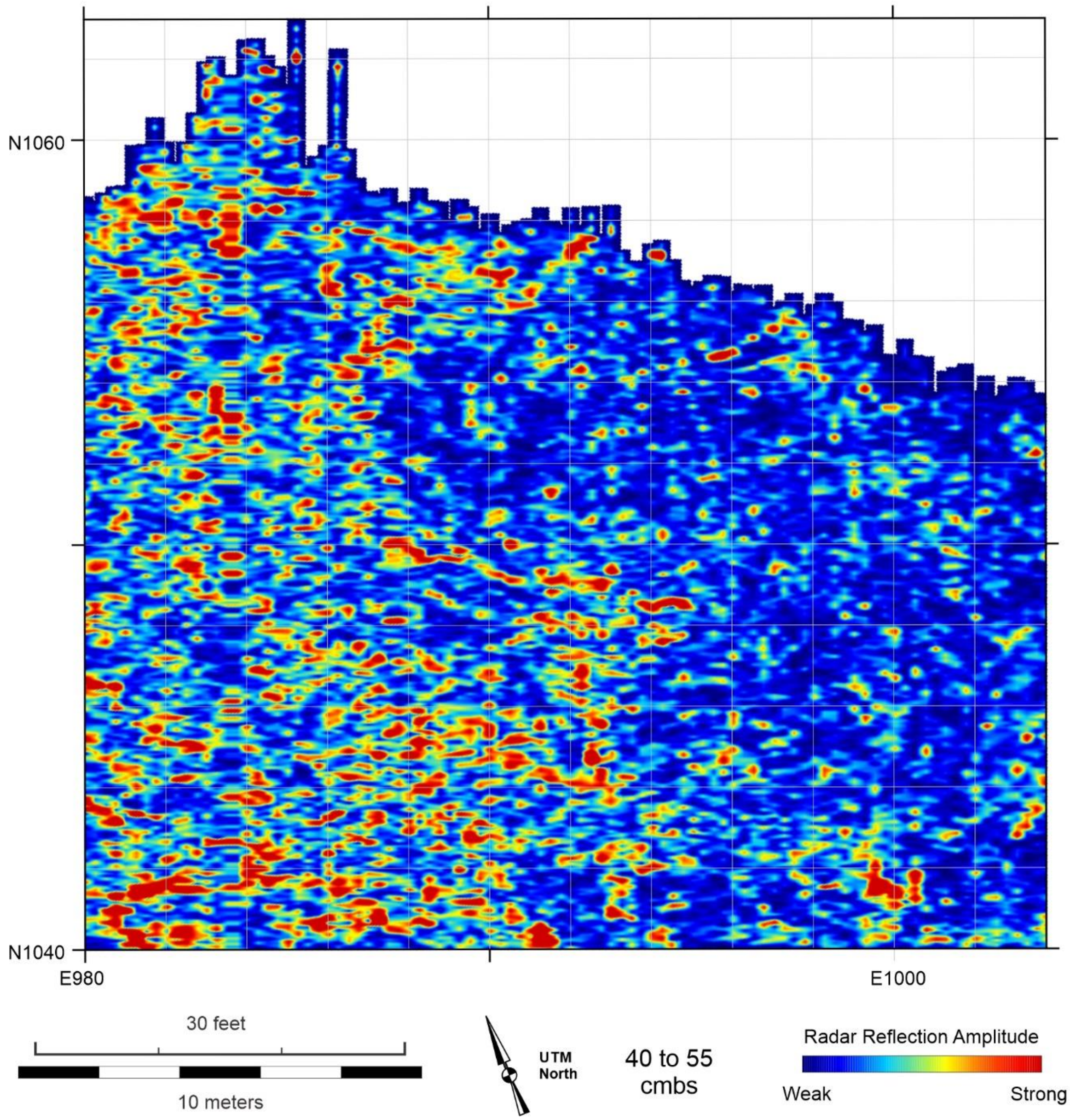
Area 2 GPR time slice at 20-35 cm below surface



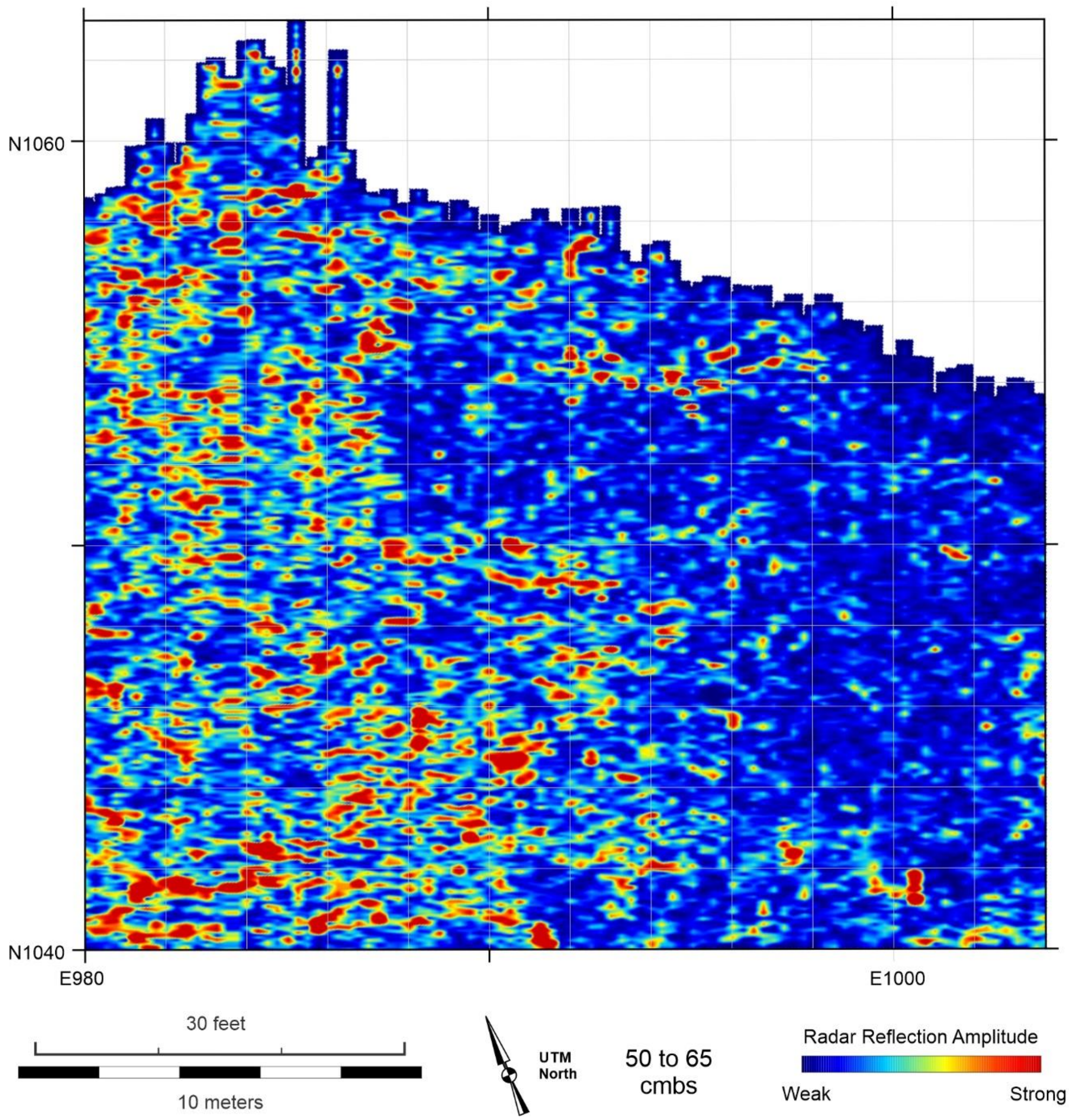
Area 2 GPR time slice at 30-45 cm below surface



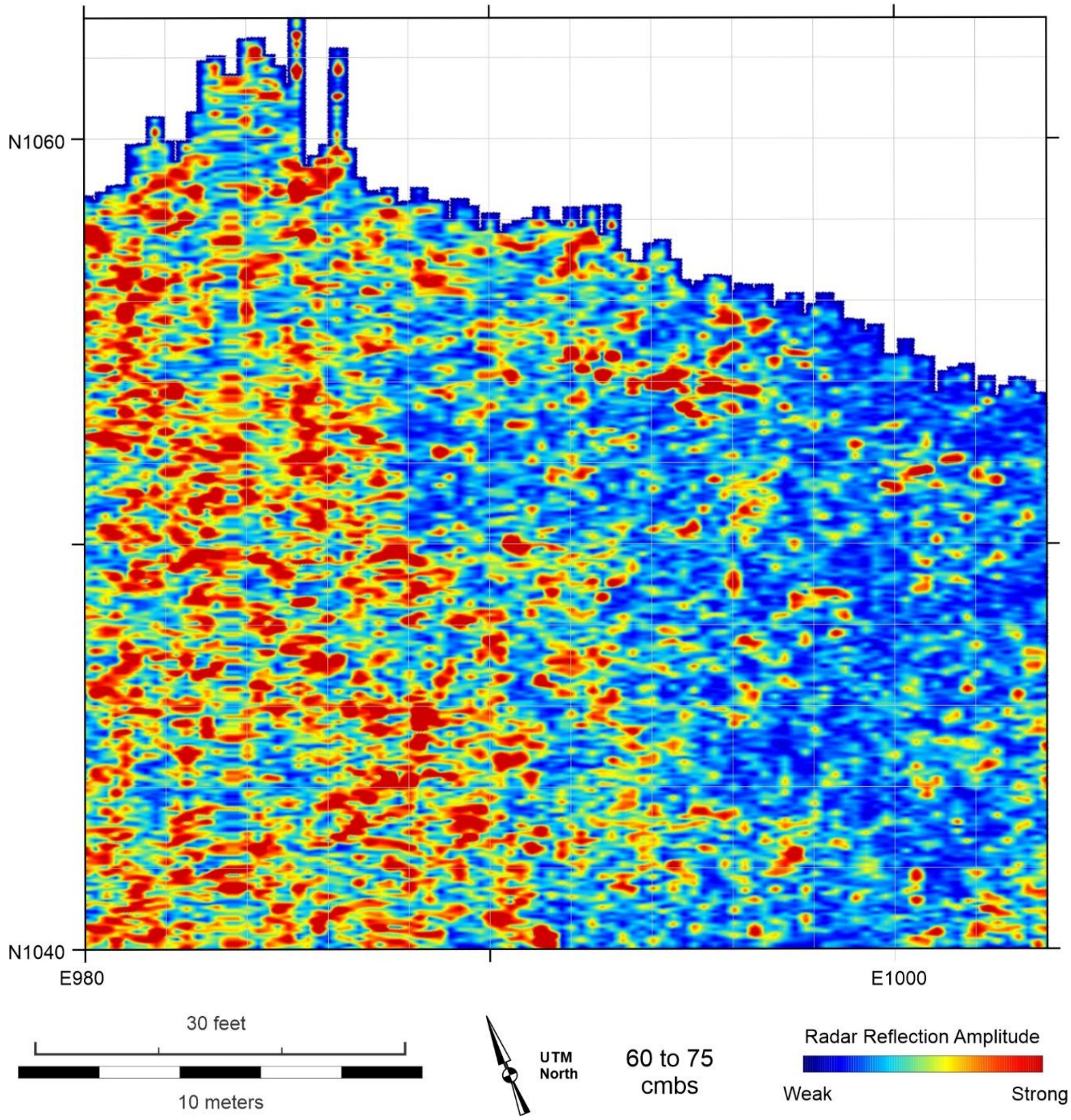
Area 2 GPR time slice at 40-55 cm below surface



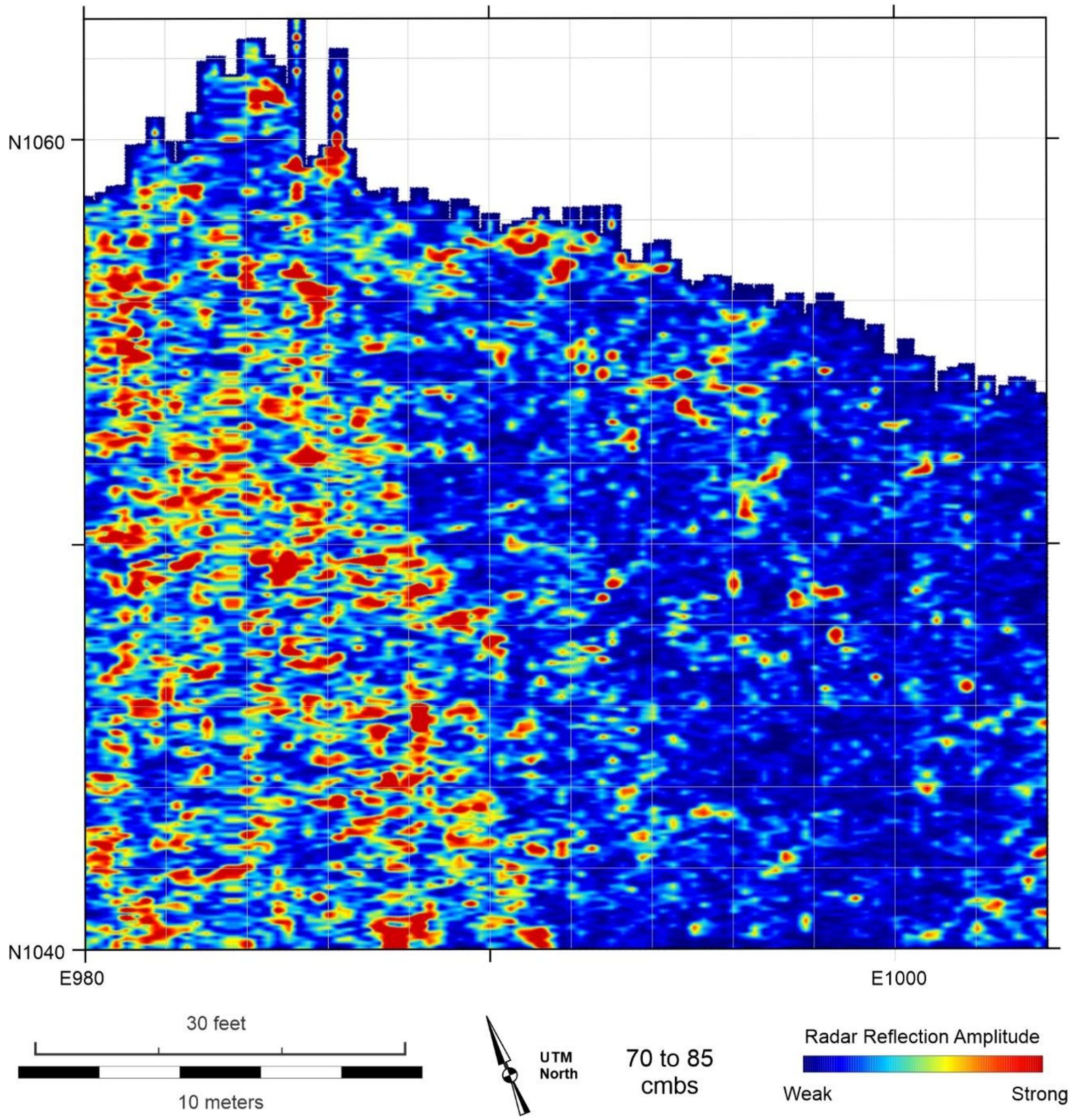
Area 2 GPR time slice at 50-65 cm below surface



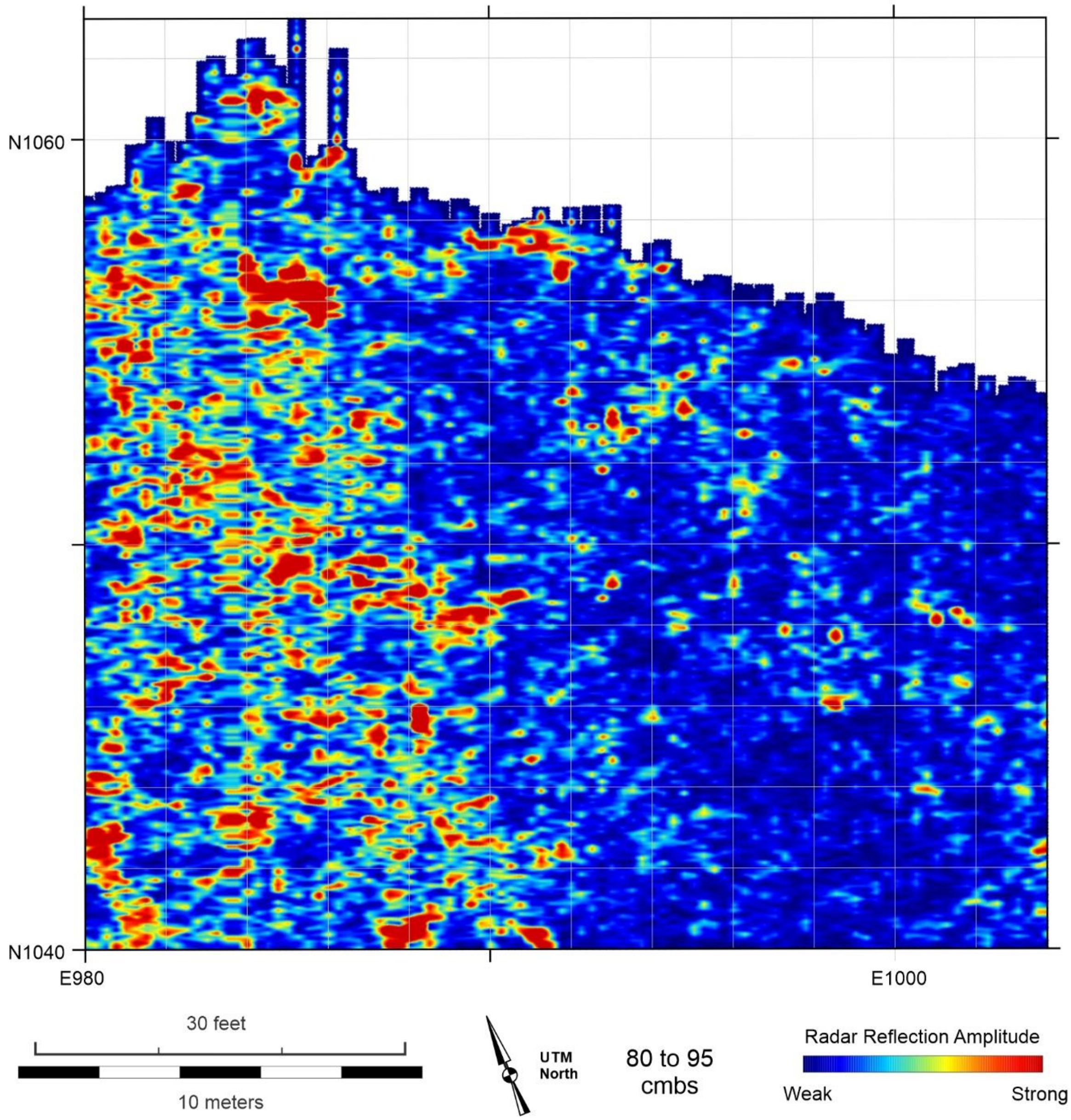
Area 2 GPR time slice at 60-75 cm below surface



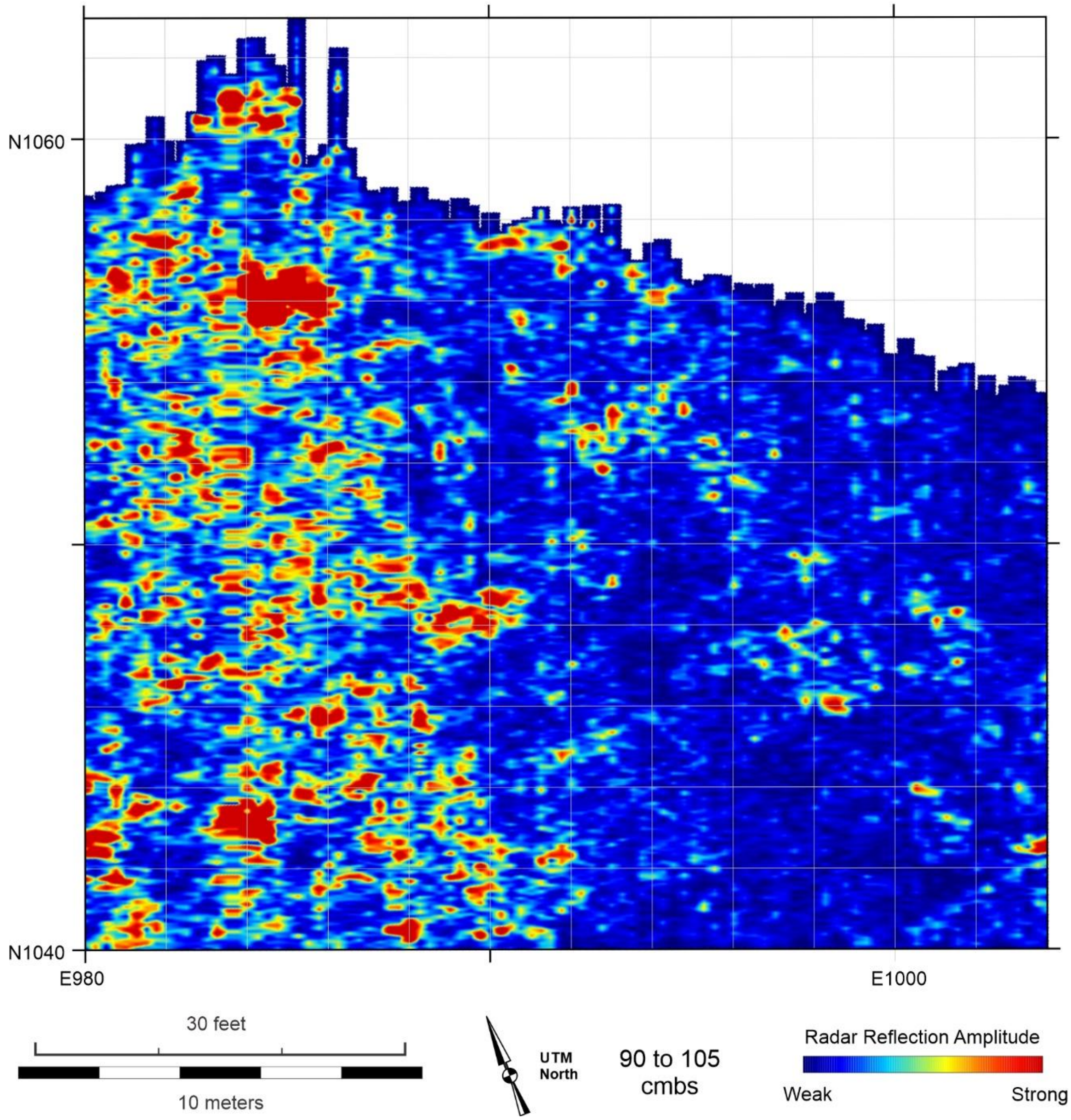
Area 2 GPR time slice at 70-85 cm below surface



Area 2 GPR time slice at 80-95 cm below surface



Area 2 GPR time slice at 90-105 cm below surface



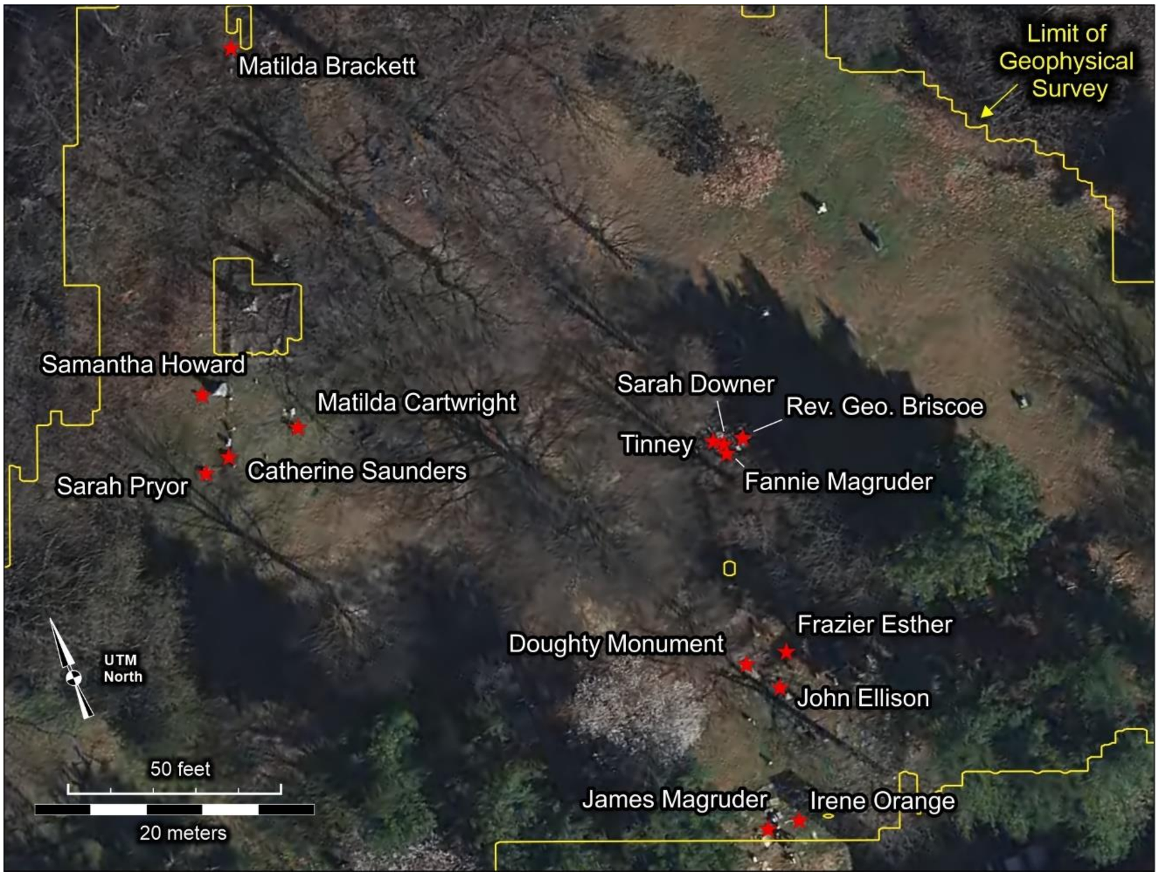
Appendix E. Photogrammetry Methodology.

One component of the survey at Mount Zion Cemetery was the use of photogrammetry to document monuments. This survey was conducted by both Ohio Valley Archaeology staff and six students working as part of the Hope Crew through the National Trust for Historic Preservation. Instruction was given in a classroom setting, and then the students put their new skills to the test by capturing photographs of select monuments on the final day of survey. In total there were 339 photos taken by students of ten (10) monuments and 1,655 photos taken of five (5) monuments by Ohio Valley Archaeology, Inc. The photographed monuments are located all across the project area (Figure Appendix E.1).

The method by which monuments were documented is broken into two parts. In order to capture the details on the face of the monument, a zig-zagging pattern of overlapping photos was taken starting at the top left of the monument face (Figure Appendix E.2). Once the initial set of photos is completed in the zigzag pattern, additional images were captured to provide the context of the stone. Contextual photos are taken in three concentric rings of "low" "medium" and "high" elevations around each monument (Figure Appendix E.3.).

Students were asked to select headstones for photogrammetry that were either in complete shadow or full sunlight and that had space around the stone so that the monument could be photographed following the above-mentioned methodology. Consistent, even lighting is important, as any shadows documented through this technique are permanently baked into the texture (the overall look of the final result) produced for the model.

Processing of photos was done in a software package called RealityCapture. This software uses an algorithm to determine each photo's location relative to the other photos that it overlaps with. Given enough overlapping images, a cloud of points with x, y, and z coordinates representative of the surface being documented will be produced. This point cloud is then converted into a mesh (the points are connected to each other via interlocking polygons), which can then be textured using the photos used to create the three-dimensional model.



Appendix E.1. Photogrammetry locations at Mount Zion.

The three-dimensional models created for the headstones were used to produce an orthorectified image (a straight on image of the face of the stone) and a digital surface model (a topographic map) for each of the modelled monuments. These files were then brought into a GIS environment (QGIS) and the surface model was hill shaded (an artificial light source is simulated, which casts shadows) to accentuate the more subtle details.

As with all photogrammetry, the resolution and number of overlapping photos taken of monuments is very important to the outcome of the modelling effort. Too few photos, or the use of cameras of a lower resolution, typically produces coarser three-dimensional models. OVAI utilizes a full frame 24.3 MP DSLR with a prime 35mm lens to ensure sufficient resolution and quality of images taken for photogrammetry. Photos taken by the students were collected with phone cameras. In some cases, it was found that students had uploaded extremely compressed images (a down-sampled jpg file). The unfortunate side effect of image compression is that the images have had much of their detail stripped away (most noticeable in the Irene Orange and Samantha Howard monuments). In many cases the modelling was complicated by the very limited total numbers of photos that were taken for many of the monuments (see Tables E1 and E2; models with insufficient photographs indicated in red). As a result, one set of photos failed to align and no model could be produced (the Elizabeth Watts monument), while the remaining nine (9) monuments produced models representative of only part of the total monument. In some cases, such as the monuments of Fannie J. Magruder and Sarah Pryor, the numbers and overlap of those photos were sufficient to encompass the entire monument and produce a complete 3D model. Other issues encountered were uneven light, such as the Catherine Saunders and Sarah Downer monuments, with noticeable shadows permanently cast on the monument.

One of the more notable discoveries revealed by the photogrammetry work was found on the John Ellison monument. A close inspection of the hill shaded version of the modelling results shows what appears to be a name (Alfred Johnson) carved upside down near the bottom of this monument. It is possible that this monument was turned upside down and then reused as a marker for Johnson's grave—perhaps after Ellison had been exhumed and moved to a different cemetery.

Table E1. Student photographs (models with insufficient numbers of photos are in red).

Headstone	Number of photographs	Model?
Catherine Saunders	16	Yes (Partial)
Samantha F. Howard	14	Yes (Partial)
Elizabeth Watts	13	No
Matilda Brackett	15	Yes (Partial)
Irene A. Orange	14	Yes (Partial)
James H. Magruder	13	Yes (Partial)
Matilda Cartwright	43	Yes (Partial)
Sara H. Downer	29	Yes (Partial)
Fannie J. Magruder	69	Yes
Sarah Pryor	111	Yes
Other	2	No

Table E2. Models made with OVAI photographs.

Headstone	Number of Photographs	Model?
Frazier Ester*	97	Yes
Rev. George Briscoe	135	Yes
Tinney Monument	449	Yes
John Ellison	227	Yes
Doughty Monument	747	Yes

* Photographs taken with an iPhone 8; others all photos taken with Nikon DSLR with a 35mm Prime lens.

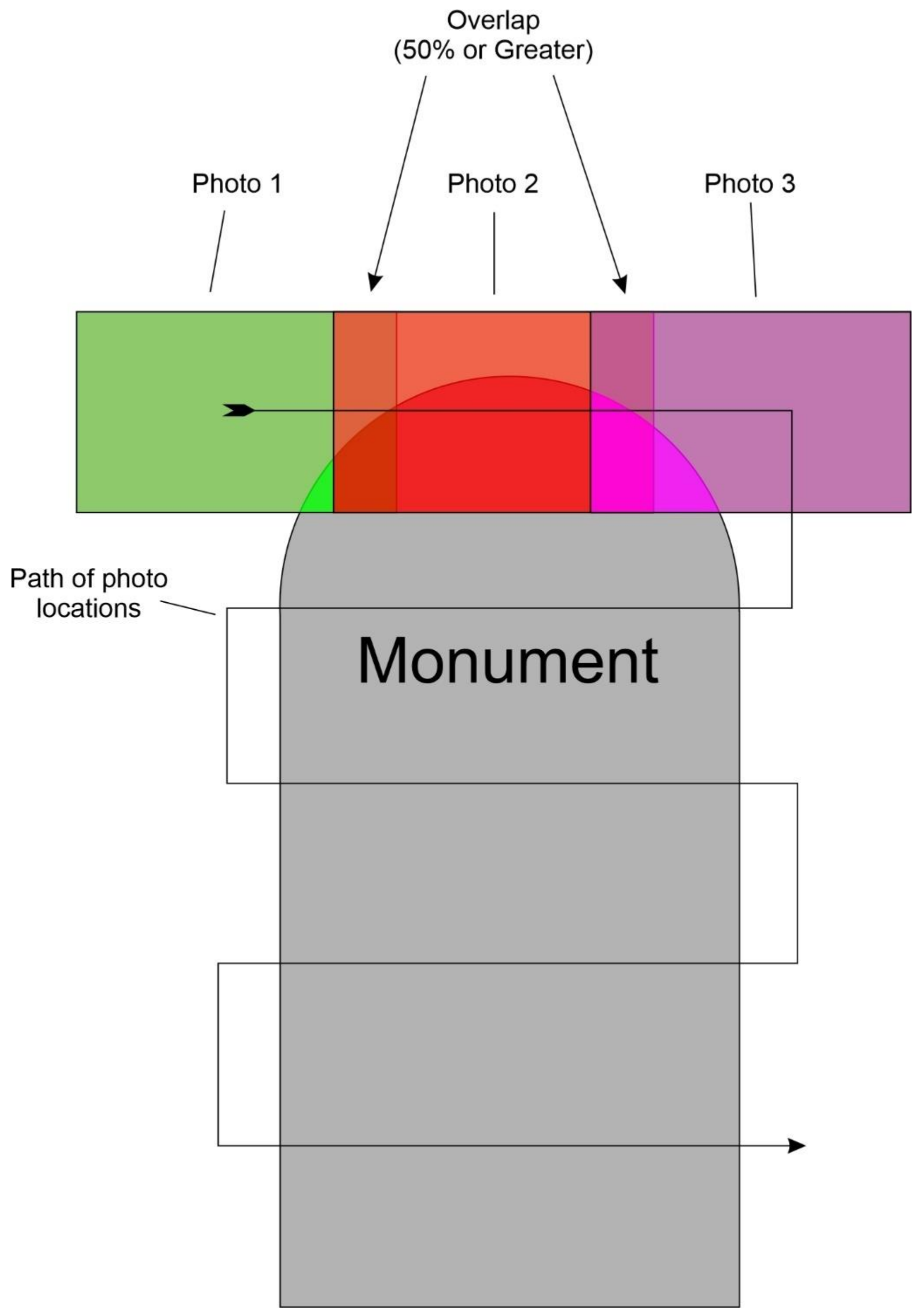


Figure Appendix E.2. Step one of photogrammetry survey, documenting the front of the monument.

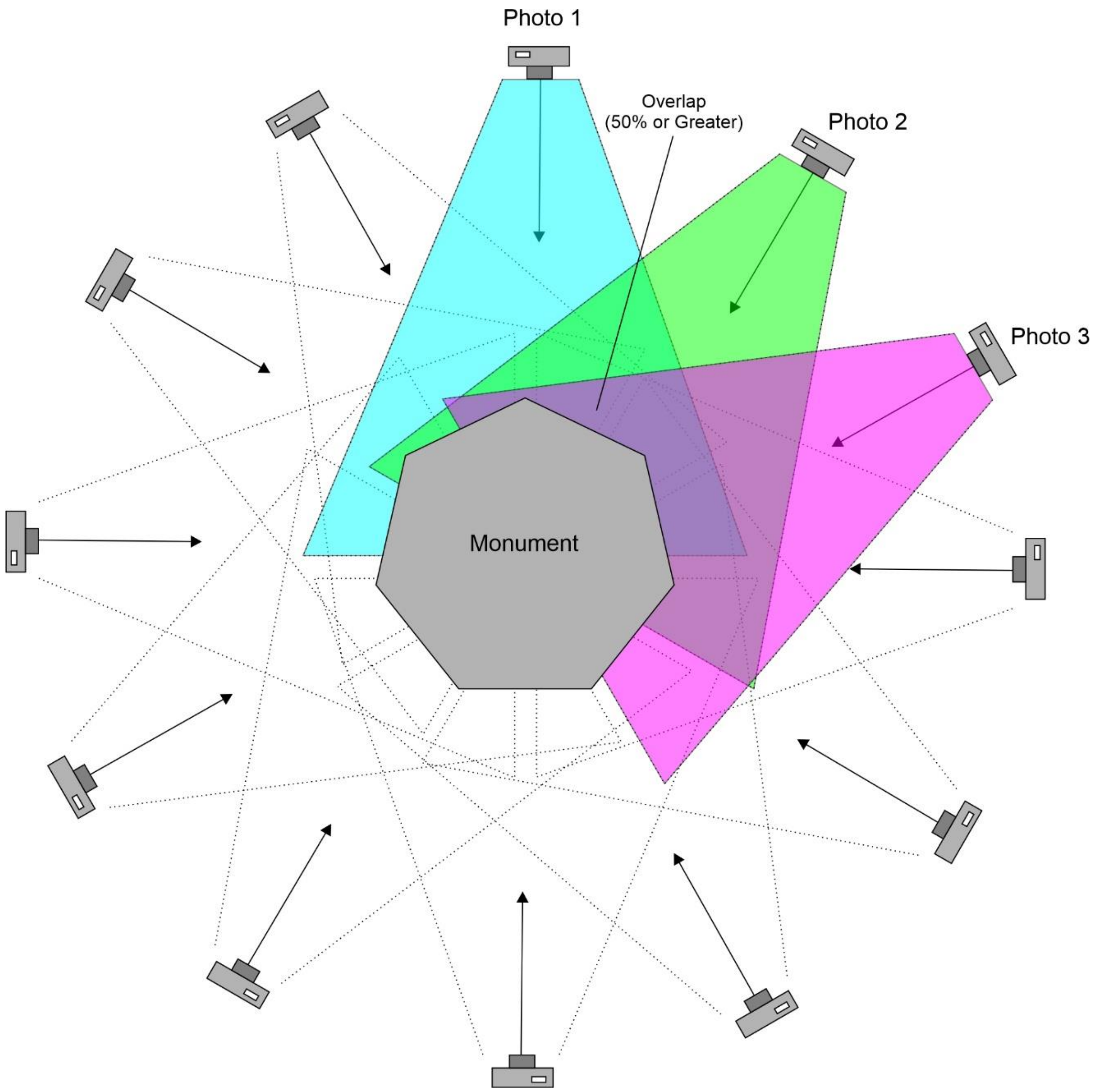
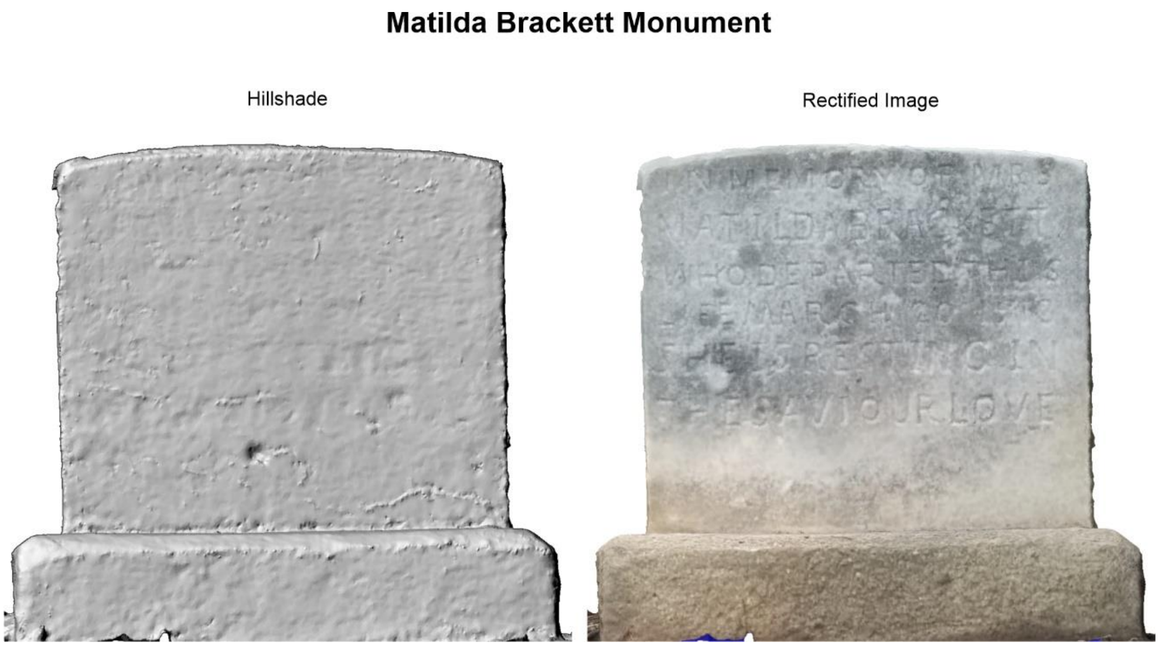


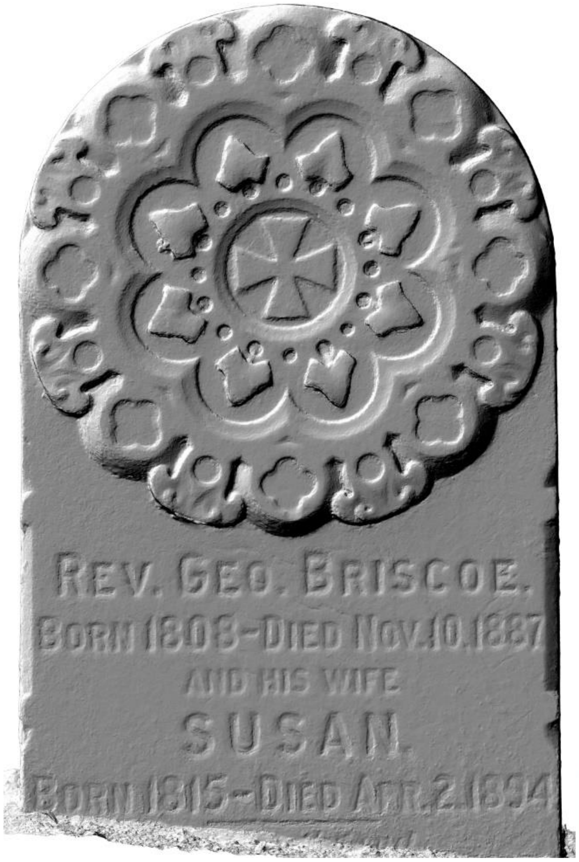
Figure Appendix E.3. Step two of photogrammetry survey, placing the front of the monument in context.

Appendix F. Photogrammetry Results



Rev. Geo. Briscoe Monument

Hillshade

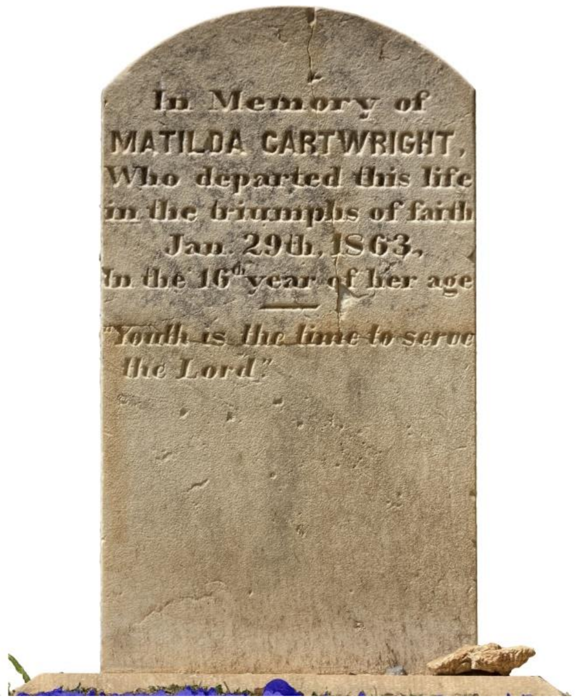


Rectified Image

Matilda Cartwright Monument

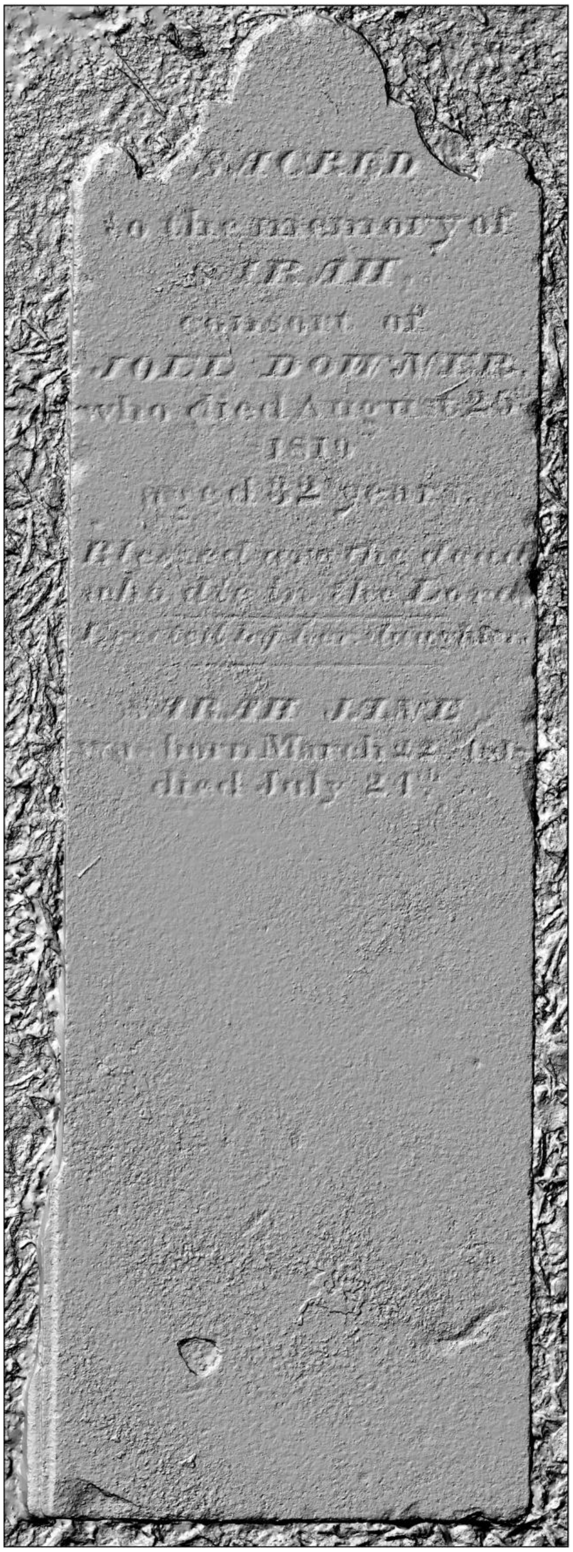
Hillshade

Rectified Image

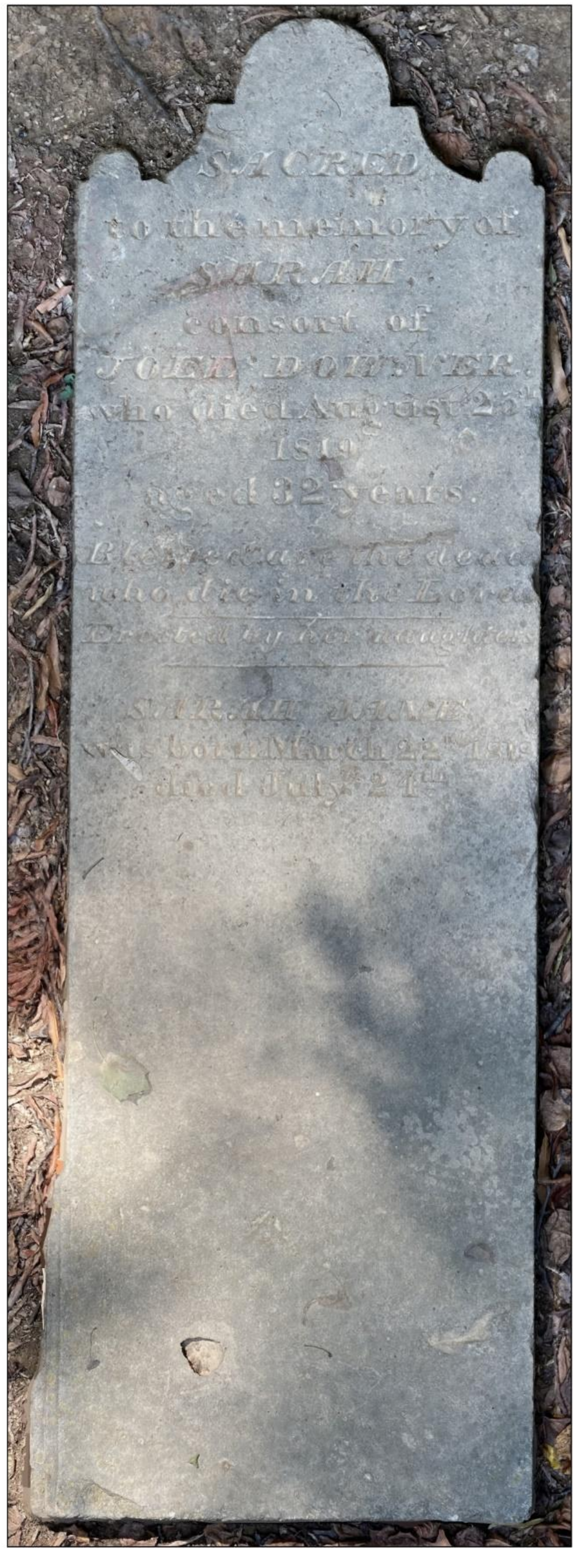


Sarah Downer Monument

Hillshade



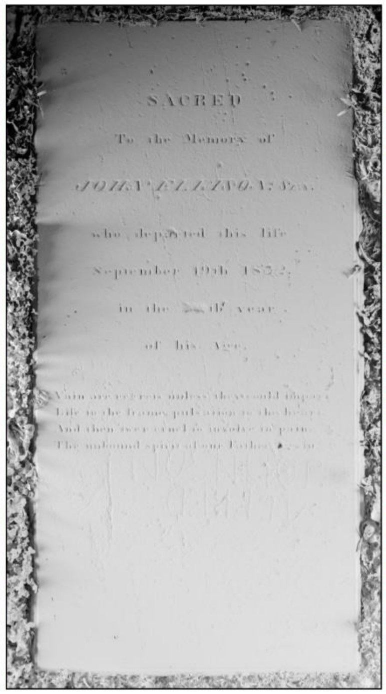
Rectified Image



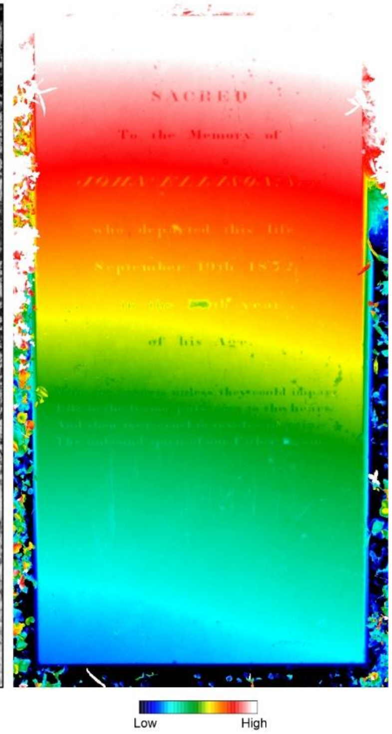
John Ellison and Alfred Johnson Monument

Textured Mesh

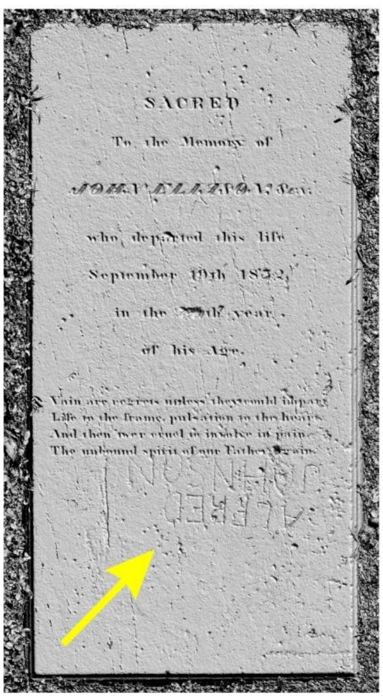
Untextured Mesh



Digital Surface Model



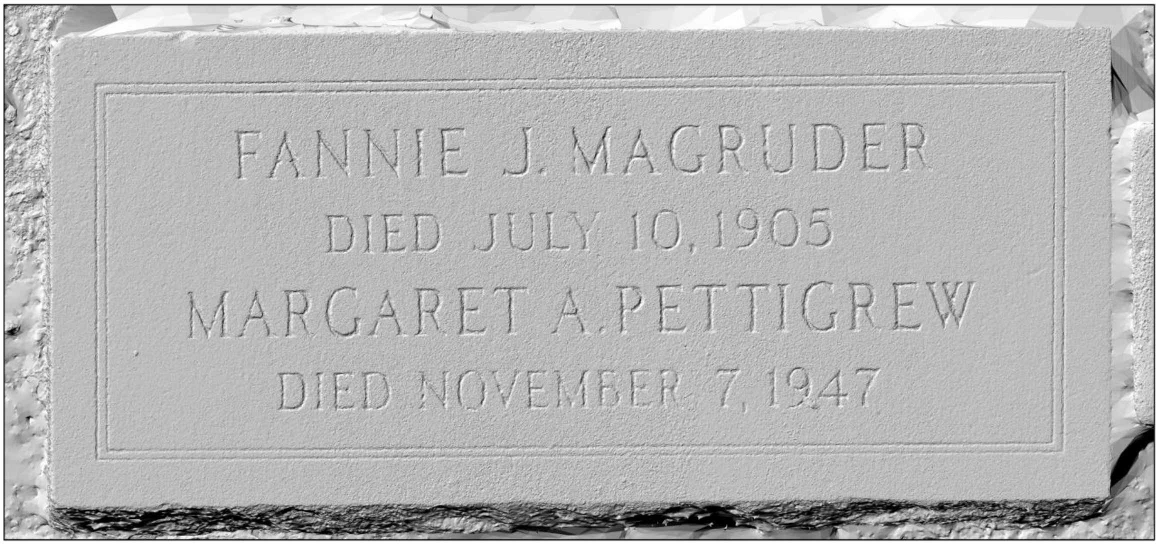
Shaded Surface Model



Local Relief Model-Flattens Background
Rotated 180˚

Fannie Magruder and Margaret Pettigrew Monument

Hillshade



Rectified Image

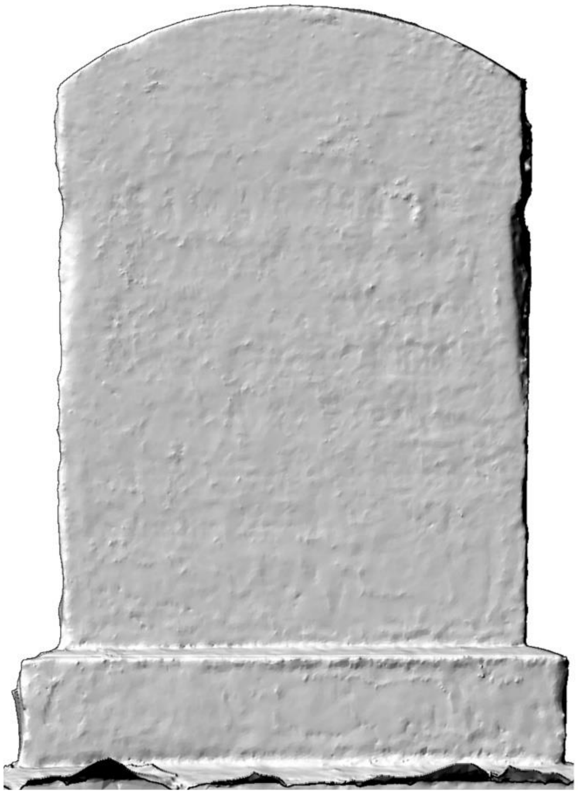
Esther Frazier Monument

Hillshade

Rectified Image

Samantha Howard Monument

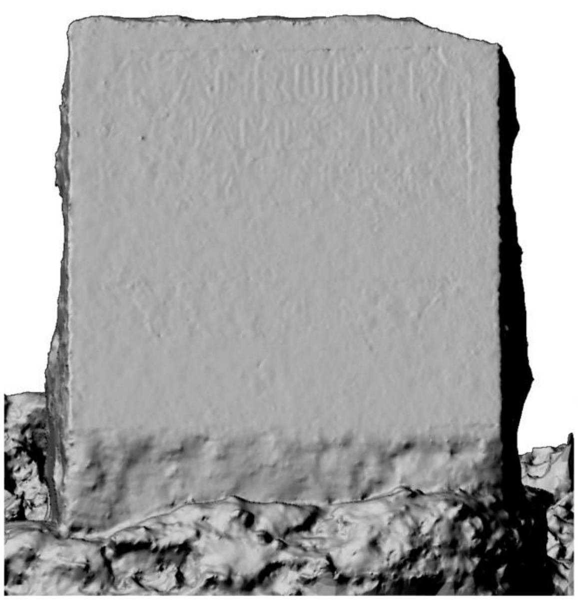
Hillshade



Rectified Image

James Magruder Monument

Hillshade



Rectified Image

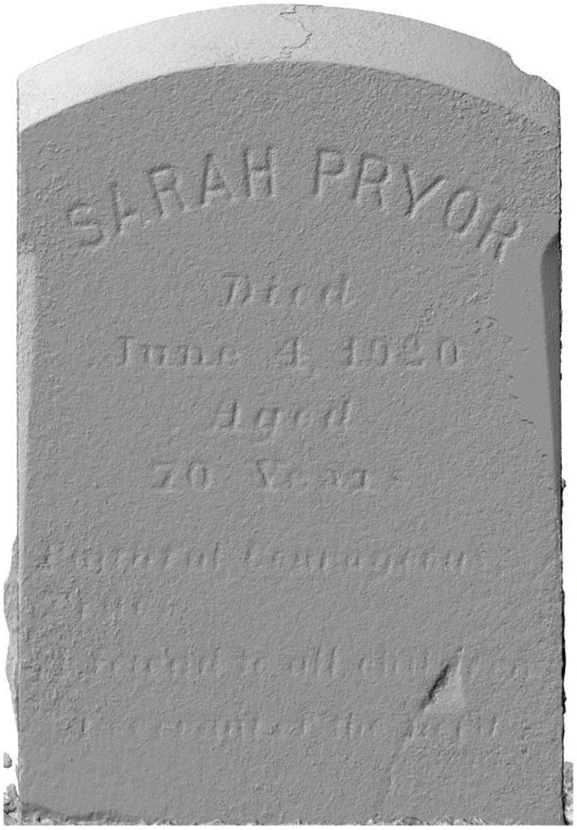
Irene Orange Monument

Hillshade

Rectified Image

Sarah Pryor Monument

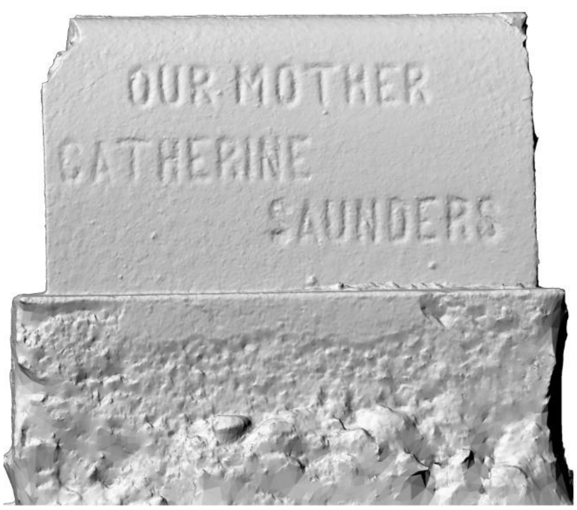
Hillshade



Rectified Image

Catherine Saunders Monument

Hillshade



Rectified Image

Tinney Monument