Ground-Penetrating Radar (GPR) Survey and Spatial Analysis of the George and Addie Giddens Cemetery, Opelika, AL

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science in Geology

Auburn, Alabama
May 7, 2022

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Abstract

Recent interest in locating and preserving the cemeteries of enslaved African Americans has increased the need for non-invasive geophysical techniques and efficient methodologies. The southeast United States provides many challenges to ground-penetrating radar (GPR) usage due to its humid climate and abundant vegetation that deteriorate burial remains, disguise burial shafts, and provide physical barriers to GPR surveys. These challenges make it difficult for many existing methodologies, which typically focus on locating caskets or burial shafts. In addition, GPR data typically are unable to provide information regarding potential decay rates and burial ages. Determining burial ages would be useful information for reconstructing the cemetery history, geophysical interpretation, and for understanding burial decay rates. To address these issues, this study uses GPR in combination with spatial and visual analyses to attempt to locate burials in a humid climate. A quantitative value system is used to determine the condition of potential burials and to allow spatial analyses to be performed. This combined effort led to the location of 129 potential burials. The spatial distribution of burial conditions allowed for the comparison between relative burial ages and decay rates within the cemetery site and highlighted statistically significant clustering of burials.

Acknowledgments

I would like to thank my advisor Dr. Stephanie Shepherd for her support and guidance with this thesis. Her direction and feedback helped to shape and guide my work and overcome challenges along the way. I would also like to thank Dr. Meghan Buchanan for her help in the field and Dr. Lorraine Wolf for her critiques, suggestions, and insights which have helped to develop my ideas and thesis further. I also appreciate the Auburn Geoscience Department and the College of Sciences and Mathematics for providing travel funding to present this research at the Geological Society of America, 2021, in Portland, Oregon.

I am deeply appreciative of the guidance and help I received through Dr. Robert Bubb, whose passion allowed for this project to exist and provided oral histories and site information which helped make this thesis possible. In addition, I would like to thank the Research to Preserve African American Stories and Traditions and their assistance in clearing the site of debris and vegetation to allow for this survey and for their continued interest in maintaining and preserving the future of the George and Addie Giddens Cemetery.

I would also like to thank to Dr. David Holt, Associate Professor at the University of Southern Mississippi, for his guidance in teaching me Ground Penetrating Radar survey techniques and including me in his survey work in Louisiana. I am also appreciative of Dr. Peter Leach, for his expertise and workshop he held at Auburn University on Ground Penetrating Radar, which was vital in surveying and processing data for the purpose of this Thesis.

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List of Abbreviations

GPR	Ground-penetrating radar
GAGC	George and Addie Giddens Cemetery
RPAAST	Research to Preserve African American Stories and Traditions
IIR	Infinite impulse response
FIR	Finite impulse response
GPS	Global Positioning System
GSSI	Geophysical Survey Systems Incorporated
MAUP	Modifiable areal unit problem

Introduction

The emancipation of African Americans led to impoverishment and migration of their communities (Mandle, 1992). This impoverishment and migration left former plantation cemeteries containing enslaved burials to become neglected and abandoned. These sites are often poorly marked and lack documented information. Burial markers are often removed, relocated, or have eroded away (Proulx and McGary, 2019; Rainville, 2014). Recent efforts have been extended towards the rediscovery and restoration of these burial sites to preserve their historical and cultural significance (Graham et al., 2014; Proulx and McGary, 2019). These efforts have led to an increasing need for non-invasive techniques and efficient methodologies that account for the regional variation and unique burial conditions of antebellum African American cemeteries.

The George and Addie Giddens Cemetery (GAGC), located in Opelika, Alabama, is an example of one of these cemeteries (Figure 1). The site contains numerous marked and unmarked graves, with some dating back prior to emancipation (Bubb, personal communication, January 15, 2021). The Research to Preserve African American Stories and Traditions (RPAAST) is a research group affiliated with Auburn University which seeks to preserve and share undocumented African American history. RPAAST is seeking to combine communal involvement with scientific research to preserve the site and identify burials. Non-invasive methodologies are required out of respect for the deceased and community members.

Geophysical techniques are effective for surveying historic cemetery sites in a non-invasive manner. Examples of previously implemented methods include ground-penetrating radar (GRP), electrical resistivity, magnetometry, and gravity surveying (Conyers, 2006; Moffat, 2015; Büyüksaraç et al., 2014). Of these methods, GPR is the most commonly used geophysical method for surveying historic cemetery sites because of its high mobility, non-invasiveness, and ability to detect soil disturbances as well as buried materials, including human remains (Conyers, 2006; Moffat, 2015).

GPR data collection and interpretation are region-specific. The data are susceptible to a variety of site factors such as the soil types, burial methods, age of burials, and climate; therefore, it is important to understand variations among different research environments (Fiedler et al., 2009; Conyers, 2012). Many existing methodologies rely on interpreting casket reflections and have not been tested in humid environments (Conyers, 2012).

Spatial data analyses are useful in areas where detailed local data is unavailable (Knitter and Nakoinz, 2018). Enslaved African American cemeteries often lack site information, creating an opportunity for spatial data to contribute additional information and site interpretation. Combining GPR data and spatial analyses addresses these issues by allowing for a more comprehensive understanding of the spatial pattern observed and contributes to the geophysical interpretation of potential burials.

Antebellum African American cemeteries contain a number of challenges for GPR surveys due to the humid climate and vegetation of the southeastern United States, which deteriorate burial remains, disguise burial shafts, and provide physical barriers. In addition, GPR data are unable to provide information regarding the decay rate of the burials located (Fiedler et al., 2009). Antebellum African American cemeteries often lack this information, which is unfortunate for those trying to preserve or study these cemeteries. Our study seeks to address these issues and demonstrate an alternative methodology to assist in identifying potential burials in this challenging and historically significant region. In the process, our goals were to:

1. Determine if a combination of GPR survey, visual analysis, and spatial analysis can be used to locate burials within a humid climate.
2. Use spatial data of the GPR survey to provide information regarding the relative ages and decay rates of burials.
3. Establish a methodology to address the unique challenges of surveying an enslaved African American cemetery site.

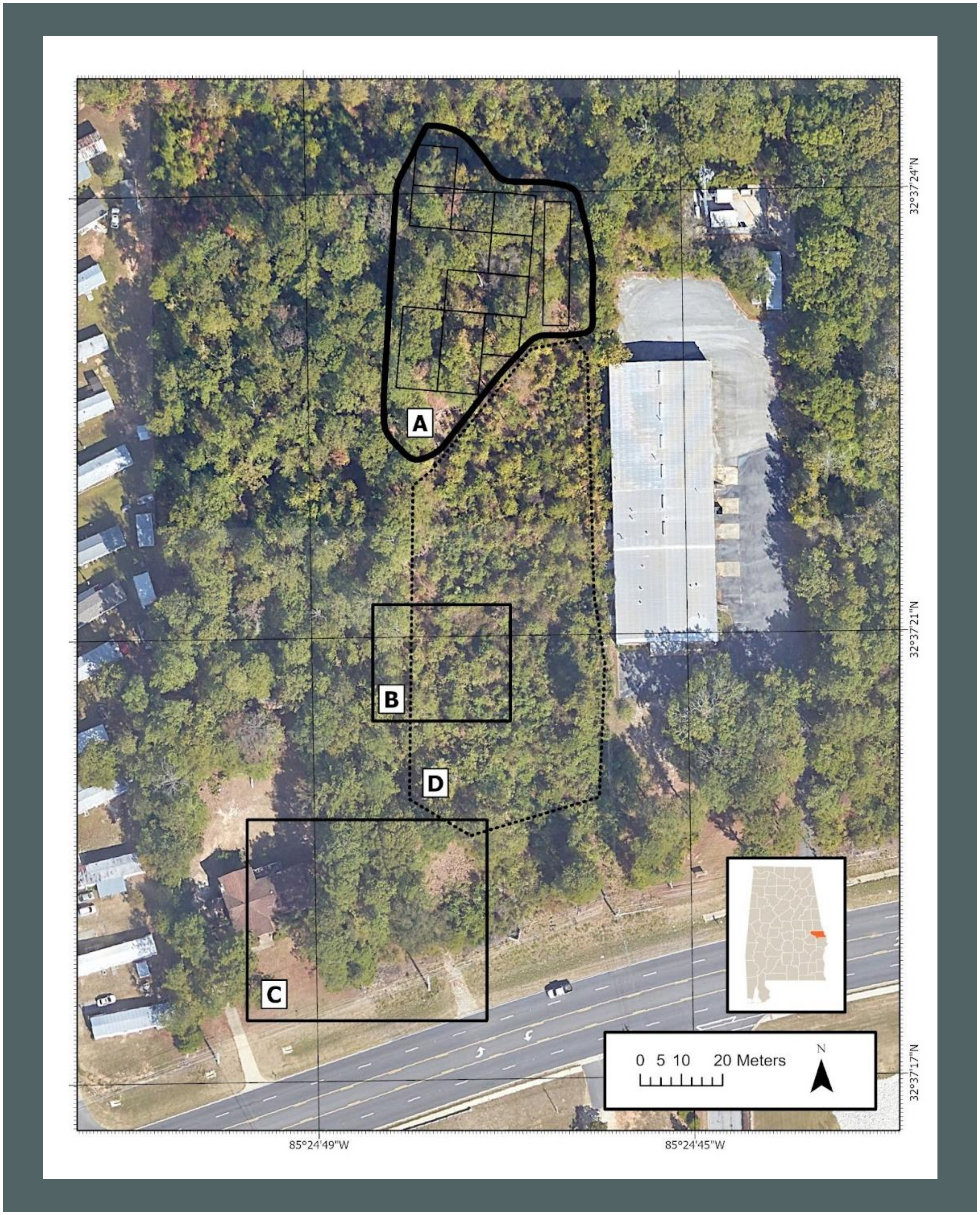

Figure 1. Map of the study area in Opelika, Alabama, with Lee County marked in the lower right. A: Survey area with 10 grids outlined. B: Site of previous cemetery site confirmed by two oral histories. C: Site of the previously existing house as well as gravesites confirmed by one informant and aerial photographs. D: Area that was clear cut in 2011. Aerial photograph from Google Earth™ 10/19/2016.

Historical and Geomorphological Setting

Prior to emancipation, the GAGC land was likely used as a plantation and contained burials of enslaved people (Bubb, personal communication, January 15, 2021). In 1901, 104.5 acres were purchased by the formerly enslaved George and Addie Giddens. Most of this land was used as farmland; however, a portion was set aside to allow for the continued burial of African Americans who could not afford the local cemetery at Rosemere (Bubb, personal communication, January 15, 2021). The land also contained homes for the Giddens family from 1901-2007 that were adjacent to the gravesites. However, none of the homes are still standing today.

The study area for the survey was outlined by RPAAST and the boundaries are based on geomorphologic features such as streambeds to the south, a gully to the east, and property boundaries to the west. Aerial photographs from 1964 confirm oral histories of housing and three potential cemetery sites in the northern, central, and southern section of the study area. Aerial photographs from 2011 indicate that parts of the site were clear-cut. The northern site and survey area was excluded from the clear cutting; however, the southern and central burial sites may have been affected. Oral histories also suggest that heavy machinery was stationed and used at the northwestern entrance to the surveyed area and may have caused damage to burial sites in the area or led to some relocation of burial markers (Bubb, personal communication, January 15, 2021).

Concrete slabs, fencing, and buried metal wires, and debris are found close to or within the study area, often near the locations where the houses used to be. There is also metal and plastic debris, barbed wire, and buried metal cables. The research site is largely overgrown with vegetation, containing trees, roots, stumps, logs, animal burrows, and vines, which may impact survey collection and geophysical interpretation.

The study site contains many burial markers, including both headstones and footstones, and are all made of metamorphic rock. There are numerous soil depressions, many coinciding with the burial markers (Figure 2). There are currently no detectable grave markers in the two southern sites; however, oral histories from local families suggest burials were once present (Bubb, personal communication, January 15, 2021).

The GAGC is dominated by two soil groups, Uchee loamy sand and Pacolet sandy loam, both of which contain high clay and sand contents (Natural Resources Conservation Service, 2019). The soil types are well-drained with a very low runoff class, and water-table depth is estimated to be more than 2.0 meters. The soil maintains a high level of foliage cover throughout the year and contains a variety of vegetation. The study area has some slight elevation changes throughout, containing a 6-10% slope (Natural Resources Conservation Service, 2019). A small dry stream channel is present in the southwest of the study area and may be a remnant of pathing and roads previously visible in the 1964 aerial photographs.

Figure 2. Entrance to the study site where numerous headstones and footstones can be found along with burial depressions. Photo taken March 20, 2021.

Previous Studies

Ground-penetrating Radar (GPR)

GPR is the primary geophysical method for surveying historic cemetery sites (Moffat, 2015). GPR emits high-frequency-pulsed electromagnetic waves into the soil in a conical pattern through a transmitting antenna. These waves reflect and refract as they come into contact with subsurface anomalies (Figure 3). Reflections and diffracted energy return to the GPR, where the receiving antenna records their amplitude and travel time to produce information on the subsurface stratigraphy and anomalies. Differing dielectric constants, electrical conductivity, and magnetic permeability in the subsurface material contribute to the resulting radargram.

Travel time is recorded as the electromagnetic wave penetrates downward, encounters an object or material change, and reflects back to the receiving antenna. Travel time is used with the dielectric constant to calculate the approximate depth of the reflector. The maximum depth recorded before the signal attenuates is based on the antenna frequency and the site conditions. Sites having materials that contain low electrical conductivity—such as sands or granite—allow for greater depth penetration. Conversely, sites with high electrical conductivity—such as dense clays, shales, or some saturated sediments—will reach a much shallower depth before attenuation.

The shape of previously excavated trenches will impact GPR reflections, often creating X-shaped features or “bow-ties” in the radargram, as the waves reflect off the floor and corners of the trench (Conyers, 2012; Lemmens et al., 2013). These reflections vary depending on the shape and size of the trench: square trenches create bow-tie reflections, v-trenches create an X-shape, and semi-circle trenches create concave downward reflections (Figure 4).

GPR antennas are selected based on the depth, resolution, and mobility required by the study area. The lower frequency antennas come with lower image resolution and less mobility but provide greater depth penetration of the signal. By contrast, higher frequency antennas offer higher resolution and greater mobility, but penetrate to shallower depths. Studies primarily use an antenna frequency close to 400 MHz because it allows for a good mix of depth, resolution, and mobility suitable for the site conditions at most cemeteries (Proulx and McGary, 2019; Ruffell et al., 2009; Fiedler et al., 2009). However, there are cases in which 100 and 200 MHz antennas in conjunction with 400 MHz have also been used to successfully identify gravesites to locate potential burials at depths greater than 2 meters (Ruffell et al., 2009).

Cemetery-specific techniques and workflows for processing GPR data into 2-D reflection profiles and 3-D amplitude maps have previously been established (Leach, 2019). Most GPR data are processed and interpreted in the reflection profile format, which excels in displaying shallow soil stratigraphy and anomalies. However, amplitude maps can also be processed to clearly display site burial patterns and identify burial anomalies that are otherwise more difficult to discern with only reflection profiles (Conyers, 2006; 2012).

GPR data collection can be substantially influenced by the study site conditions. Soil textures and soil conditions such as high clay content, moisture, and the presence of animal burrows, roots, buried debris, and metals make interpreting data more difficult (Barone et al., 2015; Hansen et al., 2014; Jones, 2008). Soils with high clay and silt may contain a high electrical conductivity that interferes with GPR signals and causes attenuation (Jones, 2008).

Data collected can even be disrupted by site-specific electromagnetism, which can decrease image resolution (Conyers, 2012). Data processing offers solutions to reduce noise and improve data quality through processes such as background removal, infinite impulse response (IIR) filters, and finite impulse response (FIR) filters; however, IIR and FIR filters must be used with care as they can remove important information from the reflection profiles (Leach, 2019; Geophysical Survey Systems, Inc., 2011).

A hot, humid regional climate, such as that found in the study area, is expected to influence the ability to effectively locate burial-related anomalies. Burials in wooden coffins or in more exposed conditions, such as shrouds would likely decompose readily in wet climates, making it difficult to locate and interpret burial remains (Conyers, 2012). In a study on the decay of human remains, Ross and Cunningham (2010) found that bodies buried in tropical climates deteriorate significantly within 20-30 years, causing bones become soft and warped or only shadows of skeletal elements remain. While GPR does have the ability to detect chemical differences in soil, it is only if the dielectric differs from the surrounding soil. In studies done by Conyers (2012) the bones were not significantly different and could not be easily distinguished in the reflection profiles. In these instances, relying on other analytical methods and information may become important for interpreting results. For instance, locating burial shafts has proved effective for identifying graves when the remains themselves had completely decomposed (Conyers, 2012).

Many existing geophysical interpretations for historic cemetery sites rely on locating caskets. Caskets may show the burial shaft of disrupted soil, a reflection from the top of a casket, and reflections from the base or corners of a casket (Conyers, 2012). The presence of void space inside caskets can be determined by the polarity of the reflected wave, with normal polarity showing up as white-black-white from top to bottom as the result of an increase in wave velocity as the signal comes into contact with air; the opposite is seen for filled or collapsed coffins, where a pattern of black-white-black is observed (Figure 5) (Conyers, 2014). The angle of orientation at which the projected waves come into contact with burial remains has a drastic impact on how the reflected energy will behave and appear in the reflection profile and should be considered when interpreting results (Figure 6). In addition, the age and condition of the burial remains will impact the images, resulting in fainter images as the burial material breaks down (Figure 7).

GPR data interpretations rely on geophysical analysis combined with information about the site background and visual analysis of the surveyed area. Without excavation, subsurface anomalies cannot truly be identified with full confidence; however, as discussed above, excavation is rarely an option as burials are protected by law. Therefore, burial identification requires consideration of a variety of factors that—when viewed together—will offer a compelling narrative. Examples of these factors may include anomaly depth, size, hyperbolic curve shape, hyperbolic curve complexity, gravesite clustering, gravesite directional facing, surface depressions, surface burial markers, fencing or zoning methods, non-native plant life, evidence of soil disturbance, oral histories, and written records.

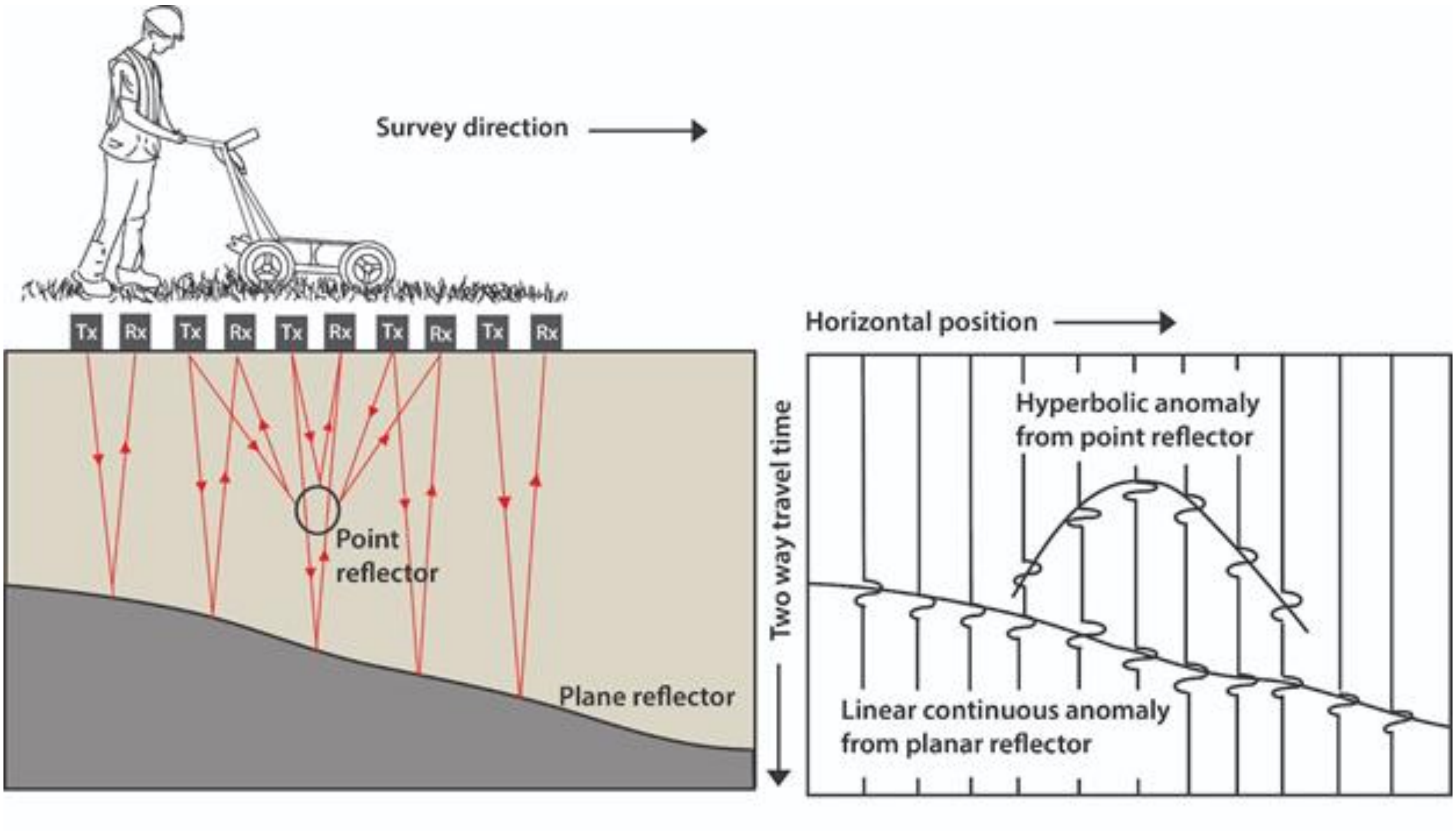

Figure 3. GPR projection, reflection, and collection of electromagnetic waves and how a point of reflectance is then represented in the reflection profile as a hyperbolic curve (Abbas, 2017).

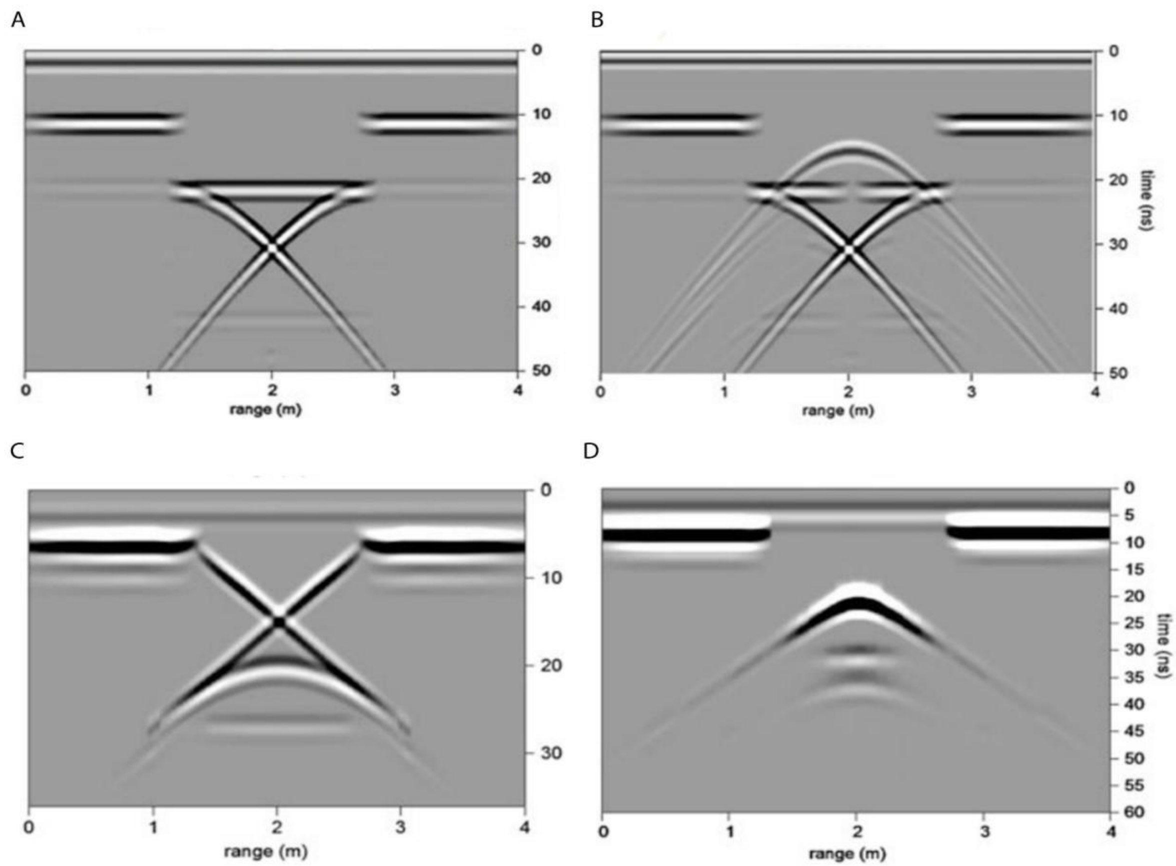

Figure 4. A: Square trenches create a bow-tie reflection as waves bounce off the sides of the trench sides and floor. B: A pipe located in the same trench creates a hyperbola above the bow-tie and a gap in the centerline where reflections are blocked by the pipe. C: V-trenches create X-shaped reflections that are highly sensitive to the shape and size of the trench and narrow V-trenches will not produce the X-shaped reflection. D: Semi-circular trenches can create reflections that concave downward (Lemmens, et al. 2013).

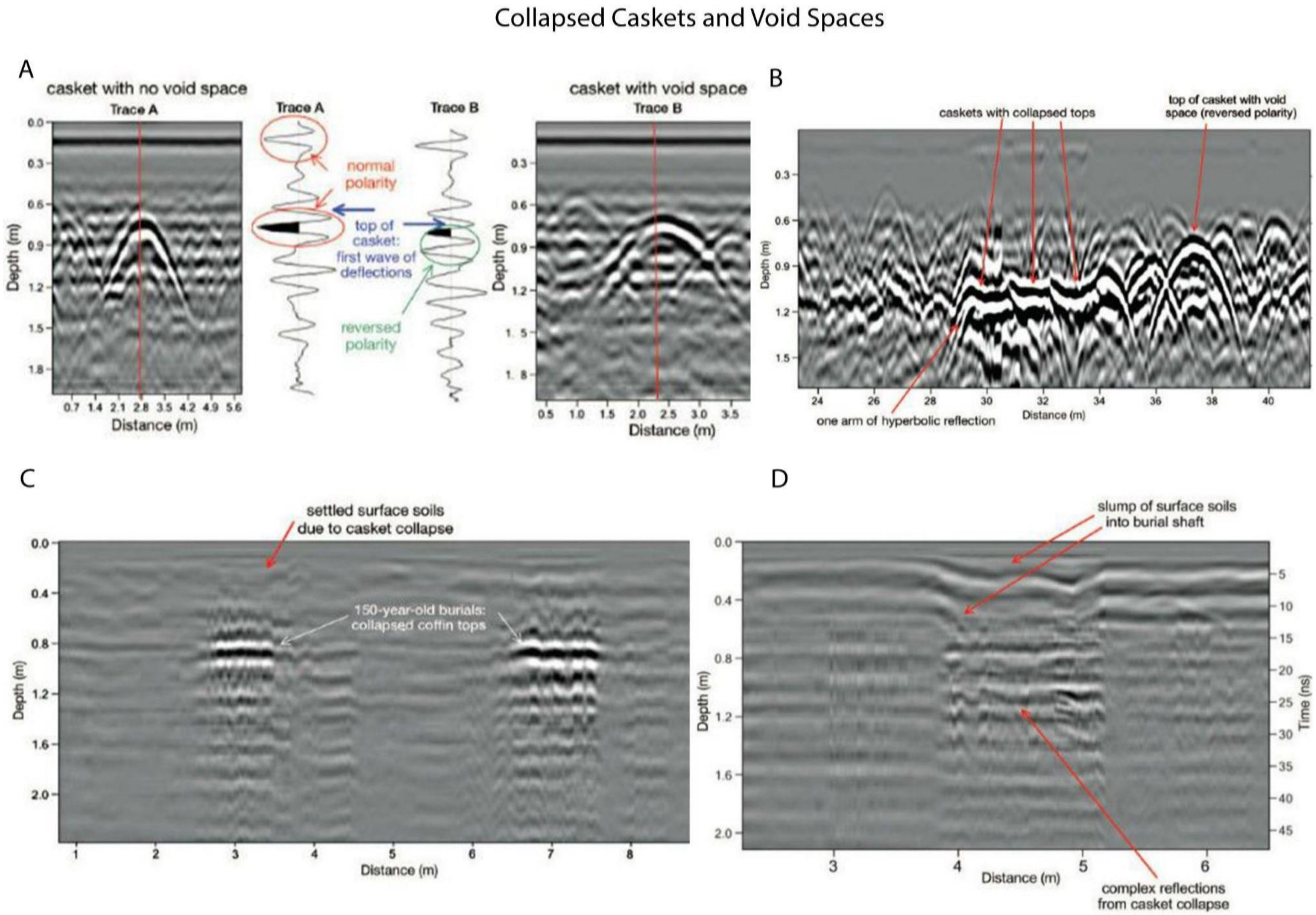

Figure 5. A: Normal polarity and reversed polarity reflection in caskets with void space and without void space. B: Collapsed coffins in close proximity displaying collapsed inward hyperbolas (Conyers 2012). C: Older burials with collapsed coffins displaying horizontal layers. D: Deteriorating collapsed coffin displaying horizontal reflections and evidence of a burial shaft (Conyers, 2012).

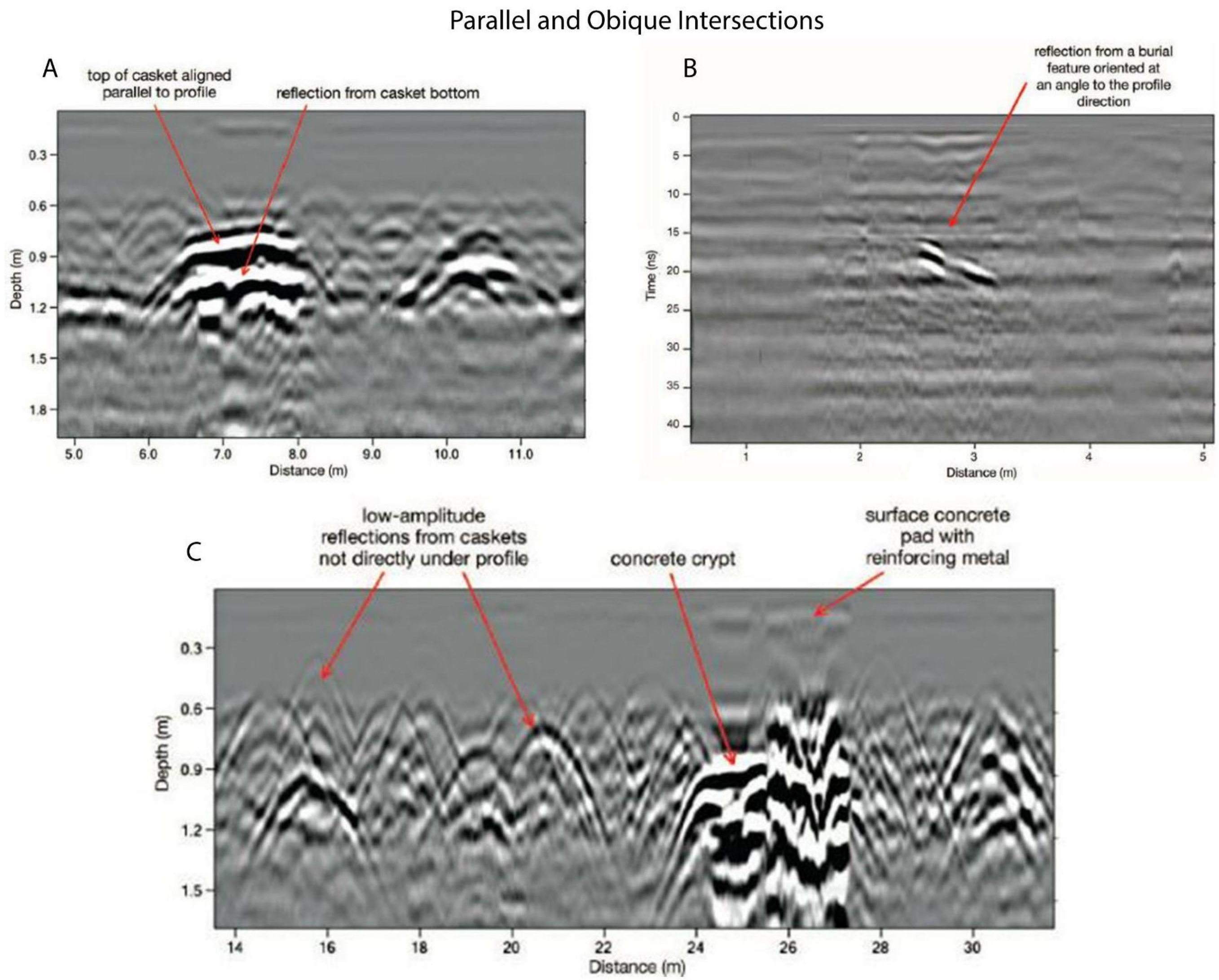

Figure 6. A: Casket aligned parallel to profile (Conyer 2012). B: Burial feature that is at an oblique angle to the profile direction. C: Numerous low-amplitude reflections from caskets not directly under the profile (Conyers, 2012).

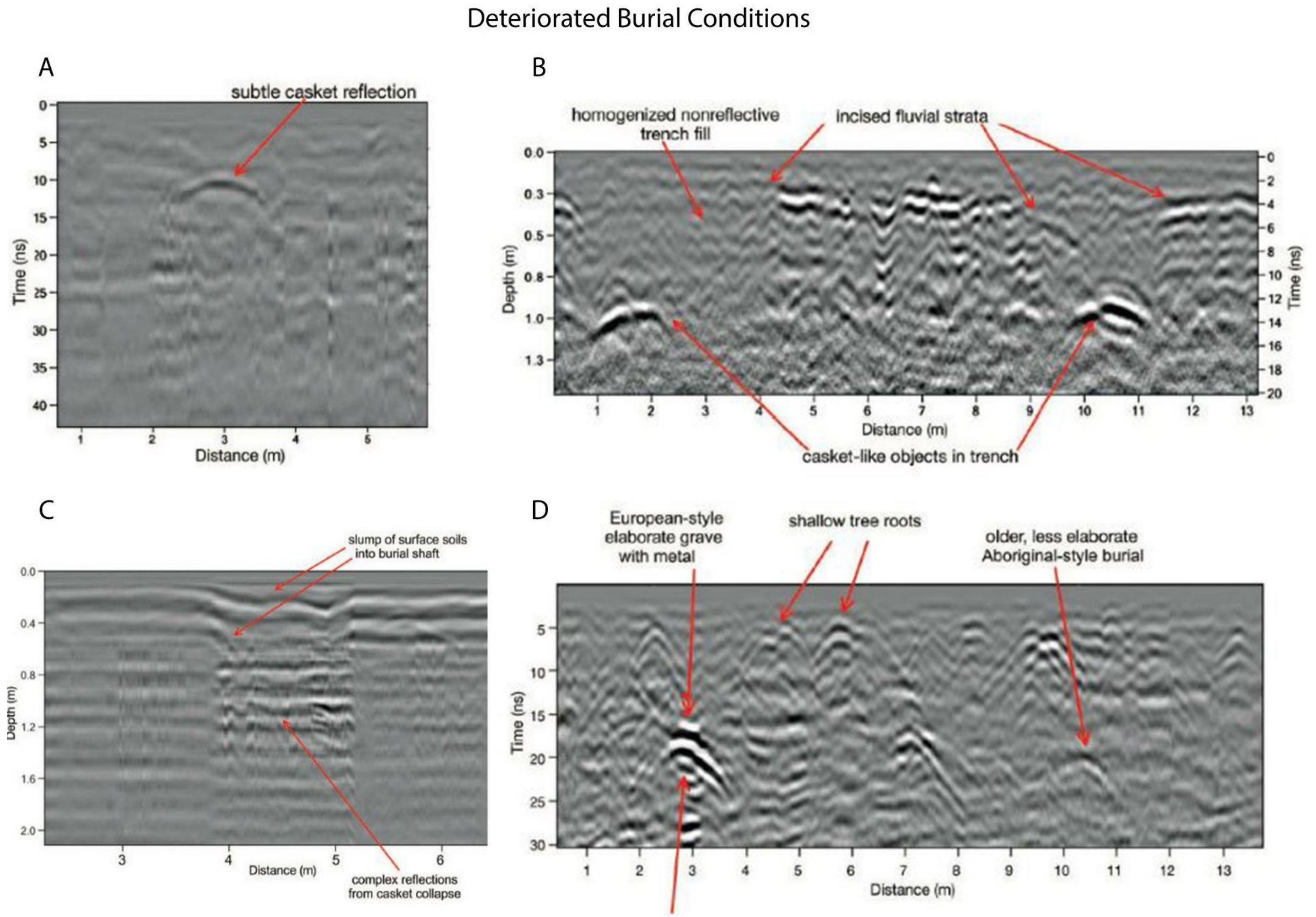

Figure 7. A: Subtle reflections from a poor condition casket. B: Old burial site with casket-like objects, trench fill and incised fluvial strata. C: Older burial showing horizontal subtle reflections of a collapsed casket. D: Subtle reflections of an Aboriginal-style burial compared with European-style and shallow tree roots (Conyers, 2012).

Archaeological Approaches and Cultural Burial Practices

Archeological practices for surveying historic cemeteries involve referencing written records, oral histories, and performing a visual analysis of surface soils and surface vegetation in the field (Conyers, 2006; Rainville, 2014). Other methods employed in the past include physically probing the soil (Killam, 1990) and using cadaver dogs (Schlosshardt, 2017; Killam, 1990). While some surveys have historically had success relying on these methods, they often lack the reliability, scientific measurability, and the non-invasive nature that can be offered by geophysical techniques. Recent archaeology cemetery surveys have largely incorporated geophysical techniques as an effective method of locating burials (Bigman, 2013). GPR is used in enslaved African American cemeteries as a community-oriented archaeology tool due to its non-invasive nature (Honerkamp and Cook, 2012).

Knowing the cemetery site and burial practices is instrumental for determining which geophysical techniques to use and for considering geophysical interpretations of the datasets. Site conditions to consider include burial practices, cemetery age, soil conditions, landscape features, ethnicity and status of the buried, presence of metals and debris, and on-site vegetation (Jones, 2008). Any debris or artifacts buried with the deceased may also help gradiometry surveys used in conjunction with GPR to locate burials.

Determining common burial methods practiced within the cemetery is important for interpreting GPR results, as different caskets and burial methods have unique expression in the GPR reflection profiles. Unmarked graves often have a wide range of orientations, depths, and degrees of decomposition that should also be considered for geophysical interpretations of reflection profiles (Moffat, 2015). While GPR can be utilized to find potential burials, it does not provide detailed enough information to determine specifics about body degradation and therefore is not very helpful in drawing conclusions about burial age or decomposition rates (Fiedler et al., 2009).

Christian burials, including enslaved African American cemeteries that may have had a more complex religious diversity, tend to be oriented west-east (Pearson, 1999; Rainville, 2014). Many enslaved African American traditions buried bodies being buried near rivers (Rainville, 2014). Burial markers can be used to locate potential burial sites. Unmodified fieldstones are often located in enslaved African American cemeteries as burial markers, sometimes containing initials or hand-crafted unusual designs (Rainville, 2014; Proulx and McGary, 2019). The fieldstones often contain both a headstone and footstone, with the footstone typically being of the same material but smaller. While fieldstone markers are a prominent sign of potential burials, there are some instances where grave markers do not reflect true burial positions and therefore are not reliable indicators (Fiedler et al., 2009). In addition, it is not uncommon for burial markers to have been relocated or removed from these types of cemeteries, including within the GAGC (Proulx and McGary, 2019; R. Bubb, personal communication, 2021). The most common preserved markers are stone, the second most common is wood, and the third most common is organic or impermanent memorials, such as flowers or trees (Rainville 2014). Plot markers may also be present, including poles, posts, and fencing. Family plots can exist but are typically in fee-based private cemeteries (Rainville 2014). Soil depressions may also indicate unmarked graves as the caskets have collapsed and (Proulx and McGary, 2019).

Enslaved African American cemeteries often lack documentation or written records, and therefore are primarily identified and located through oral histories (Proulx and McGary, 2019). Rainville (2014) describes three primary burial locations for enslaved African Americans: (1)

burial within the cemetery of the plantation owner, possibly segregated in a corner but not always; (2) buried outside of the white cemetery often near a churchyard or a family burial ground; and (3) buried in a separate segregated cemetery for only African Americans.

Non-native vegetation can also indicate potential burial sites. Examples of non-native vegetation to eastern Alabama are Periwinkle or vinca, which are common in Virginia cemeteries (Rainville 2014). It is important to note that modern trees are likely second or third generation from the original burial sites and this may make it difficult to determine the historic landscape design (Rainville 2014). The GAGC contains spirea in the northern site, however; it is unclear if it was planted for the cemetery or the previous existing homes.

Spatial Analyses

Spatial autocorrelation measures how spatial data are related. Tober's first law of geography indicates that variables close together are more likely to be related than distant variables (Tobler, 1970). In a cemetery setting, this would indicate that adjacent graves are more likely to share trends than distant graves. These trends may relate to similar ages, burial methods, and preservation conditions, as well as other potential site factors and histories. Outliers may indicate family plots, where more recent burials are placed adjacent to older ones; however, family plots are unlikely to be found in an enslaved African American burial site (Rainville 2014).

Spatial data are never truly random and therefore create potential problems and biases such as the modifiable areal unit problem (MAUP), scale and edge effects, and the ecological fallacy (O'Sullivan and Unwin, 2010). It is important to consider these inherent flaws of spatial data when performing and discussing analyses and how they may influence interpretation.

The combination of quantitative methods, such as spatial analysis with archeological data, has been used to successfully improve interpretations for archeological sites (Carrer, 2015; Knitter and Nakoinz, 2018). Point pattern analysis has been performed examining multiple burial sites to determine density trends of megalith burials to support cultural dynamics of a region (Knitter and Nakoinz, 2018). When performed on a smaller case scale, such as the GAGC, spatial analysis has the potential to highlight statistically significant trends of each potential burial to allow further support to interpretation and discussion about burial trends and cultural practices.

Quantitative values have been previously assigned to GPR results to allow greater discussion around the confidence of potential burial remains where survey conditions proved challenging (Nobes, 1999). However, the values given in past studies were based only on reflection profiles and did not provide a scale or methodology for future researchers.

Methodology

Site Survey

Dividing the study area into measurable grids was essential for the organization of the survey to ensure maximum coverage (Figure 8). The measuring tape was restrained using aluminum stakes to ensure that there is no movement of the tape during the survey and to mitigate magnetic effects on the GPR. Global Position System (GPS) coordinates were collected at the corners of each grid to allow for georeferencing during map creation in ArcGIS™.

A visual analysis of the site involved making notes of trees, burial markers such as headstones and footstones, soil depressions, debris, and geomorphological features that impact grid creation, data collection, geophysical interpretations. The grids were cleared of excess vegetation to allow for better instrument contact with the soil and to assist in identifying surface features such as burial markers or burial depressions. Data collection occurred during dry or average soil moisture conditions to improve resolution.

Terrain conditions in the surveyed area provided challenges and likely introduced error. Some of these challenges include the unlevel ground, the necessity of occasionally lifting the GPR unit during the process of surveying, and the dense trees. Collectively, these led to interruptions in survey lines, requiring additional measurements or preventing data collection altogether in some sections. To address some of these challenges, differing survey direction patterns and intervals were tested and compared. The goal was to find a method to minimize error and provide a more accurate and comprehensive survey.

Data collection in uneven topography covers a greater distance than originally gridded, which creates errors that are propagated by bilateral collection methods. This is evidenced by the misalignment of the adjacent reflection profiles and the amplitude maps. Unidirectional collection is believed to minimize this error because it matches the terrain more closely when approached from the same direction. Therefore the unilateral survey method was used to survey all 10 grids. Datasets were initially collected at both 1-meter and 0.25-meter intervals to test the effectiveness of these two different spacings. The 1-meter intervals were found to be insufficient for locating burial remains because remains were more deteriorated than originally expected.

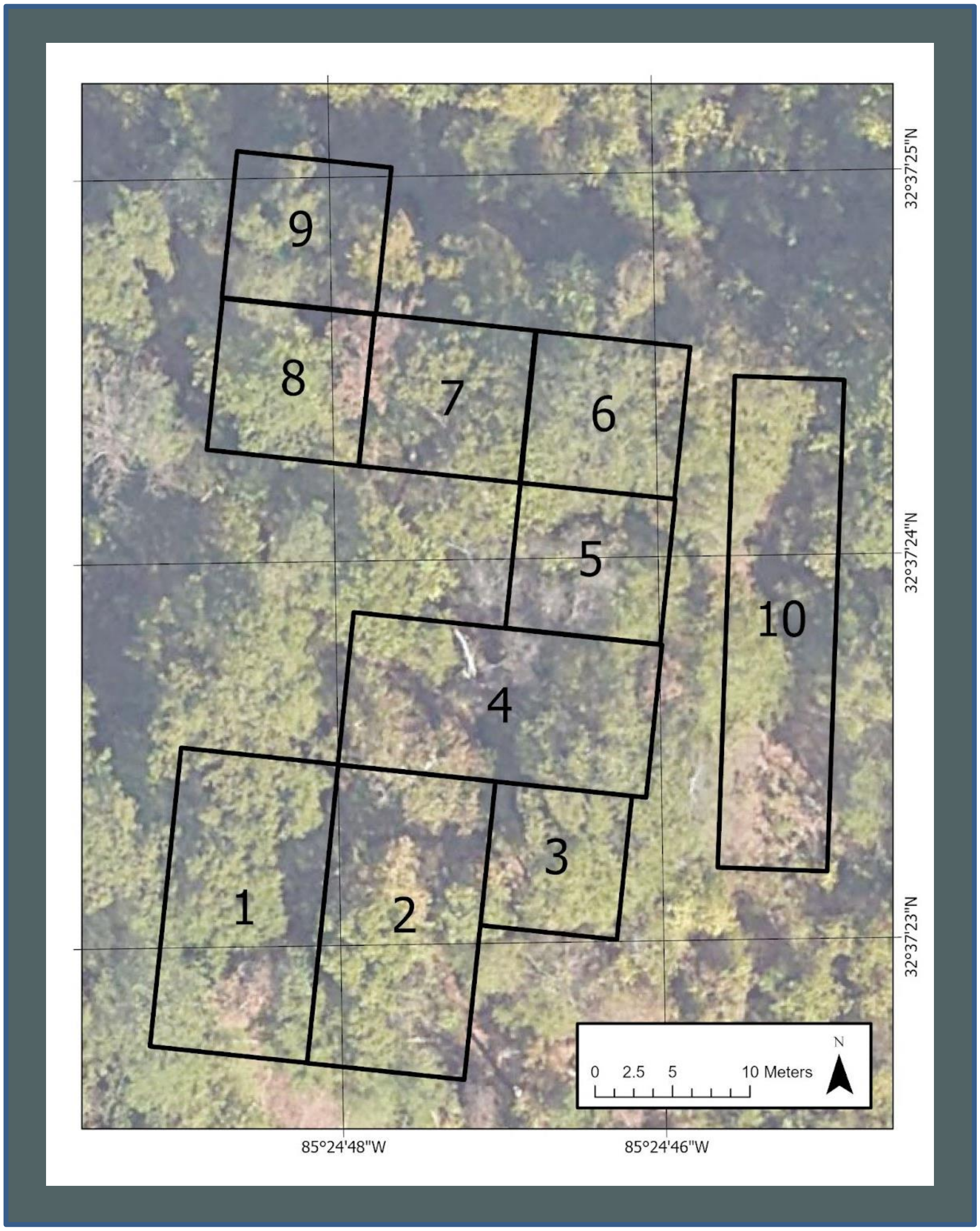

Figure 8. Map of the GPR survey area divided into 10 grids. Aerial photograph accessed from Google Earth™ 10/19/2016.

Data Collection

The GPR field survey was conducted using a GSSI SIR 4000 GPR unit with a 400 MHz antenna placed on a three-wheel cart recording 50 scans per meter. The data was collected primarily between 8/19 – 9/26 to provide similar environmental conditions. A 400 MHz antenna was selected to maximize data resolution while covering an appropriate depth for potential burials. The setting parameter created by GSSI, 400MHz_3W_cart, was used in the primary setup, with minor adjustment to depth range, filters, dielectric, and exponential gain to ensure that quality data were being collected. The depth setting was adjusted until approximately 25 percent of the base depth was attenuating to ensure that the maximum achievable depth was being recorded. A relatively flat area was chosen on-site for wheel calibration. The calibration was set to 10 meters and was double-checked by revisiting the path taken. To maintain this calibration, the wheels were periodically cleaned to remove materials such as dirt and fungi that adhered to the wheel and that could contribute to error.

The GPR data were collected in a unidirectional pattern at 0.25-meter intervals. The 0.25-meter interval was chosen over larger spaced intervals such as 0.5-meter and 1.0-meters to allow for higher resolution amplitude maps that would assist in the interpretation of all subsurface landscape features, in addition to potential burials. Survey interruptions in places where the GPR had to be lifted off the ground to bypass obstacles, holes, trees, and debris, such as barbed wire, were also recorded. When encountering a barrier such as a tree or a log, the dataset was ended followed by the start of an additional dataset on the other side of the obstacle.

GPR Data Processing

The software program RADAN 7™, version 7.0.4.9, was used for the post-processing of the collected datasets and for the creation of 3-D amplitude maps. Each grid was processed with very similar or identical settings to allow an equitable comparison among grids. The processing workflow involved (1) exponential range gain, which applies a gain curve between chosen points to modify gain and boost the signal, (2) IIR filter, to remove noise, (3) a second exponential range gain, to restore gain that was reduced the by the IIR filter, and (4) migration, which determines an average value for the velocity of the subsurface and uses it to remove hyperbolic tails (Figure 9). Each step was saved as a separate file and the dielectric constant, determined from the migration in step 4, was applied to each stage of processing in order to accurately represent the depth when viewing the reflection profiles. Reflection profiles from the third step were primarily used for geophysical interpretations, as the hyperbolic curves help to highlight and emphasize features such as trenches and caskets (Conyers, 2014).

Amplitude maps were created by combining the reflection profiles with their recorded x and y coordinates. Lines that had been broken up during collection due to obstacles were manually placed within the grid based on coordinate locations. This process was followed for grids 1-10. Grids 1-9 shared adjacent borders and were combined into a super 3-D file to display most of the study area. The data were then extracted into four depth layers: 0.50-0.75 meters, 0.75-1.0 meters, 1.0-1.25 meters, and 1.25-1.50 meters to isolate anomalies and their association with depth within the grids.

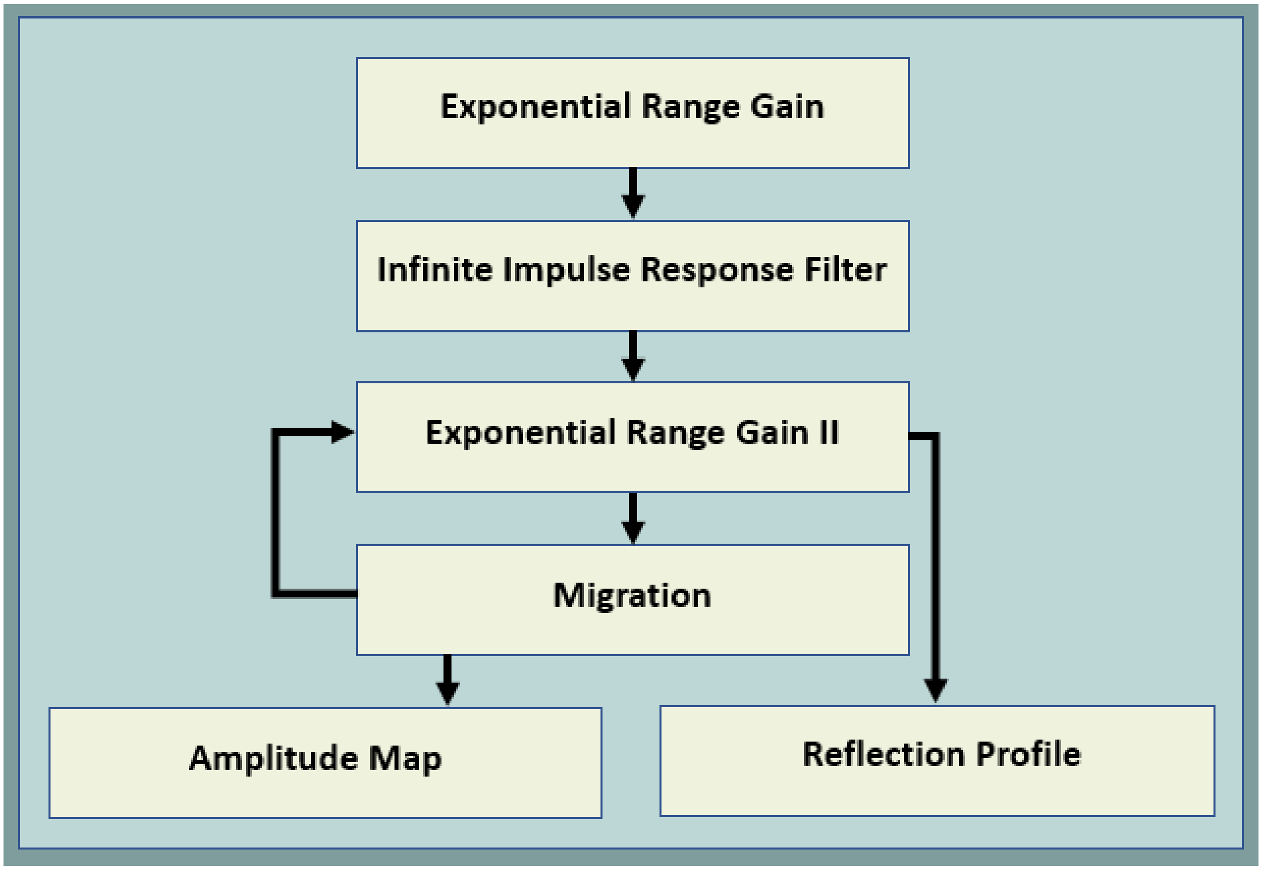

Figure 9. Workflow for GPR data processing. Workflow starts with exponential range gain followed by an IIR filter, a second exponential range gain, and migration. The migrated data are used to produce amplitude maps and the dielectric constant calculated by the migration is used to adjust the depth of the second exponential range gain file to produce the reflection profiles.

Spatial Analyses

The study area and amplitude maps were projected using ArcGIS Pro™ version 2.8.3. The projected coordinate system selected was WGS 1984 UTM Zone 16N to minimize distortion in the area and allow for distance and area measurements for working with grids. The workflow began by creating a shapefile to contain 2-meter by 1-meter polygons created to represent potential burial remains (Figure 10). These polygons were then converted to point data using the "Feature to Point" tool.

The created polygons were each assigned a quantitative value called "Condition," based on their likelihood to be a potential burial (Table 1). To determine the Condition value, a grading system scaled from 0-14 was created. Burials with a range of 1-4 are considered low confidence burials, 4-7 are medium confidence burials, 8-10 being high confidence burials, and 11-14 being very high confidence burials. Confidence refers to the likelihood that the feature was indeed a burial.

Burial markers are defined as being partially buried in the ground and generally rectangular in shape. They may contain either a headstone, footstone, or both and are given a higher value due to their likelihood of being adjacent to burials. Stones are seen as potential burial markers because they are often not buried firmly into the soil, do not contain a rectangular shape and are less indicative of burials than more formal burial markers. Surface depressions are identified during the surface analysis as any area where the topography has a significant change from the norm. Burial shafts are identified using reflection profiles and often indicate burials even after remains have decomposed. Hyperbolic reflections are typically seen in cemetery settings and used to identify caskets and burial remains. Burials often are contained in rows; for this study a row is considered 3 or more burials within approximately two meters of one another.

Potential burial remains that appear linear in the amplitude map are given additional value as this reduces the possibility of being related to roots or other potential sinuous anomalies. Lastly, orientation is considered, as many African American cemeteries are west-east facing, as is common in Christian burials.

The “Average Nearest Neighbor” tool was applied to the point data and found a mean distance of 2.0 meters. This value was used to determine parameters for the creation of a polygon fishnet, which was clipped to encompass the survey area. The fishnet polygons were given a Condition value of 0 to represent areas surveyed areas where no potential burials were found before being spatially joined with the point data to allow spatial analyses. A hot spot analysis was performed on the data points, using the “Hot Spot Analysis (Getris-Ord Gi*)” tool within ArcGIS Pro™.

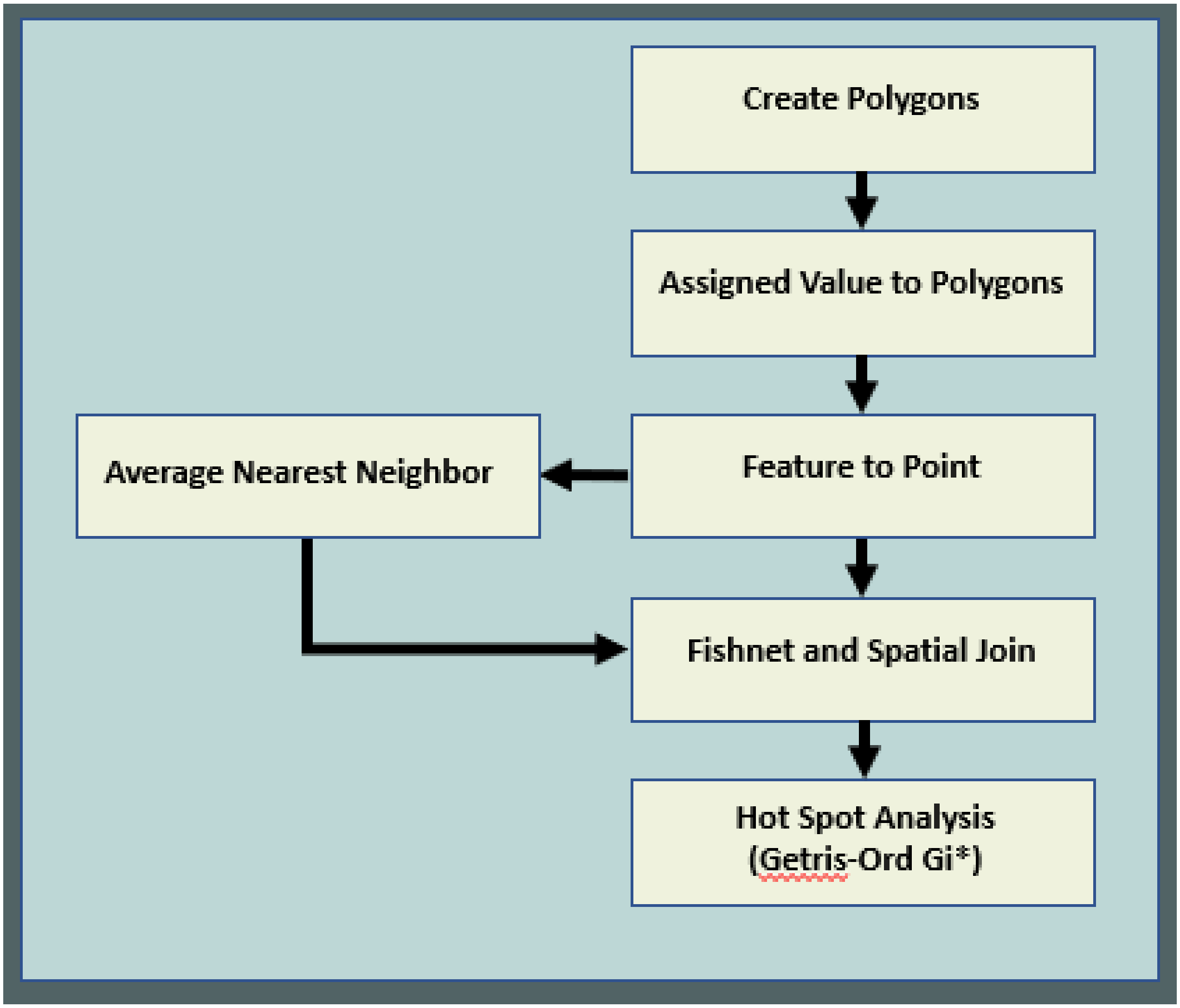

Figure 10. Workflow for performing the spatial analysis. Polygons representing potential burials were created and assigned a number based on the cumulative condition value from Table 1. The polygon features were converted into points to allow point pattern analysis. Average nearest neighbor was calculated to determine a distance when creating a fishnet to encompass the study area. The fishnet was assigned a value of 0 for each grid and spatially joined to our created points. This allowed for a hot spot analysis to be performed to locate statistically significant clustering.

Table 1. Features considered for the burial condition value, which ranges from 0-14. Values added for each feature are listed as positive numbers next to the feature descriptions.

Potential Burial Feature	**Feature Description**	**Burial Condition**
Burial Marker(s)	Rectangular headstone and/or footstone.	+4
Stone	Non-rectangular stones that may indicate burial markers.	+3
Surface Depression	Where the topography has a significant change from the surrounding landscape.	+3
Burial Shaft	Burial shafts are identified using reflection profiles.	+2
Hyperbolic Reflection	Hyperbolic reflections that may represent burial remains.	+2
Row	Three 3 or more burials within approximately two-meter of each other.	+1
Linearity	Potential burial remains that appear linear in the amplitude maps.	+1
Orientation	West-east facing.	+1

Results

Results show approximately 129 potential burials: 34 low, 50 medium, 21 high, and 24 very high condition burials (Figure 11). GPR reflection profiles were able to locate burials associated with the majority of burial markers and burial depressions and show primarily deteriorated or collapsed wooden caskets, with a few wooden caskets containing void spaces (Figure 12). Examples of potential concrete caskets, as well as one casket with a metal lid, are shown in Figure 12. These burials are identifiable by hyperbolic reflections at a depth of approximately 0.50 - 1.50 meters which is a common depth range for burials seen in other studies (Conyers 2012). Discontinuous reflectors are observed at 0.75 m in most profiles. These discontinuous reflectors may be linked to discontinuous or interbedded clays. The visual analysis located 62 burial markers, correlating to 41 burials, and 48 surface depressions. For further detail on specific burial features assigned to each potential burial see Appendix Figures A16-21.

Examples of rows of burials can be seen in the GPR data from Grid 1 (Figure 8). Grid 1, Sections A through F, contains numerous potential west-east-aligned anomalies interpreted to be burials (Figures 13 and 14). Section A contains a row of approximately 1-meter-long potential casket remains at a depth of 0.50 - 0.75 meters (Figures 13 and 14a) but does not contain any adjacent burial markers or surface depressions. Two burial markers were located adjacent to the meter-long potential caskets located at Section B (Figures 13 and 14c). Similarly, an additional burial marker was located at Section C, as well as west-east-facing potential casket remains. The hyperbolas in the reflection profiles of Grid 1 show potential caskets that have collapsed, as well as some with air voids, and the presence of shallow roots, metal debris and oblique-angled burial remains. For Grids 2-10 see Appendix Figures A1-A14.

The majority of potential burials with high condition values are located within Grids 4, 5, 6, and 7, with the lowest values in Grids 2 and 3. This burial condition value distribution is reflected in the hot spot analysis, which indicates Grids 4 - 7 as the primary locations of statistically significant clustering (Figure 15).

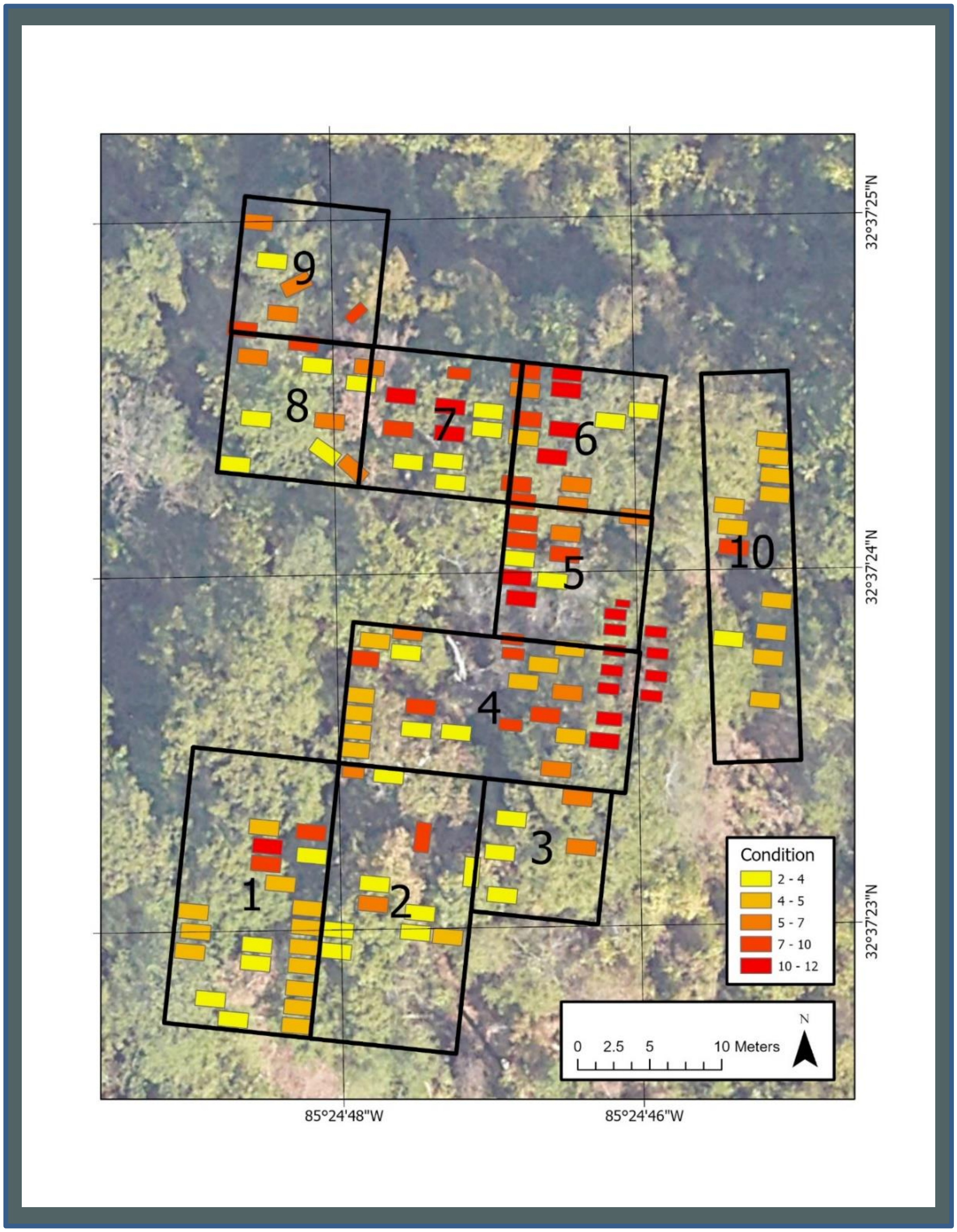

Figure 11. Map of the surveyed area displaying the 10 marked grids containing 129 potential burials color-coded by condition value. These condition values represent the likelihood of being a burial and range from low (2) to high (14). Aerial photograph accessed from Google Earth™ (2021).

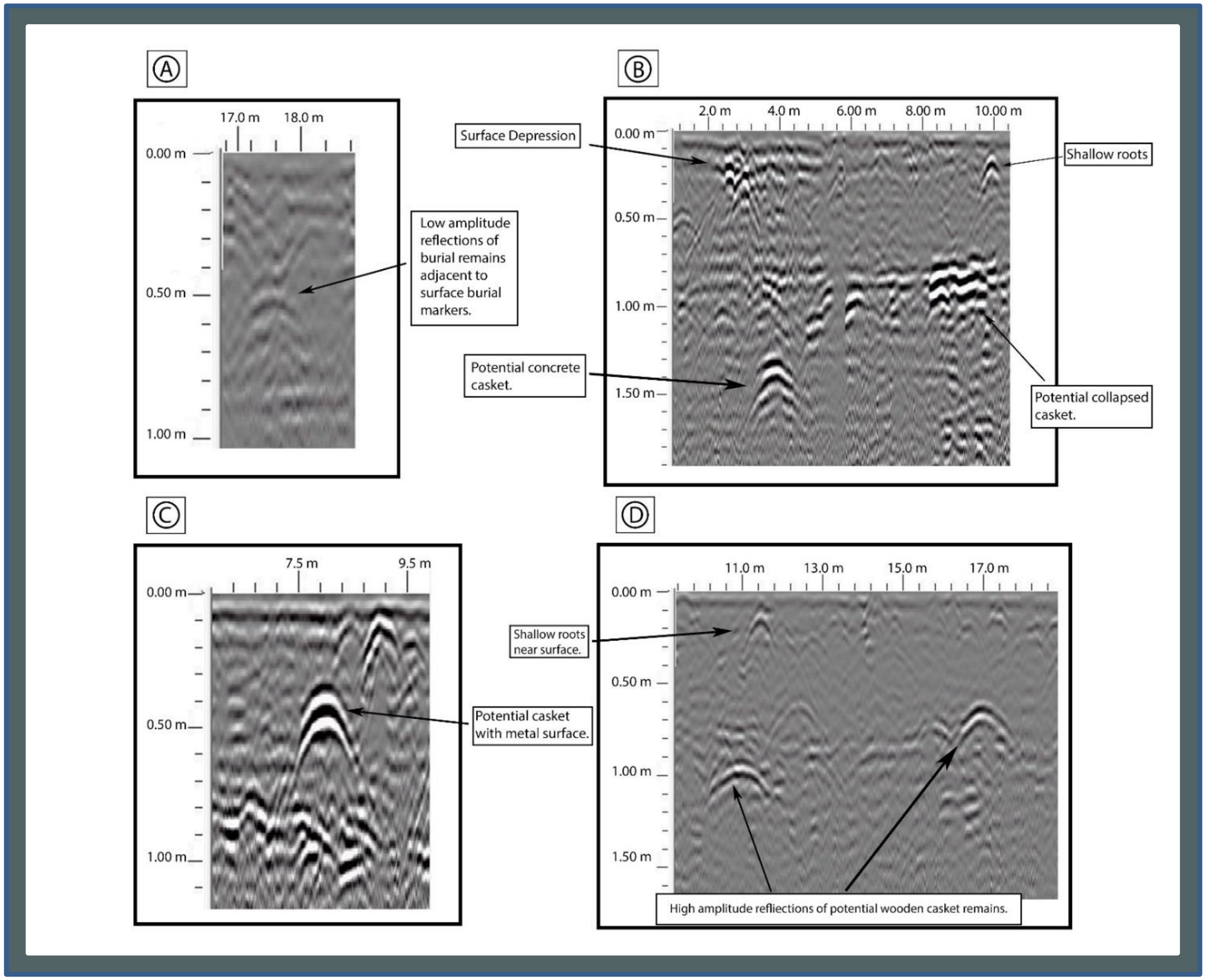

Figure 12. Reflection profiles of diverse casket burial remains. A: Low amplitude reflections suggest a potential shroud burial or highly deteriorated wooden casket. B: High amplitude reflection of a potential concrete casket and a potential collapsed casket. C: Very high amplitude reflection of a casket likely with a metal lid. D: Reflections of potential wooden caskets.

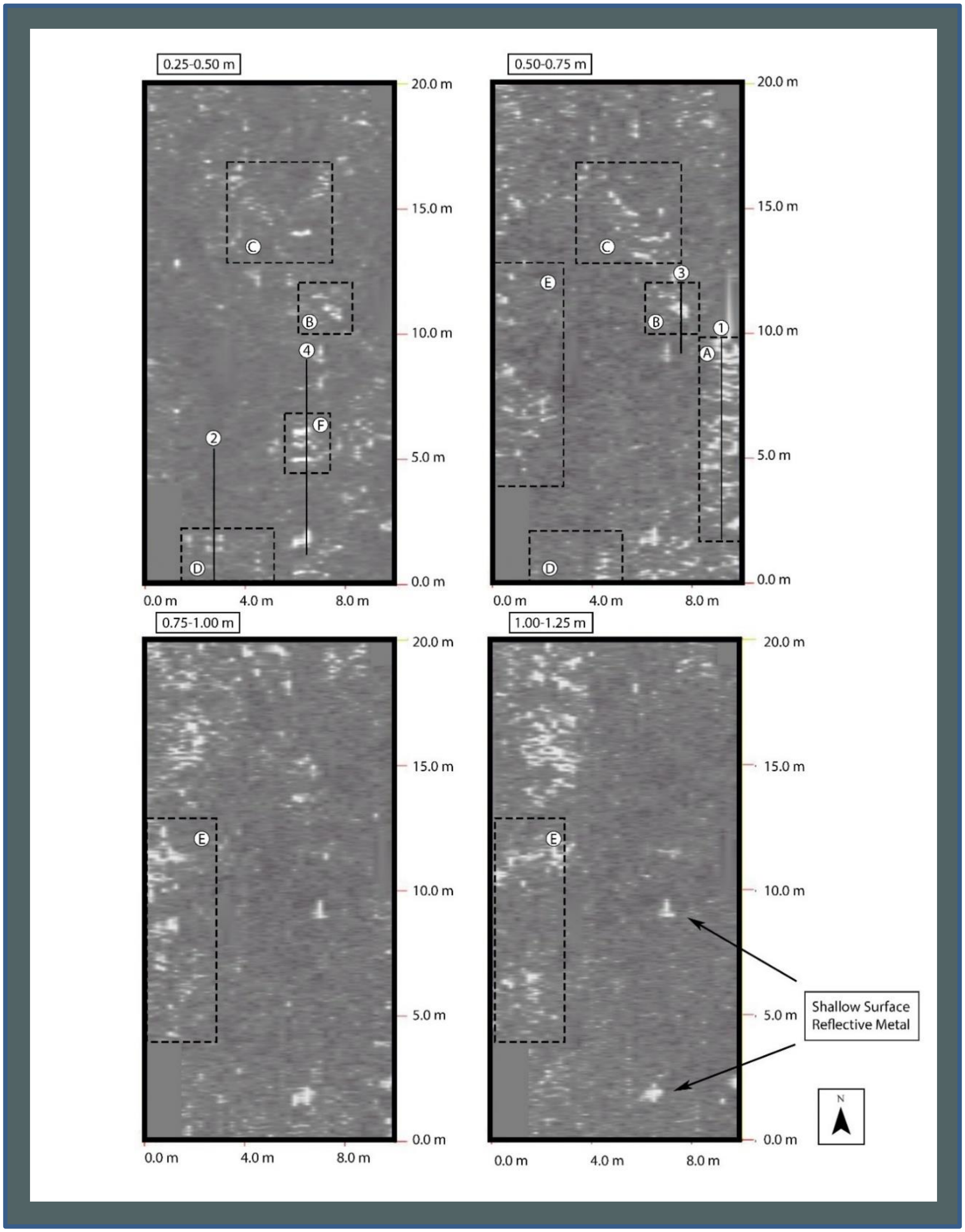

Figure 13. Amplitude map of Grid 1 showing depth 0.25 - 1.25 meters with sections of interest outlined. Numbers 1-4 correlate with the reflection profiles of Figure 14. Section B and C contain surface burial markers and depressions. Sections A, E, D, and F contain west-east facing potential burial remains in rows.

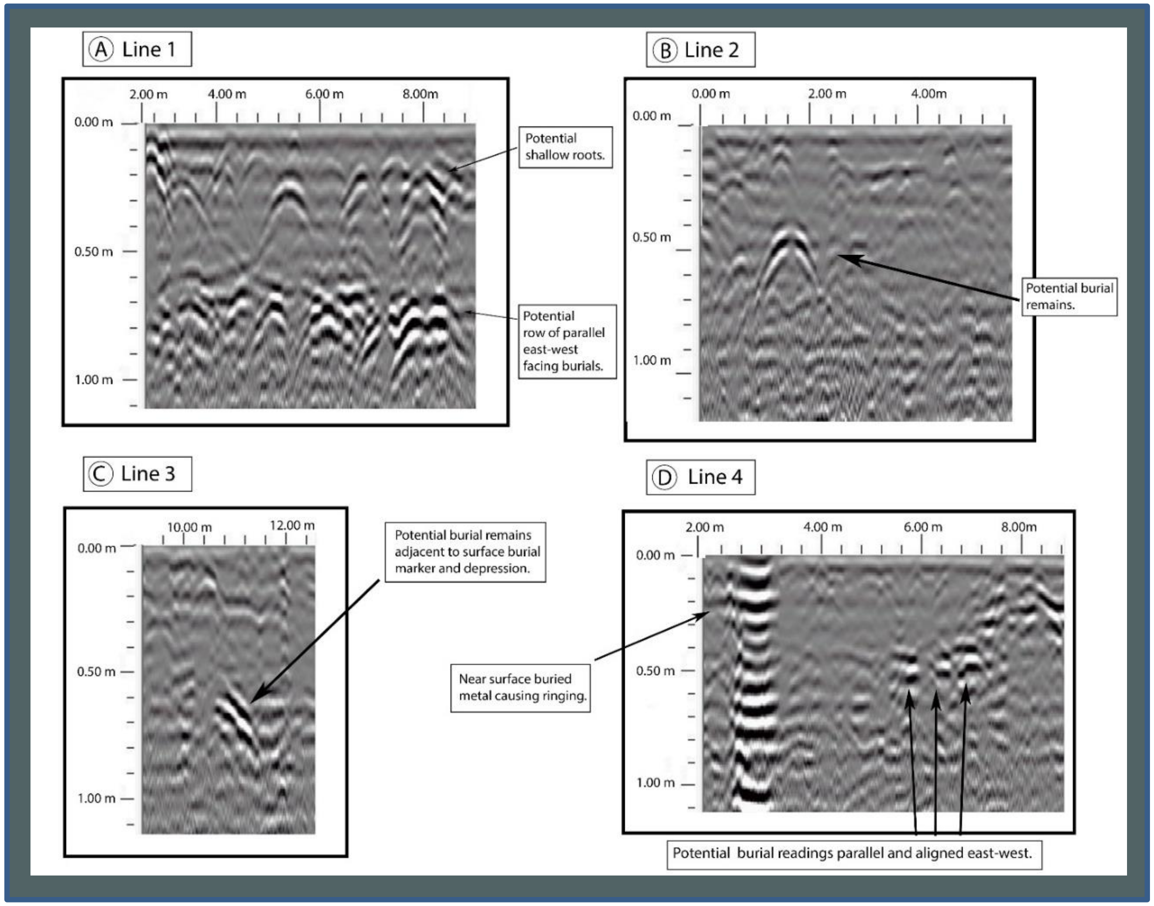

Figure 14. Reflection profiles from Grid 1 with corresponding lines from Figure 13 labeled. A: Potential row of wooden casket remains found in section A. B: Hyperbolic curve of potential burial remains with a burial shaft located in section D. C: Potential burial remains recorded at an oblique angle. Found in section B with adjacent surface burial markers and burial depression. D: Potential burial remains located in section F at a depth of approximately 0.50 meters.

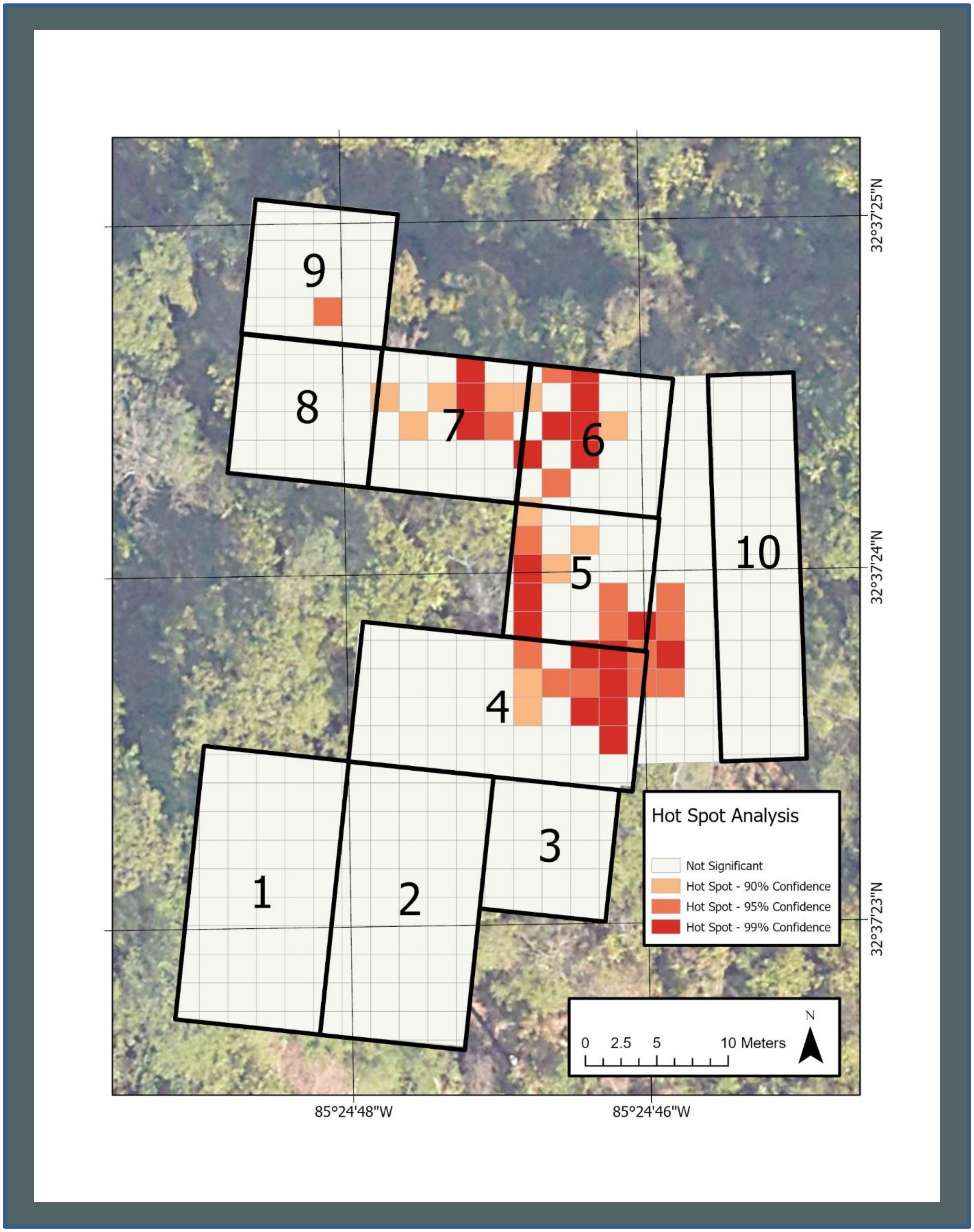

Figure 15. Hot Spot Analysis demonstrating statistically significant clustering. Grids 4, 5, 6, and 7 contain the highest confidence levels of statistically significant clustering of high condition burials. No significant cold spots were identified in the analysis.

Discussion

Site Survey

The study area was confined to private land borders but potentially extends further west to areas not included in the survey. The study area is known primarily through oral history with very little written records of the burial ages (Bubb, personal communication, January 15, 2021). Detailed written records, especially for cemeteries like this, are typically very difficult to find (Rainville 2014). More information about the site could support interpretations and strengthen future research. The goal of this survey was to specifically use non-invasive techniques, however careful collection of a few sample soils to verify geophysical interpretations could still be relatively non-invasive and support the validity of the research.

Burial markers were made up of metamorphic rock and formed headstones and footstones that were primarily rectangular in shape. Simple metamorphic stones were also found within the site and used to mark burials. It is not uncommon for antebellum African American Cemeteries to contain wooden burial markers (Rainville 2014). If this were the case within the GAGC, these wooden markers have likely either been removed or deteriorated beyond recognition.

Geophysical Interpretations

Potential burial remains are primarily identified as hyperbolic curves which are common in most cemetery sites (Conyers, 2006; Nobes, 1999). West-east linear reflections were located throughout the study area which is common for burial orientations of Christian and African American Cemeteries (Pearson, 1999; Rainville, 2014). Hyperbolic reflections that were consistently observed on adjacent lines formed linear patterns in amplitude maps and were determined to be burial related. Long sinuous patterns were attributed to roots. Nearby tree locations were also noted to consider when forming interpretations and when determining the potential for hyperbolic reflections to be associated with a burial as opposed to roots.

Fourteen potential burial rows were located by the GPR survey and spatial analysis. Alternative conditions that may produce the appearance of rows, such as buried garden plots, were considered (Conyers 2012). For example, while it is very possible that gardens existed nearby, the depth of the reflections and west-east orientation support the interpretation of burials. In addition, the fact that the cemetery is located at the top of a slope suggests that erosion is more likely to occur than deposition. Surface burial markers also suggest that there has not been significant deposition or erosion since the burials took place. The presence of flat areas lacking surface depressions, such as in Grid 1, may indicate unique, anthropogenic historical backgrounds such as construction or lumber projects. which may have influenced the site surface and removed burial markers and depressions.

Many grids likely contained discontinuous reflectors at 0.75 m depths. These reflectors may indicate discontinuous or interbedded clay. These reflectors often had burial markers, surface depressions, and burial shafts which indicate they likely contain burial remains. The layer itself also occasionally has metallic ringing suggesting that burials may have been placed at or within the clay layer. It is possible that the burials are placed on top of clay, as digging would become too difficult. The use of heavy machinery will produce scarred and marked areas similar to the stratigraphic layer as well as homogeneous sediments akin to burial shafts and could leave metallic objects and debris behind similar to burial remains (Conyers 2012); however, this is unlikely as the surface above many of these discontinuous reflectors contains burial markers and surface depressions which implies that even if it occurred in the past, it would have been prior to the burials and therefore burial remains would exist in them presently. Given the widespread distribution, similar depth range, burial shafts, depressions, surface burial markers, and metallic ringing, it is likely a combination of both the discontinuous reflectors combined with burial remains.

Bow tie and X reflections seen on the GPR profiles are associated with some burials within the study site. These reflection profiles indicate square and V-shape trenching likely associated with burial shafts. It is not known why some burials retain these trenches while others do not. Burial shafts were also not consistently preserved, and this may be due to the dense low-lying vegetation and vine growth that was present throughout the site prior to the survey.

Polarity of some reflection profile hyperbola suggests that most caskets contained no void space and had collapsed. Few caskets showed reversed polarity black-white-black patterns indicating void space with a casket was still intact. This observation is consistent with the notion that humid environments breakdown and decompose many of the burial remains, potentially making GPR surveys more difficult in humid climates (Conyers 2012). However, the presence of intact coffins indicates that some burial features will likely remain even in humid climates.

Potential metal and concrete caskets were located in Grid 4 (Figure 8). These caskets produced high amplitude hyperbolas, possibly from metal framework within the concrete, and at greater depths than other burials. These anomalies could indicate that Grid 4 was used postbellum, as metal and concrete are more costly and formal than wooden caskets. The cemetery site was used until approximately the 1930's, acting as a cemetery site for those who could not afford the more formal cemetery at Rosemere. Those who were buried in the metal or concrete caskets may have had the means to afford other burial arrangements, but chose the GAGC for other reasons, such as being close to family members. Grid 4 contained clustering of burials with high condition values, and combined with the unique burial arrangement, suggests that the grid may contain the most recent burials within the cemetery.

Grids 1 and 2 contained only a few burial markers and depressions. Barbed wire is found across Grid 1 and indicating a fence line may have marked the boundary of the cemetery site; however, it is not uncommon for African American burials to be located along or just outside of a fenced area, and therefore it does not indicate a firm boundary line (Rainville, 2014). The site contains topographic changes in elevation likely due to stream erosion along preexisting cemetery pathways. Grid 2 contains very deteriorated remains, suggesting that the area may be an older part of the cemetery and that there may be far more burials than were detected by the GPR survey.

Only a few potential burials were located in Grid 3, which had only one burial marker close to the border with Grid 4. Grid 4 contained the largest variety of burial depth ranges, with shallow burials along the marked row in the eastern section and deeper, potentially concrete and metal caskets in the center. Grid 4 also contained two well marked rows as well as an unmarked row in the far western corner.

Grids 5-7 shared many similarities in that they contained rows of burial depressions, burial markers, and were largely dominated by discontinuous reflectors. Burials in these grids were more located along a downward slope and preserved some evidence of burial shafts and trenching. Burial markers and corresponding depressions are all west-east facing. Grid 8 contained potential burials lower condition values, with only two burial markers and some depressions that were not west-east facing. These characteristics were shared with Grid 9, suggesting a more chaotic pattern present in this area that may be either an older section of the cemetery or overflow from the more structured rows seen in Grids 4-7.

The site history for Grid 10 is unique in that the area was clear-cut and the surface used as an access road for heavy equipment during the 2011 clearcutting. This history would likely have an impact on any existing surface and subsurface burial indicators. There are sections that lack reflections. This may indicate homogenous soils, burial shaft, or trenching. The site also is exposed, with no tree coverage, and is adjacent to a cell tower, which may have led to the extra noise in the data. There are some shallow surface west-east facing potential burials; however, it is difficult to discern from potential roots of preexisting trees or debris that could have been placed or removed during the clearcutting.

Spatial Analyses

The high value in Grids 4-7 is related to the condition of burials in the area indicating that burials within those grids may contain: (1) lower decomposition rates, (2) younger burials, or (3) a unique regional history that helped to preserve burials. This interpretation is further supported by the reflection profiles, which indicate potential concrete and metal caskets found in Grid 4. Grids 1, 2, 8, and 10 contain lower burial condition values and—in some cases—also demonstrate lower amplitude readings and lack burial markers and surface depressions. These lower amplitude readings may indicate (1) high rates of decomposition and deposition, (2) older burials, and/or (3) a unique regional history in which surface features have been removed.

The hot spot analysis indicates Grid 4 - 7 as having the most significant clustering and the most likely grids to contain high condition burials. However, the space between the burials is likely not empty, as cemeteries generally follow burial patterns and rows. Spaces in clustering may be explained by pre-existing pathways through the cemetery or burial sites which have deteriorated to a point where surface analyses and GPR cannot collect quality data.

The quantitative grading scale was helpful for interpreting the GPR and spatial analysis data. The assigned values created a clear means for displaying and discussing GPR datasets and the condition and confidence in the potential burials located. It allowed for additional interpretation and analysis related to regional trends and cultural behaviors found throughout the study area. Additionally, it served to provide a means of discussing relative decay rates and ages.

The values on the quantitative scale could be adjusted based on study sites or available data. Currently, high value is placed on the surface analysis features such as burial markers and depressions, as it was uncertain whether the GPR could accurately locate burials in humid climates. Results demonstrate that GPR can effectively locate burial remains and therefore it may be useful to grant higher value to the reflection profiles. Additionally, reflection profiles could provide a quantitative range by themselves (Nobes, 1999), as some reflections demonstrate clear casket behavior and others are more subtle or deteriorated casket behavior.

It is important to be aware of the potential for the condition value to be in error. Naturally occurring slopes and stones would have been given a high value as a potential burial by the system used in this study. Grids 8 and 9 contain depressions that are not aligned west-east and may be naturally formed, which may have inflated the values of potential burials within them.

Conclusion

The GPR was able to detect approximately 129 potential burials: 34 low, 50 medium, 21 high, and 24 very high condition burials. The shallow depth and deteriorated condition of many burials highlight the importance of preserving and protecting the historic cemetery against further erosion and disruption. These results were able to provide RPASST with important information about the extent of unmarked burials and their approximate locations within the surveyed area.

GPR can be an efficient method for surveying antebellum African American cemeteries within humid environmental site conditions to a general degree. GPR is not able to provide consistent and clear results by itself. Many clearly marked burials failed to produce noticeable anomalies within the reflection profiles. This result suggests the site contains high rates of burial deterioration and site alteration, which can prevent a clear results and interpretations. However, some potential caskets still appeared to contain void space, indicating minimal decomposition. This mixed success rate indicates that using GPR in humid environments may be complicated and further research into understanding burial decay factors and rates may be necessary.

Applying additional geophysical techniques such as electrical resistivity and gradiometers may be necessary for more accurate interpretations of the material left behind by decayed burial remains as well as to distinguish potential stratigraphic layers in the soil. Minimally invasive techniques, such as collecting soil cores, may provide helpful information for geophysical interpretations while still maintaining a culturally respectful survey.

Creating a quantitative value system to determine the condition of potential burials was useful in demonstrating and discussing spatial trends of the collected GPR data. Previous GPR surveys have been incapable of determining the state of decay of specific burials (Fiedler et al., 2009). The quantitative value system developed in this study addresses this issue through a comparison of burials within the cemetery, allowing for greater confidence in the interpretation of decay rate, potential burial age, and potential regional site histories. Burials often reflected similar values within close proximity to each other. This supports Tobler's first law and indicates that the neighboring burials are likely to be related in age, burial methods, and preservation condition. This result supports that the application of spatial analysis to cemetery sites will improve interpretations and highlight statistically significant spatial trends. Similar quantitative value systems and spatial analyses would likely be helpful in other studies that utilize GPR data and where detailed information may be lacking.

Surveying enslaved African American cemeteries with GPR in the southeast United States provides many unique challenges. The addition of a quantitative value system to combine GPR data, visual observations, and spatial analysis provided for a more comprehensive survey and allowed for a more confident interpretation of results.

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Appendix

The appendix contains additional processed GPR amplitude maps and reflection profiles for grids 2-10. It also contains labeled potential burials with details on specific burial features assigned to each potential burial. Lastly, it contains the aerial photograph of the GAGC taken in 1964.

Figure A1. Amplitude map of Grid 2 with marked areas of interest. Section A contains a marked burial of a collapsed casket. Section B contains a surface depression. Section C contains some faint amplitude reflections and a burial marker. Section D contains hyperbolic reflections which may relate to the row located in Grid 1. Section E contains deeper hyperbolic reflections which may indicate potential burials. Refer to Figure A2 for lines 1-5.

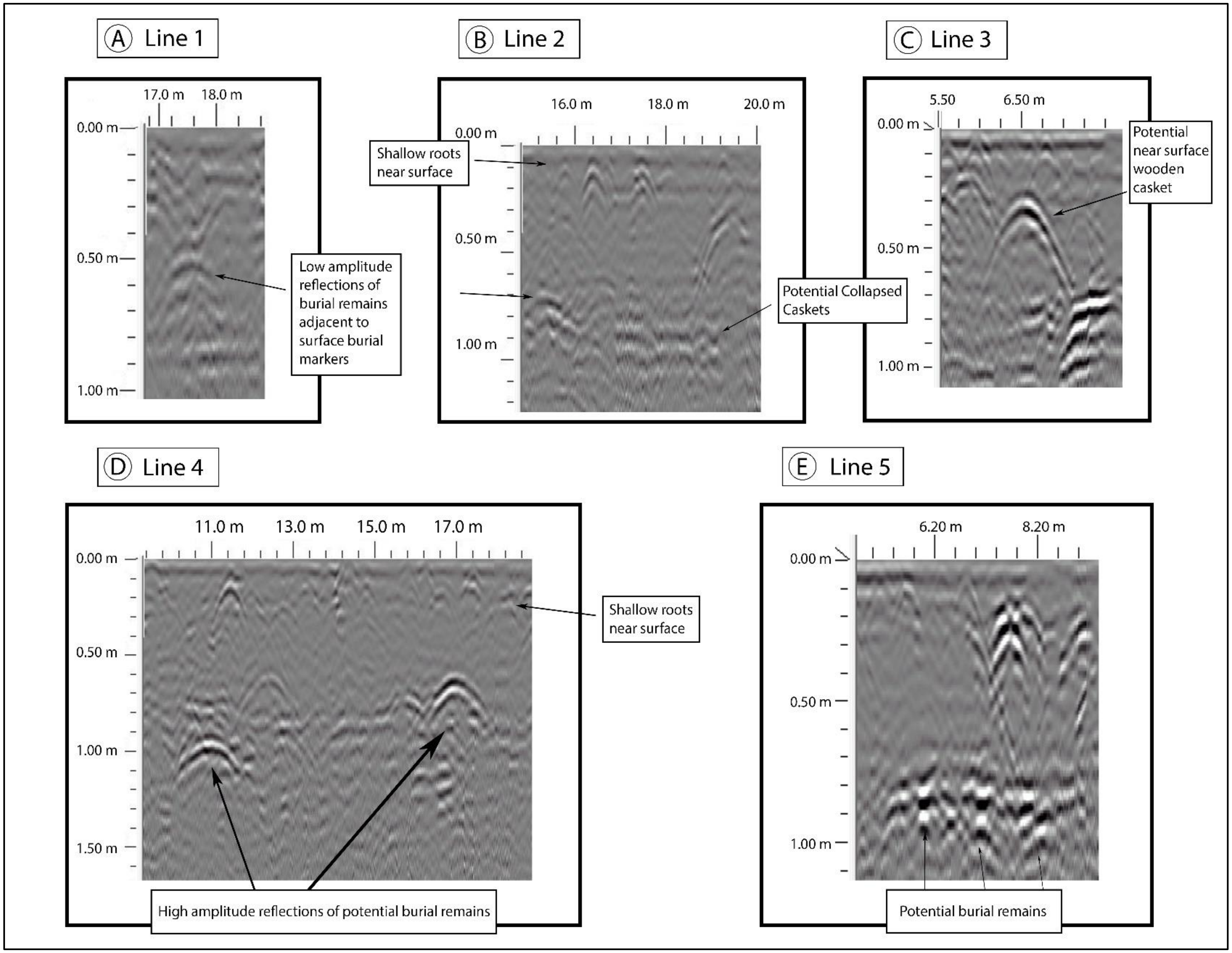


Figure A2. Reflection profiles correlating with the amplitude map of Grid 2.

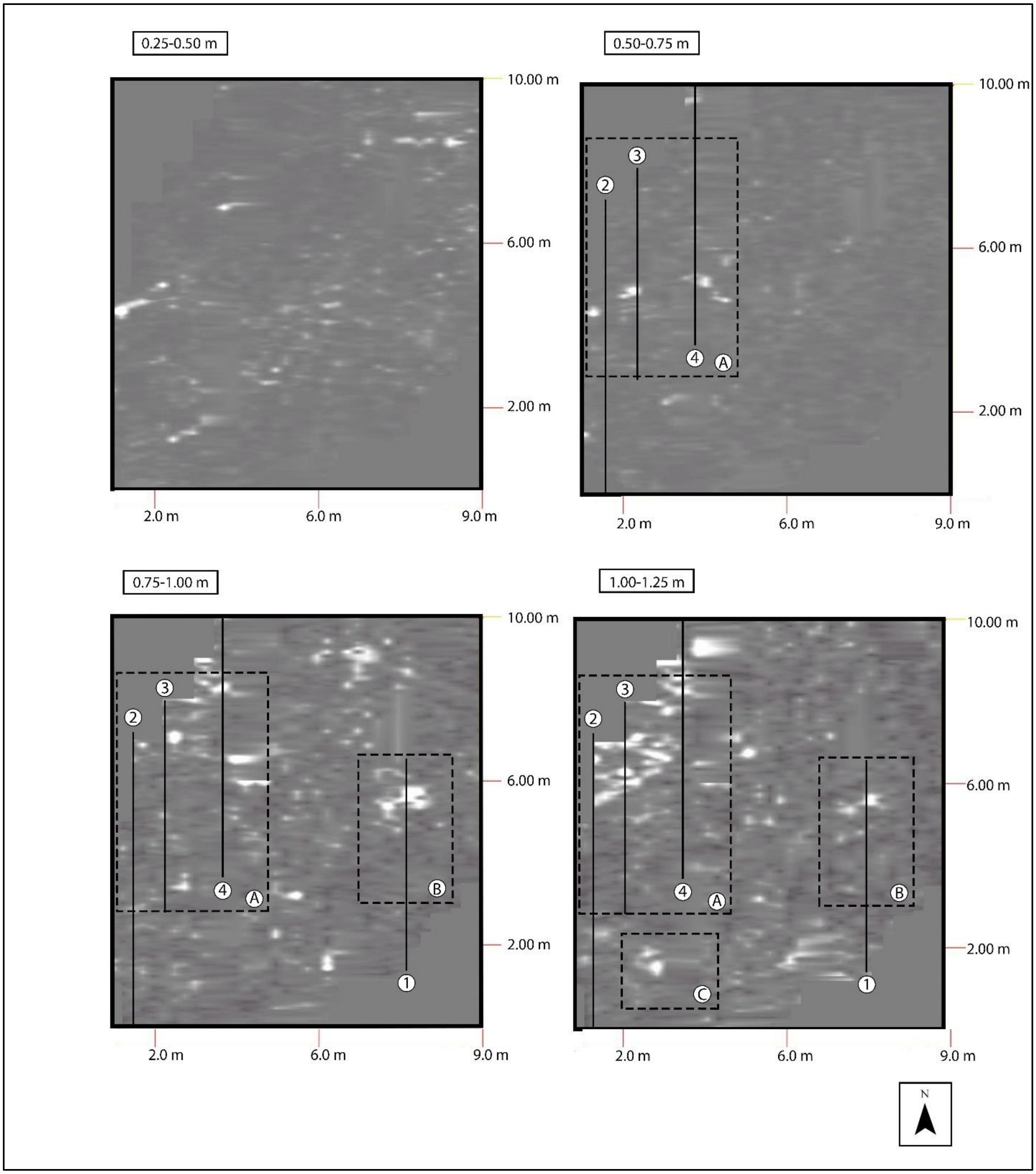


Figure A3. Amplitude map of Grid 3 containing marked areas of interest. Section A contains hyperbolic reflections which indicate burial remains. Section B contains a potential burial. Section C contains a low probability burial based on hyperbolic reflections. Refer to Figure A4 for lines 1-4.

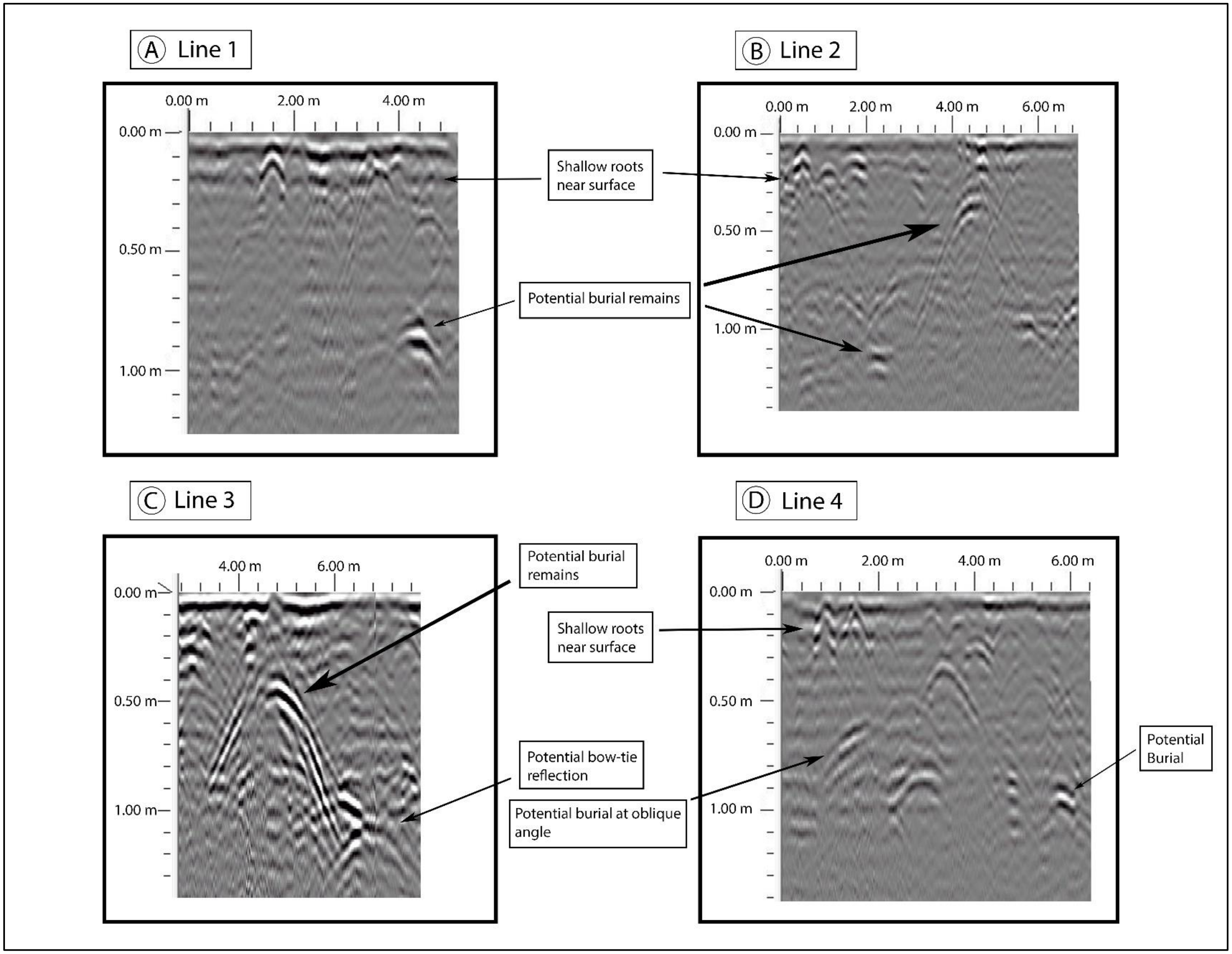


Figure A4. Reflection profiles correlating with the amplitude map of Grid 3.

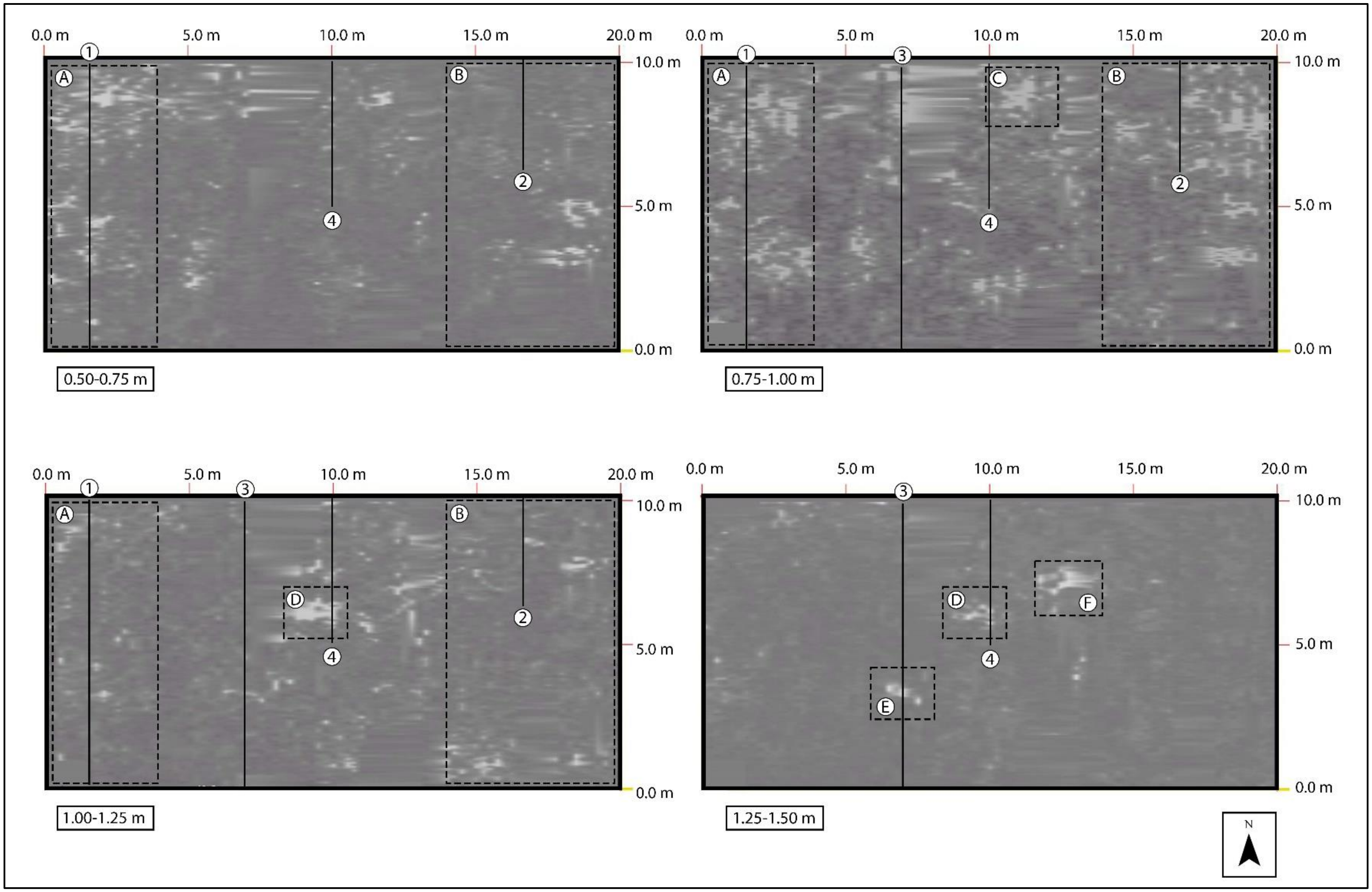


Figure A5. Amplitude map of Grid 4 containing marked areas of interest. Section A contains a potential row of burials as well as a burial marker and surface depression. Section B contains well marked burials with markers and depressions on the eastern half and a less well marked row on the western half containing burial markers but no depressions. Section C contains a marked burial along with markers. Section D, E and F contain potential concrete caskets with high amplitude reflection and at deeper depths. Refer to Figure A6 for lines 1-4.

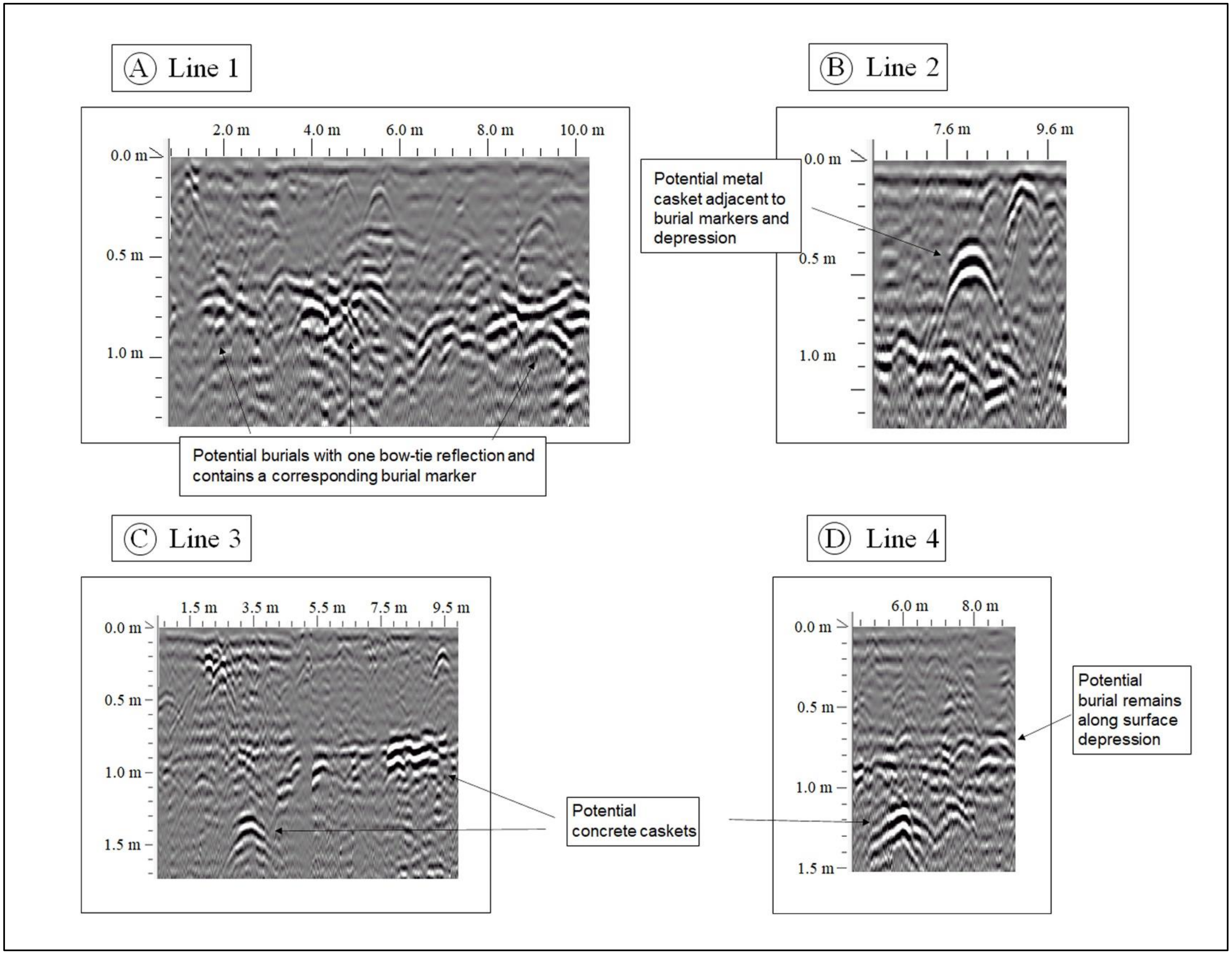


Figure A6. Reflection profiles correlating with the amplitude map of Grid 4.

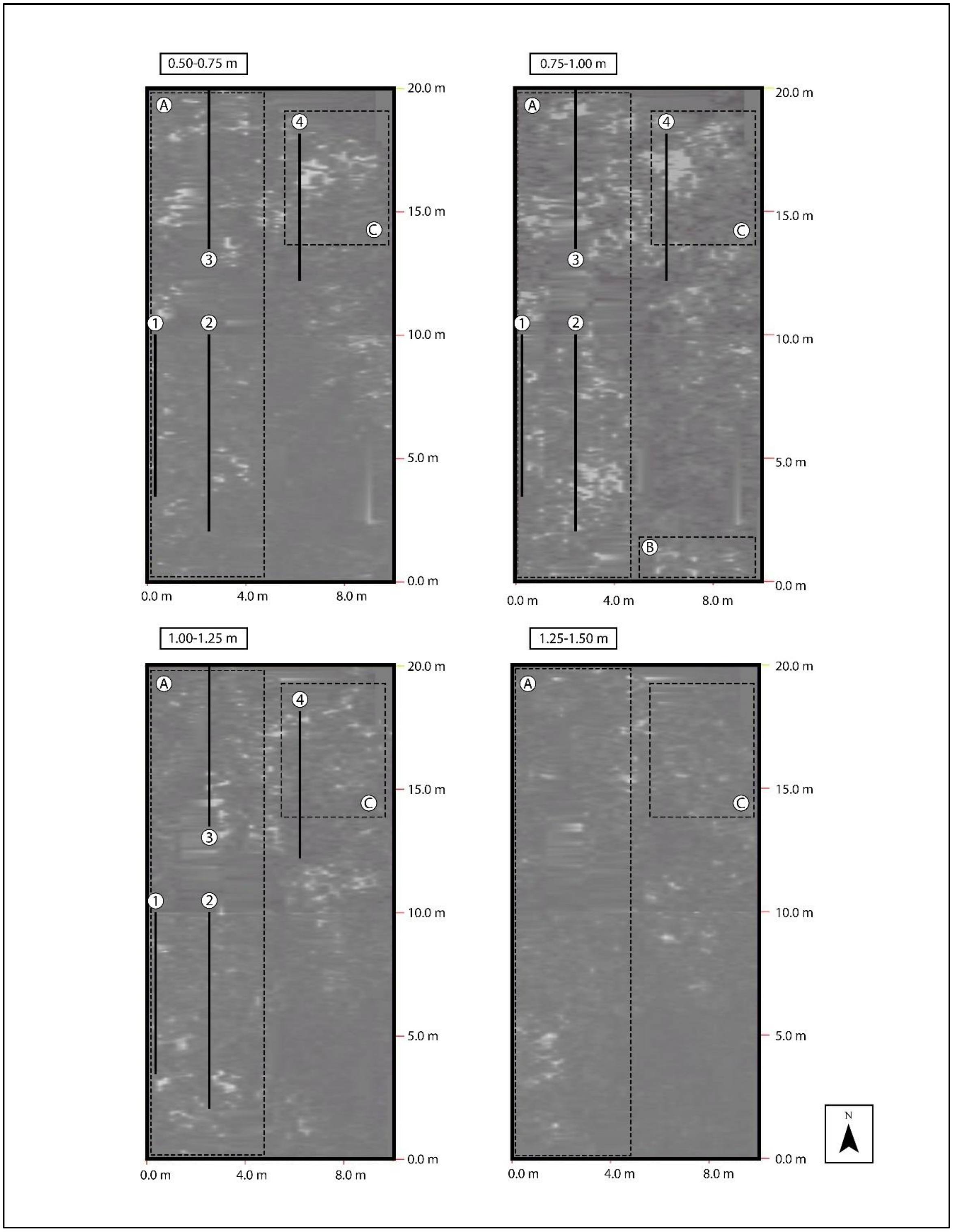


Figure A7. Amplitude map of Grid 5 and Grid 6 containing marked areas of interest. Section A contains two burial rows containing burial markers and surface depressions. Section B continues the row from Grid 4 section B with three well marked burials. Section C contains potential burials based on GPR reflection profiles. Refer to Figure A8 for lines 1-4.

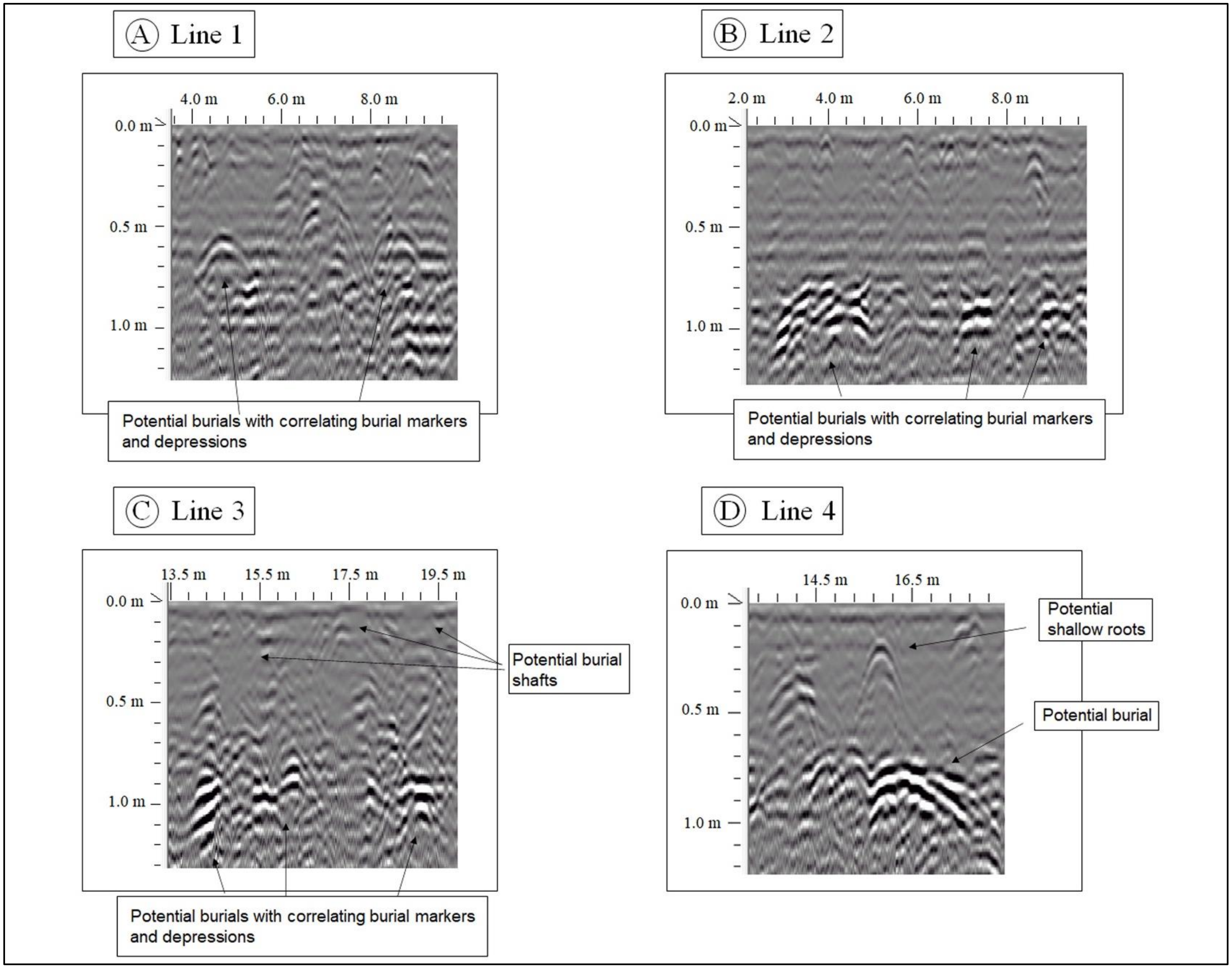


Figure A8. Reflection profiles correlating with the amplitude map of Grid 5 and Grid 6.

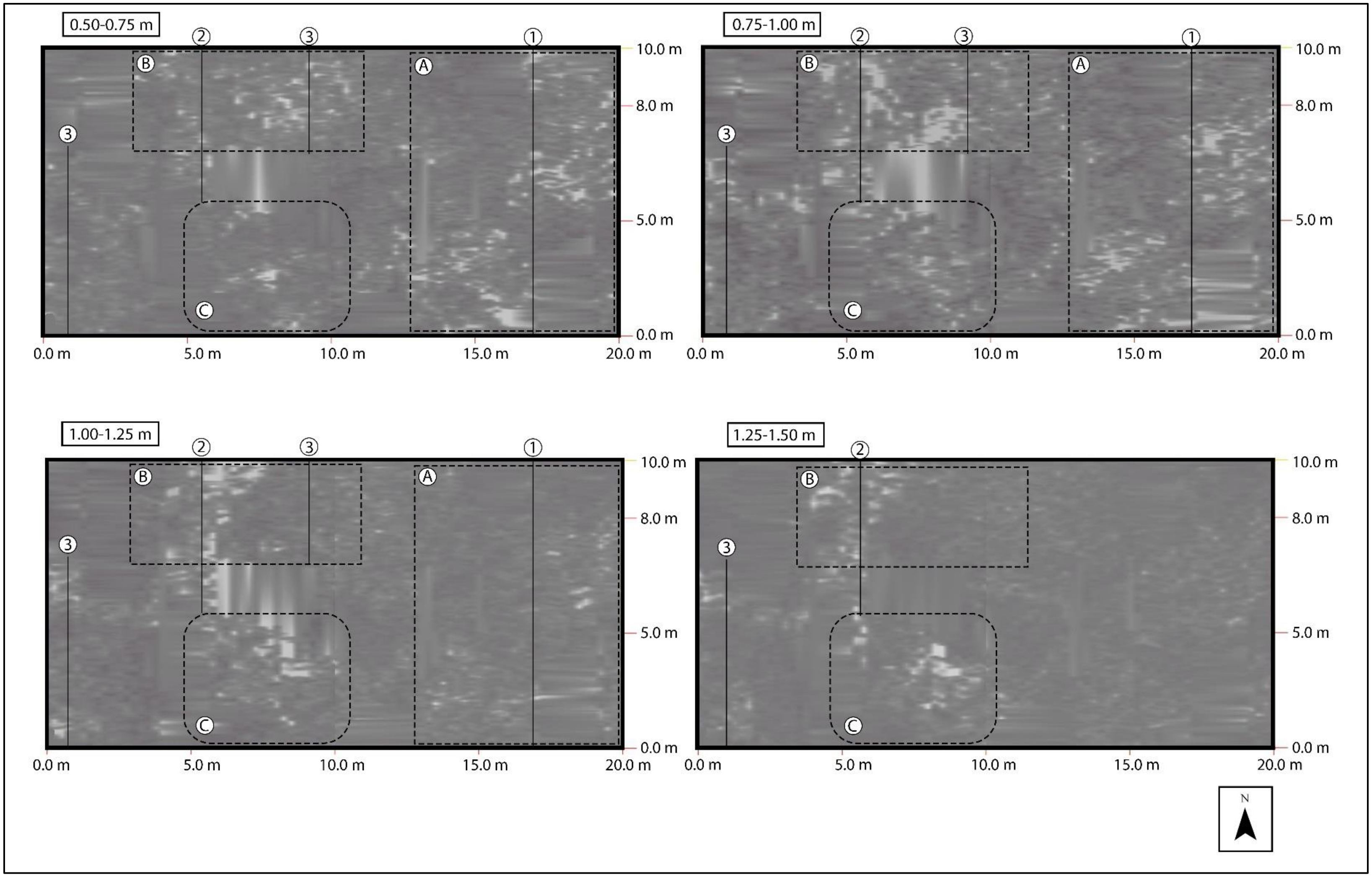


Figure A9. Amplitude map of Grid 7 and Grid 8 containing marked areas of interest. Section A contains well some well-marked burials and some hyperbolic reflections which may indicate potential burials. Section B contains some poorly marked burials with some hyperbolic reflections. Sections C contains some hyperbolic reflections which may contain potential burials as well as some surface depressions which face northwest-southeast. Refer to Figure A10 for lines 1-4.

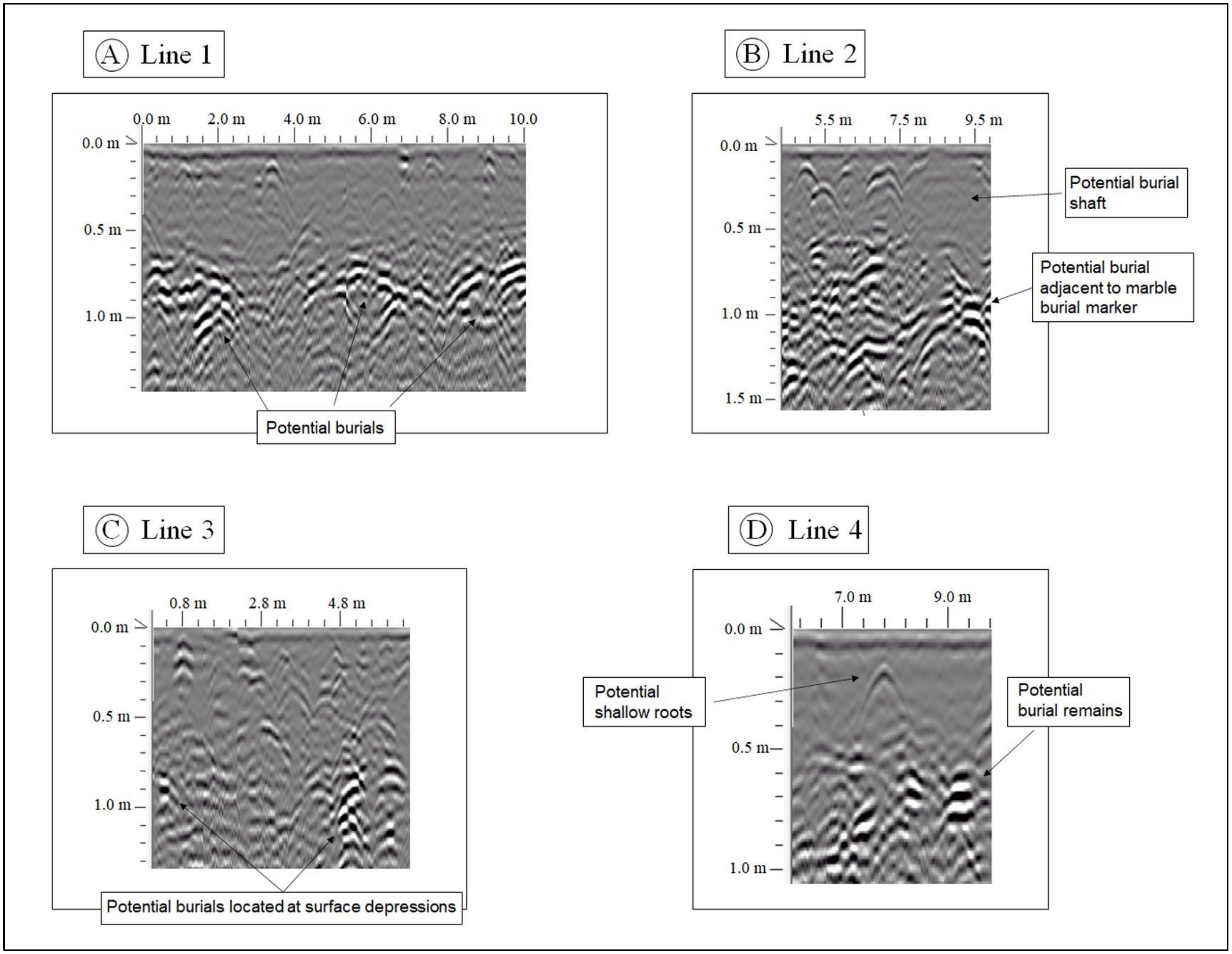


Figure A10. Reflection profiles correlating with the amplitude map of Grid 7 and 8.

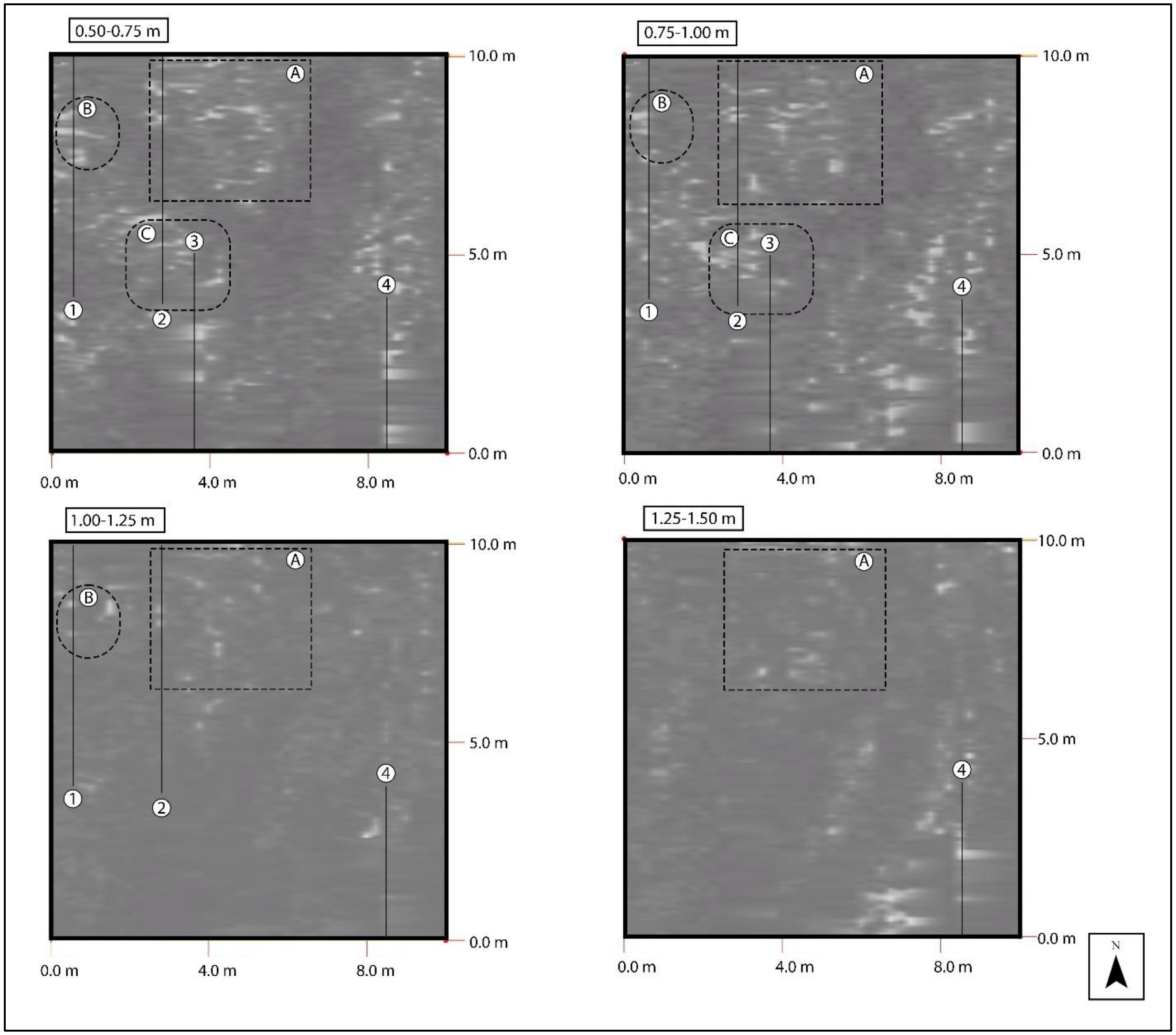


Figure A11. Amplitude map of Grid 9 containing marked areas of interest. Section A contains some hyperbolic reflections which may indicate burials. Section B contains potential burials associated with a slight surface depression. Section C contains reflections which correspond to surface depressions. Refer to Figure A12 for lines 1-4.

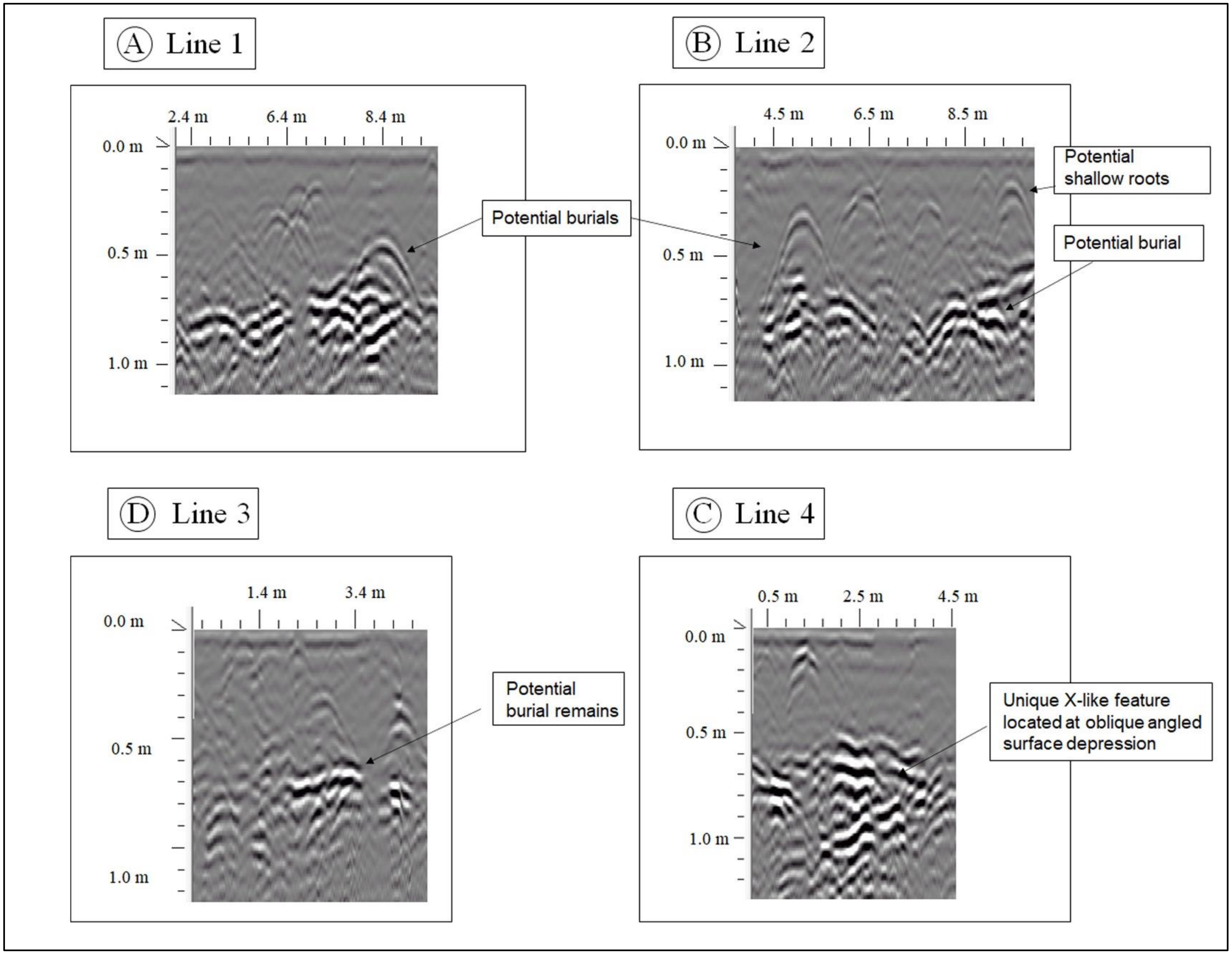


Figure A12. Reflection profiles correlating with the amplitude map of Grid 9.

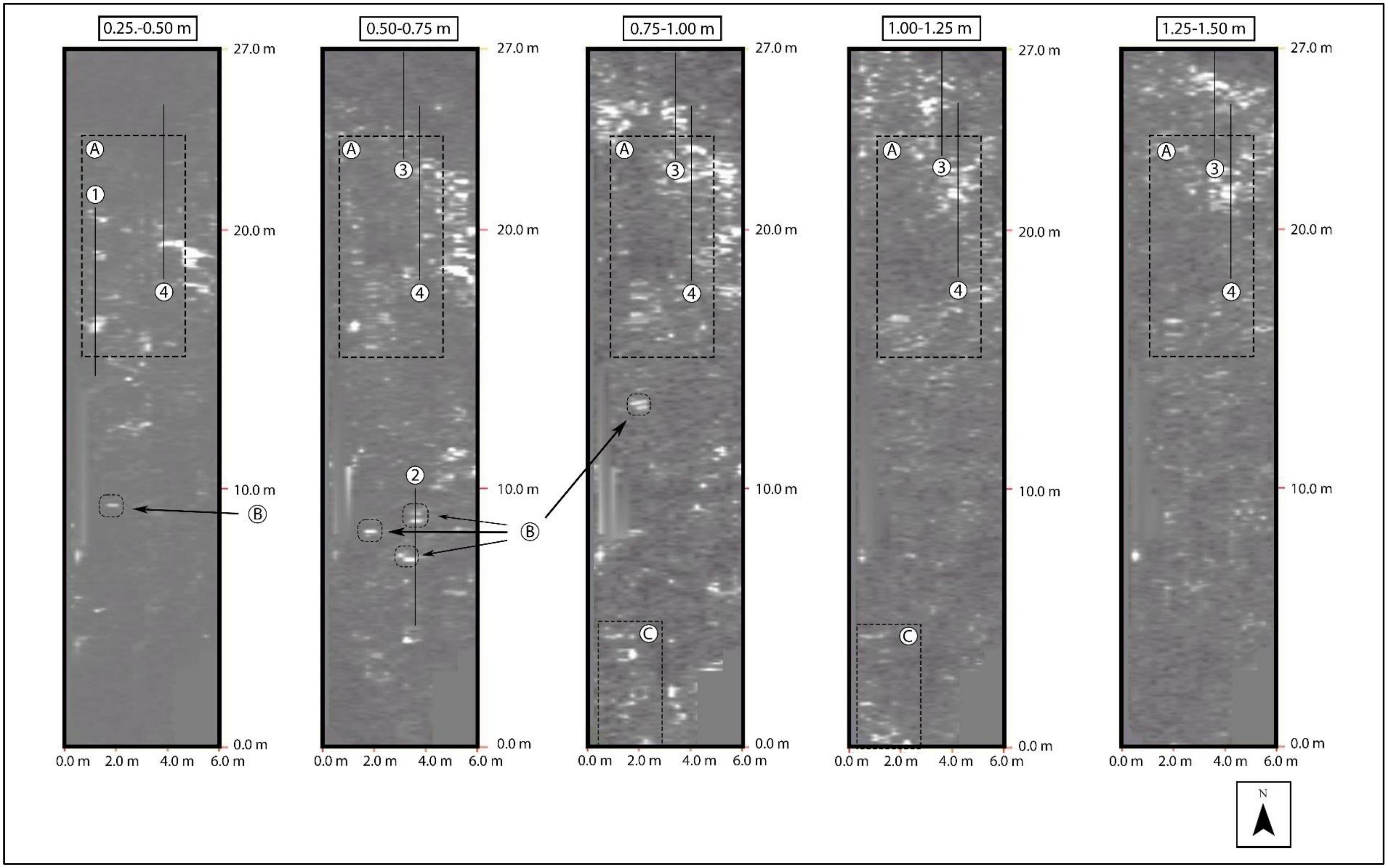


Figure A13. Amplitude map of Grid 10 containing marked areas of interest. Section A contains two potential burial rows however there is only one potential burial marker and no surface depressions. Section B contains a row of linear features which may be related to burial remains. Section C contains linear hyperbolic reflections which could indicate potential for burials. Refer to Figure A14 for lines 1-4.

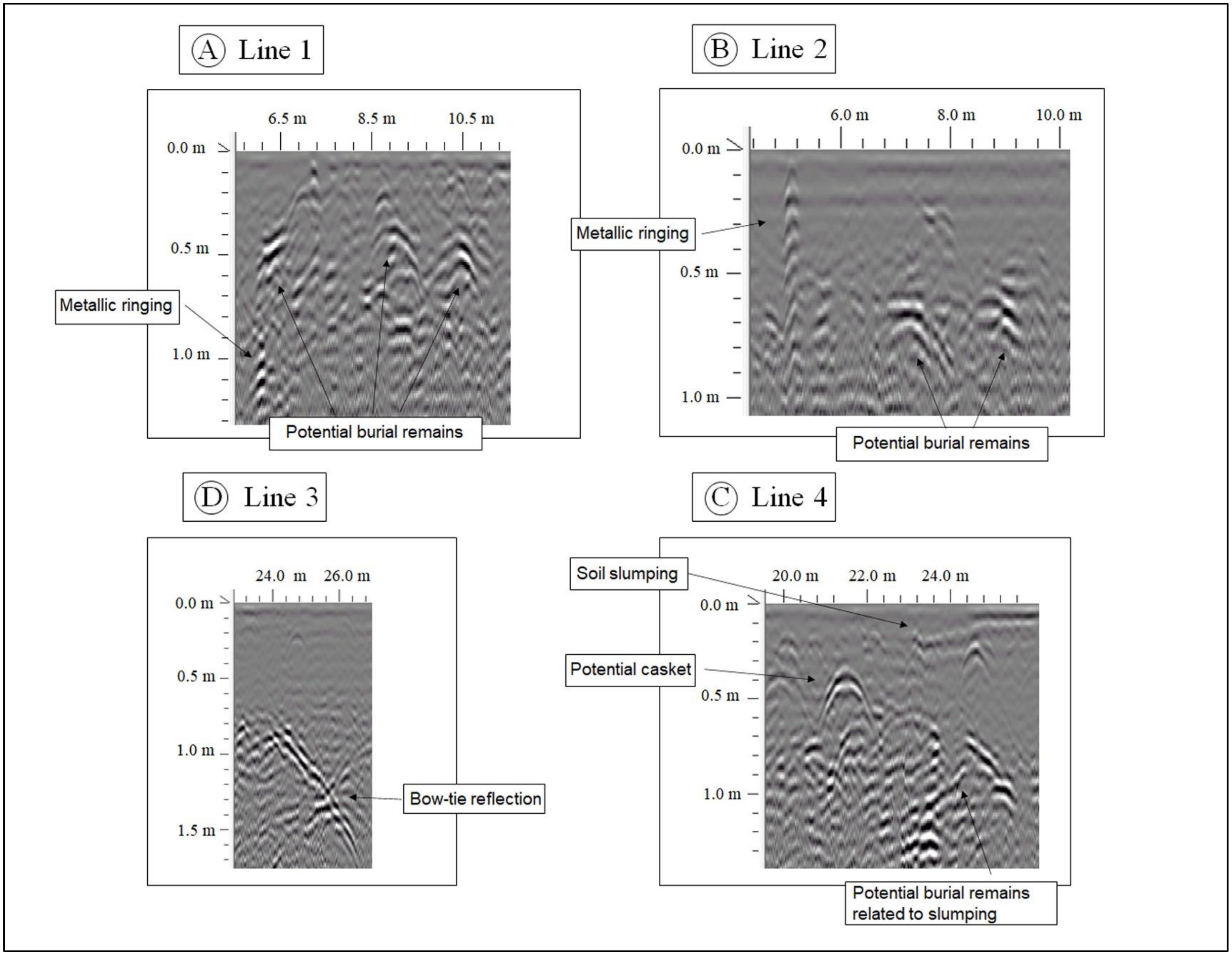


Figure A14. Reflection profiles correlating with the amplitude map of Grid 10.

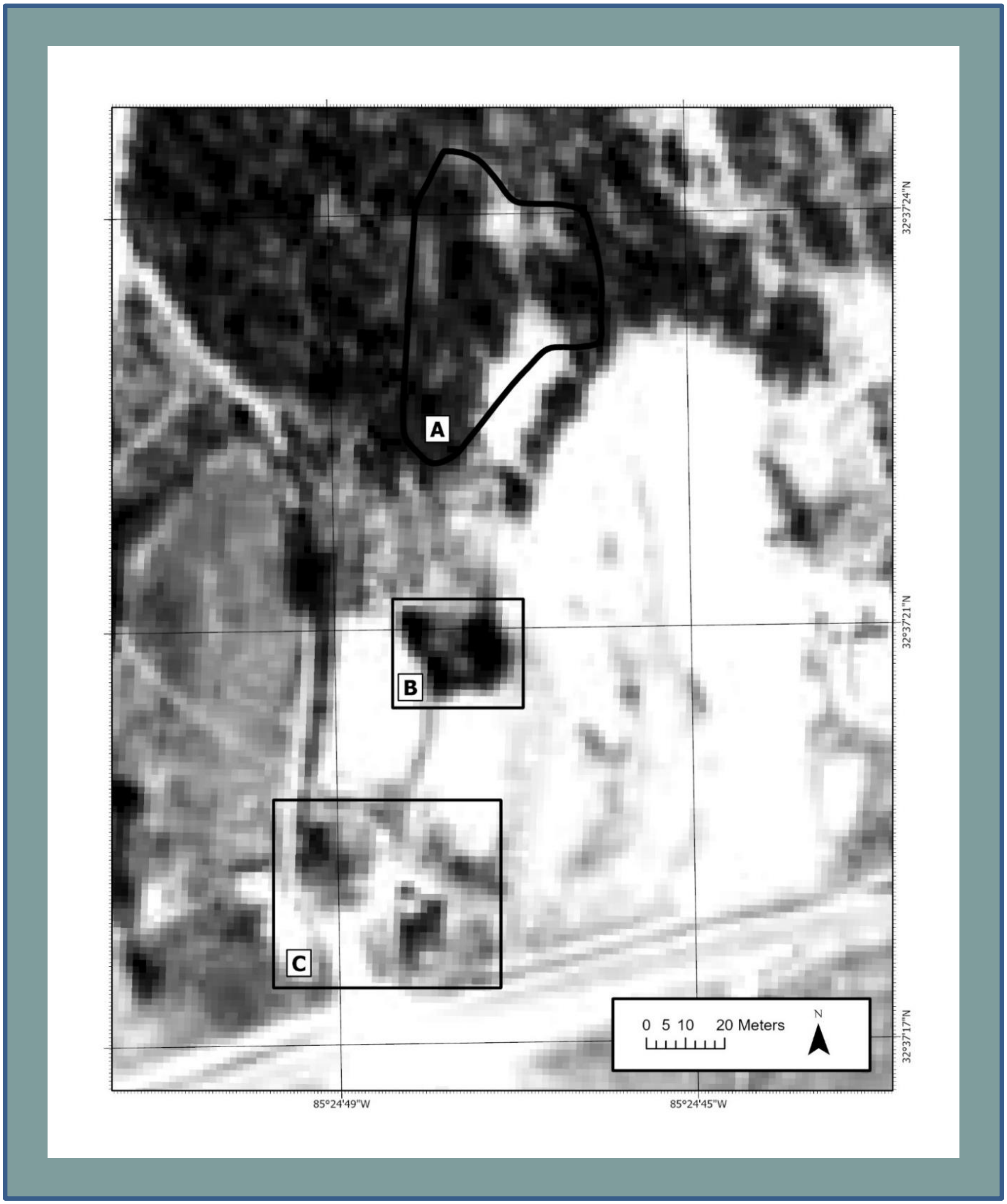
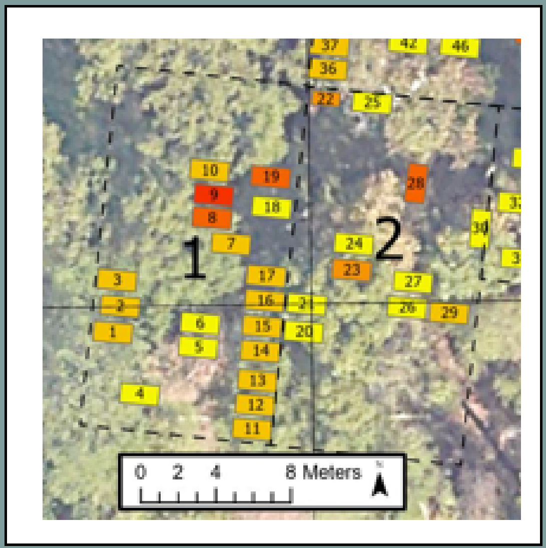
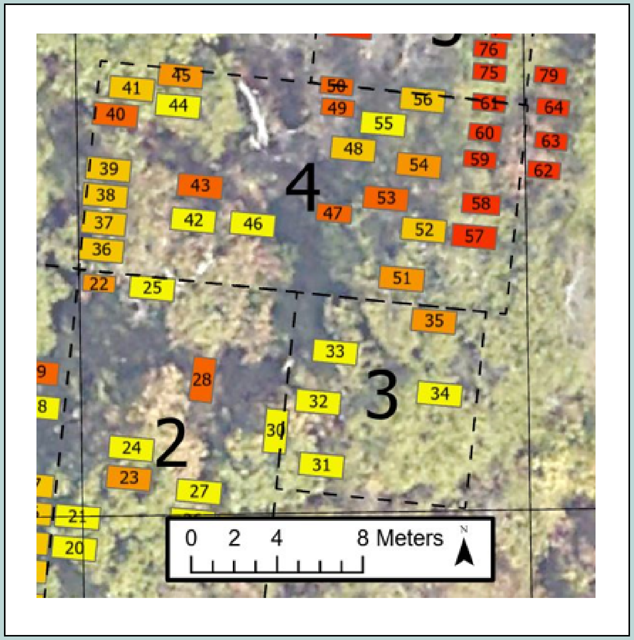


Figure A15. 1964 aerial image of the GAGC located in Lee County, Opelika, Alabama. A: The survey area. B: Site of previous cemetery site confirmed by two oral histories. C: Site of the previously existing house as well as gravesites confirmed by one informant and aerial photographs. Image from Alabama Maps, Cartographic Research Laboratory, College of Arts and Sciences at the University of Alabama.



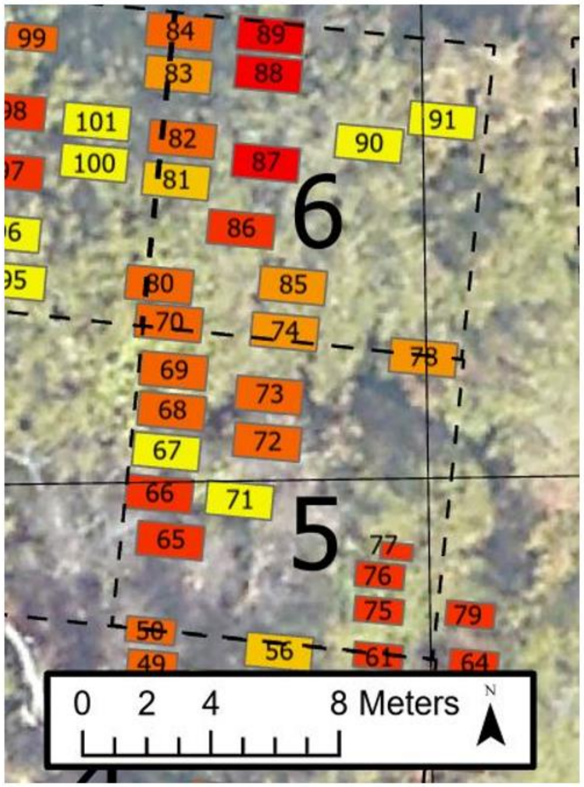
Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
1	5	N	N	N	N	Y	Y	Y	Y
2	5	N	N	N	N	Y	Y	Y	Y
3	5	N	N	N	N	Y	Y	Y	Y
4	4	N	N	N	N	Y	N	Y	Y
5	4	N	N	N	N	Y	N	Y	Y
6	4	N	N	N	N	Y	N	Y	Y
7	5	N	N	N	N	Y	Y	Y	Y
8	8	N	N	Y	N	Y	Y	Y	Y
9	12	Y	Y	N	N	Y	Y	Y	Y
10	5	N	N	N	N	Y	Y	Y	Y
11	5	N	N	N	N	Y	Y	Y	Y
12	5	N	N	N	N	Y	Y	Y	Y
13	5	N	N	N	N	Y	Y	Y	Y
14	5	N	N	N	N	Y	Y	Y	Y
15	5	N	N	N	N	Y	Y	Y	Y
16	5	N	N	N	N	Y	Y	Y	Y
17	5	N	N	N	N	Y	Y	Y	Y
18	3	N	N	Y	N	N	N	N	N
19	8	Y	Y	N	N	N	N	N	Y
20	4	N	N	N	N	Y	N	Y	Y
21	4	N	N	N	N	Y	N	Y	Y
22	6	N	Y	N	N	N	Y	N	Y
23	7	Y	N	N	N	Y	N	Y	Y
24	4	N	N	N	N	Y	N	Y	Y
25	4	N	N	N	N	Y	N	Y	Y
26	4	N	N	N	N	Y	N	Y	Y
27	4	N	N	N	N	Y	N	Y	Y
28	9	Y	Y	N	N	Y	N	N	N
29	5	N	Y	N	N	N	N	N	Y
30	4	N	Y	N	N	N	N	N	N

Figure A16. Grids 1 and 2 containing 30 labeled potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.



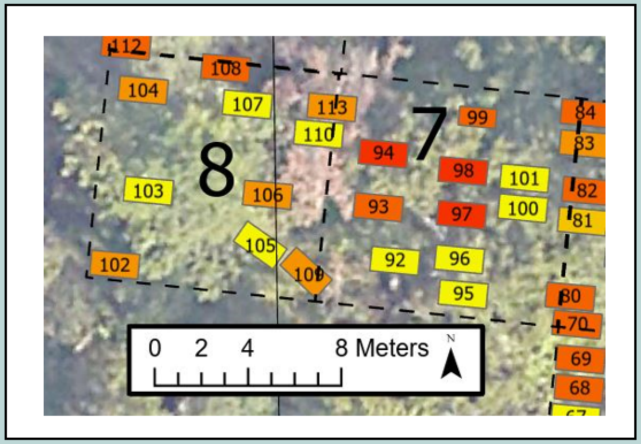
Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
31	2	N	N	N	N	Y	N	N	N
32	2	N	N	N	N	Y	N	N	N
33	2	N	N	N	N	Y	N	N	N
34	4	N	N	N	N	Y	N	Y	Y
35	7	N	N	Y	N	Y	N	Y	Y
36	5	N	N	N	N	Y	Y	Y	Y
37	5	N	N	N	N	Y	Y	Y	Y
38	5	N	N	N	N	Y	Y	Y	Y
39	5	N	N	N	N	Y	Y	Y	Y
40	9	N	Y	N	N	Y	Y	Y	Y
41	5	N	N	N	N	Y	Y	Y	Y
42	4	N	N	N	N	Y	N	Y	Y
43	8	N	Y	N	N	Y	Y	Y	N
44	4	N	N	N	N	Y	N	Y	Y
45	7	Y	N	N	N	Y	N	Y	Y
46	4	N	N	N	N	Y	N	Y	Y
47	8	N	Y	N	N	Y	N	Y	Y
48	5	N	N	N	N	Y	Y	Y	Y
49	9	N	Y	N	N	Y	Y	Y	Y
50	8	N	N	Y	N	Y	Y	Y	Y
51	7	N	N	Y	N	Y	N	Y	Y
52	5	N	N	N	N	Y	Y	Y	Y
53	9	N	Y	N	N	Y	Y	Y	Y
54	7	N	N	Y	N	Y	N	Y	Y
55	4	N	N	N	N	Y	Y	Y	N
56	5	N	N	N	N	Y	Y	Y	Y
57	12	Y	Y	N	N	Y	Y	Y	Y
58	12	Y	Y	N	N	Y	Y	Y	Y
59	12	Y	Y	N	N	Y	Y	Y	Y
60	12	Y	Y	N	N	Y	Y	Y	Y
61	12	Y	Y	N	N	Y	Y	Y	Y
62	12	Y	Y	N	N	Y	Y	Y	Y
63	12	Y	Y	N	N	Y	Y	Y	Y
64	12	Y	Y	N	N	Y	Y	Y	Y

Figure A17. Grids 3 and 4 containing 33 labeled potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.



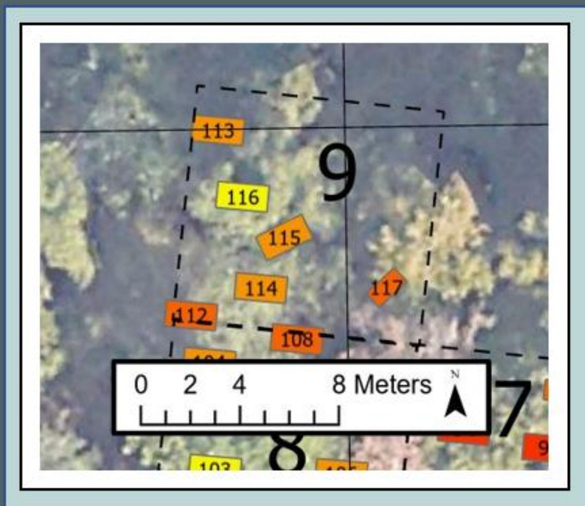
Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
65	11	Y	N	Y	N	Y	Y	Y	Y
66	11	Y	N	Y	N	Y	Y	Y	Y
67	4	N	N	N	N	Y	N	Y	Y
68	8	N	N	Y	N	Y	Y	Y	Y
69	8	N	N	Y	N	Y	Y	Y	Y
70	9	Y	Y	N	N	N	Y	N	Y
71	3	N	N	N	N	Y	Y	N	N
72	8	Y	N	N	N	Y	Y	Y	Y
73	8	Y	N	N	N	Y	Y	Y	Y
74	7	N	Y	N	N	Y	Y	N	N
75	12	Y	Y	N	N	Y	Y	Y	Y
76	12	Y	Y	N	N	Y	Y	Y	Y
77	12	Y	Y	N	N	Y	Y	Y	Y
78	7	Y	N	N	N	Y	N	Y	Y
79	12	Y	Y	N	N	Y	Y	Y	Y
80	8	Y	N	N	N	Y	Y	Y	Y
81	5	N	N	N	N	Y	Y	Y	Y
82	8	Y	N	N	N	Y	Y	Y	Y
83	7	Y	N	N	N	Y	Y	N	Y
84	8	Y	N	N	N	Y	Y	Y	Y
85	6	N	Y	N	N	Y	N	N	N
86	12	Y	Y	N	N	Y	Y	Y	Y
87	14	Y	Y	N	Y	Y	Y	Y	Y
88	14	Y	Y	N	Y	Y	Y	Y	Y
89	14	Y	Y	N	Y	Y	Y	Y	Y
90	4	N	N	N	N	Y	N	Y	Y
91	4	N	N	N	N	Y	N	Y	Y

Figure A18. Grids 5 and 6 containing 27 labeled potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.



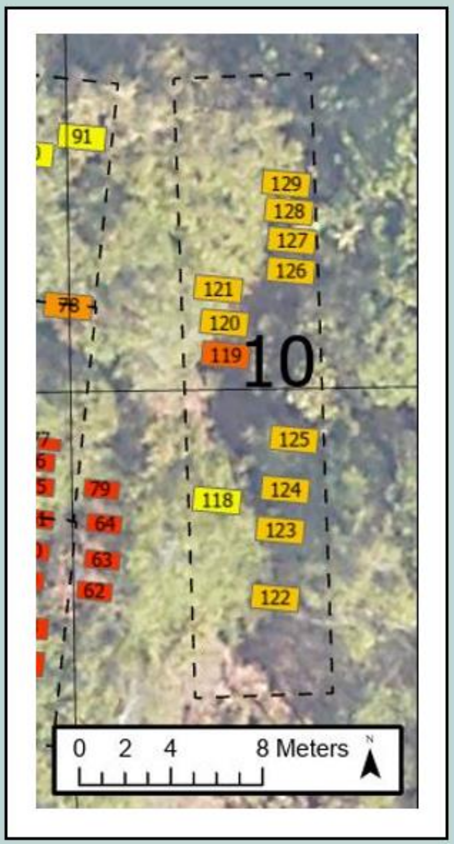
Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
92	4	N	N	N	N	Y	N	Y	Y
93	8	Y	N	N	N	Y	Y	Y	Y
94	11	Y	Y	N	N	Y	N	Y	Y
95	4	N	N	N	N	Y	N	Y	Y
96	4	N	N	N	N	Y	N	Y	Y
97	12	Y	Y	N	N	Y	Y	Y	Y
98	12	Y	Y	N	N	Y	Y	Y	Y
99	10	Y	Y	N	N	N	Y	Y	Y
100	4	N	N	N	N	Y	N	Y	Y
101	4	N	N	N	N	Y	N	Y	Y
102	6	Y	N	Y	N	N	N	N	N
103	3	Y	N	N	N	N	N	N	N
104	7	Y	N	N	N	Y	N	Y	Y
105	3	N	N	N	N	Y	N	Y	N
106	7	Y	N	N	N	Y	N	Y	Y
107	4	N	N	N	N	Y	N	Y	Y
108	10	Y	N	Y	N	Y	N	Y	Y
109	6	Y	N	N	N	Y	N	Y	N
110	4	N	N	N	N	Y	N	Y	Y
111	9	Y	N	Y	N	Y	N	N	Y

Figure A19. Grids 7 and 8 containing 22 labeled potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.



Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
112	9	Y	N	Y	N	Y	N	N	Y
113	7	Y	N	N	N	Y	N	Y	Y
113	7	Y	N	N	N	Y	N	Y	Y
114	7	Y	N	N	N	Y	N	Y	Y
115	6	Y	N	N	N	Y	N	Y	N
116	4	N	N	N	N	Y	N	Y	Y
117	9	Y	N	Y	N	Y	N	Y	N

Figure A20. Grid 9 containing 6 labeled potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.



Number	Condition	Surface Depression	Burial Marker	Stone	Burial Shaft	Hyperbolic Reflection	Row	Linearity	Orientation
118	4	N	N	N	N	Y	N	Y	Y
119	8	N	N	Y	N	Y	Y	Y	Y
120	5	N	N	N	N	Y	Y	Y	Y
121	5	N	N	N	N	Y	Y	Y	Y
122	5	N	N	N	N	Y	Y	Y	Y
123	5	N	N	N	N	Y	Y	Y	Y
124	5	N	N	N	N	Y	Y	Y	Y
125	5	N	N	N	N	Y	Y	Y	Y
126	5	N	N	N	N	Y	Y	Y	Y
127	5	N	N	N	N	Y	Y	Y	Y
128	5	N	N	N	N	Y	Y	Y	Y
129	5	N	N	N	N	Y	Y	Y	Y

Figure A21. Grid 10 containing 12 potential burials with corresponding burial features labeled in the adjacent table. Y indicates the presence of the feature while N indicates the absence of the feature.