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GEOPHYSICAL SURVEY OF GREENWOOD CEMETERY, ORLANDO,
FLORIDA

by

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B.A University of Georgia, 2002

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Arts
in the Department of Anthropology
in the College of Sciences
at the University of Central Florida
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2009

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ABSTRACT

Advances in geophysical and remote sensing technology, specifically with ground penetrating radar (GPR) and geographic information systems (GIS), have led to increased use for archaeological research within cemeteries. Because of its non-invasive manner and high resolution of subsurface anomalies, GPR is ideal for surveying areas with marked or unmarked graves within cemeteries. Using a GIS assists cemetery research by facilitating integration of datasets and projection of spatial data. What has not been attempted to this point is systematic attempting to correlate detection rates of marked graves using a GPR with the time frame of the grave while incorporating the data within a GIS.

This research project is the first to correlate rates of detection with a GPR and the age of marked graves with the data integrated into a GIS platform. Greenwood Cemetery, located in downtown Orlando, FL, was chosen for the study. A total of 1738 graves (ranging in date from 1883-2008) were surveyed with a GPR and then paired with probe data to address whether there is a correlation between rates of detection and age of the surveyed grave. Further, the correlation between the rates of geophysical detection to an independent verification by a T-bar probe and the relationship between the depth and age of the grave by decade were examined. Finally, the problem of collating the relevant survey data was addressed by using a GIS for data integration.

The results of the geophysical survey show a correlation between ages of graves and rates of detection. Older graves were detected less with a GPR compared to higher detection rates of more recent graves. The results also support the utility of pairing GPR with probe data for independent verification of findings but show no relationship between ages of grave and depth of burial. Finally, the integration of the survey data to a GIS helps to address the issue of data

storage and management, the accuracy of the spatial data, and the ability of the data to be viewed and queried in meaningful ways.

Dedicated to Katie

ACKNOWLEDGMENTS

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CHAPTER ONE: INTRODUCTION TO PROJECT

Introduction

Since its invention in the early twentieth century, ground penetrating radar (GPR), has been utilized in a variety of contexts including the survey of soils and geological formations, concrete and other structural foundations, archaeology, and other forensic applications (Reynolds 1997; Davis 2004; France et al. 1992; France et al. 1997; Cheetham 2004; Schultz 2007; Conyers 2004; Gaffney and Gater 2003; Hertz and Garrison 1998; Weymouth 1986). Ground penetrating radar offers relatively rapid, nondestructive, and repeatable surveys of areas of archaeological interest. These abilities have direct implications for archaeologists who are interested in surveying large landscape features such as old village sites in both the old and new world (Leckebusch 2003; Kvamme 2003), and also for identifying smaller archaeological features, such as privies (Pomfret 2006). The abilities of a GPR are also applicable to archaeologists who are interested in mortuary environments. Ground penetrating radar can be used to survey a mortuary environment in a noninvasive manner and has the potential to locate features that could be missed using traditional archaeological field methods. Ground penetrating radar detects differences in soil compaction and composition, and can detect burials (including vaults and coffins) by the unique geophysical signatures produced by their materials (Conyers 2004).

While there have been various applications of GPR research to cemeteries, there has been no systematic attempt to utilize GPR surveys of historic graves to identify detection rates of graves over time. Greenwood Cemetery (28.533350°, -81.358165°), located in downtown Orlando, Florida, offers an excellent location to address this paucity of data in the literature. This

cemetery is one of the largest in the Central Florida area and has an extensive chronological range of historic burials, dating as far back as the 1880's. This research project involved the survey of multiple cemetery sections to create a geophysical sample of graves at Greenwood. This research addressed the following questions: 1) what is the correlation of grave detection by GPR to the grave age by decade?; 2) what is the correlation of geophysical detection rate to an independent verification by a T-bar probe?; and finally, 3) is there a correlation between the depth of a grave detected by the GPR to the age of the grave by decade? This research also incorporated all data into a geographic information system (GIS) platform. This data integration was conducted to address issues of efficient data storage, to accurately project the spatial data, and to allow for the data to be queried in meaningful ways

Ground Penetrating Radar

A GPR is a near-surface geophysical instrument that measures contrasting electrical properties of soils and materials within the soil. For a comprehensive review of the theoretical principles of GPR see Reynolds (1997) and Shamra (1997). Ground penetrating radar has been used in archaeology on prehistoric and historic sites since the 1970's (Vickers and Dolphin 1975; Bevan and Kenyon 1975). Ground penetrating radar uses electromagnetic waves as the energy source from which measurements are collected and interpreted. The electromagnetic waves produced by the GPR antenna are quantified in units of hertz, which are measured in units per second.

As a rule of thumb in antenna selection, the lower the frequency of the antenna the greater of the depth, and conversely, the higher the antenna frequency, the less the depth. A

compromise noted for both archaeologists and those interested in forensic application of GPR would be to select an antenna in the middle of the frequency, around 500 MHz. This provides a compromise of depth of penetration and resolution of subsurface features (Sternburg and McGill 1995; Schultz 2003). The GPR, when activated, sends a constant signal into the ground. These signals reflect, refract, and scatter as they encounter materials that have different electrical properties. The individual waves are compiled to form what is called a trace. These traces are then displayed in a profile with the two-way travel time or approximate depth plotted on the vertical axis and the surface location plotted on the horizontal axis (Conyers 2004).

Geographic Information Systems

Conolly and Lake (2006:11-13) define a GIS as a software platform for the acquisition and integration of spatial datasets and break down the tasks of a GIS into five groups: data acquisition, spatial data management, database management, data visualization, and spatial analysis. These functions are directly applicable to incorporating geophysical data for archaeological purposes. The data acquisition would be the initial integration of the geophysical (in this case, GPR) data into the GIS. The spatial data management is the assigning of the proper spatial coordinates to the GPR data. Current GPR units allow for GPS navigation that can be edited in GPR post-processing software, which can then be turned into a file format compatible with a GIS. A GPR survey can also contain spatially represented data provided by a global positioning system (GPS) and measurements from survey wheels mounted on the GPR. Database construction is the creation of attribute data that gives meaning to the GPR data. Data visualization is the processing of the GPR data within the GIS. The complex processing does

allow for the data to be represented by integrative, discrete and continuous methods (Kvamme 2006; 2007). The spatial analysis is the analysis, querying, and modeling of the GPR data in the GIS. This integration of prospection data into a GIS helps to maintain the data and inform archaeologists about future directions regarding archaeological sites (Neubauer 2004).

Research Objectives

This research had two primary objectives. The first was to investigate the detection rates of graves of varied age at Greenwood Cemetery. This portion of the research is divided into three phases: initial collection of the GPR data, processing and scoring of the GPR data, and finally, probing the graves previously surveyed to confirm the GPR data. The findings of this portion of the research were the subject of the second chapter of this thesis.

The second objective of this thesis was the integration of the survey data generated by this research into GIS. An extensive GIS database for Greenwood cemetery already exists and has been provided by the cemetery sexton, Mr. Don Price. This research addressed the logistics of incorporating the relevant GPR data into the existing GIS in a meaningful way that will allow the data to be readily accessed and also spatially represented. The findings of this portion of the research were the subject of the third chapter of the research.

The fourth and final chapter will summarize the findings of the research. The results of this study will contribute to the formulation of guidelines for using GPR in cemetery research and highlight the utility of integrating geophysical data into a GIS. All radargrams from the survey are given in the Appendix of the thesis.

CHAPTER TWO: DETECTION RATES OF GRAVES USING GROUND PENETRATING RADAR

Introduction

Cemeteries are often the last resting place of humans. This makes cemeteries invaluable repositories of data to anthropologists. Anthropological efforts with mortuary artifacts, such as headstones, vaults, coffins, etc. have focused on the reconstruction and explanation of larger social trends of society through mortuary artifacts and behavior. Archaeologists have also focused their efforts on identifying historic graves using non-invasive methods such as employing geophysical methods (Ellwood 1990, Ellwood et al. 1994; Owsley et al. 1997; Conyers 2006). One of the most applicable geophysical instruments to be used by cemeteries by archaeologists is the ground penetrating radar (GPR). A GPR offers data in real-time, can cover large survey areas quickly, and the surveys can be repeated if necessary. While the utility of GPR in a cemetery setting has been established, what has been not addressed is any systematic analysis of detection rates of graves by decade. This purpose of this study is to conduct a geophysical survey of Greenwood cemetery (28.533350°, -81.358165°), located in downtown Orlando, Florida. The goals of this project are to address the following: 1) what is the correlation of grave detection by GPR to the grave age by decade; 2) what is the correlation of geophysical detection rate to an independent verification by a T-bar probe; and finally 3) is there a correlation between the depth of a grave detected by the GPR to the age of the grave by decade?

To address these questions, it is important to provide a context for this research. First, an overview of GPR methodology will be discussed. This will be followed by a literature review of

GPR applications to cemeteries. Also, an expanded history of Greenwood cemetery will be provided.

Ground Penetrating Radar

Ground-penetrating radar is a near-surface geophysical instrument that measures contrasting electrical properties of soils and materials within the soil (Reynolds 1997; Shamra 1997). Current GPR units consist of three different components: the control unit, the antenna, and the display unit. The control unit consists of the pulse generator, computer, and software. Current GPR units also have the option of the display screen mounted on the GPR facing the operator. This allows the operator to directly see what the GPR is documenting. This set-up also allows for data to be stored within the control unit. Current GPR units can also be mounted on carts. This allows for easier maneuvering of the GPR unit. Finally, GPR units mounted on a cart can also be fitted with a survey wheel that is connected to the control unit. This allows the operator to take precise measurement of distance travelled along a given transect.

Ground penetrating radar uses electromagnetic waves as the energy source from which measurements are collected and interpreted. The antenna is where the radar energy, in the form of an oscillating energy current, is produced in the GPR. Ground penetrating radar antennae come in two varieties: bistatic and monostatic. Bistatic antennae are units with two antennae: one antenna is used to propagate the radar waves while the other antenna is used as the receiver. The monostatic antenna uses only one antenna acting as both the antenna and the receiver. In this case the antenna transmits the radar wave and immediately switches modes to receive the radar wave refraction (Conyers 2004).

The electromagnetic waves produced by the GPR are measured in units of hertz, which is defined in units per second. The range of frequencies depends on the GPR antenna, varying between 10 and 1,500 MHz. The upper end of the range is also used by personal communications devices such as cell phones, television and radios. Most antennae have a two octave bandwidth (Conyers 2004). This means that the antenna of a GPR with a center frequency of 500 MHz will generate energy with wavelengths of 250 to 1,000 MHz. The size of the antenna varies with its defined frequency output. Lower frequency antennae such as an 80 MHz, are about the half the size of a 42 gallon oil drum while a 900 MHz antenna is around the size of a shoe box (Conyers 2004).

As a rule of thumb in antenna selection, the lower the frequency of the antenna the greater of the depth, and conversely, the higher the antenna frequency, the less the depth. The trade off is that with increased depth, less detail is obtained. The amount of detail obtained from the high frequency, while shallower in depth, is significantly greater. This occurs because low frequency antennae generate radar waves that are large while the higher frequency antennae generate smaller wavelength. The low frequency antennae are capable of surveying up to depths of over 50 meters (Smith and Jol 1995). Higher frequency antennae such as 900 MHz antennae may only have be useful for depths of one meter or less. A compromise noted for both archaeologists and those interested in forensic application of GPR would be to select an antenna in the middle of the frequency, around 500 MHz. This provides a compromise of depth of penetration and resolution of subsurface features in archaeological and forensic research (Sternburg and McGill 1995; Schultz 2005).

The GPR, when activated, sends a repetitive signal into the ground in the shape of a cone and reflect and scatter as they encounter materials that have different electrical properties. As the antenna is moved by the operator, the conical beam of the antenna will encounter objects before the antenna is directly over the objects. The conical beam antenna will also detect the object after the antenna has passed over. This type of reflection is called a point source hyperbola (Conyers 2004; see figure 1).

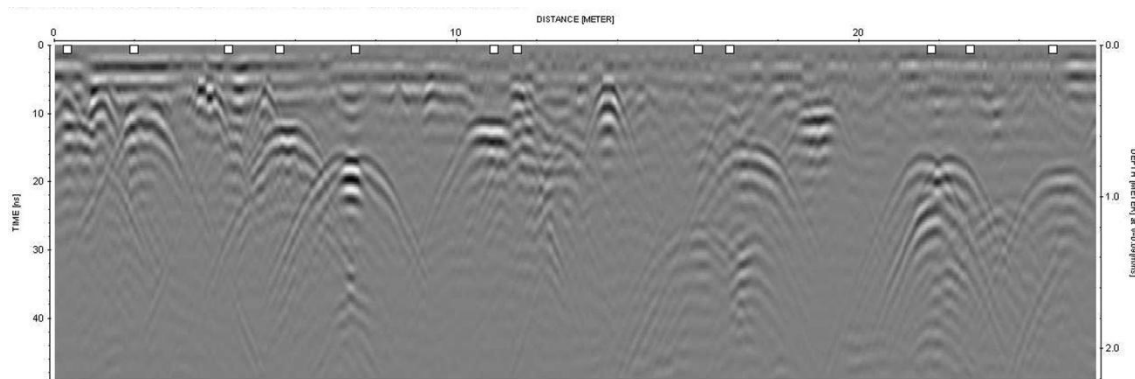


Figure 1: Examples of Hyperbolas Associated with Marked Graves from Section I from Greenwood Cemetery.

The individual waves are interpolated to form what is called a trace. These traces are then interpolated within the control unit and then displayed in a profile with the two-way travel time or approximate depth plotted on the vertical axis and the surface location plotted on the horizontal axis (Conyers 2004). These readings are commonly called radargrams and are used to represent the subsurface surveyed by the GPR. Radargrams vary depending on antenna selection, settings applied before data collection, and also on post-processing steps applied after data has been collected. Ground penetrating radar is subject to variables that limit its effectiveness. All soils and rocks, those materials that allow electromagnetic energy to pass through are referred to

as dielectric. Relative Dielectric Permittivity (RDP), or dielectric constant, is the measure of the electrical and magnetic properties of buried materials. Relative dielectric permittivity also measures the buried materials ability to store a charge from an electromagnetic field and then allow the transmission of the energy (Conyers 2004). The RDP scale is a progressive scale that goes from 1 (which is air) to 88 (which is salt water). The lower the RDP of a material the faster the radar energy will travel through it. The opposite is true for objects of higher RDP (for example, there is no penetration of energy waves through sea water). Soils that contain large amounts of clay or salts will have a high RDP value and a higher attenuation of wave energy. A more applicable example would be materials such as the wood of coffins and concrete used to make the vaults surrounding the coffin which have varied RDP values, and thus create a different reflection pattern that are visible on the GPR profiles.

It is important to keep in mind that environmental factors will influence RDP values. The amount of water in the soil from a heavy rainfall, for example, can change the soil RDP in the course of an evening. A GPR needs to be calibrated daily to ensure accurate data collection. Another factor that will affect a GPR survey is the ability of the medium to become magnetized with the passage of an energy wave through it (i.e., magnetic permeability) (Conyers 2004: 53). A soil that has a high magnetic permeability, like sands with high iron content, will cause a higher rate of energy wave attenuation. These are factors that the GPR operator needs to be aware of before, during, and after data collection.

GPR Applications to Historic Cemeteries

The earliest published archaeological application of GPR to a cemetery context dates back to the mid-1980's (Vaughn 1986). This study was conducted in Canada and consisted of

two GPR surveys of archaeological sites. The site of particular interest to this project was a Basque whaling station (dating to the sixteenth century) on Red Bay that included marked historic burials. The site was gridded with 1m transects, which was chosen as part of an adaptive strategy so that an anomaly, such as a grave, with an extent of 1-2m would not be missed during the GPR survey (Vaughn 1986:597). Two different survey antennae were used on this project: a 350 MHz and a 100MHz. Overall, the author felt that the GPR was successful at quickly and efficiently locating archaeological features, including historic graves (Vaughn 1986), but there is no mention of whether the proposed location of the graves was checked with intrusive methods to confirm the validity of the GPR survey.

Bevan (1991) conducted a more extensive investigation of historic cemeteries, specifically examining the capacity of GPR and a resistivity meter to discern graves of varying ages and geographic location across the United States. This work also provided valuable information regarding how historic graves can be detected using geophysical methods. The author notes that the most distinctive feature of a historic grave is the disturbed soil resulting from digging the grave (Bevan 1991). This type of soil disturbance may result from inversion of the soil. For example, the topsoil that is dug out first may be deposited at the bottom of the grave shaft. This type of inversion alters the natural stratification of the soil and can create an anomaly when surveyed using geophysical methods. Bevan (1991) further notes that coffins and associated coffin architecture can create air-filled voids that will also be detectable using GPR. Changes resulting from the introduction of topsoil to the top of a grave depression due to erosion can also be detected with GPR. Finally, the author makes the important observation that despite

the noted abilities of GPR, this geophysical method can also be seriously handicapped by the presence of unkempt vegetation as well as litter on the surface (Bevan 1991).

Bevan (1991) performed GPR surveys on seven historic cemeteries with varying results. The earliest cemetery surveyed was the Touro cemetery in Newport Rhode Island and dates to around the 17th century. The survey resulted in the detection of one grave out of two surveyed as well as two potential graves (Bevan 1991). The most interesting results came from the GPR survey of George Washington's home on Mount Vernon. Bevan (1991) concluded that fifty unmarked graves were located using GPR. However, the study does not provide any data on whether or not these unmarked graves were excavated to determine the accuracy of the survey. The author concludes that of all the geophysical methods explored during this wide survey, the GPR had the most potential (Bevan 1991).

A GPR survey conducted on the Plains cemetery in Maryland produced positive results (King et al. 1993). The GPR survey located 17 potential graves in this cemetery. The authors further tested these findings by examining 13 of the 17 potential graves. In the excavation units, six of them contained a total of nine graves. The authors noted that the findings with the GPR were not exceptional. When the GPR data is not paired with known archaeological data the GPR had a success rate slightly over 25%. However, when the GPR survey was paired with the information gained from archaeological excavation of the cemetery, the GPR identified two-thirds of the graves while only missing one-third. The authors noted that with improvement to GPR technology, GPR will become even more useful in archaeological investigations of historic cemeteries (King et al. 1993).

Another cemetery study involving GPR was conducted on a traditional Maori burial ground in New Zealand (Nobes 1999). This study utilized two different antennae: a 450 MHz and 200 MHz antenna. However, the usefulness of the GPR was inhibited at this cemetery as the soil was clay-rich in content. The GPR was used in concert with a magnetometer for this project to delineate both the known and marked graves as well as to identify unknown graves. While the author did not list the specific findings of known or possible graves, the combined data of the GPR and magnetometer were used to construct an availability map. This map divided the area into three categories: areas available, unavailable, and marginal (Nobes, 1999). This study showed that while it is possible to locate unrecorded graves with a GPR, GPR is also useful in showing areas of interest that did not register any anomalies and thereby exclude these areas from having graves. The validity of this research has never been verified through archaeological excavation.

Finally, GPR was employed to locate the graves of miners in a Norwegian cemetery who were believed to have died from the Spanish flu of 1918 (Davis et al. 2000). The researchers constructed a 25m by 25m grid with 1m transect. The grid allowed for the creation of an amplitude slice map. The researchers positively identified the location of the graves. Interestingly, the researchers noted that the ground also had detectable disturbances around the graves that occurred from the surface to a depth of 2m. The authors attributed this to dynamite being used to loosen the frozen soil to create the graves. The location of these graves was later confirmed by excavation (Davis et al. 2000).

What these previous applications demonstrate is the utility of GPR in a cemetery setting. These studies also provide parsimonious explanations of how and why graves are detected using

GPR (i.e., disturbances to soils caused by digging the grave shafts, air voids created by the grave, and the remains contained within the graves). What is lacking from these studies is detail in the discussion sections that directly relates to the methodology of the studies. These studies do provide information such as antenna selection, transect interval spacing, and age ranges of headstones, but there is no discussion correlating detection rates using GPR to the ages of the graves detected. While no one study can effectively demonstrate the absolute age range of graves that a GPR can detect given the variables within and between cemeteries, reported detection rates of graves with known ages or age ranges should not be ignored. Reporting this data can help to develop a body of knowledge that can help future researchers with some insight for their studies.

The Greenwood Cemetery

Greenwood is a large, open cemetery situated in downtown Orlando. The cemetery is mostly kept grass on top of sandy soils with a mixture a large hardwoods and shrubs located in the different sections. The soils are a Florahome fine sand, a sandy marine sediment that drain moderately well and has a slope that ranges from zero to five percent (Calhoun and Doolittle 1989). The land for Greenwood cemetery was first purchased in 1880 (see Figure 2 and 3). Prior to the opening of Greenwood Cemetery and other cemeteries in the Central Florida area families would bury the deceased on family property or in small, isolated cemeteries (Bacon 1975). In 1880, eight individuals formed a stock company and purchased 26 acres southeast of Orlando to be used as a cemetery. The cemetery was purchased by the city of Orlando in 1892. At this time, a local ordinance was passed requiring that all burials within the city limits be placed in a designated cemetery area. According to Don Price, the cemetery sexton, the regulation was

passed as a measure to help the state of public health in Orlando. As a result of this regulation, several local cemeteries had graves dug up and reinterred within Greenwood, specifically in Section H of the cemetery (Price, personal communication). It was not until 1915 that the cemetery had its name changed to Greenwood cemetery (Gore 1947). Current online records of the Orange County property appraisers states that Greenwood cemetery encompasses 68.7 acres. The cemetery consists of multiple sections that have individuals who were involved in important periods of American history. Greenwood has sections for veterans of the Civil War, the Spanish American War, World War I, and World War II. Currently, the cemetery is still run by the city of Orlando and continues to sell plots for burials. The earliest marked graves found in Greenwood cemetery are in the southern portion of the cemetery which is divided into different sections that are designated by letters. The northern portion of the cemetery contains more recent interments and is also divided into different sections, but is designated different by numbers instead of letters.

Materials

A total of 29 out of the 36 sections in Greenwood were surveyed (see Figure 4 and Table 1) using a MALA RAMAC X3m GPR. A 500 MHz antenna was used and mounted on a cart with a survey wheel and a T-bar probe. A total of 1738 graves were surveyed for this project. The major focus of the survey was on the lettered sections in the southern portion of the cemetery (these sections contain the oldest burials located within the cemetery and thus offered the opportunity for sampling graves from different time periods. One section, section R, and a



Figure 2: Aerial View of Greenwood Cemetery



Figure 3: Plot Map of Greenwood Cemetery

portion of section O were later dropped from the analysis as it was determined that the surveyed graves from these sections only had headstones memorializing the dead and did not contain an associated burial casket or vault. Nine out of the 15 numbered sections in the northern section were also sampled. While the numbered sections are more recent in date, it was appropriate to survey these sections to gain a larger sample from within Greenwood. None of the Babyland sections, which exclusively contain the interments of young children, were surveyed. Babyland #1 and #2 had large trees rendering survey transects extremely difficult and also detrimental to interpreting the associated radargrams; the third section, Babyland # 3, had very narrow rows and multiple obstructions of memorial items left in front of the graves that did not make the section conducive for survey.

Grave rows were selected for survey within each section. The rows were selected if they meet certain criteria: the rows of graves were linear in their orientation; no large obstructions present along the row; finally, the rows offered a range of interment dates. It should be noted that in some instances the graves selected did not necessarily make up the entire row, rather a portion of graves within the row as some rows did contain obstructions. Once the graves were selected, the last name and dates (or lack of) from the first interment on the start of the row were collected.

Methods

Before each day of data collection, the GPR was calibrated by pulling the GPR over a modern grave which produced a hyperbola visible on the control monitor. The T-bar probe and a tape measure were then used to get an accurate depth measurement of the top of the surveyed grave. The GPR depth calibration was then changed accordingly.

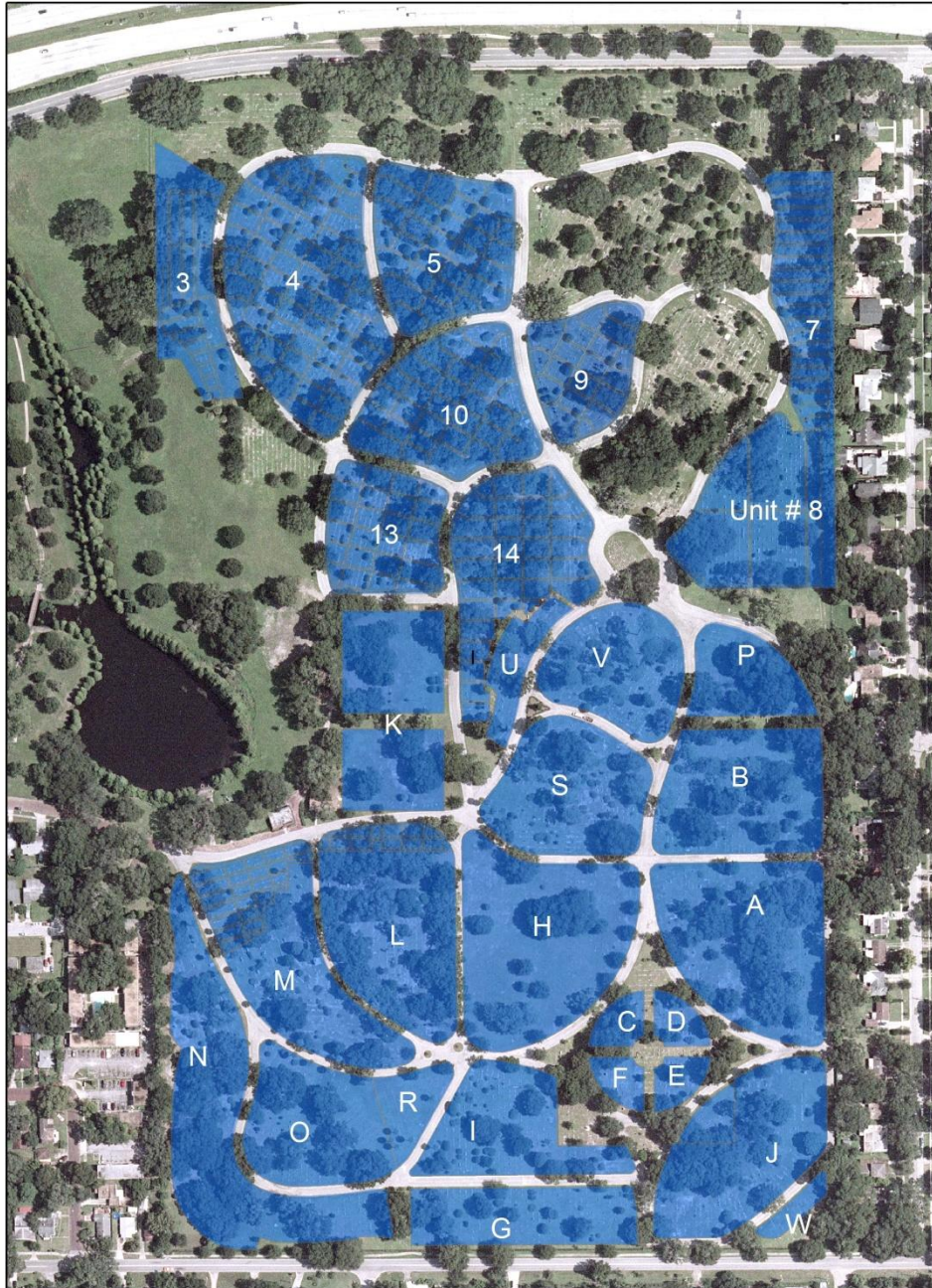


Figure 4: Surveyed Sections within Greenwood Cemetery

Table 1: The Sections Surveyed, the Number of Marked Graves Surveyed in Each Section, and the Range of Dates for the Surveyed Graves within Each Section of Greenwood Cemetery.

Cemetery Section	Graves Surveyed	Interment Range
A	79	1883-1983
B&P	92	1911-2006
C	35	1959-2004
D	29	1886-1999
E	31	1887-2006
F	14	1891-1976
G	118	1925-2003
H	24	1887-1962
I	135	1935-2000
J	62	1902-1996
K	26	1912-1978
L	53	1913-1997
M	92	1920-2004
N	35	1944-1993
O	51	1927-2001
S	99	1930-2005
U	96	1929-2007
V	86	1930-2005
W	81	1934-1993
3	27	1947-1992
4	78	1960-2006
5	64	1945-2007
7	33	1960-2000
8	83	1983-2007
9	70	1957-2001
10	81	1951-2008
13	50	1967-2000
14	41	1918-1991

This method of calibration is a variation of the direct method of calibration, which is the most accurate method of GPR calibration (Conyers and Lucius 1996).

To start data collection on the individual transects, a tape was pulled perpendicular from the closest corner of the first grave to mark the beginning of the GPR transect. Another tape was set in at a meter past this tape and intersected the tape between 50cm and 85cm from the headstone. This tape was extended the entire length of the transect to ensure that the GPR did not meander off the tape line that ran parallel to the headstones. While the GPR data were collected, surface markers were added to the radargrams as the GPR passed over each marked grave. These markers leave a definitive mark on the radargram as to the exact location of each mark grave surveyed.

Once the GPR data were collected, the data was downloaded to a desktop computer. The post-processing program REFLEXW was used to process each individual radargram. Five processing steps were used to process the radargrams as they were recommended by the programs author and were found to be the most effective in processing the data (see Figure 5). The first was subtract mean (dewow). This step creates a mean of each trace which is then subtracted from the central point of each trace (Sandmiere 2008:187). The second was a static correction which serves to adjust the data to correct for the near-field zone (Conyers 2004). The next step is applying gain along the vertical axis of the data. This step increases the amplitude of the data, which can highlight anomalies that might otherwise go undetected. The fourth step is background removal. This processing step removes “ringing” that is common in GPR data. The “ringing” is caused by “system noise” caused by the GPR unit or by another close by source emitting electromagnetic frequencies that interfere with the GPR unit (Conyers 2004:123). The

final step is a bandpass filter. This step removes frequencies above and below assigned thresholds (Conyers and Cameron 1998).

After the data were processed and filtered the radargrams were analyzed to develop a count based on the presence or absence of a hyperbola related to the interment or the remains of the interment. Hyperbolas that were within a meter of the surface marker were counted as being associated with the recorded grave. The marked headstones along the transects varied in shapes and sizes so the meter threshold was established to accommodate for variation of the different headstones. These radargrams were also used to assess the depth of the burial. Graves that were less than 50cm in depth were arbitrarily counted as a shallow burial; burials that were over 50cm in depth were counted as a deep burial. Current Florida law requires burials to be at least 12 inches (or 30.5cm) below the surface (unless this regulation is waived by the family deceased) so the arbitrary 50cm was selected as it exceeds the minimum requirement and does not leave ambiguity for categorizing burials that are at or near the required minimum depth of burial.

The probe data was collected using a T-bar probe as its utility has been recognized for locating graves (Owsley et al. 1995; Dupras et al. 2006). The area in front of the each surveyed grave was probed regardless of whether or not the marked grave along the transect produced a hyperbola. The probe was pushed into the ground surface in front of the headstones until contact was made or to the maximum depth allowed with the probe. Detection was noted when the tip struck a coffin or burial vault as it was possible to discern whether contact was made with a tree root, a cement vault, an intact casket, or an eroding casket. The detection or absence of the grave was noted and entered onto the sheet containing the radargram of the appropriate graves being examined. From this data, tables were created to report the collected data.

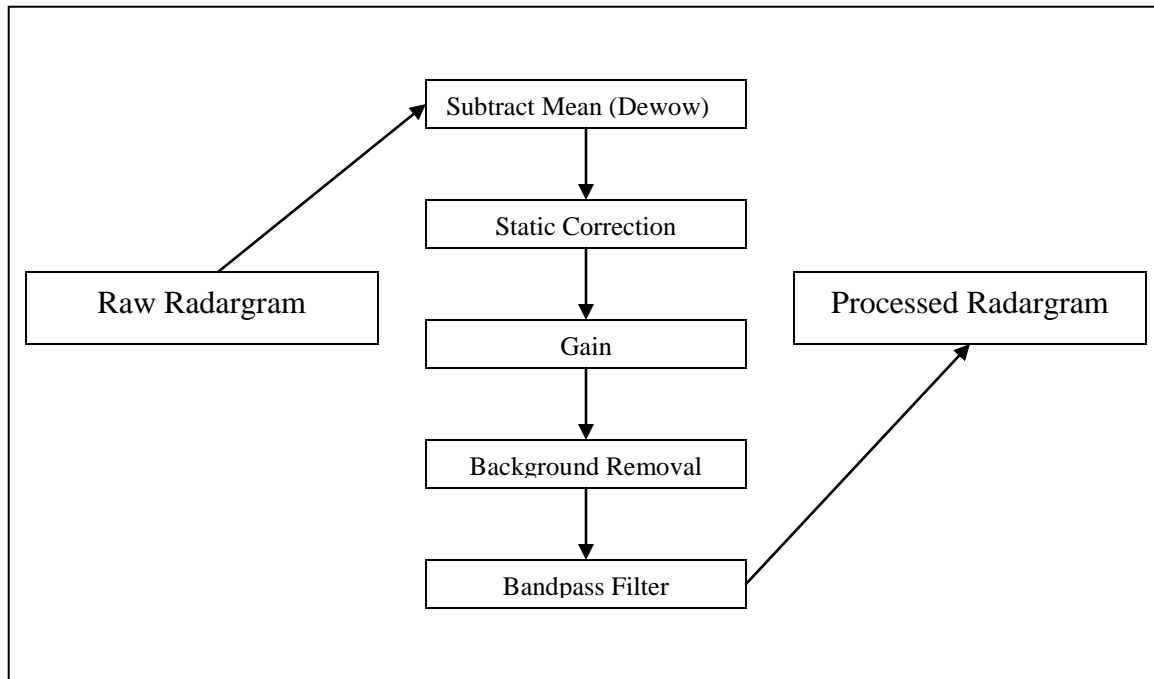


Figure 5: Flow Chart of Processing Steps for GPR Data

Results

The first results to be reported are from the lettered sections (Figure 6). These sections from the southern portion of the cemetery contain the oldest interments in Greenwood and also have a range of interments that spans to modern day. The next to be reported are the numbered sections of the northern portion of the cemetery (Figure 9). This section contains interments that do overlap in age with the lettered sections, but are generally of a more recent in age. Next, a composite of combined data from the lettered and numbered section is discussed (Figure 10). Finally, the percentages of occurrence of depth of burial of all surveyed graves are reported (Figure 11).

Lettered Section

The lettered sections from the southern portion of Greenwood Cemetery have the largest distribution of graves that were surveyed (see Figure 17). From these sections a total of 1211 graves were surveyed. A total of 18 graves from the 1880's were surveyed with the oldest dating to 1883 (both from section A). Only one grave from the 1880's had an anomaly associated with the grave. This grave dated to 1888 and was found on the third transect from section D (see Figure 7).

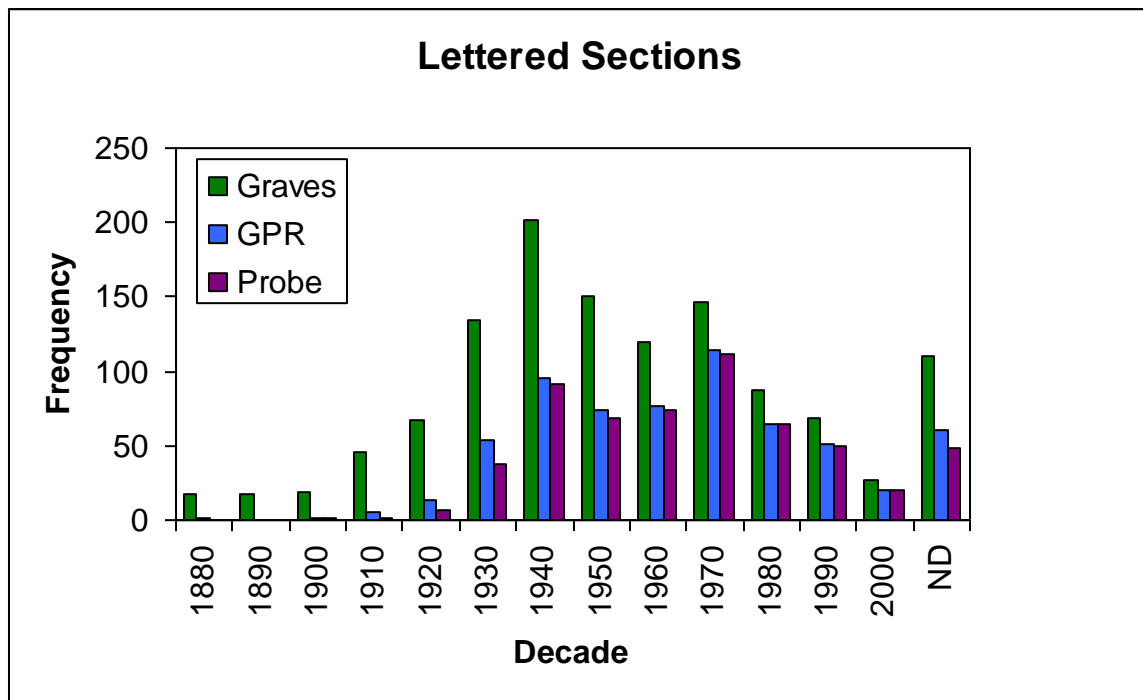


Figure 6: Frequency Distribution of Graves, Graves Detected by GPR, and Graves Detected by Probe Reported by Decade from the Lettered Sections of Greenwood Cemetery.

This anomaly is unique as it not similar to other anomalies associated with other graves of different age ranges from the other lettered sections in the southern portion of the cemetery (see Figure 8). No graves surveyed from the 1890's (N= 17) were detected using GPR or the probe. It

is not until the graves dating to the 1900's that graves are detected using both the GPR and the probe. A total of two graves from the 1900's were detected using the GPR and the probe. There is a significant increase in the detection of graves using both techniques through the graves dating to the 1930's and 1940's.

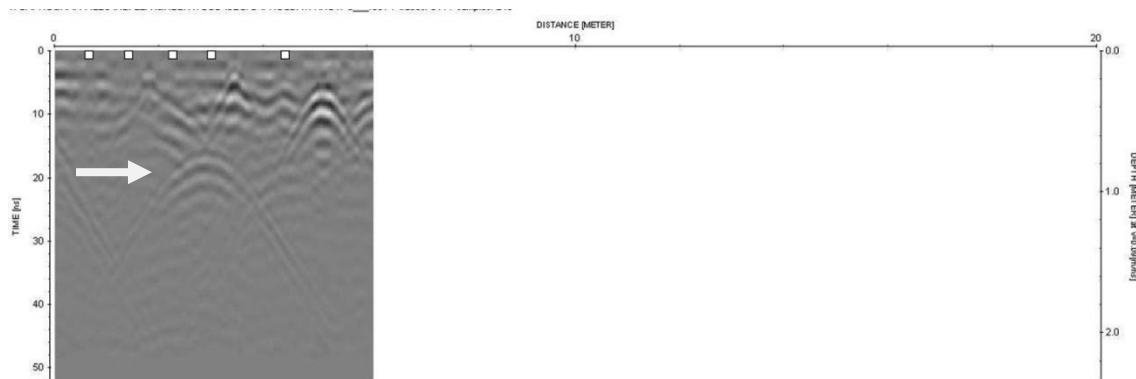


Figure 7: Transect 3 from Section D. Note the Hyperbola Associated with the Grave Dating to 1888.

There is a continued increase in the rates of detection as a percentage of total graves with the continuing decades. The graves associated with the 1970's have the highest rates of detection (77% with the GPR and 76% with the probe. With the following decades (1980's, 1990's, and 2000's) there is a decrease in the number of surveyed graves with a corresponding increase in the rates of detection using both techniques. Of the 88 graves surveyed from the 1980's, 65 graves were detected using both the GPR and probe. Of the 68 graves from the 1990's, 51 were detected using both techniques. Finally, of the 27 graves from the 2000's, 20 were detected using both techniques. From the 1980's on there is only one grave not detected with the probe and none reported with the subsequent decades.

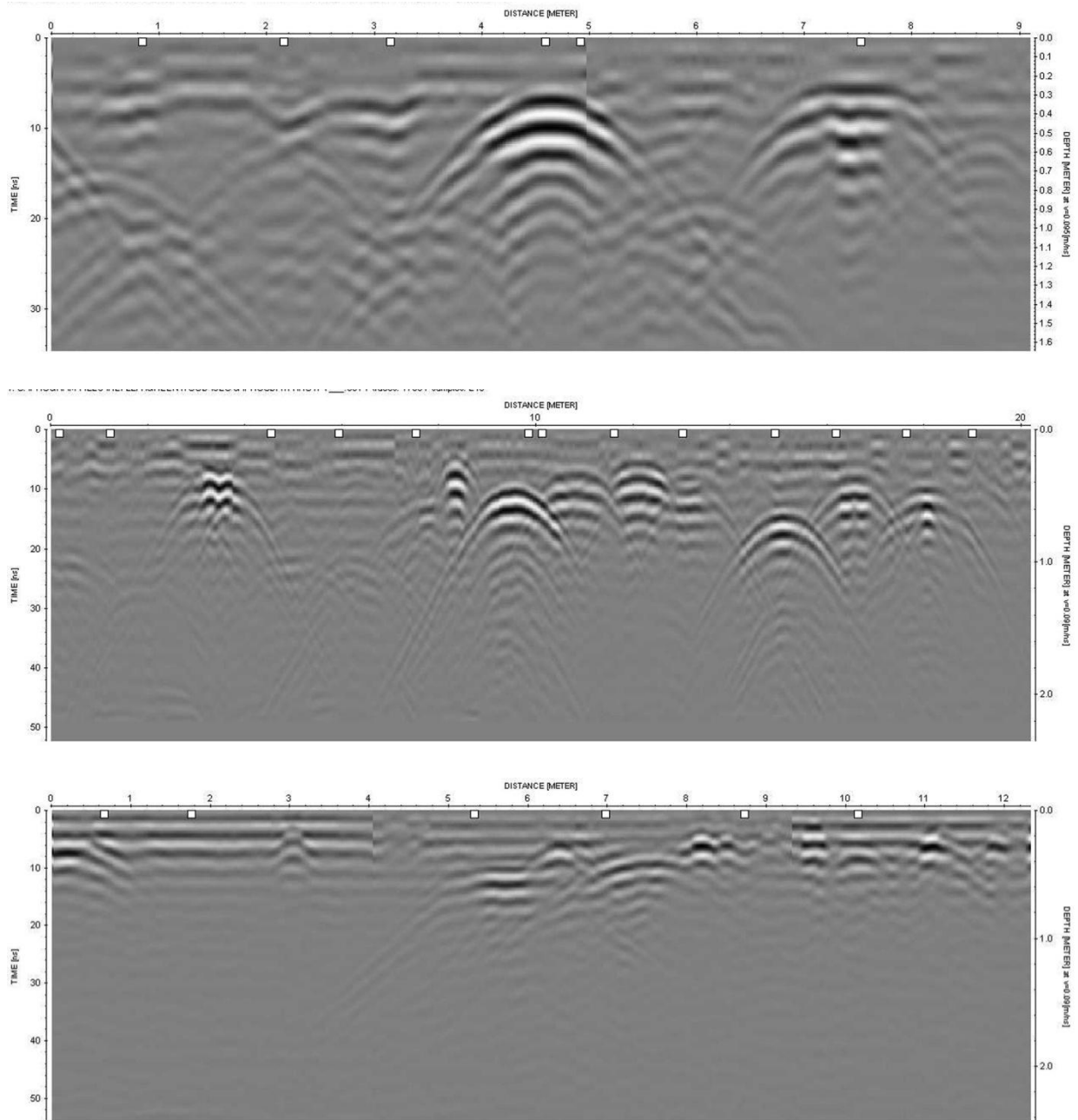


Figure 8: Radargrams from Various Sections with Different Age Distributions. The Top Radargram is from Section B&P and has an Age Range (in Decades) for the Grave Interments from the 1930 to 1950's. The Middle Radargram, from Section G, has an Age Range from the 1940's to the 1960's. The Bottom Radargram, from Section N, has an Age Range from the 1960's to the 1990's.

Numbered Section

Figure 9 illustrates the findings of the survey of the numbered sections of Greenwood cemetery. As these sections more recent in age, the range of graves is later than that of the lettered section. A total of 527 graves were surveyed from this section. The earliest graves from the numbered section date to 1910's and 1920's are found in section 14. Starting with the graves from the 1940's there is an increase with the detection rates using the GPR and the probe. The GPR has a detection rate of 50% and the probe has a detection rate of 18%. Only two graves from the 1950's were detected using the probe. The detection rates using these techniques best detected the graves dating to the 1970's. Both the GPR and the probe had a detection rate of 92 percent. It should be noted that, starting with interments from the 1960's and continuing to on to graves from the current decade, the detection rates using both techniques are identical, save for one grave from the 1980's.

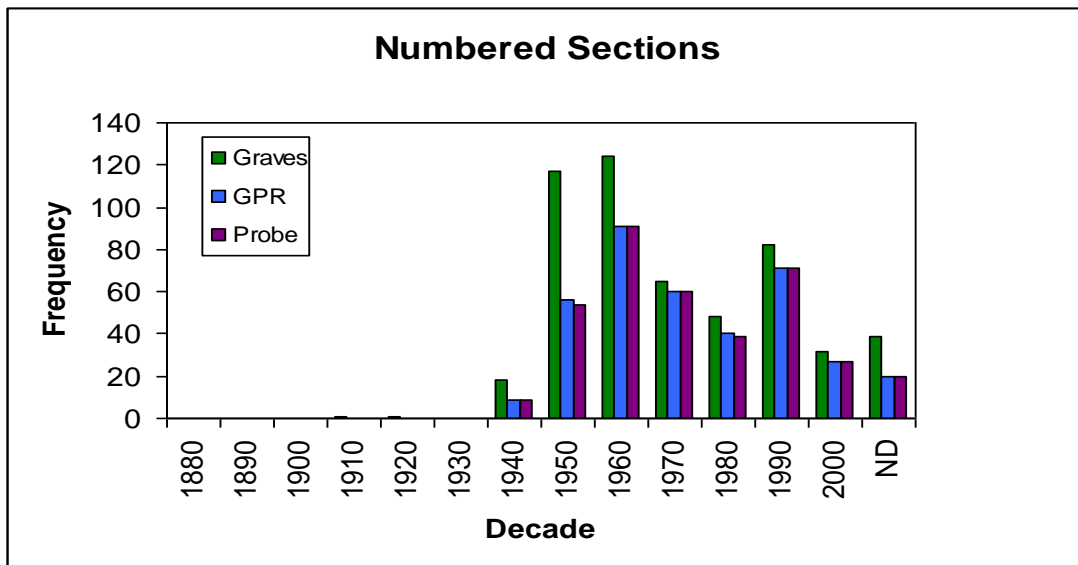


Figure 9: Frequency Distribution of Graves, Graves Detected by GPR, and Graves Detected by Probe Reported by Decade from the Numbered Section of Greenwood Cemetery.

All sections

Figure 10 illustrates all graves surveyed in both the lettered and numbered sections from Greenwood cemetery. The graves from the 1960's have a substantial increase in detection rates using the GPR and probe over the previous decades. The combined graves from the 1960's were detected 68% of the time using the GPR and 67% of the time using the probe. The detection of graves for the 1970's had only two graves detected by the GPR that were not detected with the probe. The graves from the 1980's and 1990's both had one grave that was detected with the GPR and not detected with the probe. There is no disparity reported with graves from the current decade.

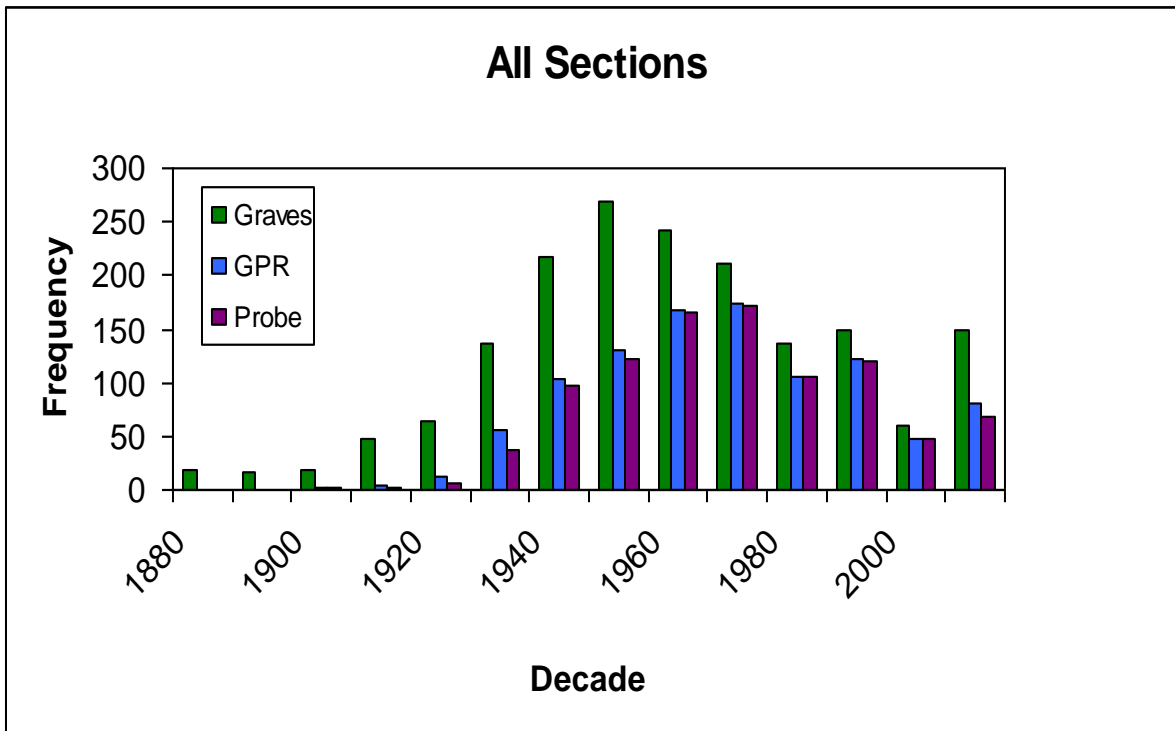


Figure 10: Frequency Distribution of Graves, Graves Detected by GPR, and Graves Detected by Probe, Reported by Decade for All Sections from Greenwood Cemetery.

Occurrence by Depth

Figure 11 illustrates the percentages of shallow versus deep burials from the survey. The single grave detected from the 1880's with the GPR was a deep burial (over 50cm in depth). The majority of the other graves surveyed were shallow in their burial (that is, less than 50cm in depth). The largest percentage of deep graves comes from the graves surveyed from the 1930's, but it should be noted that the deep graves of this decade made up only 25% of the graves from this decade. Deep burials only accounted for 15.8% of the burials surveyed from the 1940's. The graves surveyed from the 1950's to the 1980 have had less than 10% of their burials buried at a deep depth. No graves from the 1990's and the 2000's were classified as deep.

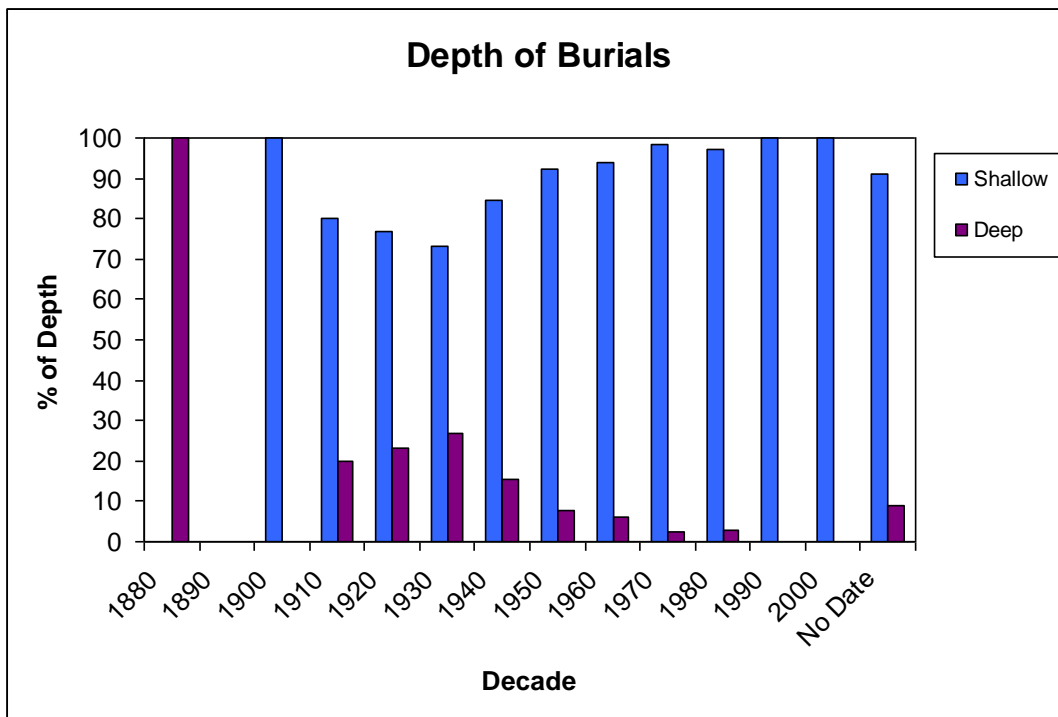


Figure 11: Percentage of Occurrence of Depth of Burial from all Graves Surveyed from Greenwood Cemetery.

Discussion

Overall, the application of the GPR to this cemetery setting did produce interesting results for two out of the three research areas of this study. The data also adds to the important studies of GPR applications to cemeteries reviewed above by further demonstrating the utility of GPR to cemeteries for archaeological research. This data also shows that it is possible to discern correlations between GPR detection rates and the age of the graves. While this data set is limited to this particular cemetery, it does suggest a new area of inquiry that relates to not only geophysical research and anthropological research but also to cemetery management.

Out of this study, the most problematic area was the investigation of the depth and its relation to the time frame of the different graves from the different sections. Referring back to Figure 11, it shows that there is a higher occurrence of graves that are buried shallower, but this pattern does not occur in any significant manner that would merit further investigation. The fact that most burials occur at a shallower depth should come as no surprise as this cemetery is in Florida where the water table is higher than other parts of the country, making deeper burial undesirable. Also, Florida law now requires that burials to be only 12 inches in depth, which can also be waived if the consent of the family members, making the necessary minimum to satisfy regulations a depth well above the arbitrary cut-off for a shallow burial. Further, according to Sexton Don Price, there has been no consistency to the depths of burials at Greenwood as the depth of burial has been at the discretion of the family of the deceased and the person digging the grave. It should be noted that a reason some older burials that were not detected could have been buried below 50cm, but have decomposed to the point that the grave no longer provides enough of a contrast with the surrounding soil to be detected by the GPR. More recent burials are more

likely to be shallow in burial depth, not collapsed, and therefore provide a contrast with the surrounding soil that is detected.

The utility of pairing a probe with the GPR needs to be emphasized. From the 1940's on there is less than a four percent disparity between the detection rates of the GPR and using the probe to confirm the anomaly (the probe was unable to detect only 7 graves that were detected using the GPR from that decade). From the numbered section there is a disparity of detection of only two from the 1940's and 1950's. Most importantly, at no point in this study did the probe locate a marked grave along a transect that was not detected using the GPR. If the GPR did not detect the grave, then the probe did not detect the grave.

Preservation is a major reason why the GPR detected anomalies associated with graves while the probe did not. A telling example is the second transect from section G (Figure 12). Only the anomaly associated with the first grave on this transect was able to be confirmed using the probe.

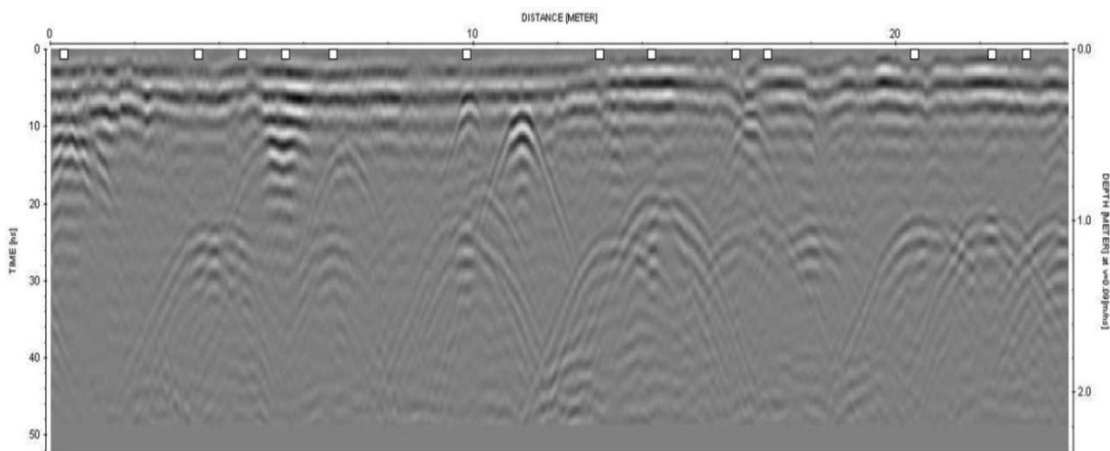


Figure 12: Transect 2 from Section G Showing Anomalies Associated with Marked Graves. Only the First Grave was Detected using a Probe.

A reasonable explanation for the continuance of the anomalies (keeping in mind that these individual cases of disparity in detection rates cannot be further investigated by excavation) is due to decay of a grave over time. As an interment decays over time it can cause the grave to collapse on itself. The collapsed grave can then leave an air void underneath the surface. This air void can produce an anomaly much like those seen in the cited examples above. While it is possible to detect changes in soil composition, the soils at Greenwood did not have such a difference that allowed for detection of air voids.

Using a probe to test an anomaly that is similar to one produced by a grave allows for a quick, minimally invasive check on whether or not the anomaly was actually produced by a casket or vault. Using a probe does not offer the real-time sub-surface view of an anomaly produced by a grave, but once a grave has been identified using both techniques, it is much simpler to assess the dimensions of the grave using a probe than a GPR. If an individual is willing to go through the trouble of taking a GPR out to a cemetery, it is essential that a probe is included.

The results of the GPR survey show interesting results for several reasons. First, the rates of detection do show a positive trend that was expected. The rates of detection are in part due to the site conditions at Greenwood. There is no clay or clay-like soils found in Greenwood which are the worst types of soils for surveying for graves with a GPR (Bevan 1991). The rates of detection are directly linked to variables that are found within Greenwood, within individual sections of the cemetery, and to individual graves on transects surveyed on this study. Expanding on these results will show further show the utility of GPR to cemetery surveys, but it will also touch on its limitations for its applications to other cemetery environments.

The results of this study do show an increase in detection rates using both techniques with more recent graves within Greenwood cemetery. This study does show that with increased age, a grave is less likely to be detected with these methods. Preservation, again, is a major factor in explaining this trend. External conditions acting on the older graves in Greenwood that were constructed of materials, like for example, wooden caskets, would adversely affect levels of preservation. The soils found at Greenwood, combined with frequent rain, would facilitate decomposition of the graves and the individuals within the grave. Also, not all graves decompose in such a manner as to create an air void as touched on earlier. There is also no uniform pattern to preservation of graves over time. Preservation of graves is site specific, but it also dependent on the immediate surroundings of the individual grave (Henderson 1987).

Preservation alone cannot explain the trends of detection rates of graves over time. Factors directly related to burial of that are decided by the individual, family, etc., are important as the materials that are chosen can and do directly impact levels of preservations. Since the establishment of the deathcare industry in the 19th century in the United States (Haberstein and Lamars 1981), there has been an increase in the options of how a person will be interred. By the end of the 19th century it was possible to have marble, iron, and cement for burial materials. Vaults, large containers that are now usually constructed out of concrete, have been around since the 1870's. Vaults, whose original use started in Connecticut, were designed to protect the body from ghouls and marauders. By the early 1900's, vaults already made up between five and ten percent of burials (Haberstein and Lamars 1981; Mitford 1963).

Vaults are an important variable in preservation in Greenwood. They are important in that since the mid-1960's it has been required by Greenwood cemetery that all coffin burials must

have a vault (Price personal communication). This move most likely followed a national trend of the time to require vaulted burials to prevent grave collapse, and to limit the liability of the cemetery (Mitford 1963). This regulation is a good explanation of why there is noted increase in detection rates from the 1960's over the previous decades (the GPR detection rate was 67 percent from the 1960's compared to 48 percent from the 1950's). It should also be noted that it is not a federal or a state of Florida requirement that all graves must be buried within a vault.

This requirement at Greenwood is important to the discussion of preservation, but other choices that individuals make do influence the rates of detection. For a better understanding of the rates of preservation at Greenwood, Sections B&P, which occupy the same plot of land within the cemetery (and were combined as one section for this project), were chosen to investigate why more recent graves (from the 1960's on) were not being detected despite of the existing regulation to require a vault. Within this section, five graves met this criterion. From the records at Greenwood cemetery, three of these individuals were cremated and buried in urns. Since the beginning of professional crematoriums in the United States, cremation has only increased in popularity (Haberstein and Lamars 1981; Mitford 1963). Cremations urns that are buried have never been required to be of a certain type of material, to be contained within a vault, or to be buried at one specific location within the space owned by the individual. These urns are much smaller than that of a adult sized casket contained within a cement vault. It is not unreasonable to expect the preservation of these urns to be less than a non-cremation burial.

The other two burials were a mystery at first. According to the records the individuals were buried in vaults in the ground. Re-examining these graves with just the probe, it was discovered that the burials were in fact put in the ground so that the burial was on the back-end

of the head-stone and not along the transect as expected. Combining records was useful for exploring individual variation for these graves.

As mentioned in the methods sections, section O and a portion of section R were dropped from this analysis. These sections of the cemeteries were set aside for fallen soldiers from past wars. The headstones did not serve to mark the location of the physical grave, but rather as a memorial. If this data were kept, the detections rates for graves from the 1940's, 1950's, and 1960's would be distorted to be lower than would be otherwise.

Conclusion

There is a considerable amount of variation within Greenwood cemetery. These variations include the distribution of the age and types of graves throughout the cemetery. In spite of this variation, there are several conclusions that can be taken from this study. First, there is a weak correlation between depth of burial and the date in which the person was buried. Second, when using a GPR in a cemetery it is necessary to also have a probe. A probe can provide a verification of the GPR data. Finally there is a general trend in the pattern of preservation of graves over time that is detectable using a combination of a GPR and probe. The results show an increase in rates of detection with more recent graves. Caution should be exercised before the results of this study are applied to any other cemetery that has a similar distribution of graves. Variation that is seen at Greenwood cannot be expected at all other cemeteries of the same age. It is not know how the detection rates would be, for example, for a cemetery from North Georgia that has predominately clay soils and does not require vaults.

Based on this research there can be guidelines given for similar research. After permission is obtained for using a GPR and probe, it is important to record all pertinent information of the graves being surveyed. This information should include the age of death and burial on the headstones. The GPR should be calibrated in a manner similar to the one described in the methods section. This will allow for an accurate assessment of the depths of anomalies recorded by the GPR. A global positioning system (GPS) reading should be taken at the beginning of each transect. A GPS reading will ensure accurate spatial records of the placement of the GPR transects. Also, it is important to make sure the GPR survey wheel is calibrated accurately to record the exact distance of all transects. The probing should be done along the same transect used for the GPR. The probe should be inserted in the ground at several locations near the headstones to confirm the presence or absence of the interment. By following these procedures it will be possible to replicate the same type of analysis used for this study.

While the detection rates cannot be inferred for other cemeteries, the methodology of this study is directly applicable to other researchers that are interested in grave detection rates over time using geophysical equipment. Replication of this study could prove very useful for similar research questions. One area that can be addressed is the nature of multiple interments that are found in Greenwood cemetery and other like cemeteries. In some cases, the two overlapping anomalies are produced by double interments, and in some cases large single anomalies are produced. Future work along these lines would also benefit from further incorporation of records of graves that are to be surveyed using geophysical equipment.

CHAPTER THREE: INTEGRATING GEOPHYSICAL DATA INTO A GIS

Introduction

Archaeology has always been exploratory in nature. The various means of archaeological investigation use and produce different types of data. Archaeological surveys often include aerial maps and photographs of the project area and use global positioning systems (GPS) points to record located sites. Excavations have total station data, soil profiles of test units, and voluminous spreadsheets containing the catalogue of artifacts. Surveys of archaeological sites using non-invasive methods such as ground penetrating radar (GPR) also produce different data sets. The challenge with these different datasets is to integrate them into a single source, making the data coherent and accessible. Recent technological advances, particularly in geographic information systems (GIS), have aided archaeologists in incorporating data into one digital platform (Conolly and Lake 2006; Wheatley and Gillings 2002; Kvamme 1989; 1996).

To complete a recent geophysical survey of Greenwood Cemetery, located in downtown Orlando, Florida, many different types of data were collected. The data included compass bearings, GPR and probe data, distance measurements from a mounted survey wheel on the GPR, GPS waypoints, and dates that were entered in spreadsheets. Working with these different types of datasets posed integration issues. The largest question was whether or not it was possible to collate all the survey data into a single source. Further, what would be the benefits of integrating the data in a single platform?

The goal of this research was to fully integrate the survey data with the existing cemetery GIS to create a unique digital platform. Specifically, this integration will allow for 1) efficient

management and storage of the survey data, 2) accurate projection of the spatial data, and 3) the spatial data to be displayed and queried to answer various questions.

Before giving a review of how this GIS was constructed, it is necessary to provide a review of how these different technologies (GIS, GPR, and GPS) are employed in archaeological research. The GIS overview will give a brief history of this powerful spatial technology its various applications to archaeology. The overview of GPR will give a short introduction to the methodology, how GPR has been applied to cemetery research, and how the data has been integrated into GIS platforms. The GPS overview will cover how this technology has been employed over different parts of the world to record and map landscapes, archaeological sites, and artifacts. A brief history of Greenwood Cemetery will also be provided.

GIS Applications to Archaeology

Briefly defined, a GIS is a software platform for the acquisition of spatial datasets; the functions of a GIS can be broken into five groups: spatial data management, database management, data visualization, and spatial analysis (Conolly and Lake 2006: 11-13). Wheatley and Gillings (2002:14-15) credit the Canadian Geographic Information System (given the acronym: CGIS) as being the first recognizable GIS. This GIS, which was created in 1964, was designed for the Canadian Department of Forestry to address long term issues of natural resource management. Following the lead of Canada, agencies at the state and federal level in the United States developed their own GIS platforms.

The first applications of GIS to archaeology date back to the 1980's. In the early applications of GIS to archaeology, researchers focused on site location, or predictive modeling,

and modeling prehistoric landscapes (Savage 1990). More current applications of GIS to archaeology have become as diffuse as the number of specializations within archaeology. Hunt (1992) performed a catchment analysis of prehistoric sites in the Southwestern region of New York State and demonstrated a correlation of village sites and optimal soils for farming.

Zooarchaeologists have also used GIS in the analysis of faunal remains. Marean and colleagues (2001) developed an analytical method for determining the minimum number of elements (MNE) by using a GIS to determine the overlap of the skeletal elements. Abe and colleagues (2002) applied this technique to two samples to determine if cut marks could be defined on faunal remains. The researchers found that using a GIS provided great results of cut marks on unfragmented and fragmented faunal remains. Byerly and colleagues (2005) used a GIS for analysis of the Bonfire Shelter site in Texas to determine if the site represented a mass kill site. By using a GIS to construct a digital elevation model (DEM) of the site the researchers were able to measure slope, least-cost pathways and to construct viewsheds of the upland portion of the site. The GIS analysis showed that the upland portion of the site could indeed have been used for a mass kill drive. While the zooarchaeological analysis of the faunal remains did not corroborate the GIS analysis, this research does demonstrate the utility of incorporating a GIS approach as part of the archaeological research design.

Landefoged and colleagues (1995) used a GIS to enhance the survey data of a conductivity and magnetic susceptibility survey of a pre-contact Maori fort in New Zealand. The GIS based filtering of the data enhanced the quality of the data and facilitated the delineation of subsurface anomalies. The use of GIS has been applied to a long term study of the Greek island of Kythera (Bevan and Conolly 2004). A combination of GIS and quantitative analysis were

used to examine the nature of field systems on the island, site location in its relation to surface visibility, site definition and artifact distribution, and the relationship between terrain and site location. In each instance the authors found the GIS approach to analysis useful and recommend further GIS based analysis in future research on this project (Bevan and Conolly 2004).

While GIS has become more prominent in archaeological studies there have been few examples of cemetery studies that incorporate GIS analysis into the research methodology. One of the most applicable examples of integrating archaeological cemetery research within a GIS platform comes from the excavation of Freedman's cemetery in Dallas, Texas (Davidson 2000). This cemetery was opened in 1869 for the African American population of Dallas. The cemetery closed its gates in 1907, and eventually fell into disrepair. During the course of road work, the cemetery was rediscovered and excavated. All told, 1,150 interments were excavated. All of the interments were mapped and entered into a GIS as polygons. The polygons were assigned information based on analyzed coffin hardware associated with the interments and the hardware's temporal distribution (this was possible for all but one of the excavated interments). Four temporal periods were defined based on the artifacts. Based on the analysis, it was then possible for the development of the cemetery to be viewed spatially and temporally using the GIS (Davidson 2000).

Another example of successful integration of archaeological research within a cemetery into a GIS platform is from the research at St. Michael's cemetery in Pensacola, FL (Libbens 2003). To survey the cemetery, the researchers used an electronic total station to record the corners of each grave. This total station data were uploaded to a GIS and combined with attribute data for each grave (a total of 22 types of data were recorded from the field). The result of this

integration has helped with the management by identifying usable burial plots in the cemetery by applying a buffer to the surveyed graves. This integration was also intended to allow interested parties to query the data to assist academic research (Libbens 2003). This data is now available on the internet for the general public to view and to interact with (the GIS can be viewed at the following address: <http://www.stmichaelscemetery.org>). By incorporating the results of the cemetery survey within a GIS, this project will add to this small but growing body of literature and further demonstrate the utility of GIS to archaeological research.

GPR Applications to Archaeology

Ground-penetrating radar is a near-surface geophysical instrument that measures contrasting electrical properties of soils and materials within the soil (Reynolds 1997; Shamra 1997). Ground penetrating radar uses electromagnetic waves as the energy source from which measurements are collected and interpreted. The radar energy is produced by the application of an oscillating electrical current. The GPR, when activated, sends a repetitive signal into the ground in the shape of a cone and reflect, refract, and scatter as they encounter materials that have different electrical properties.

As the antenna is moved by the operator, the conical beam will encounter objects before the antenna is directly over the objects. The conical beam antenna will also detect the object after the antenna has passed by. This type of reflection is called a point source hyperbola (Conyers 2004). The individual waves are interpolated to form what is called a trace. These traces are then interpolated within the control unit and then displayed in a profile with the two-way travel time or approximate depth plotted on the vertical axis and the surface location plotted on the horizontal axis (Conyers 2004). These readings are commonly called radargrams and are used to

represent the subsurface surveyed by the GPR. Radargrams vary depending on antenna selection, settings applied before data collection, and also on post-processing steps applied after data has been collected.

The earliest applications of GPR to archaeological sites dates back to the mid-1970's (Bevan and Kenyon 1974; Vickers and Dolphin 1975), but it was not until the mid-1980's that research on GPR applications to cemetery settings were first published (Vaughn 1986). In his research on seven historic cemeteries in North America, Bevan (1991) noted several distinct features of graves that can be detected by a GPR. The first would be the soil disturbance caused by the digging of the grave. Also the coffins and the associated coffin architecture can create air voids that would also be detected. Finally, the introduction of topsoil that is added to address grave settling or collapse would also be detected.

Other applications of GPR to cemetery settings have shown its utility in locating unmarked graves. In a survey of a Plains cemetery, Maryland, King and colleagues (1993) had a high success rate of locating unmarked graves when pairing the GPR survey data with the archaeological data. Nobes (1999) surveyed a Maori burial ground using a GPR and a magnetometer. While it was not stated whether the location of unmarked graves that were later confirmed by excavation, the author was able to create an availability map of the cemetery with three categories based on the results of his survey: areas available, unavailable, and marginal.

More recent advances in processing software have enabled GPR survey data to be interpolated to create three-dimensional time-slice, or amplitude, maps (Conyers and Goodman 1997). With these maps now available it has become possible for archaeologists to view subsurface anomalies that were not visible in a single radargram. Further advances of this

technology have focused on integrating GPR data into a digital platform. Research at the Army City site, Kansas (Kvamme 2006, 2007) has demonstrated the potential for integrating multiple geophysical datasets into a GIS. At this site, GPR and five other geophysical methods were employed to survey the site. Overlay analysis, red-green-blue (RGB) color composite analysis, and Boolean operations were some of the analytical methods used to integrate the GPR data with other geophysical datasets within a GIS platform. This research demonstrates the potential for integrating multiple geophysical datasets and the potential for enhanced resolution of subsurface archaeological features (Kvamme 2006, 2007).

GPS Applications to Archaeology

Recent advances in GPS accuracy have increased its utility for archaeological applications. Collier and colleagues (1995) have made GPS mapping an integral part of a project in Langstone Harbor, England. A total of 57,000 readings were taken with a differential GPS (DGPS) and used to create a triangle irregular network (TIN) for spatial analysis. The researchers also addressed the imprecision of this project. Previous artifacts and sites within this project area were acknowledged to have only vague spatial records. Buffers of varying size (depending on the degree of uncertainty) will be added in the future to compensate for the imprecision of assigning artifacts and sites single points (Collier et al. 1995).

Chapman and Van Noort (2001) have also successfully applied DGPS mapping to two Iron Age sites in England. These sites, which are now located in wetlands, were mapped with the data used to create a DEM. The sites were ground-truthed and found that micro-topographical features identified from the DEM were confirmed (Chapman and Van Noort 2001). Fenwick (2001) performed a similar GPS survey of the Armana plain in Egypt. These data were used to

create a DEM of the topography as well as model the road network within the plain. A total of 70 roads were mapped with a total length of 30 Kilometers.

High resolution mapping has also been applied to areas of uneven terrain. At a hill-top site in Turkey Brunting and Summers (2002) collected 1.4 million GPS points over the 271 hectare site to create a digital elevation model and they reported accuracy between 10-25cm. Capra and colleagues (2002) performed a GPS survey of the sites and surrounding landscape within the Chacas Valley, Peru. The GPS data were used to generate a digital terrain model (DTM) of the sites and surrounding area, making analysis of the site in relationship to the landscape possible.

The use of GPS for archaeological work is not limited to academic research. This technology has become so diffuse that all sites discovered will be recorded using a GPS (Banning 2002; Collins and Molyneaux 2003) regardless of whether the site was found on a cultural resource management (CRM) survey or on an academic project. What is important that the GPS operator be aware of the projection selected for data collection and the average spatial error of the particular unit being used.

The Greenwood Cemetery

Greenwood Cemetery is located in downtown Orlando. The cemetery consists mostly of kept grass on top of sandy soils with a mixture a large hardwoods and shrubs located in the different sections. The land for Greenwood cemetery was first purchased in 1880 (see Figure 13 and 14). Prior to the opening of Greenwood cemetery and other cemeteries in the Central Florida area families would bury the deceased on family property or in small, isolated cemeteries (Bacon 1975). In 1880, eight individuals formed a stock company and purchased 26 acres southeast of

Orlando to be used as a cemetery. The cemetery was purchased by the city of Orlando in 1892. At this time, a local ordinance was passed requiring that all burials within the city limits be placed in a designated cemetery area. According to Don Price, the cemetery sexton, the regulation was passed as a measure to help the state of public health in Orlando. As a result of this regulation, several local cemeteries had graves dug up and reinterred within Greenwood, specifically in section H of the cemetery (Price, personal communication). It was not until 1915 that the cemetery had its name changed to Greenwood cemetery (Gore 1947). Current online records of the Orange County property appraiser states that Greenwood cemetery encompasses 68.7 acres. The cemetery consists of multiple sections that have individuals who were involved in important periods of American history. Greenwood has sections for veterans of the Civil War, the Spanish American War, World War I, and World War II. Currently, the cemetery is still run by the city of Orlando and continues to sell plots for burials. The earliest marked graves found in Greenwood cemetery are found in the southern portion of the cemetery which is divided into different sections designated by letters. The northern portion of the cemetery contains more recent interments and is also divided into different sections, designated differently by numbers.

The Greenwood GIS

In 2004, at the request of the cemetery Sexton, Don Price, an intensive survey of Greenwood was undertaken by a local surveying company, Southeastern Survey. From this survey an extensive GIS was created. This GIS was designed to integrate spatial data from the cemetery into one source, manage the space currently in use, and to identify unused areas of Greenwood that could be sold to the public. Polygon shapefiles were created for the different

sections within Greenwood, for the lots within the sections, and for various other features within the cemetery.



Figure 13: Aerial Map of Greenwood Cemetery.



Figure 14: Plot Map of Greenwood Cemetery

While the GIS is extensive, there are defined limits to what data were integrated into the GIS. Lots and spaces shapefiles are present, but there is no information about specific interments related to these shapefiles. A specific lot can be queried within the Greenwood GIS but the names and dates of expiration of the interments within the lots cannot be accessed through this data. This GIS is a powerful tool for the management of the cemetery but somewhat limited for archaeological research.

This survey was so successful for Greenwood that the city of Orlando was almost immediately able to pay for the survey with revenue generated from lots sold that were previously unidentified (Price, personnel communication). As Southeastern Survey specializes in engineering surveys, the GIS was created using a geographic projection that is used for such work in East Central Florida. The projection used was the Florida East 0901 state plane. This projection is one of the State Plane Coordinate System (SPCS) projections, which were created in the early 1930's after the development of the Transverse Mercator Projection (Snyder 1993).

Methods

In this study, a total of 29 out of the 36 sections in Greenwood were surveyed (see Figure 15) using a MALA RAMAC X3m GPR and a T-bar probe. A total of 1738 graves from 178 transects were surveyed for this project. The major focus of the survey was on the lettered sections in the southern portion of the cemetery (these sections contain the oldest burials located within the cemetery and thus offered the opportunity for sampling graves from different time periods). One section, section R, and a portion of section O were later dropped from the analysis as it was determined that the surveyed graves from these sections had only headstones

memorializing the dead and did not contain an associated burial casket or vault. Nine out of the 15 numbered sections in the northern section were also sampled. While the numbered sections are more recent in date, it was appropriate to survey these sections to gain a larger sample from within Greenwood.

Grave rows were selected for survey within each section. The rows were selected if they meet certain criteria: the rows of graves were linear in their orientation; there were no large obstructions present along the row; and, the rows offered a range of interment dates. It should be noted that in some instances the graves selected did not necessarily make up the entire row, rather a portion of graves within the row as some rows did contain obstructions. Once the graves were selected, the last name and dates from the first interment on the start of the row were collected. Subsequent dates of the selected graves were also collected. Graves with no date were marked as “ND” (No Date). This collected data was later entered into an Excel spreadsheet.

Before each day of data collection, the GPR was calibrated by pulling the GPR over a modern grave that which produced a hyperbola visible on the control monitor. The T-bar probe and a tape measure were then used to get an accurate depth measurement of the top of the surveyed grave. The GPR depth calibration was then changed accordingly. This method of calibration is a variation of the direct method of calibration, which is the most accurate method of GPR calibration (Conyers and Lucius 1996).

To start data collection on the individual transects, a tape was pulled perpendicular from the closest corner of the first grave to mark the beginning of the GPR transect. Another tape was set in at a meter past this tape and intersected the tape between 50cm and 85cm from the headstone

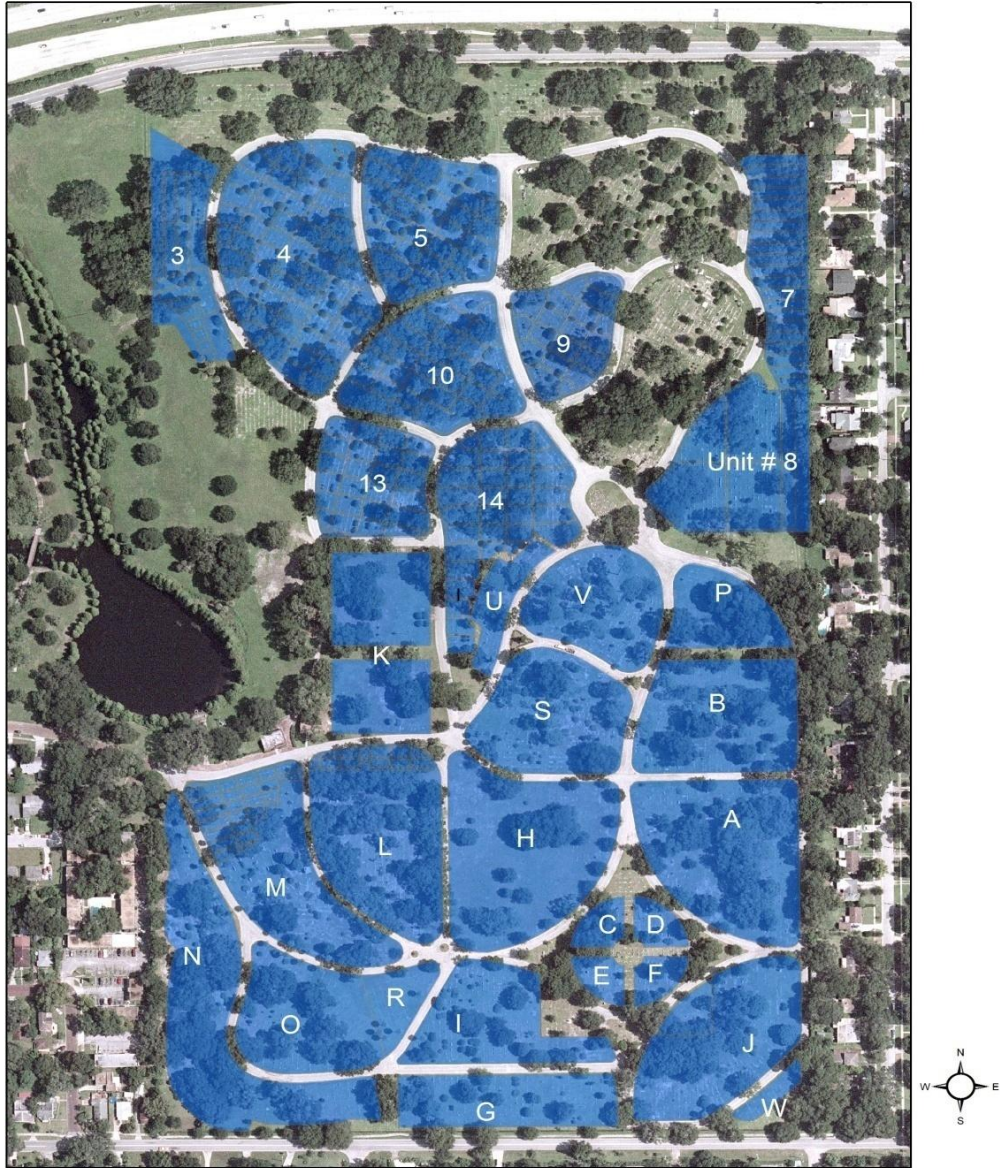


Figure 15: Surveyed Sections at Greenwood Cemetery

This tape was also extended the entire length of the transect to ensure that the GPR did not meander off the tape line that ran parallel to the graves. The angle of the transects were recorded using a handheld magnetic compass. While the GPR data were collected, surface markers were added to the radargrams as the GPR passed over each marked grave. These markers leave a definitive mark on the radargram as to the location of each mark grave surveyed. The length of each transect were recorded with the survey wheel.

Once the GPR data were collected, the data was downloaded to a desktop computer. The post-processing program REFLEXW was used to process each individual radargram. After the data were processed the radargrams were analyzed to develop a count based on the presence or absence of a hyperbola related to the interment or the remains of the interment (the data was scored as either yes 'Y' or no 'N'). Hyperbolas that were within a meter of the surface marker were counted as being associated with the recorded grave. The marked headstones along the many transects varied in shapes and sizes so the meter threshold was established to accommodate for variation of the different headstones. These radargrams were also used to assess the depth of the burial. Graves that were less than 50cm in depth were counted as a shallow burial; burials that were over 50cm in depth were counted as a deep burial (the data was scored as either shallow 'S' or deep 'D').

The probe data was collected using a T-bar probe as its utility has been recognized for locating graves (Owsley 1995; Dupras et al. 2006). Regardless of whether or not the grave along the transect produced a hyperbola, the area around the grave was probed to detect the presence or absence of the interment (the data was scored as either yes 'Y' or no 'N'). The probe was put into the ground surface along the transect until contact with the interment was made or to the

maximum depth allowed with the probe. The presence or absence of the grave noted by using the probe was entered onto the sheet containing the radargrams of the appropriate graves being examined. This data was also entered into the same spreadsheet containing all relevant information about the grave, row, and section being surveyed. From this data, tables were created to report the collected data.

A 2004 Trimble GeoXT GPS was used in this project. As discussed earlier, the projection for the Greenwood GIS is the Florida East 0901 state plan, and the GPS was also set to the same projection. The antenna height was set to four and a half feet (about chest height). The Trimble unit has wide area augmentation system (WAAS) correction capabilities that were also used when collecting data. Wide area augmentation system is one of the four satellite-based augmentation systems that is government operated and allows for more accurate GPS readings (El-Rabbany 2006). Folders were created for each section with all waypoints for that particular section stored within the designated folder. Waypoints were collected at the beginning of each transect with data collected at one second intervals with a minimum of 30 collected for each waypoint.

The Trimble unit is supported by Terrasync software. This software allows the files containing the GPS points to be written directly into shapefiles, which are then downloaded from the GPS. Once the folders have been downloaded from the GPS unit they can be uploaded to a GIS, given the appropriate projection, and then projected in ArcGIS version 9.3. With the shapefiles projected it was then possible to combine shapefiles for sections into larger aggregate shapefiles using the Merge function available in the toolbox. An aggregate shapefile was created from each of the surveyed lettered sections. The same step was taken for the shapefiles for

numbered sections surveyed. Finally the aggregate shapefiles for the lettered and numbered sections were combined for a master shapefile containing all the GPS waypoints collected for this project (see Figure 16).

With the data collected from the survey it was then necessary to integrate the data into the GIS. For each individual transect a polyline shapefile was created with all of the appropriate data fields needed. Each shapefile contains 13 data fields. The fields are: grave year, grave decade, GPR detect, probe detect, depth category, uneven detection, section, transect, length, angle, profile, name, and radargram. After the appropriate shapefiles for each section were created the shapefiles were all given the same projection used for this project. This ensured that the GIS would be a flat file database (Conolly and Lake 2006:52) and therefore limited compared to other database designs, but this database design does address the needs of data entry for this survey. The individual shapefiles were then added to ArcMAP with the corresponding GPS shapefiles, and were then snapped to the GPS points. The angle and distance of the transect were then entered, completing the drawing of the transect (Figure 17).

At that time the attribute table was opened for the transect shapefile. For the row directly associated with the shapefile only the section, transect, length, angle, profile, and name fields had data entered as this data was pertinent to the identification of the transect. The subsequent information from the survey transect (grave year, GPR detect, etc.) were entered in corresponding rows within the attribute data. All rows within the shapefile were given the same information for the section and transect fields. This was done so that these data can be easily identified as to what section and transect it belongs (see Figure 18).



Figure 16: All GPS Points Marking the Beginning of the Survey Transects.



Figure 17: All Survey Transects.

After all transect shapefiles for each individual section were finished, the shapefiles were combined using the same Merge function. Aggregate shapefiles were created for the lettered sections and numbered sections. A master shapefile combining all sections was also created. The same process was done for merging the GPS point shapefiles for all sections.

At this time a folder containing a geodatabase was created and project shapefiles were imported into the geodatabase (the geodatabase could not accept the GPS points shapefile, but that shapefile was stored within the same folder as the geodatabase to help with simplifying data accessibility). These files were added to the geodatabase to simplify issues of storage and to allow the radargrams (in the form of .jpegs) of all the transects from the survey to be added to the attribute data of the all transects shapefile. ArcGIS allows shapefiles within geodatabases to create fields that can hold raster images. By adding the radargrams, all relevant data from the Greenwood survey were integrated into the GIS. The radargrams were added in ArcMAP to the radargram field within the attribute data.

Discussion

The integration of the GPR survey to the Greenwood GIS delivers a dynamic visual representation of the area covered by this survey. It is possible to have a macro-view of the entire survey, of a few sections, or of a single transect depending on the scale chosen. From this

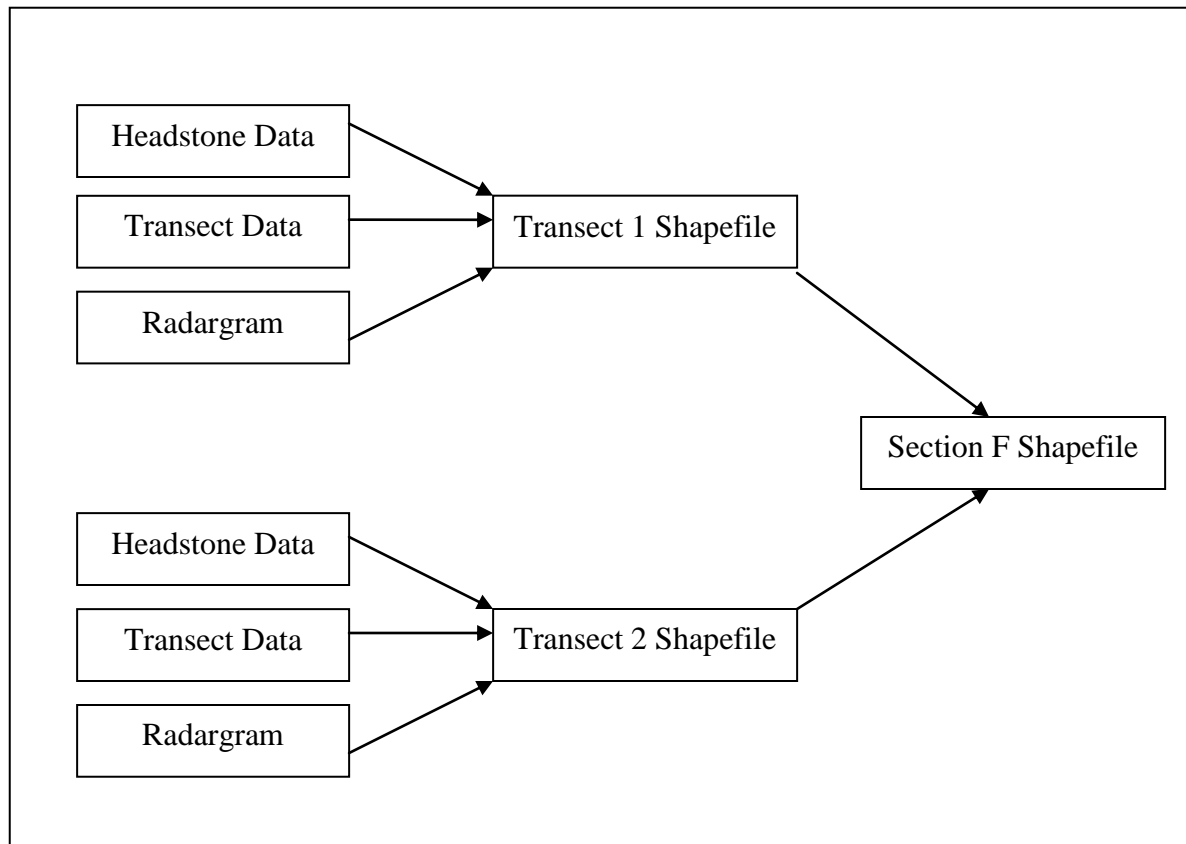


Figure 18: Flow Chart for Creating Section F Shapefile from Survey Data

view the GIS lends itself to querying the study's data. If a particular transect is of interest, the basic information (length, angle, profile, name) can be viewed using the identify feature in ArcMAP (see Figure 19). This transect can also be selected using the selection feature. The attribute table can be opened and with transect selected can then be isolated from the rest of the data within the GIS. With this information, the rest of the data from the transect, or section, can be examined. The structured query language (SQL) feature of ArcGIS also has powerful applications for this GIS. Using this feature it is possible to examine all aspects of the survey

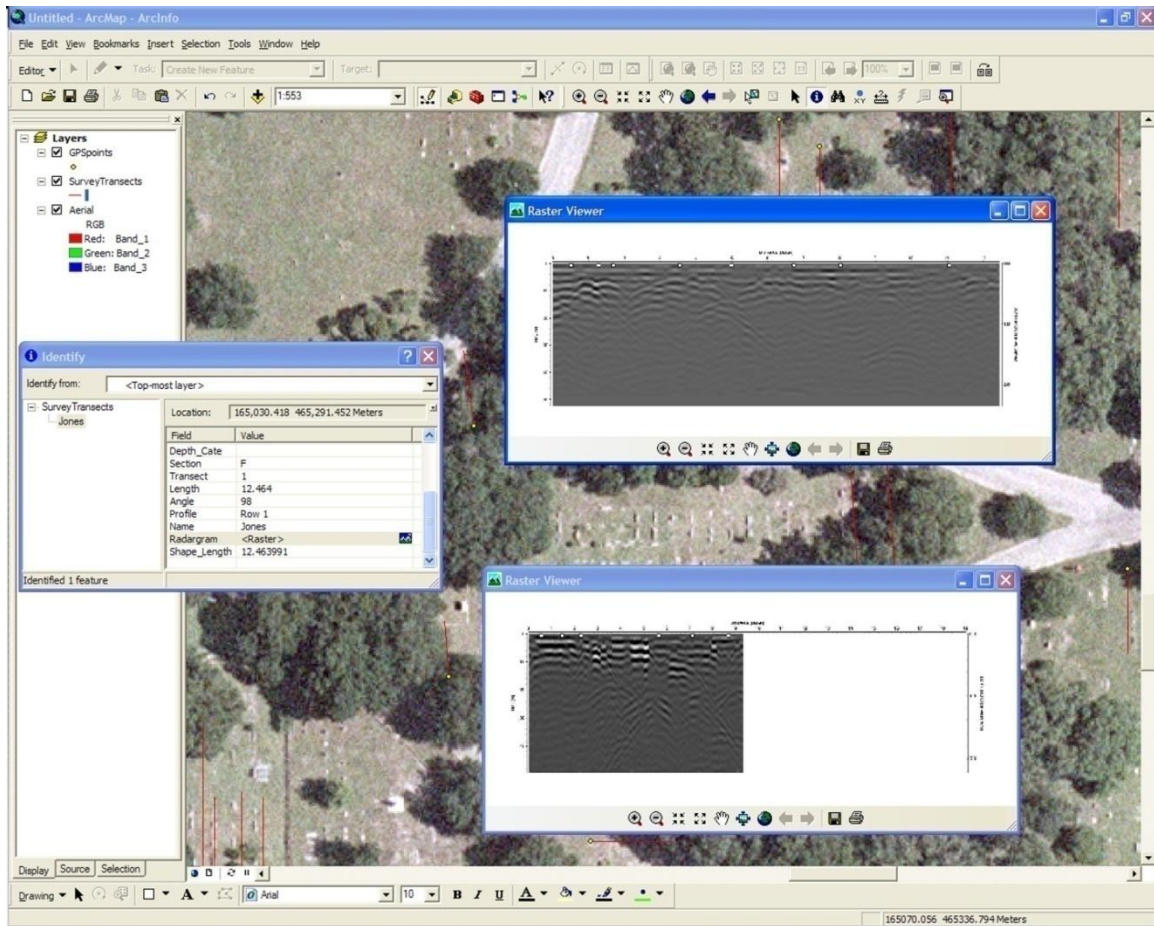


Figure 19: Viewing Transect Radargrams using the Identify Feature in ArcGIS.

data. For example, a user could see how many graves from the 1920's were surveyed, and find which section and transect those graves are located. From there, the user could examine the radargram of the transect of interest to see the hyperbola (or lack thereof) associated with the grave of interest (see figure 20). The attribute data within the master transect survey can also be easily accessed by interested parties to generate charts and statistical analysis of the data.

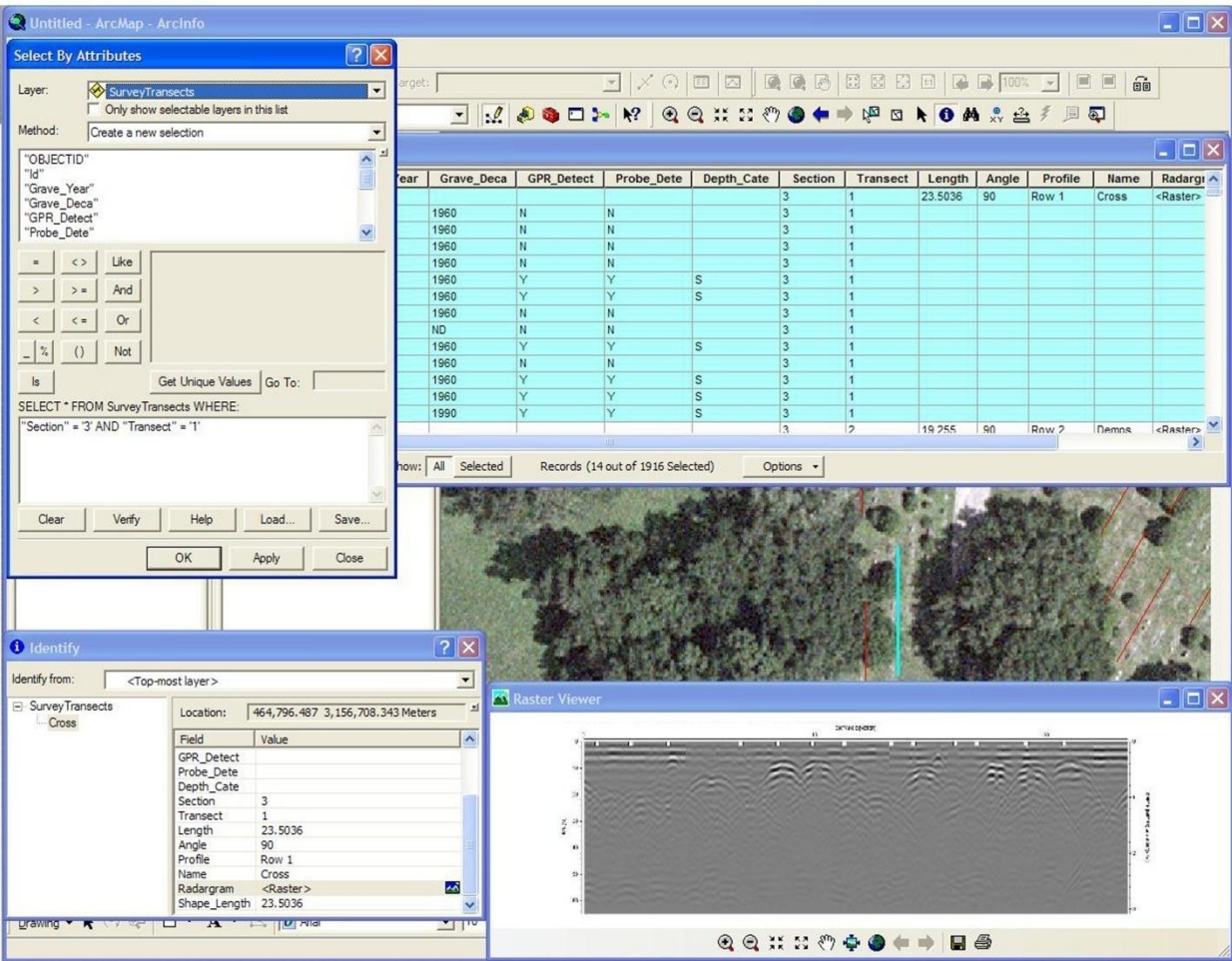


Figure 20: Attribute Querying and Viewing a Radargram from an Individual Transect

The data can be queried and displayed in unique ways. For example, by querying the uneven detection data field within the attribute data, all transects from the lettered sections, reporting graves detected by only the GPR and not the probe can be highlighted (see Figure 21). This data and the other data fields will enable future users to query and display the survey data for research purposes. It will also be possible for future users to expand on the data by adding to the sample size and existing data fields within the GIS to address various research questions.

This GIS also allows for the integration of this data with the existing data layers of the Greenwood GIS. It is possible to query the intersections of the lettered transects with the, for example, shapefiles for the spaces, lots, blocks, and sections shapefiles. While the original Greenwood GIS does contain a great deal of information regarding the cemetery, it does not have a shapefile representing each individual interment. This represents the limits of the querying ability between the Greenwood GIS and the GIS created for this project. What is possible is to isolate lots from the lots shapefile that individual transects intersect. This information can help to locate hard copy records of individual interments in the catalogue files available at Greenwood cemetery.

This combination also solves issues of storage and portability. The shapefiles for this survey are under 11 MB in size. The existing Greenwood GIS is around 70 MB, and the aerial of Greenwood used for this project is around 36 MB. The radargrams from this survey are around 39MB. However, with the combination of these shapefiles within the geodatabase with the addition of the radargrams has dramatically increased the memory size to 1.06GB. Still, this GIS can be easily stored on a USB drive (see Table 2). While this is not an unsubstancial size of memory, it is possible to carry all relevant files for this project on a jump without being a large drain on memory space (the storage space will be even less if the files are compressed). This also means the data can be transferred rapidly from one party to another. Finally, this project can be accessed as quickly as the files are connected to a GIS platform and can potentially be networked between multiple users through the internet.

This study demonstrates the potential for cemetery research to be integrated within a GIS. While the project was made easier with the existence of an existing GIS, the creation of this GIS

Table 2: Associated Files of Survey GIS

File(s)	Number of Files	Function	Storage Requirements
Aerial image	1	Aerial Map of Greenwood	36MB
Transect, GPS, and buffer master files	4	Master files created from the Survey	1.73
Radargrams	178	GPR radargrams from survey	39MB
Radargrams	1	Database containing the all survey transect shapefiles, master buffer shapefiles, and radargrams	1.06GB

could have been accomplished with an aerial base map. Current GPR processing software allows time-slice maps to be converted into shapefiles with defined coordinate systems that can be projected (Goodman 2009). This, along with the methodology employed with this research, offer benefits for the management of cemeteries. With the right environment, a cemetery can be surveyed using a GPR, processed, and then projected and stored on a digital platform. This can help cemeteries identify unused portions of land, locate unmarked graves, and help to design a management plan for future land use. However, the integration of the survey into a GIS is limited by the spatial accuracy of the technologies used. Examining the sources of error of this study and how they are addressed should help others to be aware of potential downfalls.

Sources of Error

While using advanced spatial technology does improve accuracy, it does not eliminate all error present. It is important to recognize where error can and does occur and to also be aware how it might impact the intended work. There are two sources of error that need to be addressed for this project: the GPS data collection and the use of a magnetic compass to sight the angle of

the transects. Addressing this error will help to ensure that an interested party in the future will be able to resurvey a transect (or more, if they are inclined) without the use of headstones (which may or may not be present in the near future) and will be aware of the error involved in this project.

Since the Trimble Company released this GPS unit there have been several research projects to test the accuracy of this unit with the WAAS correction active. In a white paper by the Trimble Company (2004), the GeoXT unit was tested against the GPS Pathfinder Pro XRS unit in various locations in North America. Both units were allowed to collect data for eight hours on four separate days. The GeoXT unit was found to be less accurate than the other unit. The best performance for the GeoXT was a horizontal root mean square (HRMS) of 44cm (reported from South Carolina); the worst reported HRMS was 59cm (reported from Ontario, Canada). While this output by of the GeoXT unit from this study is indeed low, the eight hour window for data collection is not directly relatable to the GPS data collection strategy for this project. In a study of five mapping grade GPS units in western Oregon (one of which was the Trimble GeoXT unit with WAAS correction active), data were collected at one second intervals for varying durations in three different settings: open sky, young forest, and closed canopy forest (Wing et al. 2008). The results of this study show the average error of the Trimble unit with thirty readings taken was averaged to be 80cm. The young forest setting had slightly better average error reported at 70cm. As the data collection procedure for the project was similar to this study the average error of 80cm for each waypoint was adopted for this study (Figures 22 and 23).

To address this error, a buffer shapefile was created for the GPS points shapefiles. The buffer radius was set to 80cm around the shapefiles. This error is also relevant to the transects of this project as they are drawn from the center of the GPS points. Buffer shapefiles with a radius of 80cm were created for the survey transects shapefile. The combination of the two buffer shapefiles provides a uniform representation of reported error of this type of GPS unit and how this error translates to the presentation of the shapefiles used to represent the survey transects.

A magnetic compass was used to sight the angle of the survey transects. Magnetic compasses are not complicated to use or expensive, and are often used for archaeological survey (Banning 2002). However, it should be noted that simple magnetic compasses do have the most error out of all survey instruments and are only recommended for use when only rough estimations of direction are needed (Bouchard and Moffitt 1968). The issue of error when navigating with a magnetic compass has not been addressed in archaeological research. Banning (2002:198) recommends sighting a landmark on a survey transect and using that as a reference instead of repeatedly referring to a compass for a bearing, but does not include in-depth discussion of error involved with surveying with a compass.

The effectiveness of electronic versus handheld magnetic compasses has been assessed as it relates to radio telemetry (Lovallo et al., 1994). In this study, targets were placed at a distance between .5-1.6km. Measurements were assessed for accuracy and the speed in which the bearing was taken. The mean error for readings taken during the daytime a mirror sighting compass was calculated to be 1.29 degrees. This amount of error is not insignificant for this study. The largest transect of this study is from section nine. This transect is approximately 39.5 meters in length and has a bearing of 60 degrees. When another transect is started from the center of the same

GPS point and given the same length and a bearing of 57.1 degrees, the resulting transect is noticeably different in direction from the original. The resulting transect ends outside the buffer created for the transects (see Figure 24).



Figure 21: The red lines represent transects with graves that were detected by GPR but not by probe from only the Lettered Sections.

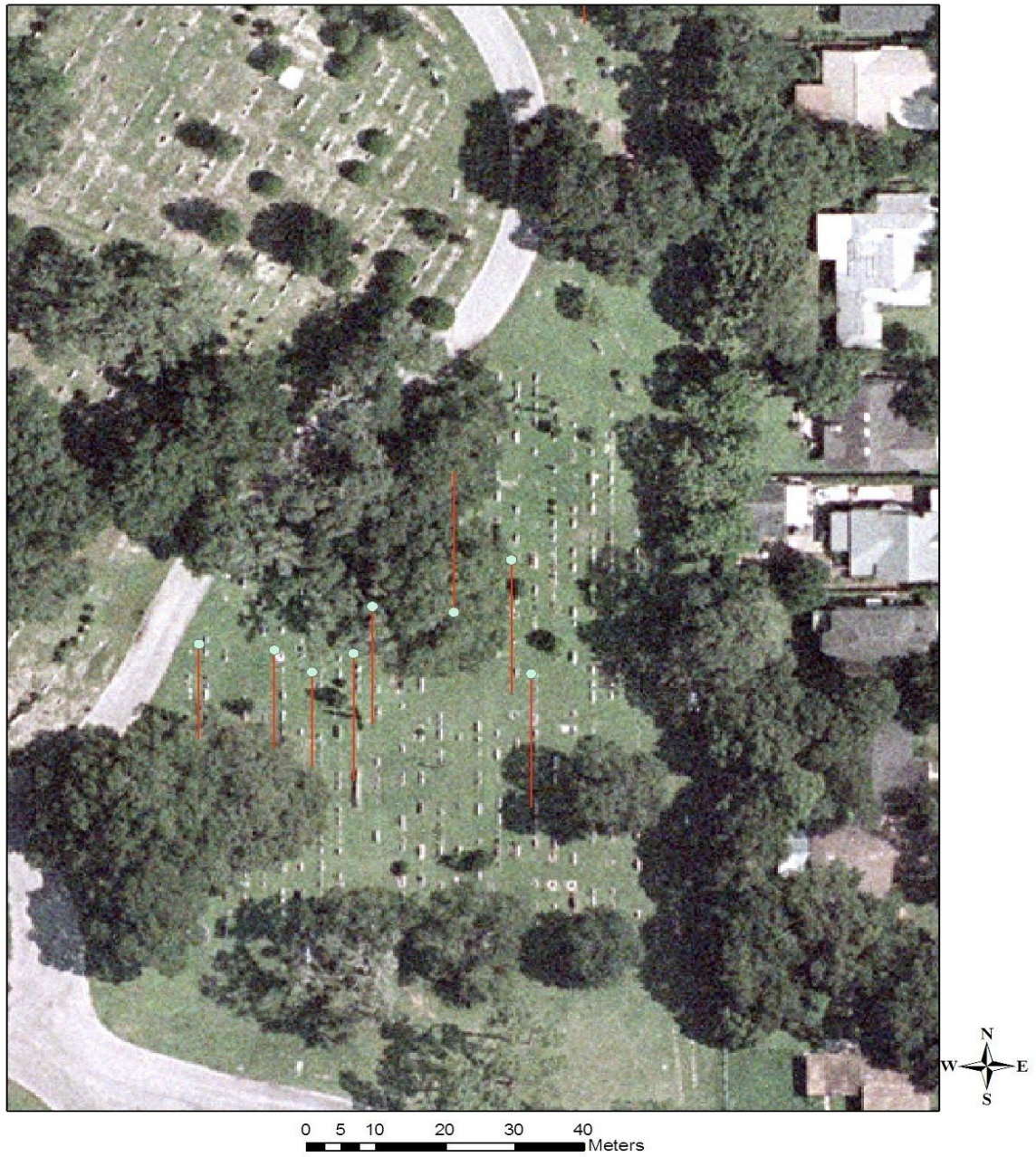


Figure 22: Section 8 Transect with Buffers around GPS Points.

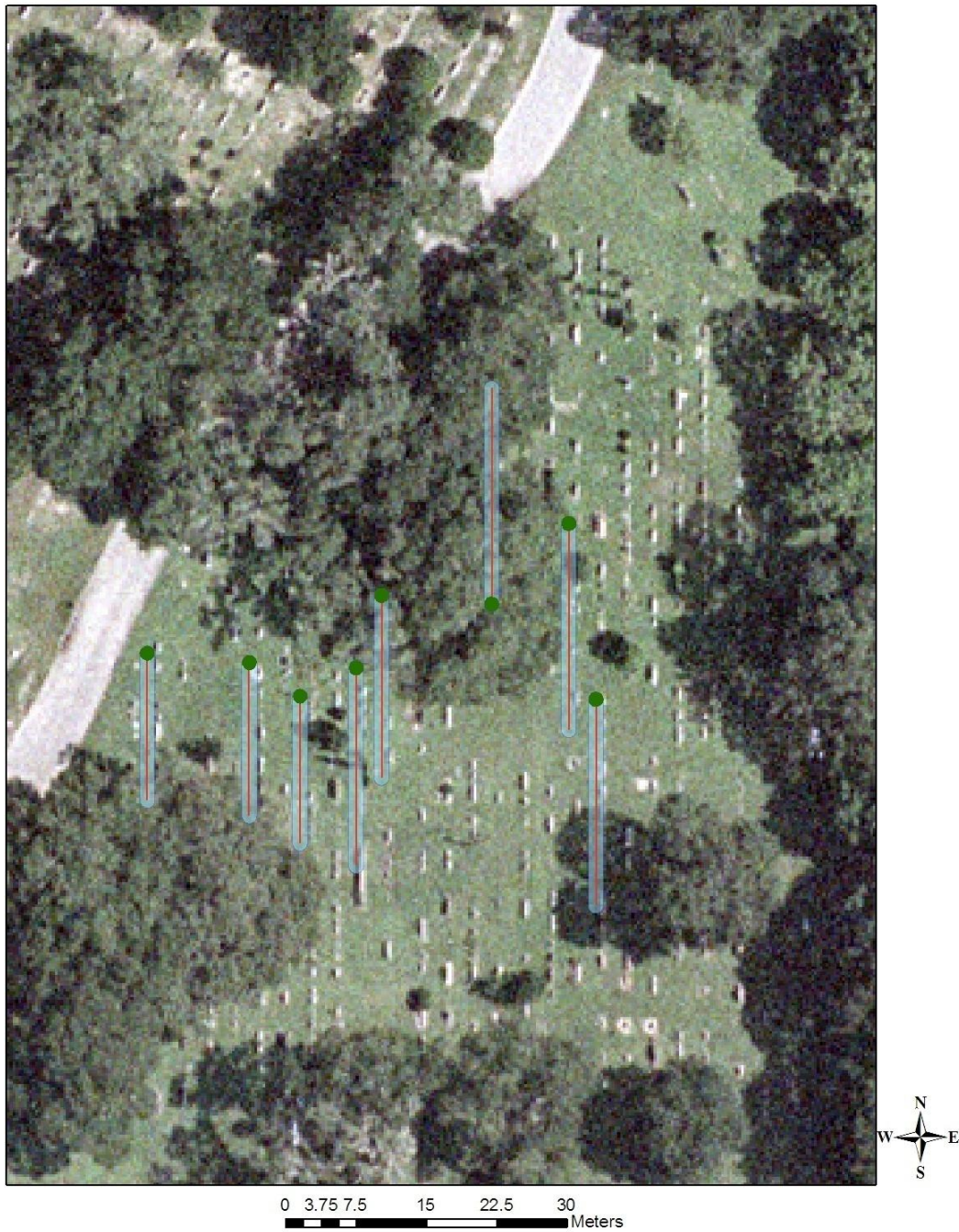


Figure 23: Buffers (80cm in Diameter) added to the GPS points and Transects in Section 8.

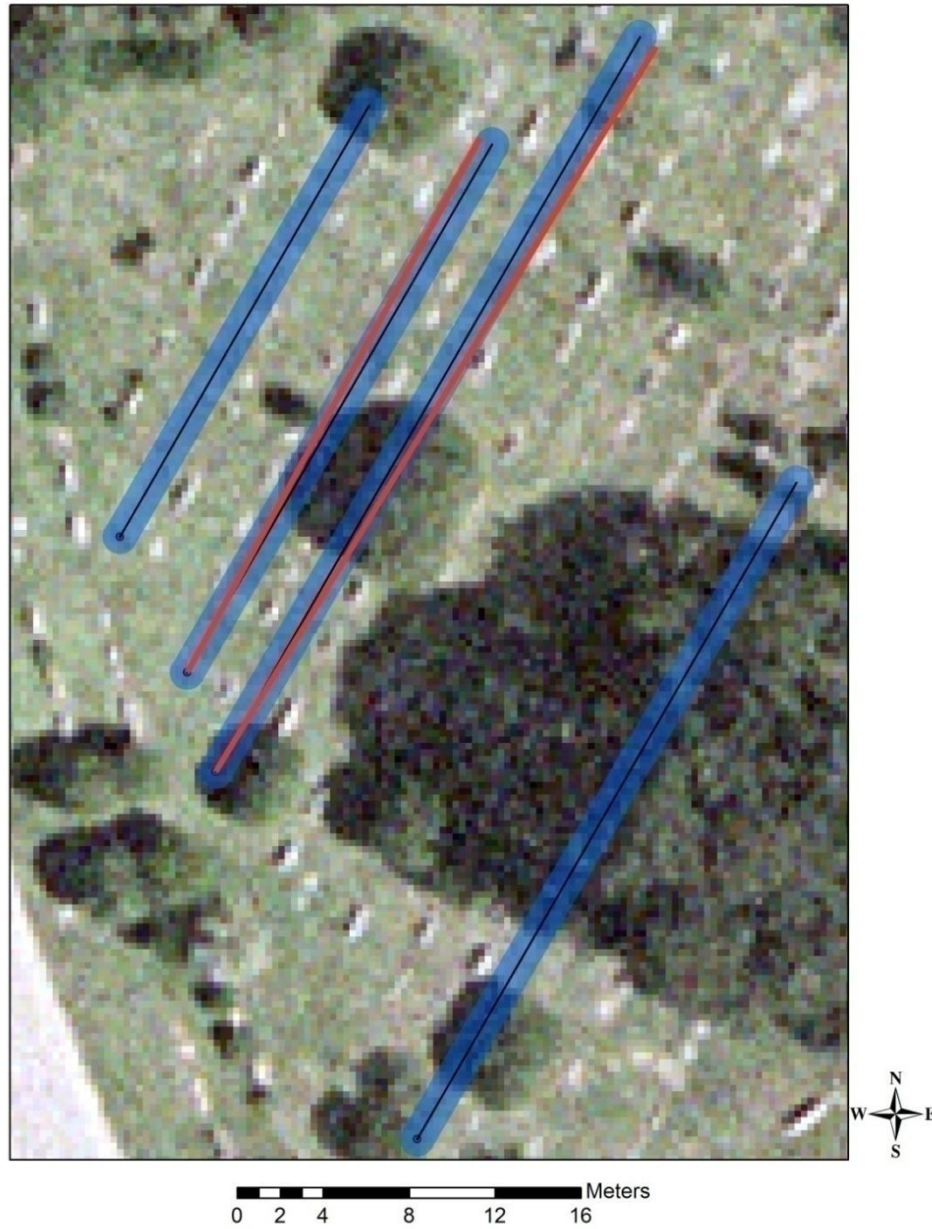


Figure 24: Potential Error Reported from Lovallo et al. (1994) Applied to the Longest Transect of the Survey (37.5m). The Same Error Applied to the Preceding has the Transect within the Buffer for GPS Error

The new transect with reported error is indeed outside the transect buffer shapefile, but by less than 10cm. The transect to the left of the longest transect is around 11 meters less in length (refer back to Figure 23). When another transect is generated with the same length but a bearing with the mean error of the telemetry study added, the resulting transect is within the buffer of the transect. When taken in total, this error is significant to this study, especially for the longer transects. However, it is important to keep in mind the differences of scale between the study and this project. In their study, Lovallo and colleagues (1994) designed their study in which the closest target was over ten times the distance of the longest transect for this project. Given the differences of scale, it is not unreasonable to assume that the error for these transects would be less than that reported from the telemetry study. As such, the error of navigating with the compass will be assumed to be within the buffer established for all survey transects. With further research it might be possible to assess the error involved using the compass with this project.

Conclusion

The results of the geophysical survey produced interesting data and its own set of challenges. Fortunately, the integration of the geophysical data into a GIS has resolved issues of data integration, management, and display. All spatial data has been given a single projection and all data generated from the survey has been entered into the GIS. It is possible to examine a radargram from one transect, section and the entire survey. With the data entered into the attribute fields any user can examine the age range of graves from a surveyed section, or the distribution of surveyed graves from a particular decade. The integration has also been important for addressing sources of error with the project. The recognition of this error should help future

archaeological endeavors not aware of similar issues and to help to take steps to minimize error.

While a GIS is not the only platform in which geophysical survey data can be integrated, it does offer great potential for storage, management, analysis, and dissemination, and merits other researchers conducting geophysical surveys taking the step of incorporating their data into a GIS.

CHAPTER FOUR: CONCLUSIONS

Recent advances in remote sensing technologies and their integration into digital platforms have proven quite advantageous to archaeological research. This study demonstrated the potential for systematic study of rates of grave detection rates across a range of grave ages using ground penetrating radar (GPR) and the utility of integrating all components of the survey into a geographic information system (GIS) platform. While this research focused on a well defined environment, the methodology of the survey and the integrative methods applied can be directly applied to future archaeological research.

The second chapter covers the geophysical survey of Greenwood cemetery. This chapter gives detailed field methodology that will allow future research to replicate this study along with the results of the survey. The results show that there is a direct increase in the detection rates of more recent interments using a GPR in more recent, compared to older interments. The study showed a large increase of grave detection beginning in the 1960's, which can be tied to a regulation started at Greenwood requiring that all interments be placed in a vault (thus increasing preservation). The graves associated with the 1970's decade had the best detection rates (81.9 percent with the GPR). This study also demonstrated the applicability of using a probe as a minimally invasive method to confirm geophysical data. At no time during the course of the research did the probe detect a grave that was not also detected by the GPR. Beginning with the 1960's and continuing to the most recent grave surveyed, a total of six graves were detected with the GPR that were not detected by with the probe. Finally, the study examined the correlation between the depth of an interment and the age of the grave. The results showed that while burials

that were classified as deep were more likely to be older in age, this correlation between age of grave and depth of burial was very tenuous.

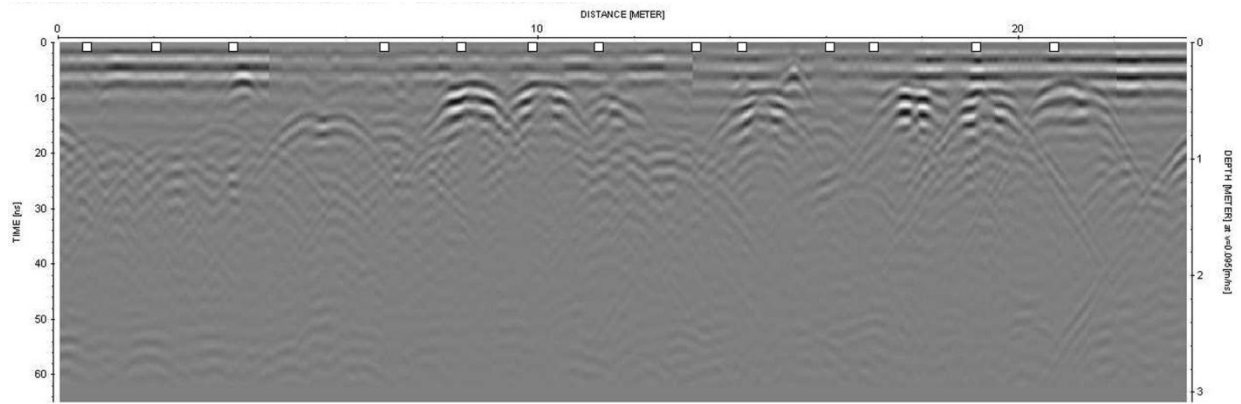
The third chapter presented the methodology for integrating all components of the geophysical survey into a GIS platform. This involved combining geophysical, survey distance, compass bearings, global position system (GPS) waypoints, and spreadsheet data into one database. The resulted in a platform where all radargrams can be viewed, the range of interments for a survey section can be queried, and the transects of the entire survey can be observed at the speed of the operating system. The GIS is unique to the needs of the project, but do demonstrate the benefits of integrating archaeogeophysical data into a GIS. Using a digital platform can help to address issue of data management and storage, accurate spatial projection, and efficient access to a projects data.

The application of geophysical methods to archaeology and forensics and integration of the data into a digital platform have produced interesting results and offer great potential for future work. The use of geophysical methods has the potential to obtain samples of archaeological sites in a manner that is non-invasive and requires minimal labor. This data can identify anomalies, show areas of interest, and to also clear areas within a site. Further, integrating this data into a GIS can facilitate the analysis and management of the data. This research has demonstrated the potential for systematic sampling of a cemetery using geophysical methods and the utility of integrating the data into a GIS, as well as demonstrating that archaeological investigations conducted within cemeteries can provide a wealth of knowledge while also being non-destructive manner.

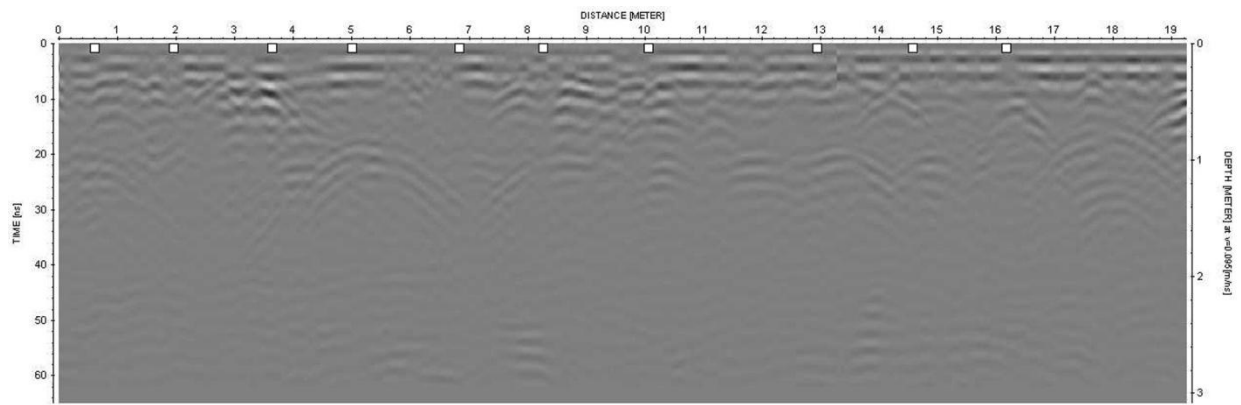
APPENDIX-RADARGRAMS

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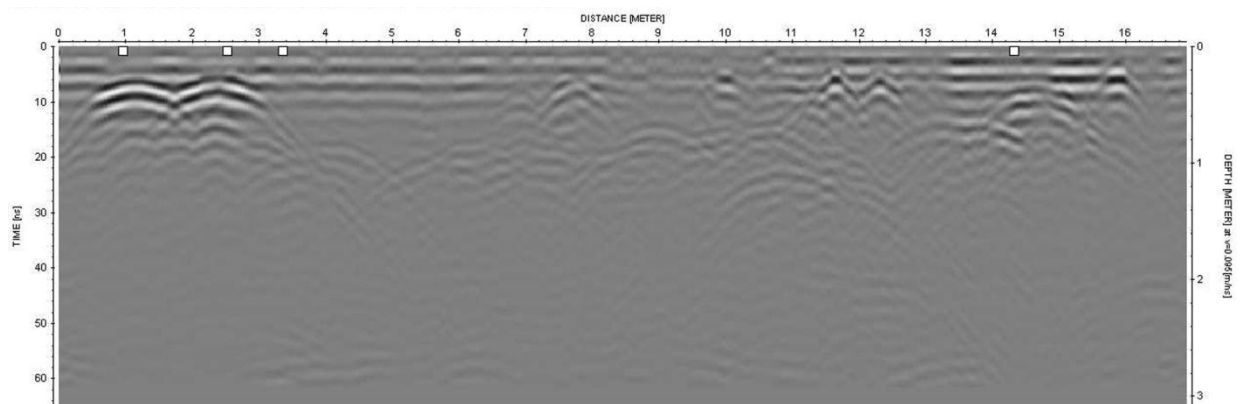
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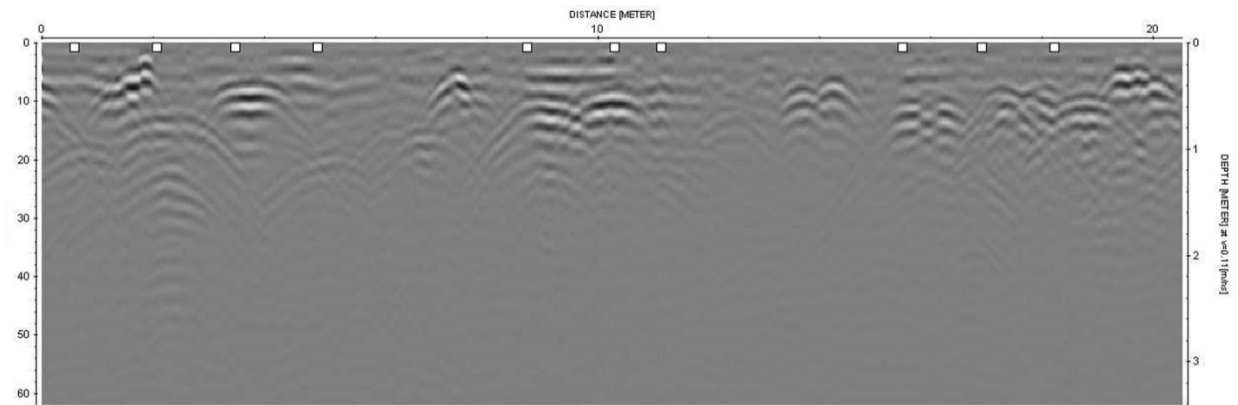


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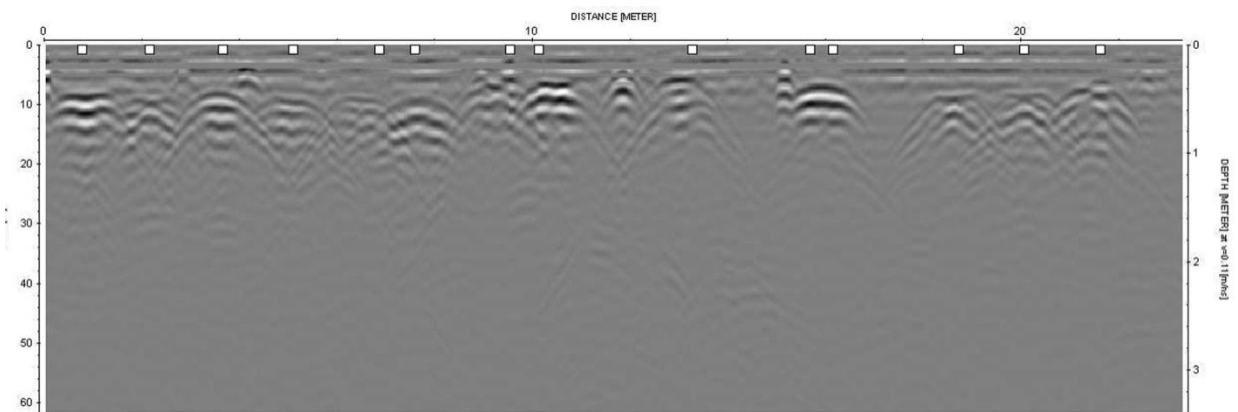


Section 4

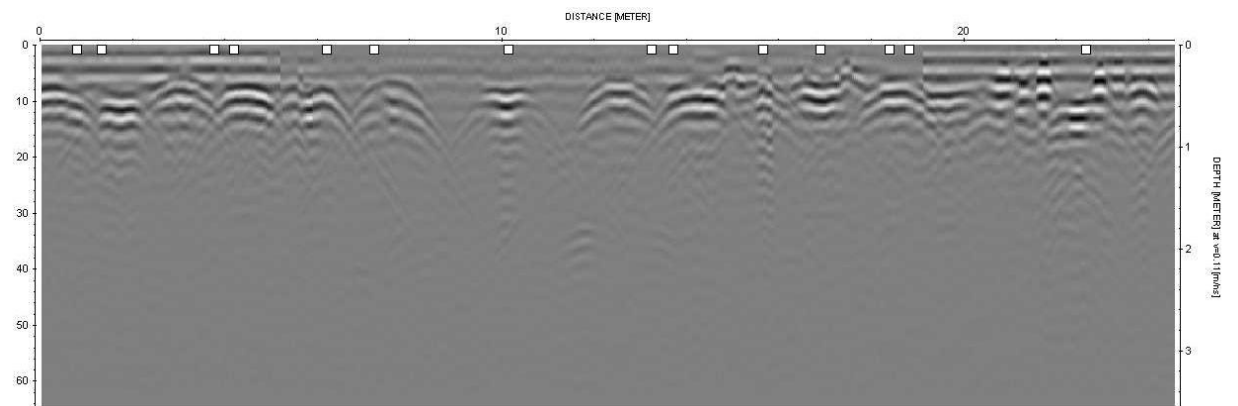
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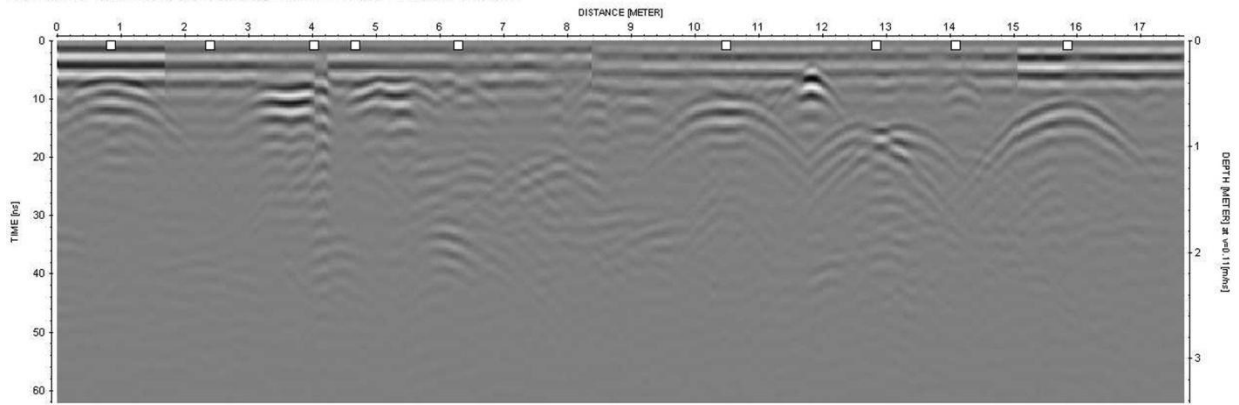
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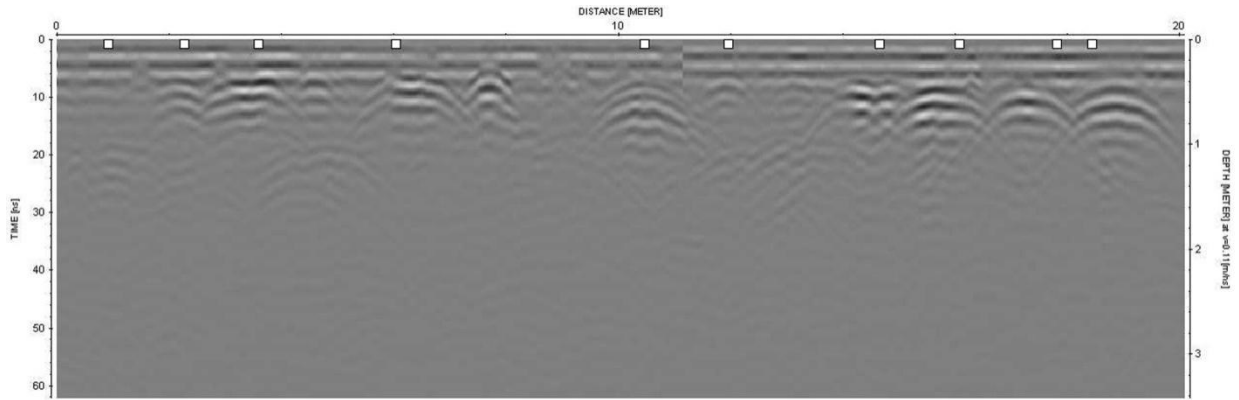
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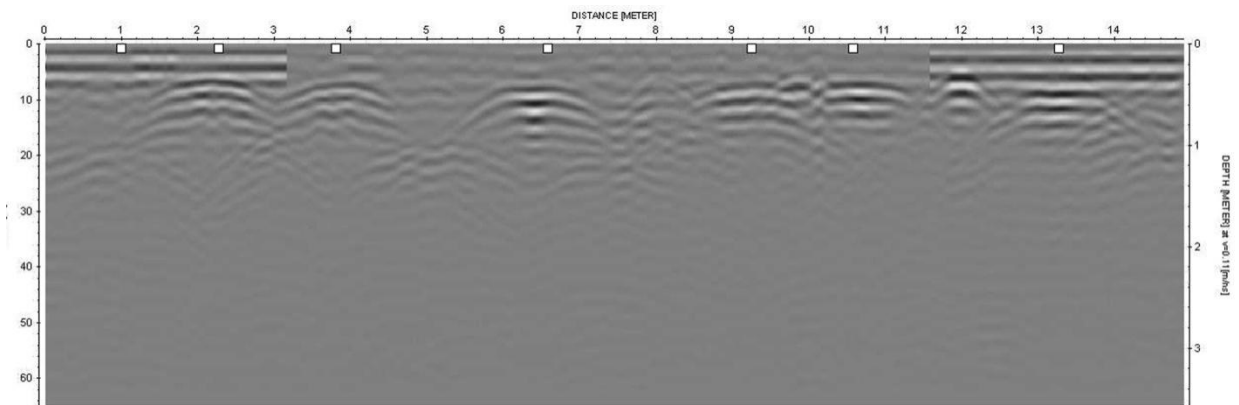
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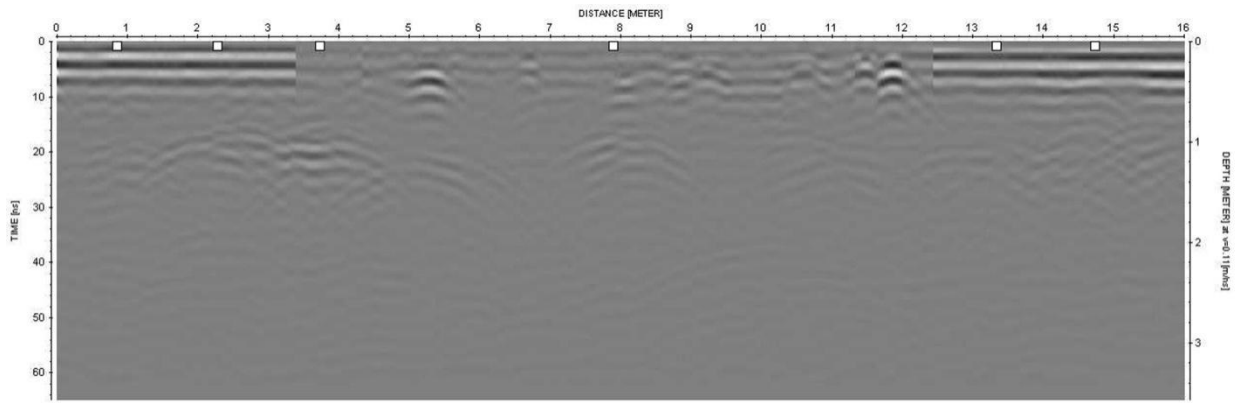
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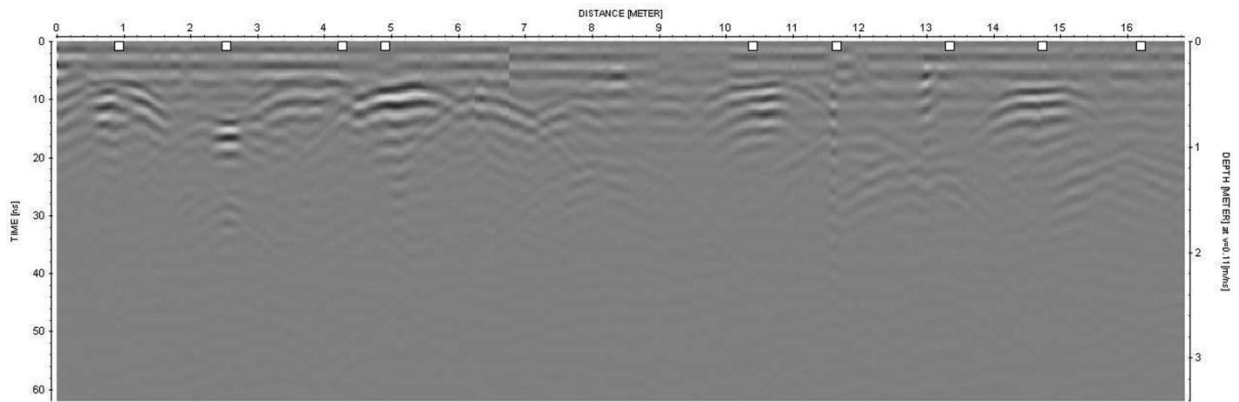
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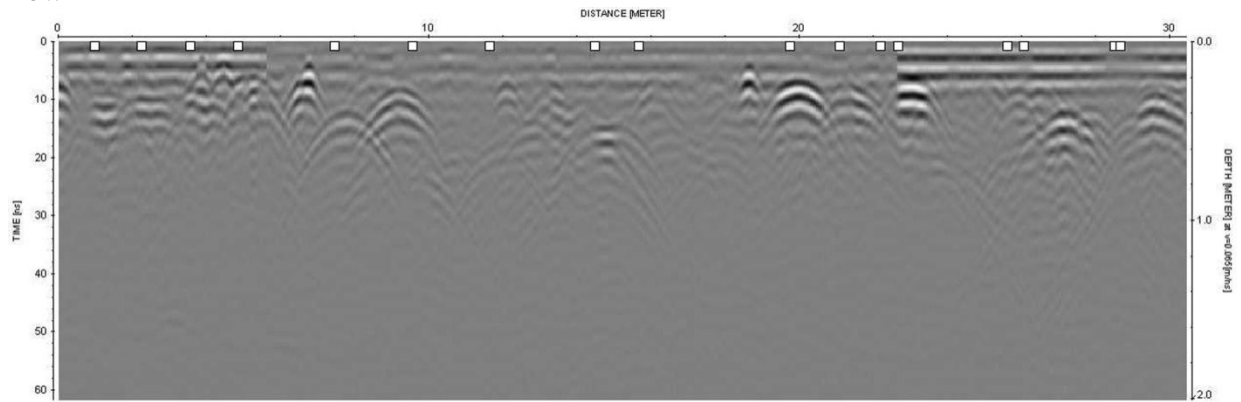


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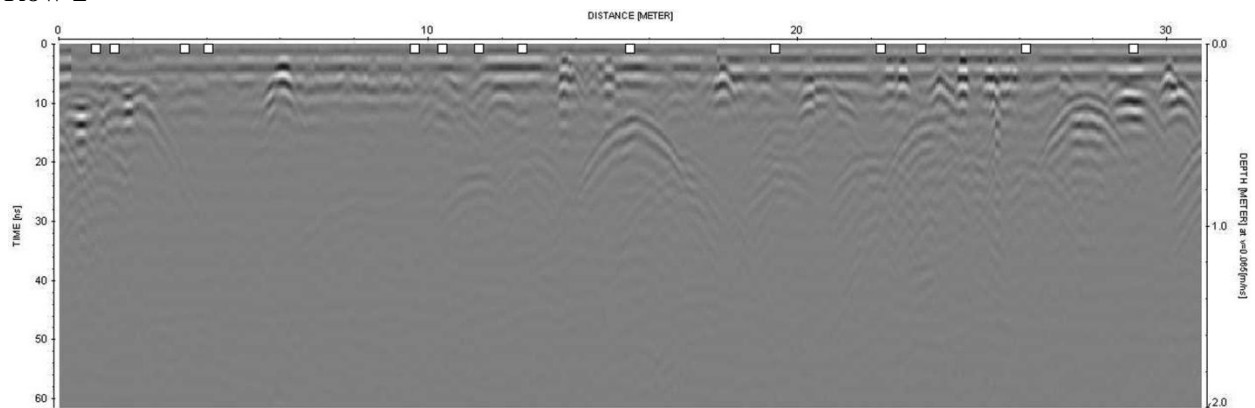


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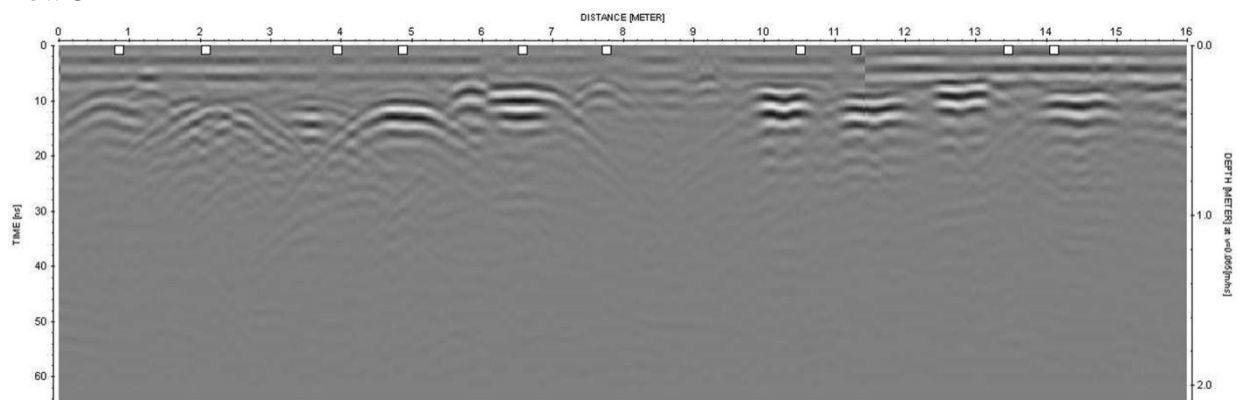
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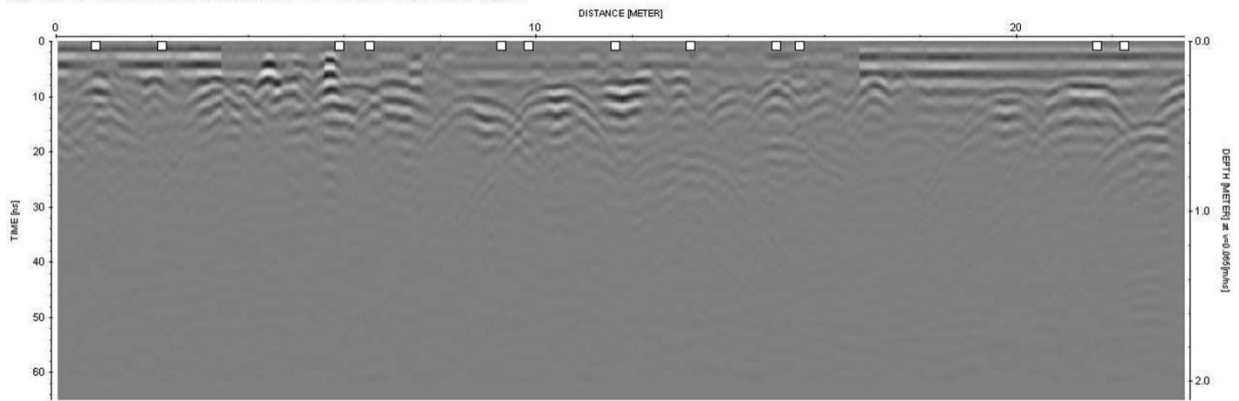
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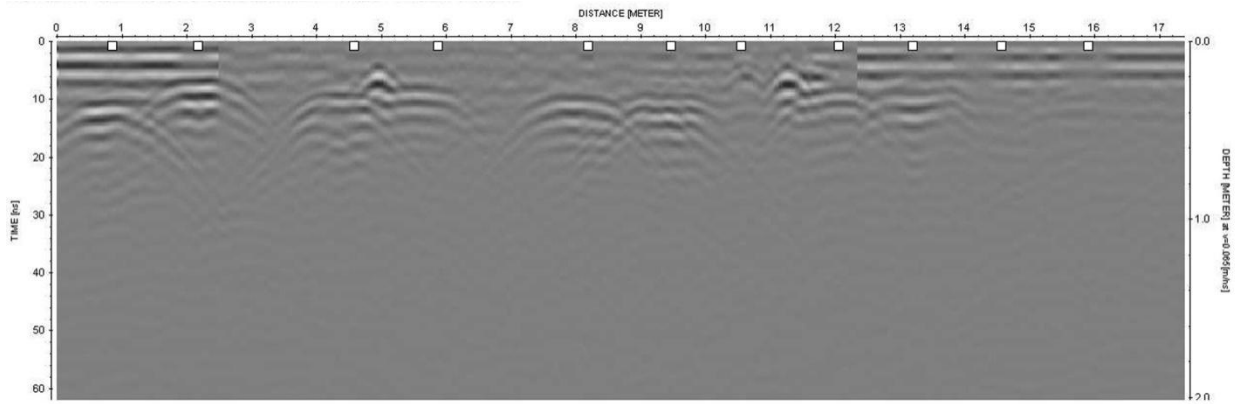
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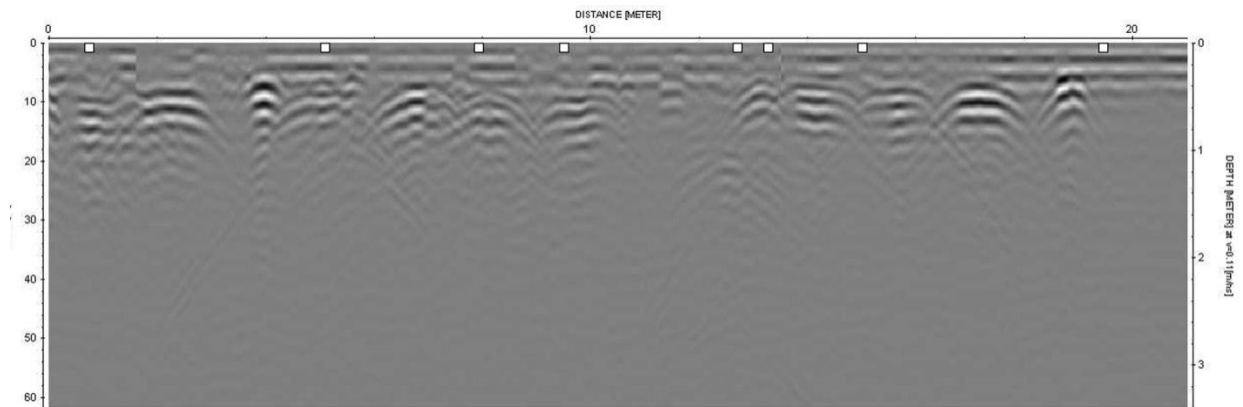


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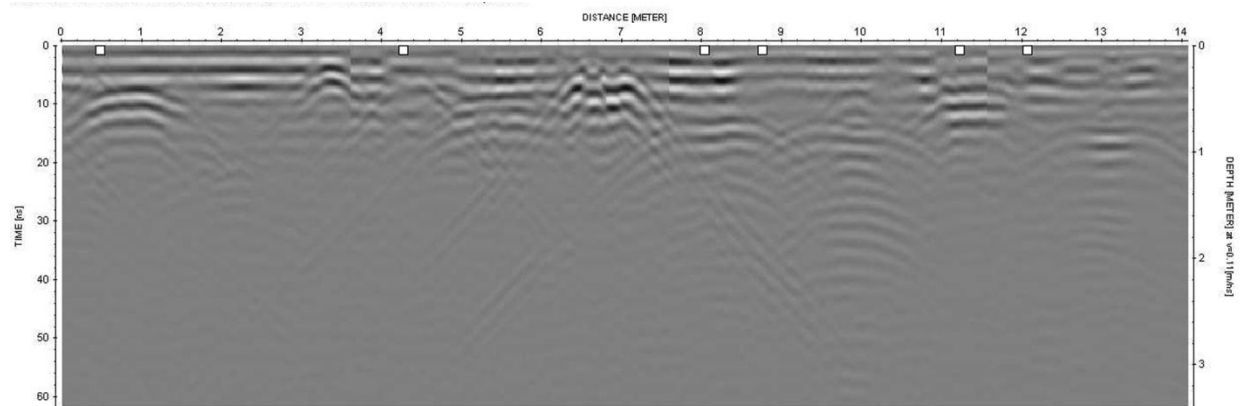


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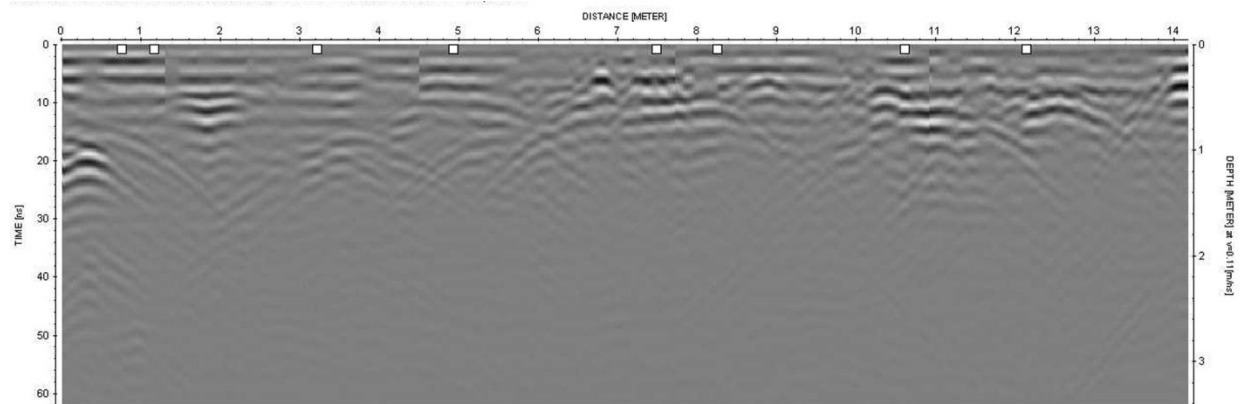
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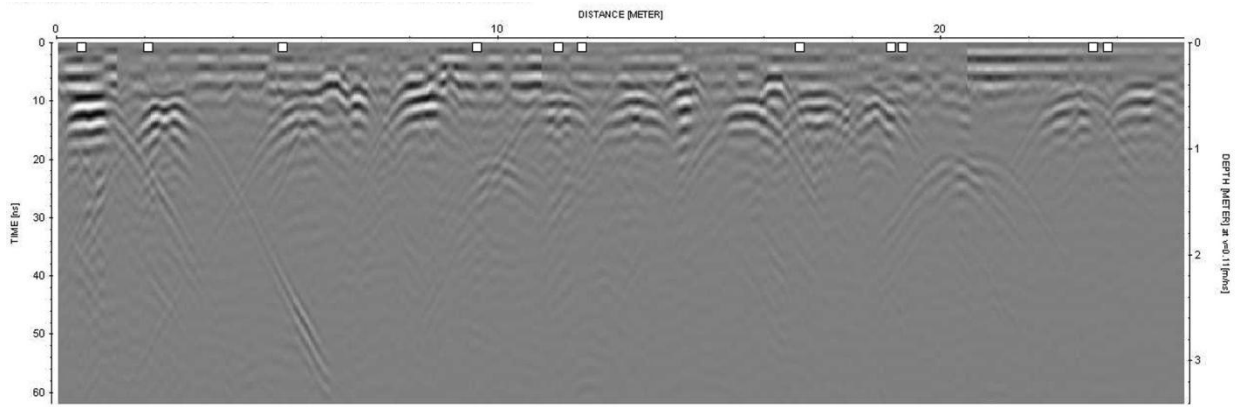
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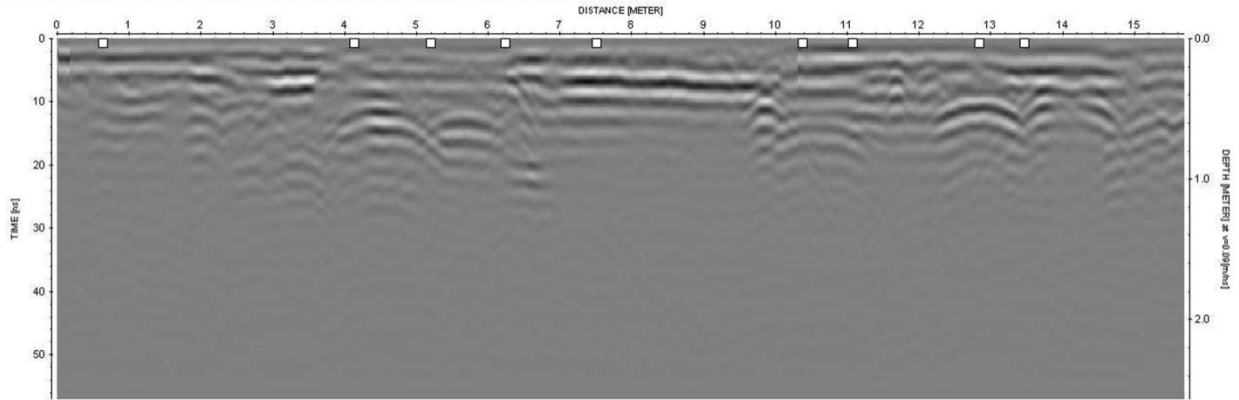


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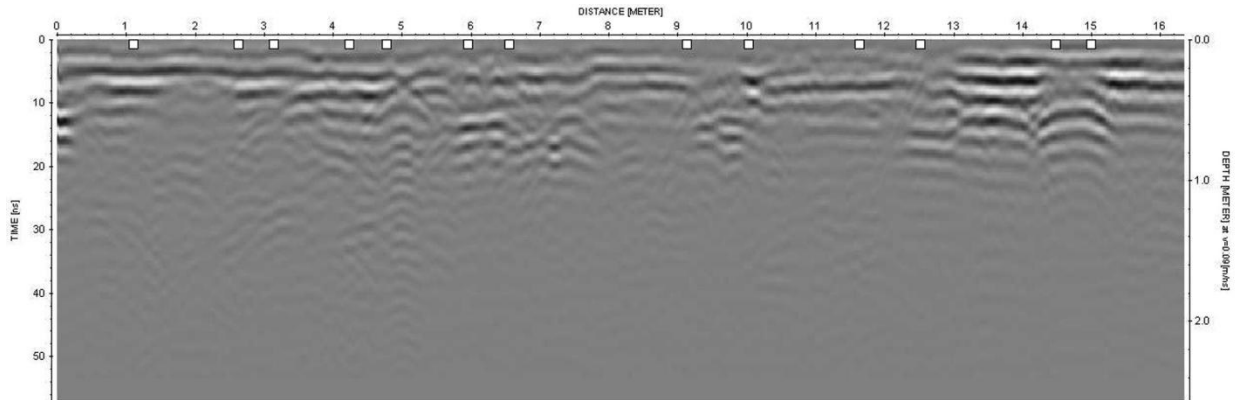


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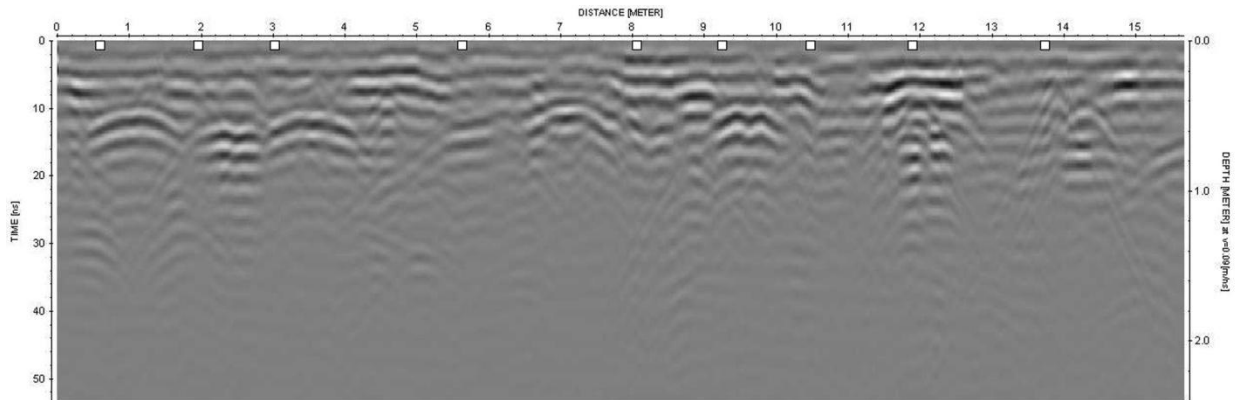
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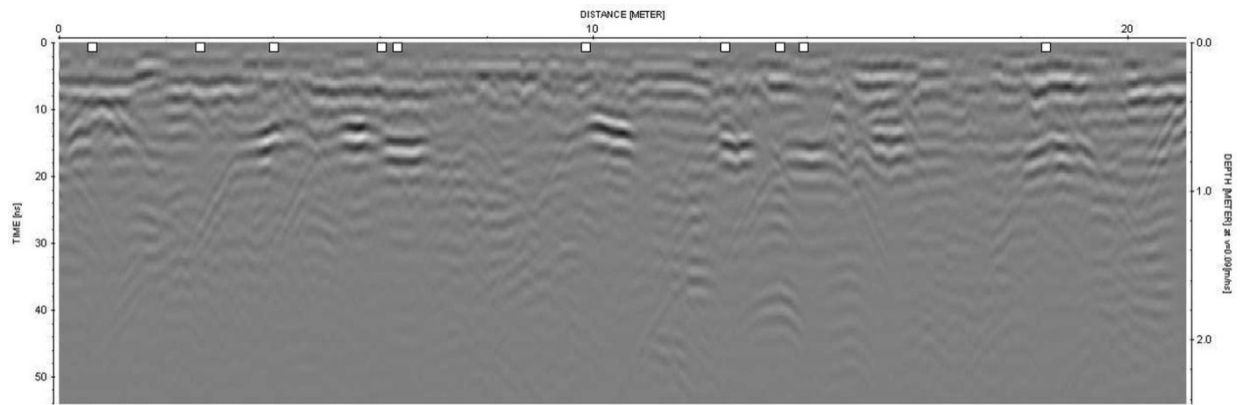
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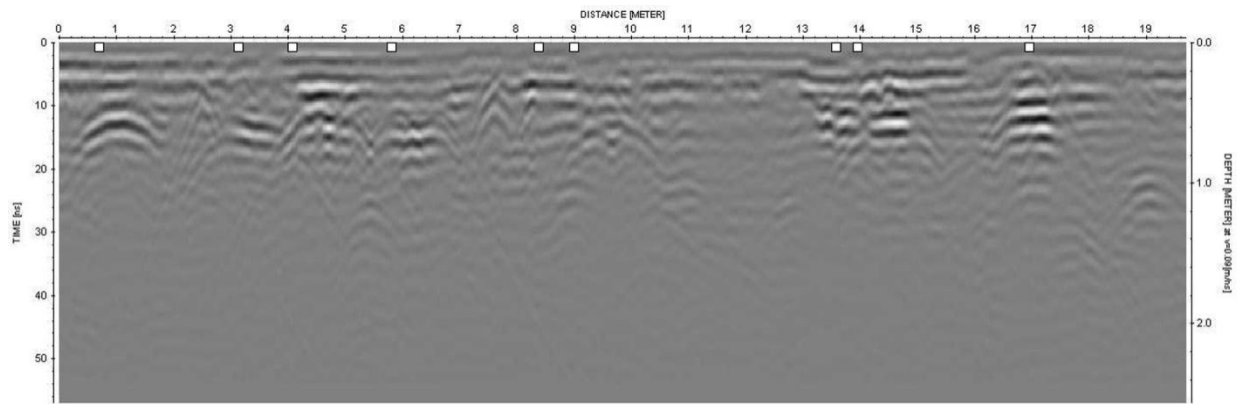
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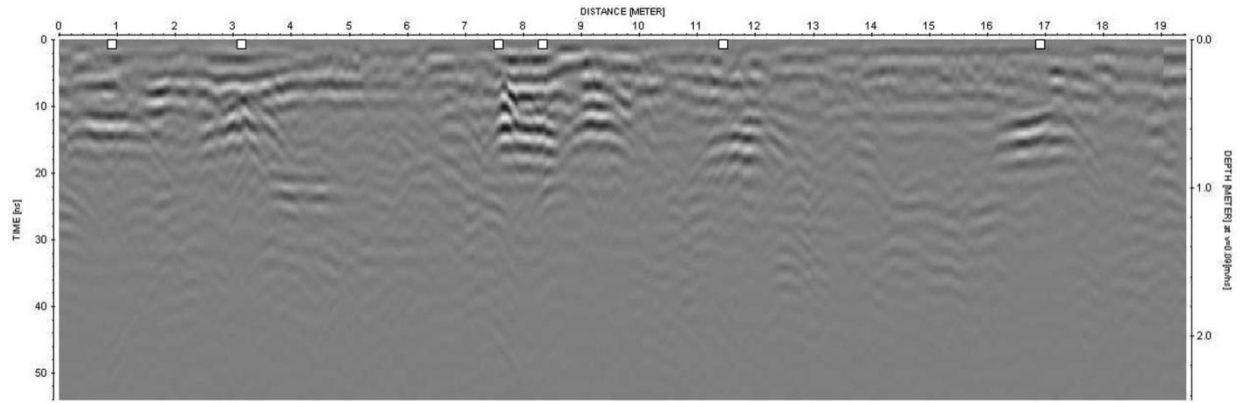
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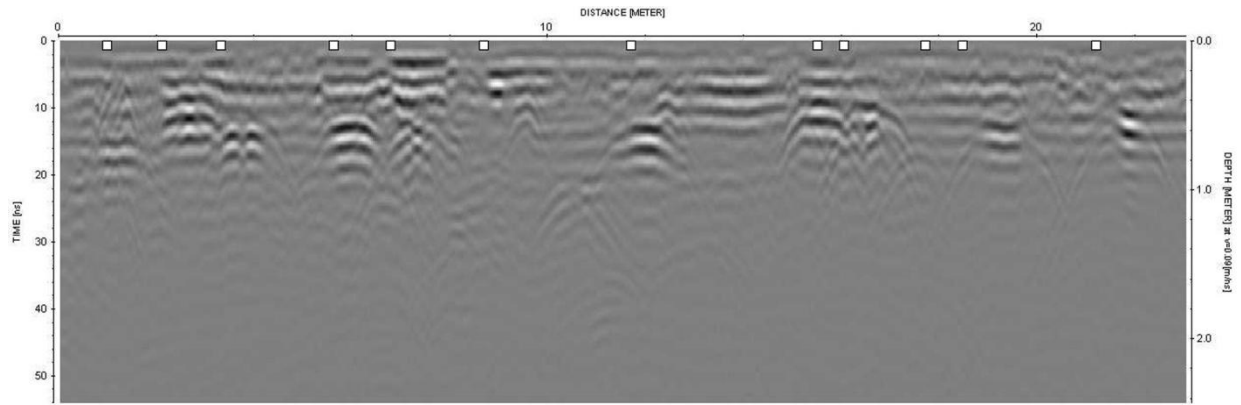
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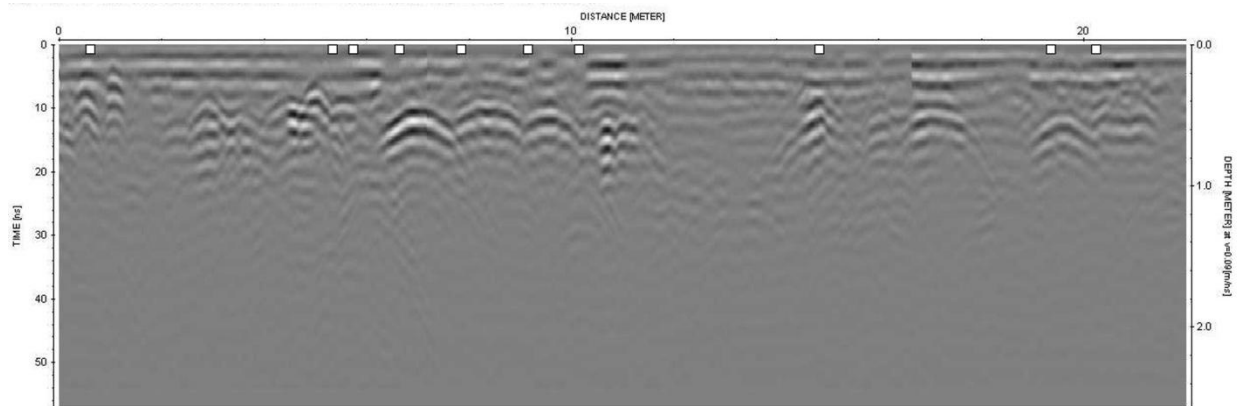
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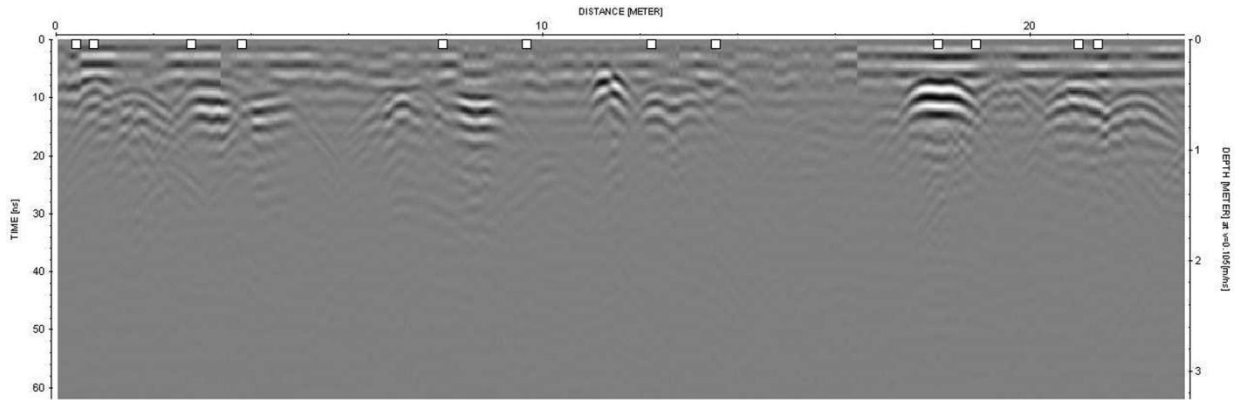


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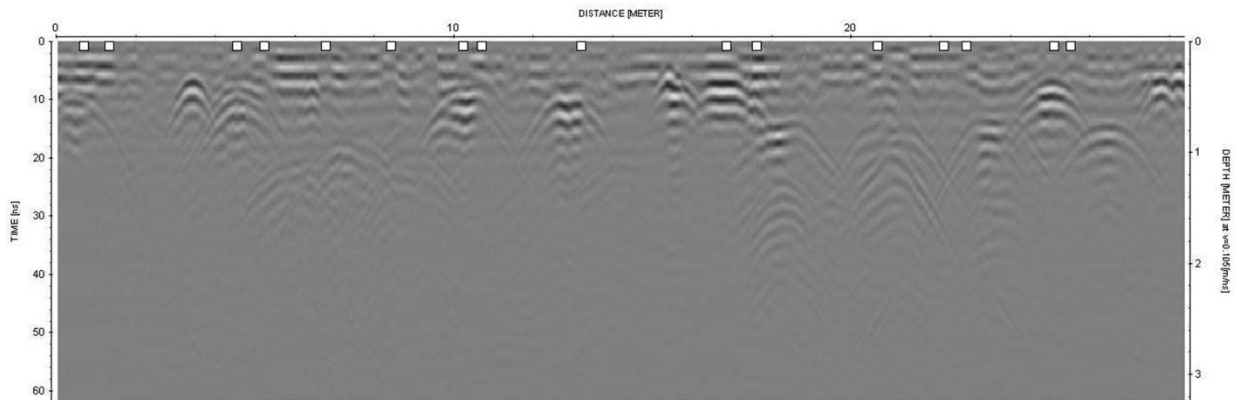


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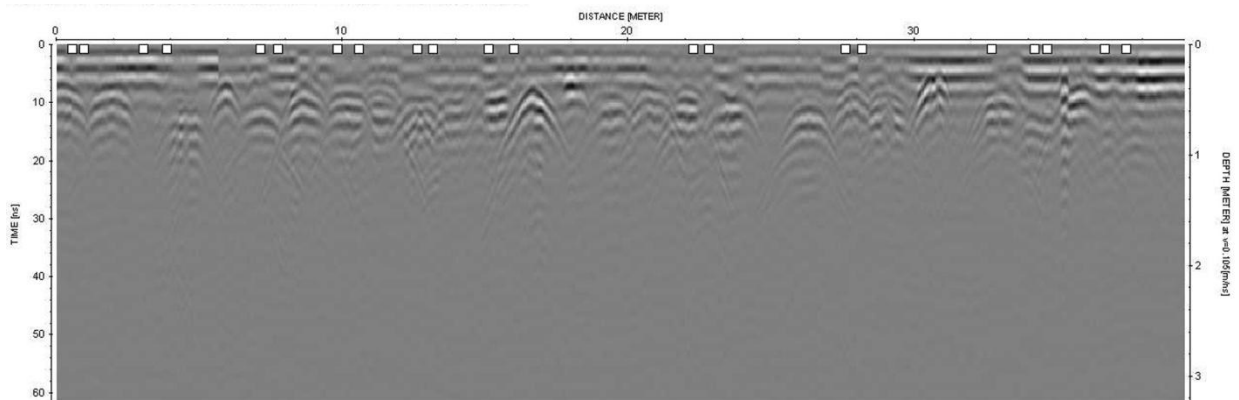
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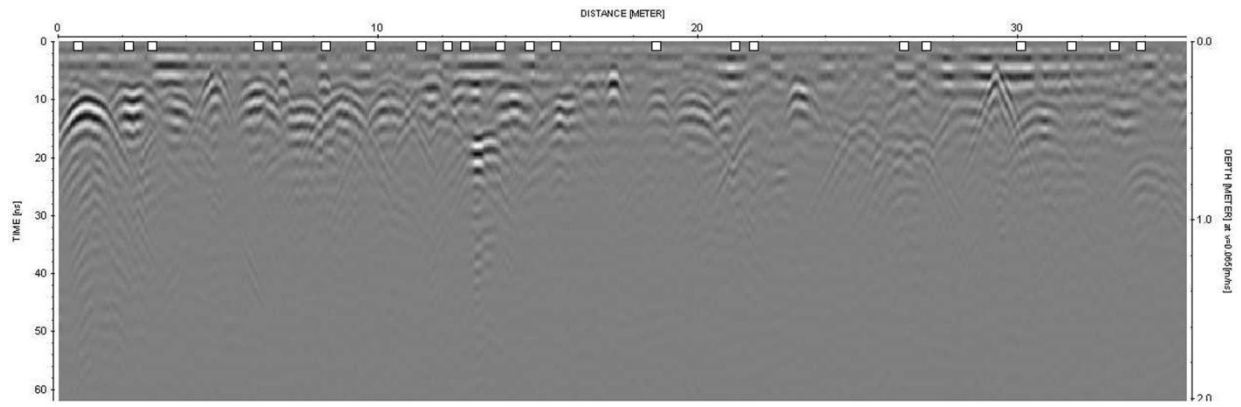
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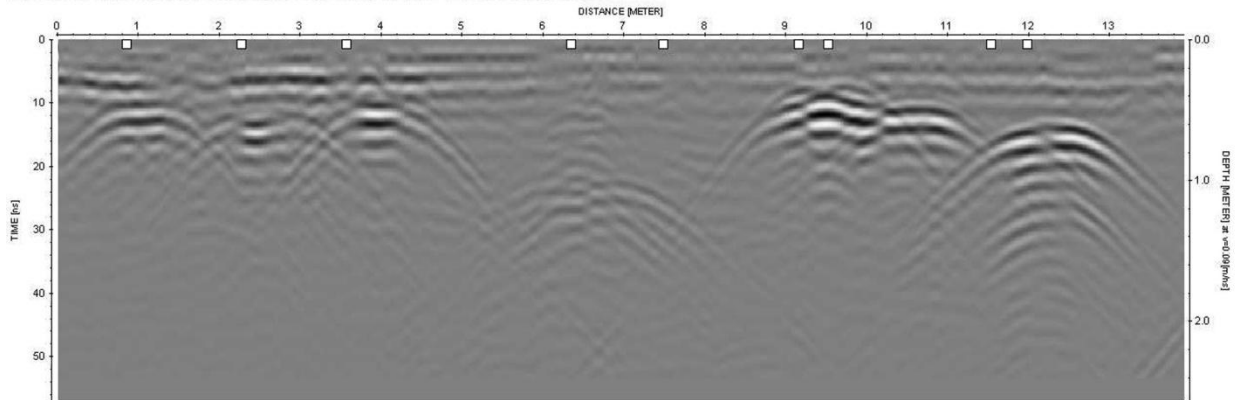


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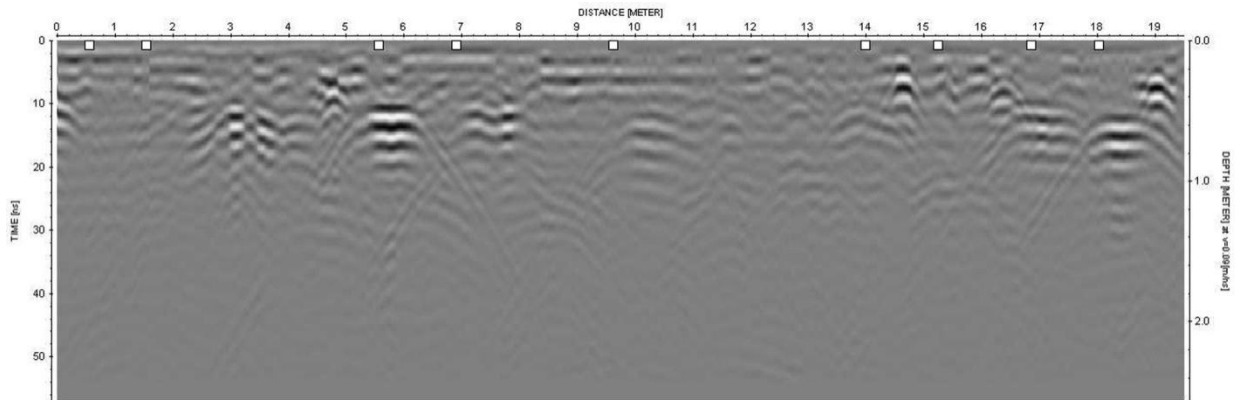


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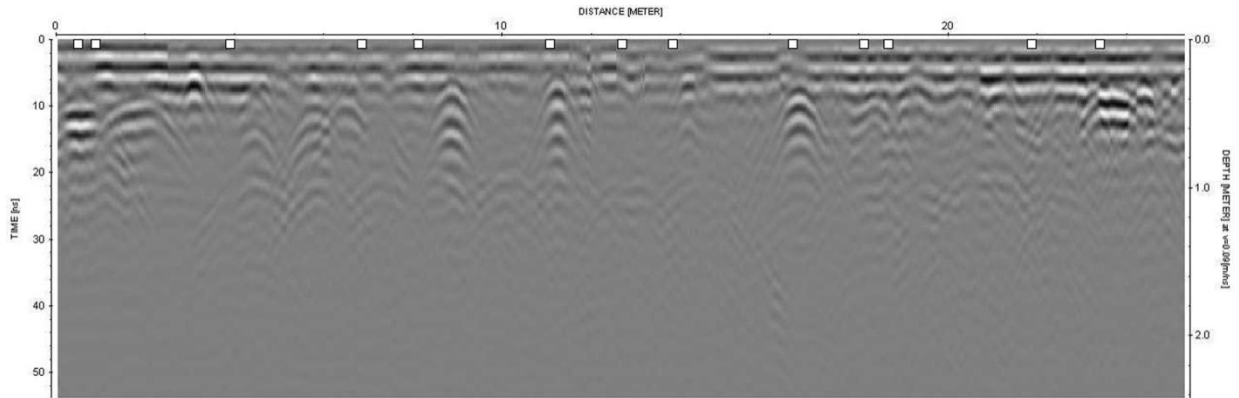
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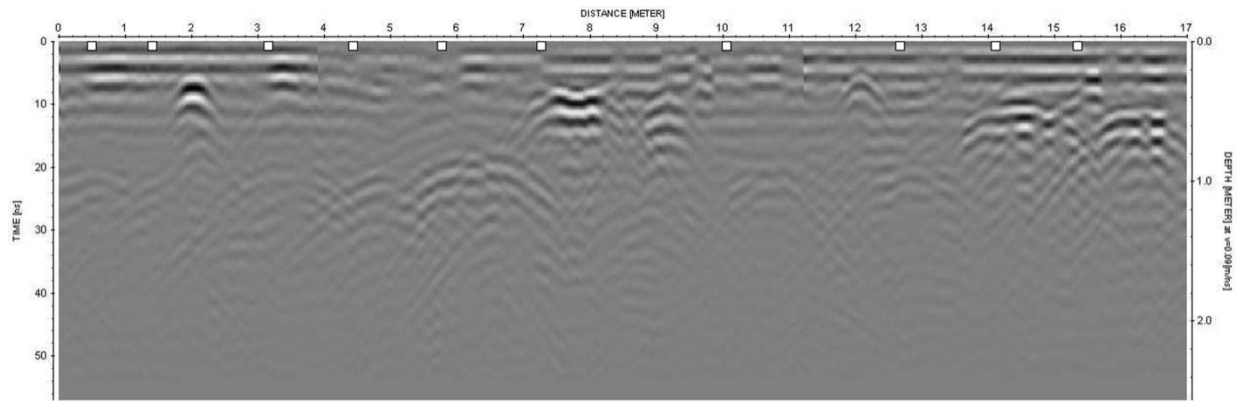
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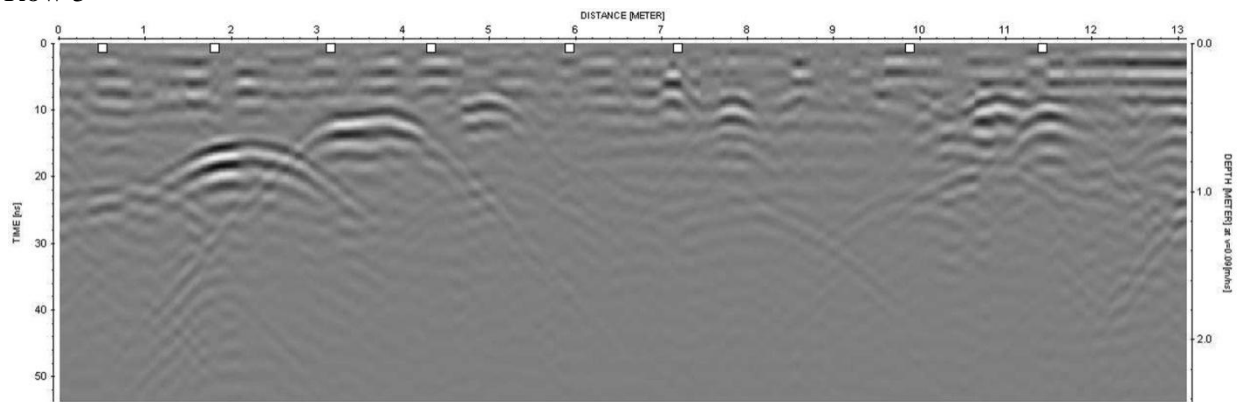
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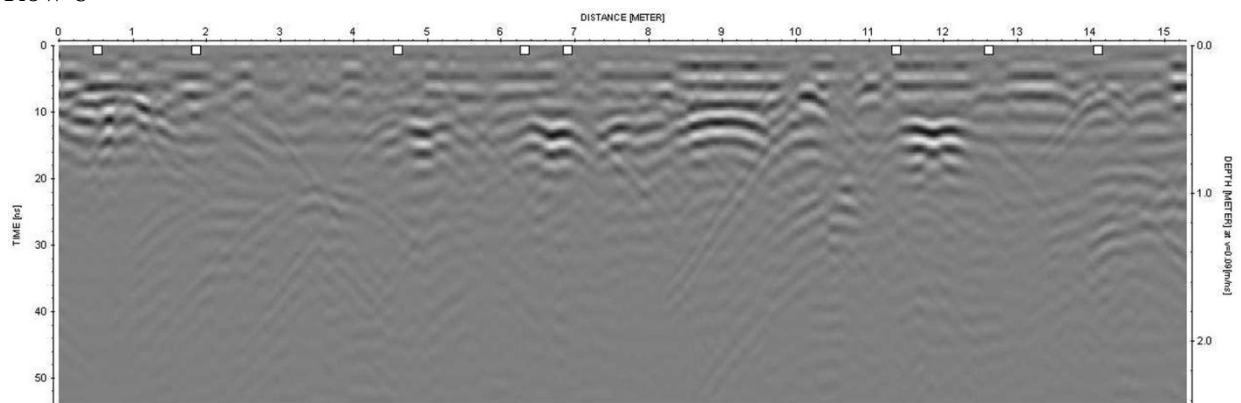
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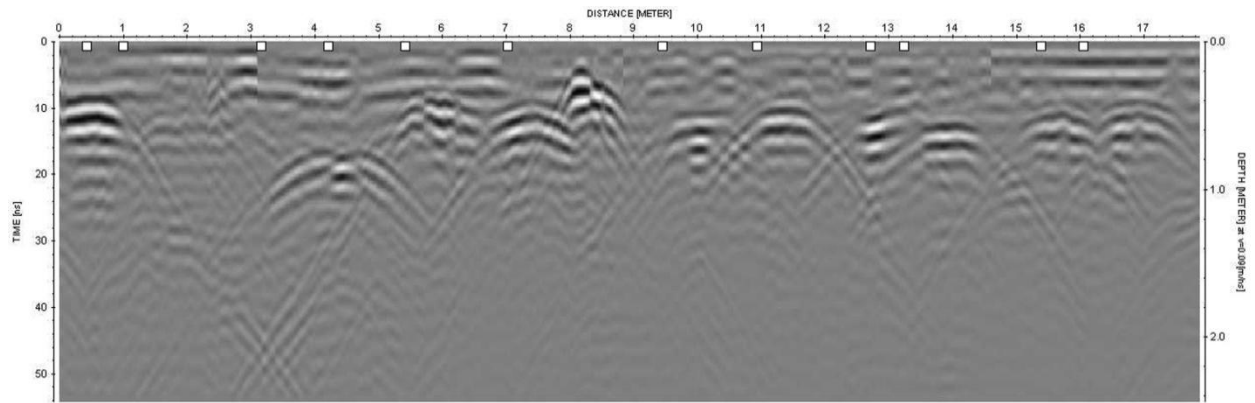
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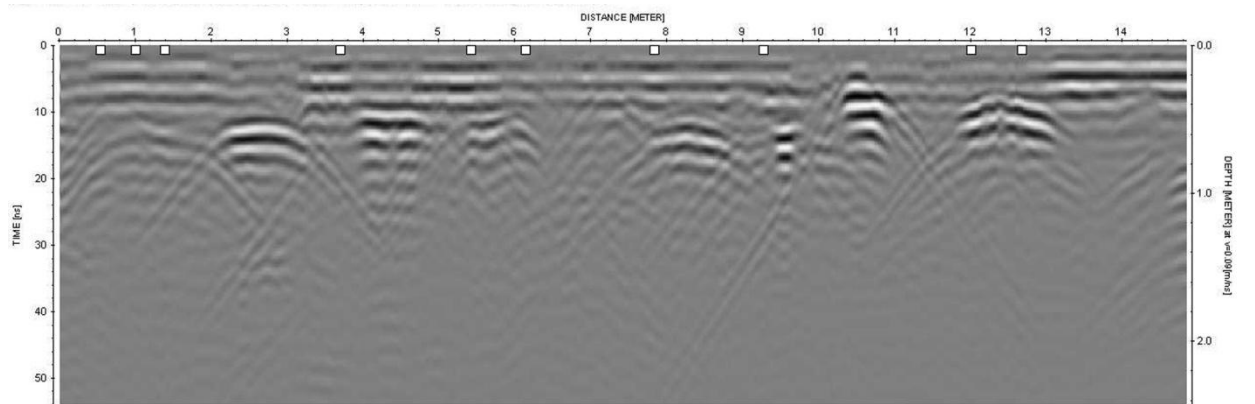
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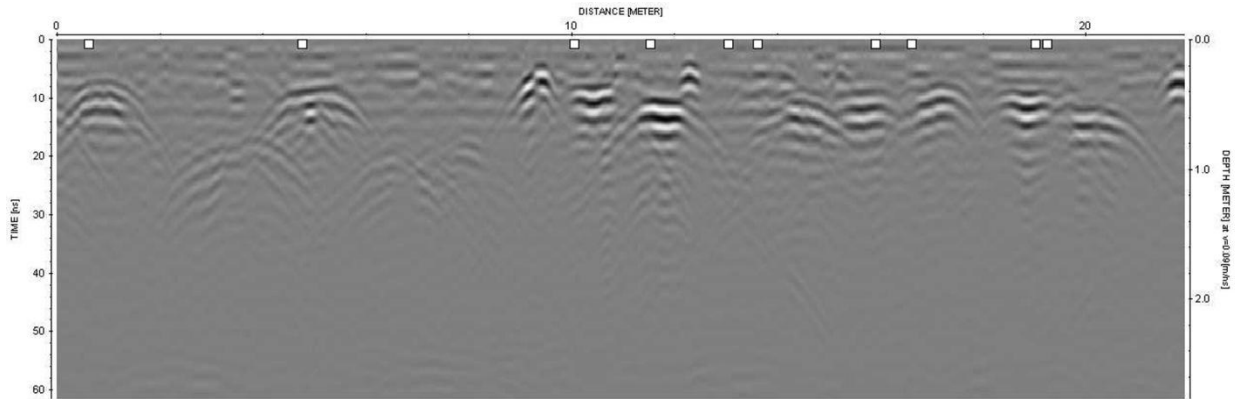


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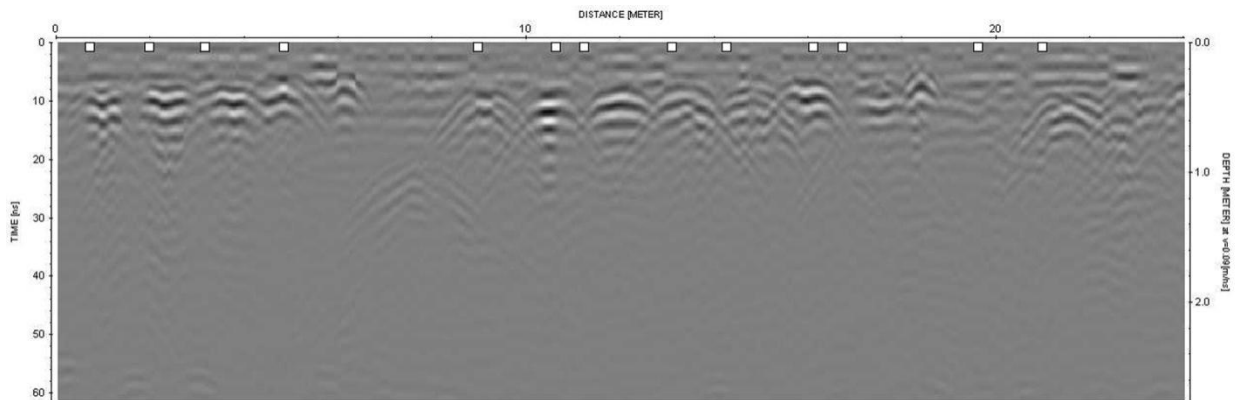


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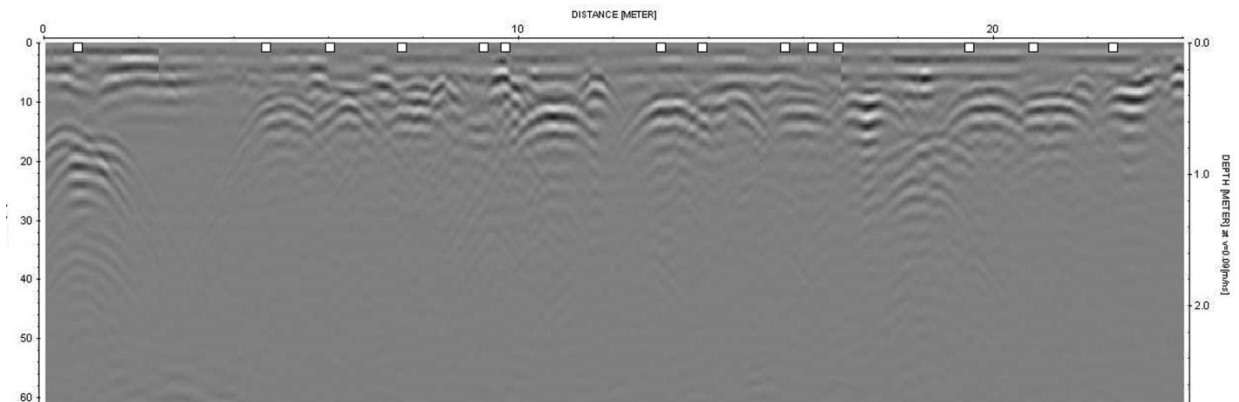
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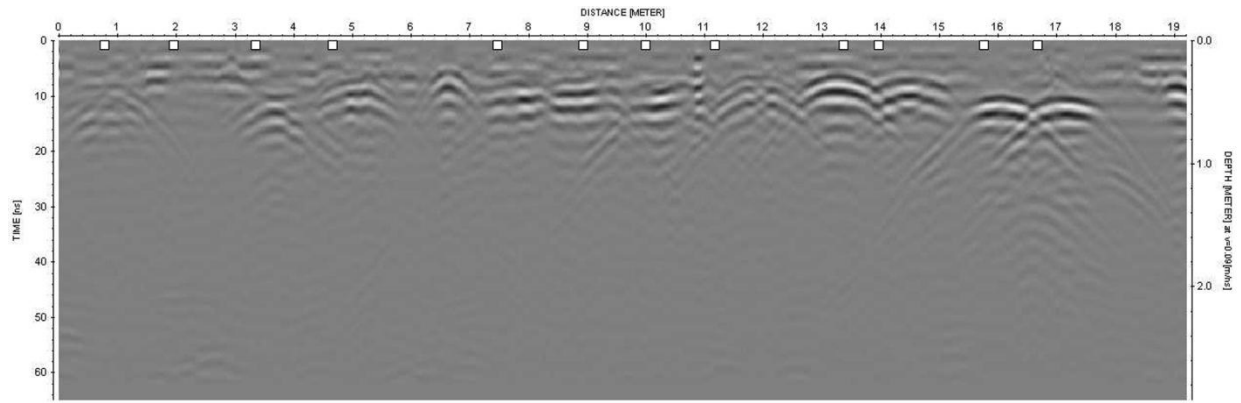
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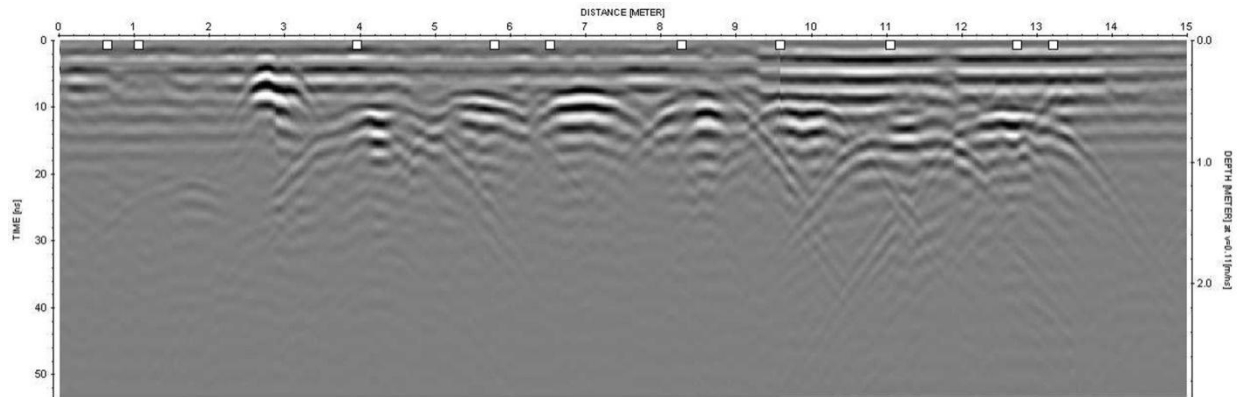


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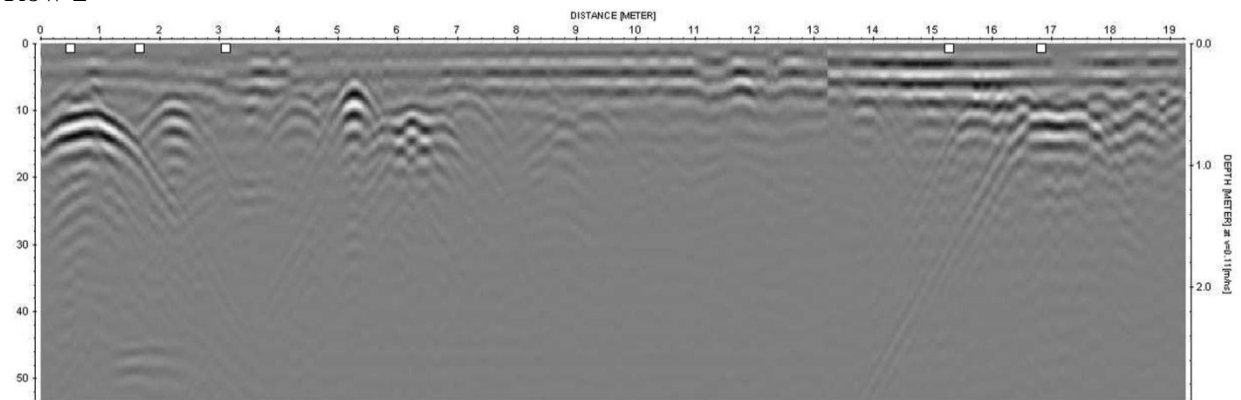


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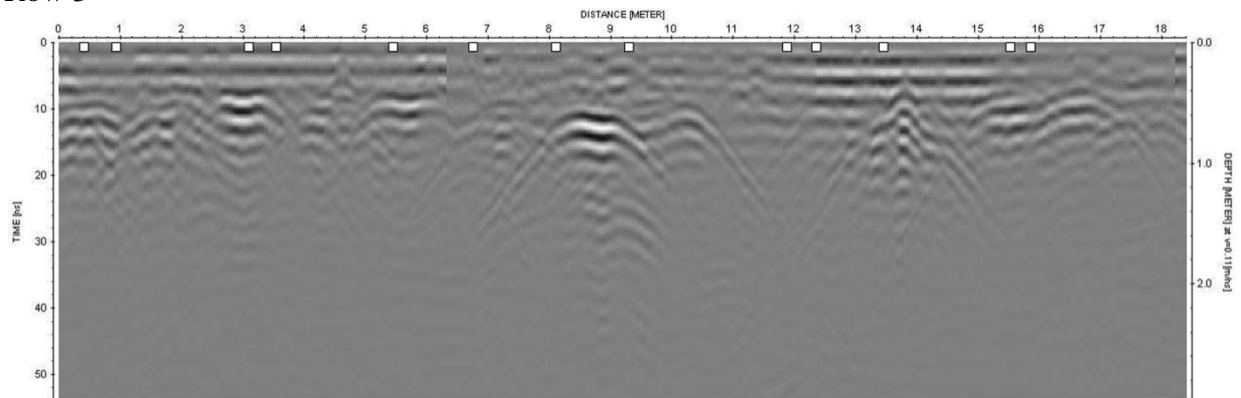
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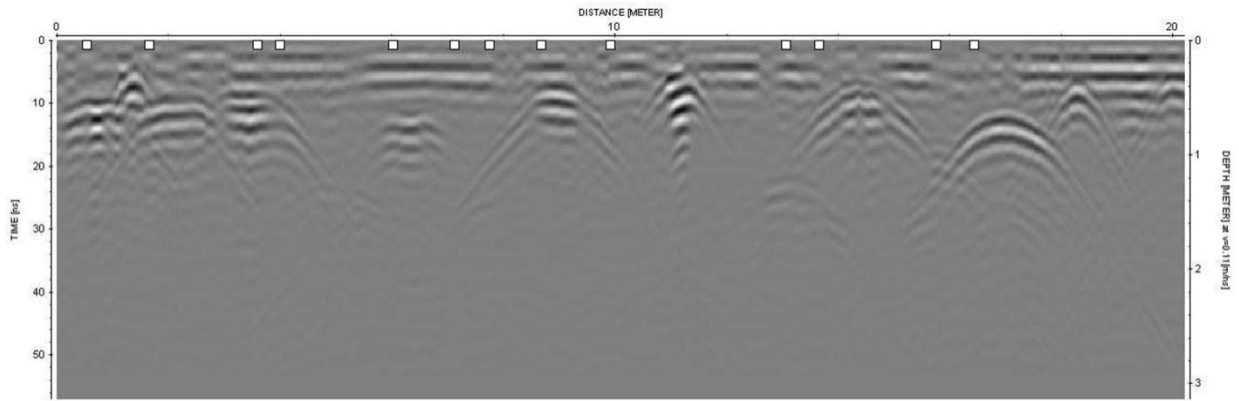
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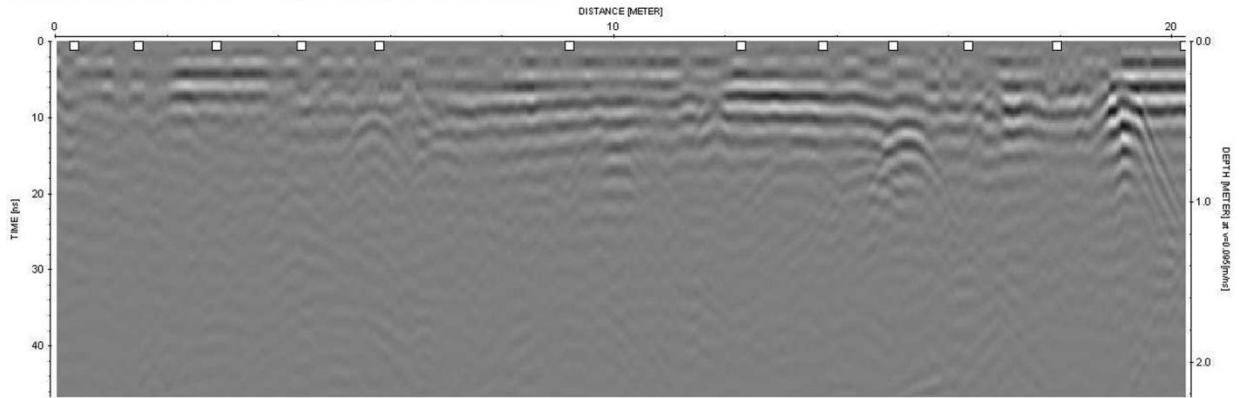


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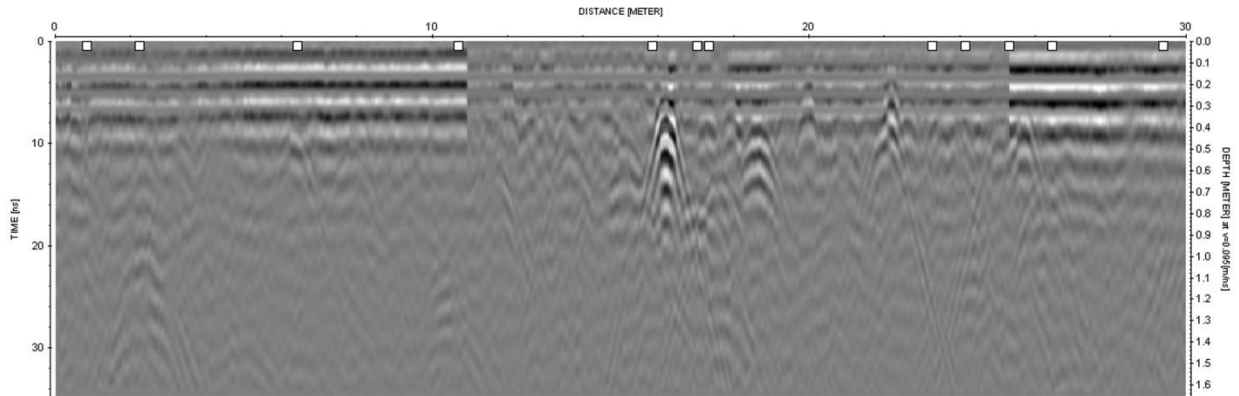


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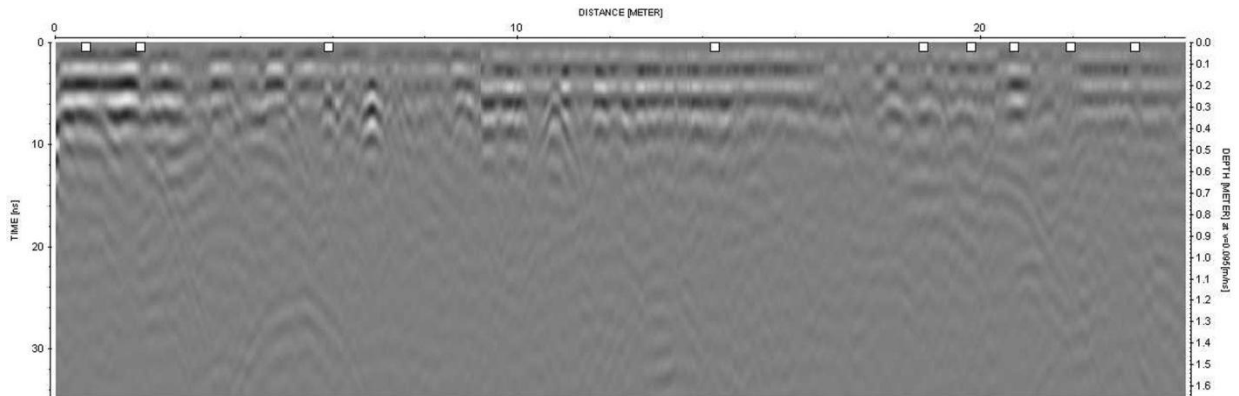
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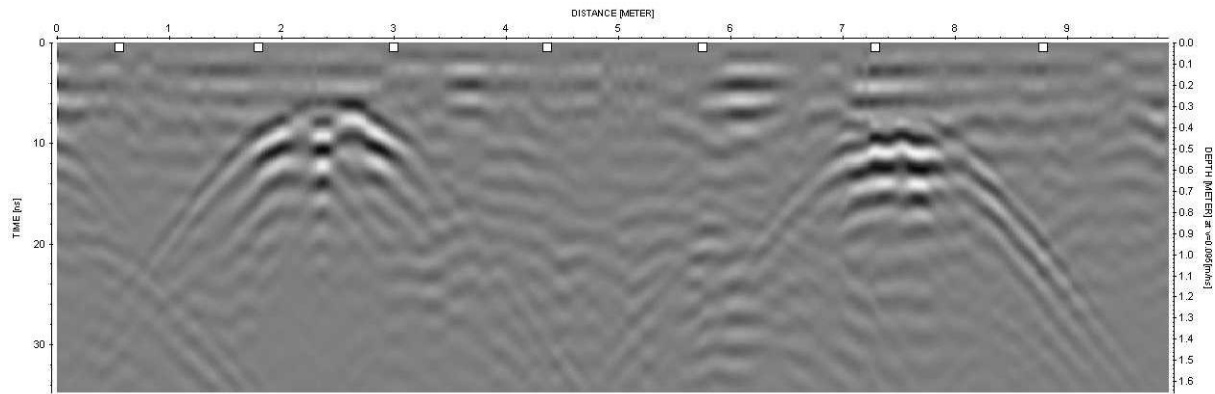
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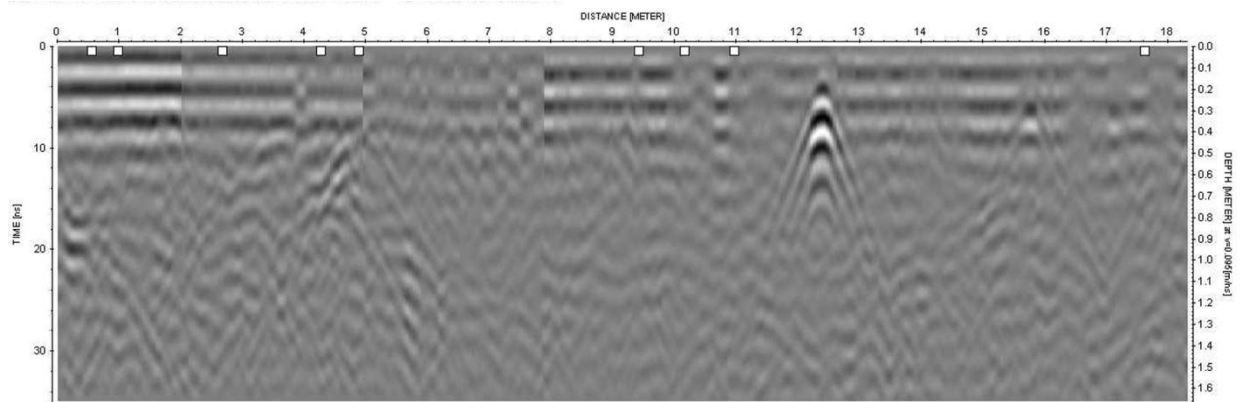
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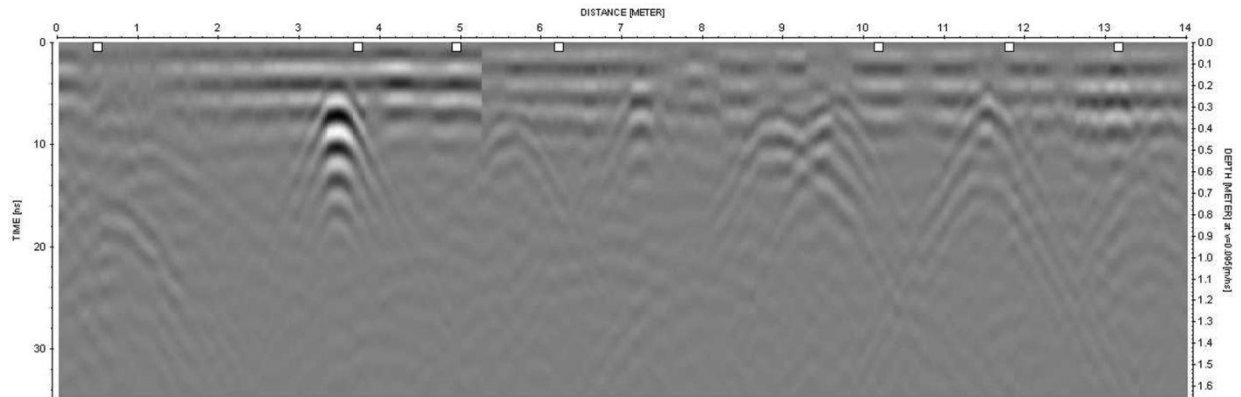
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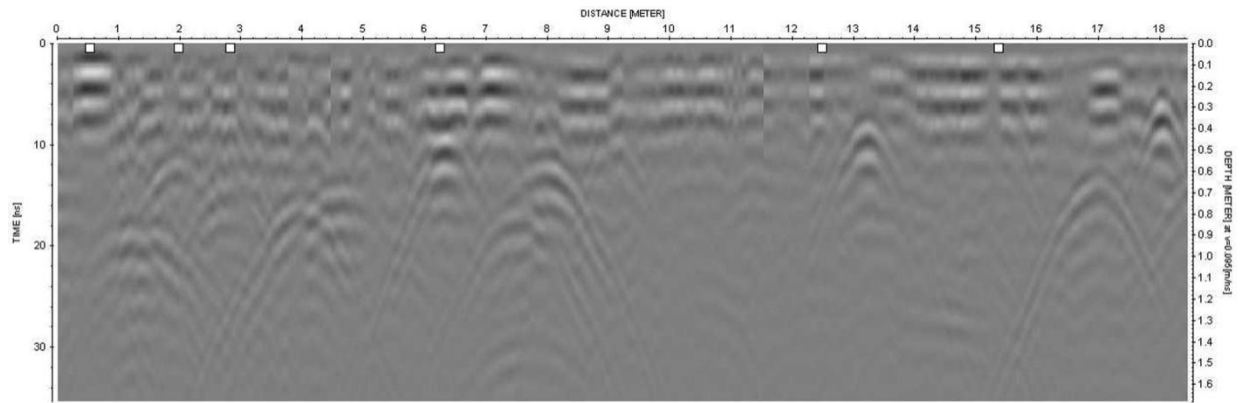
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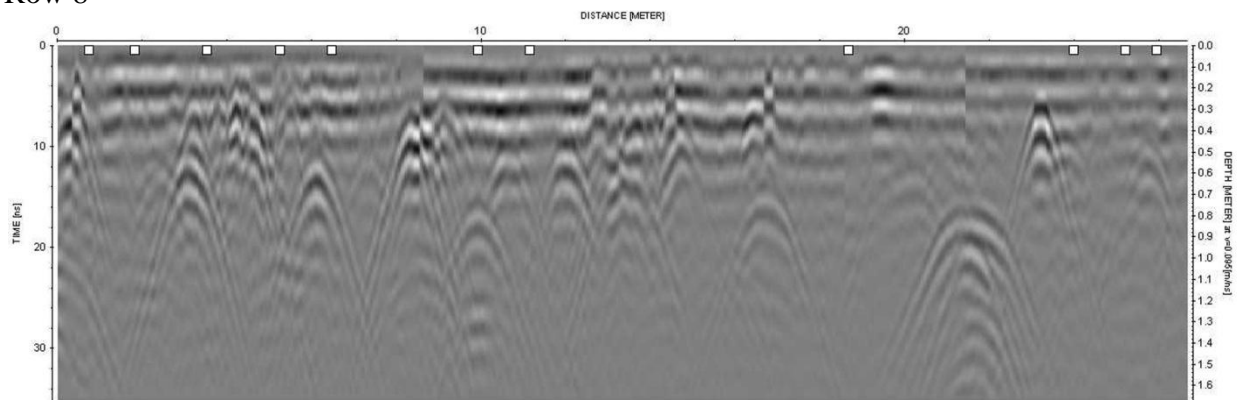
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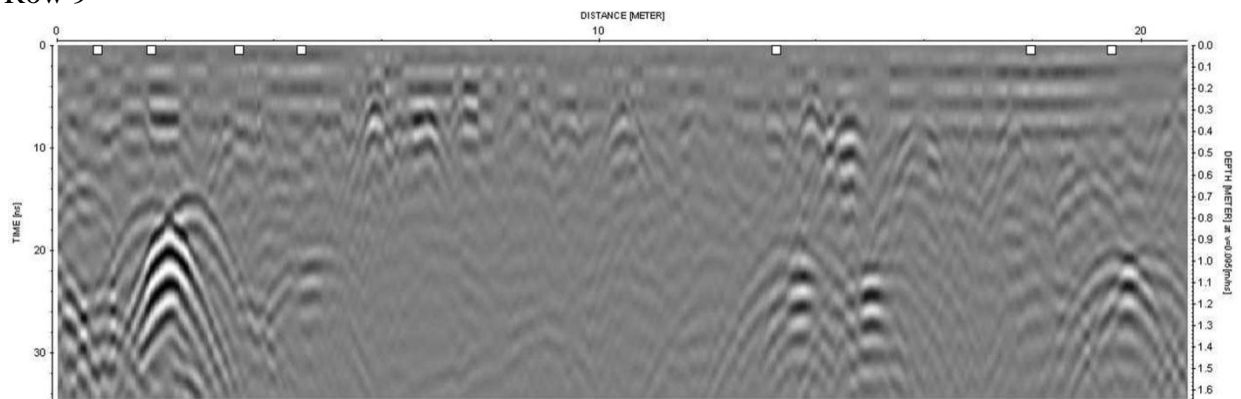
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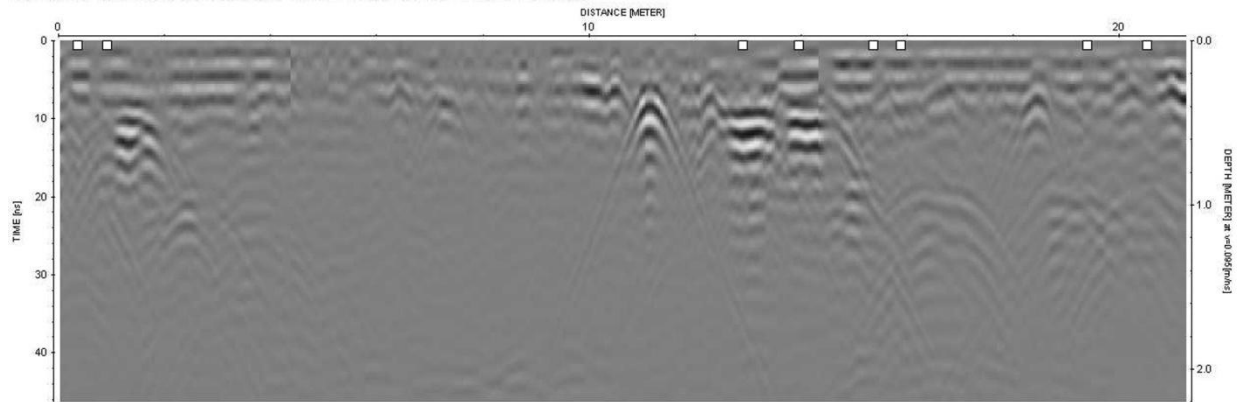


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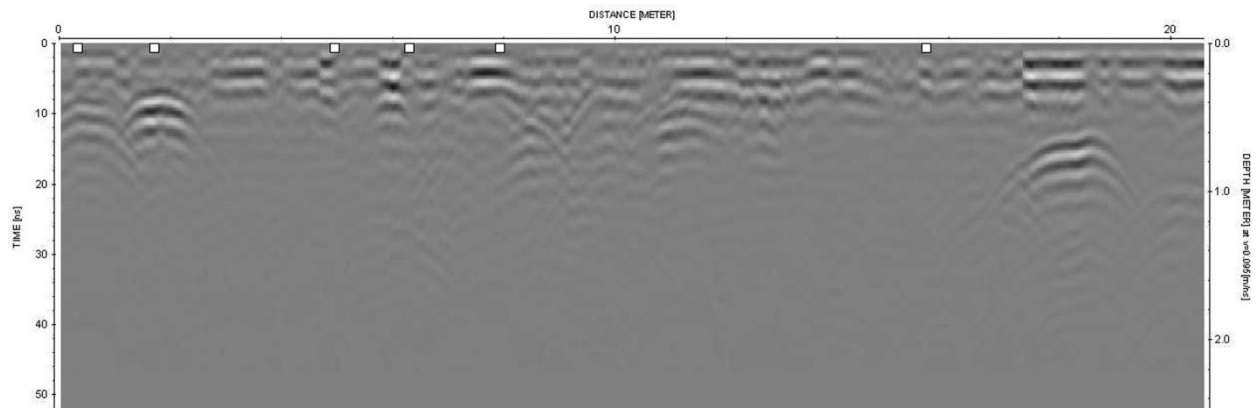


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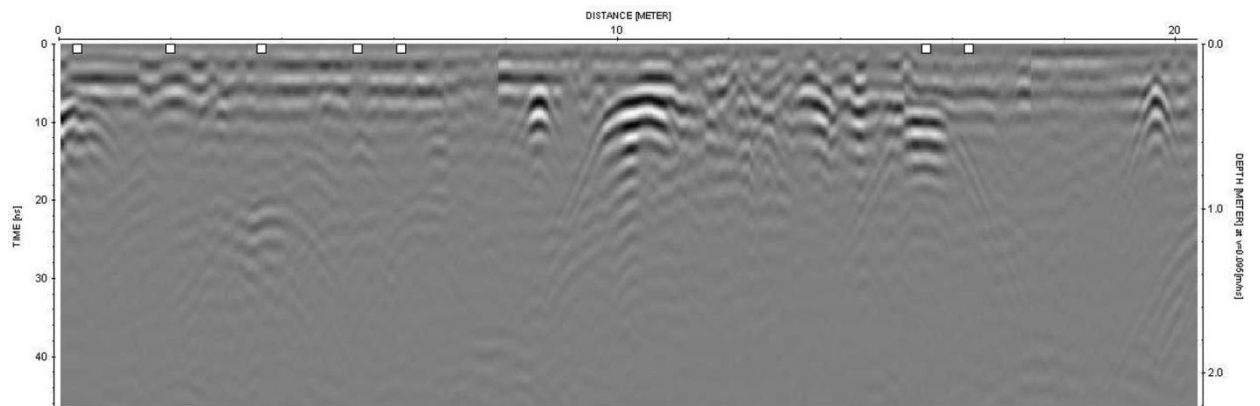
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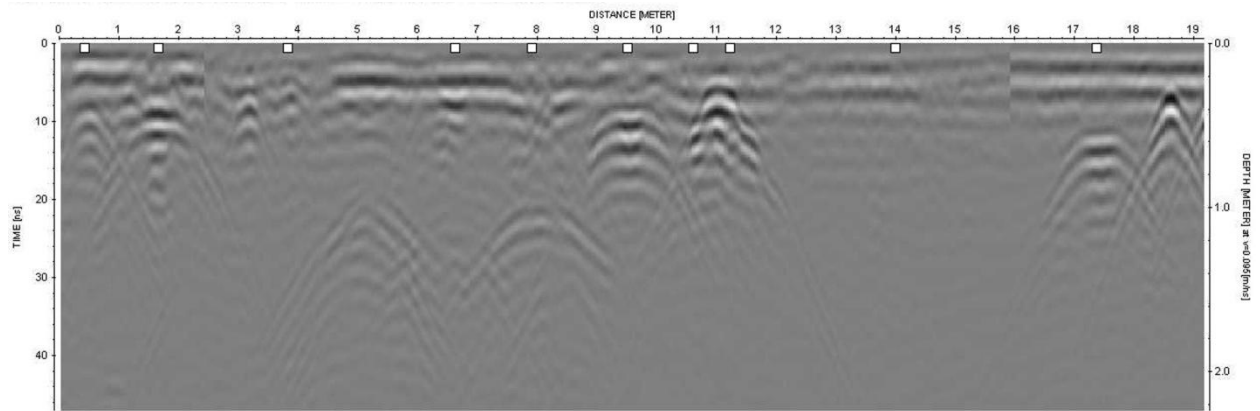
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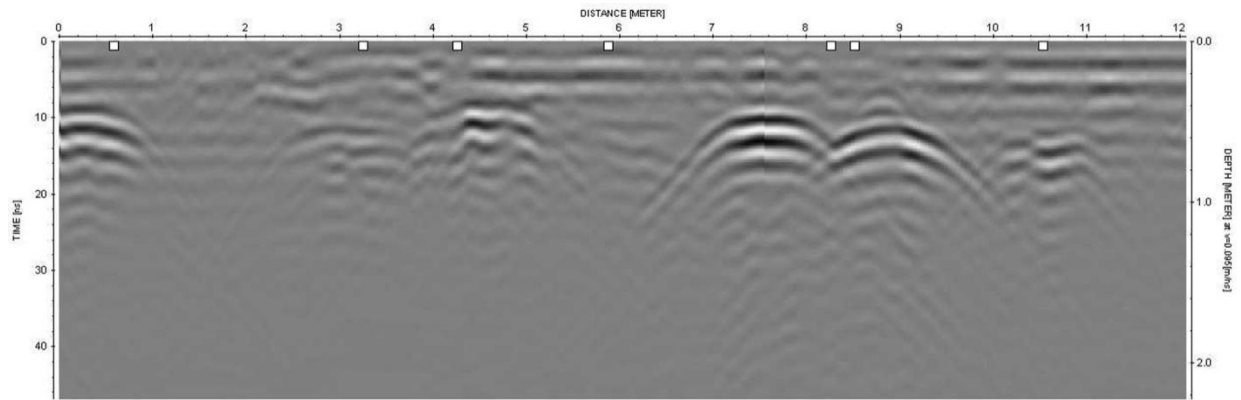
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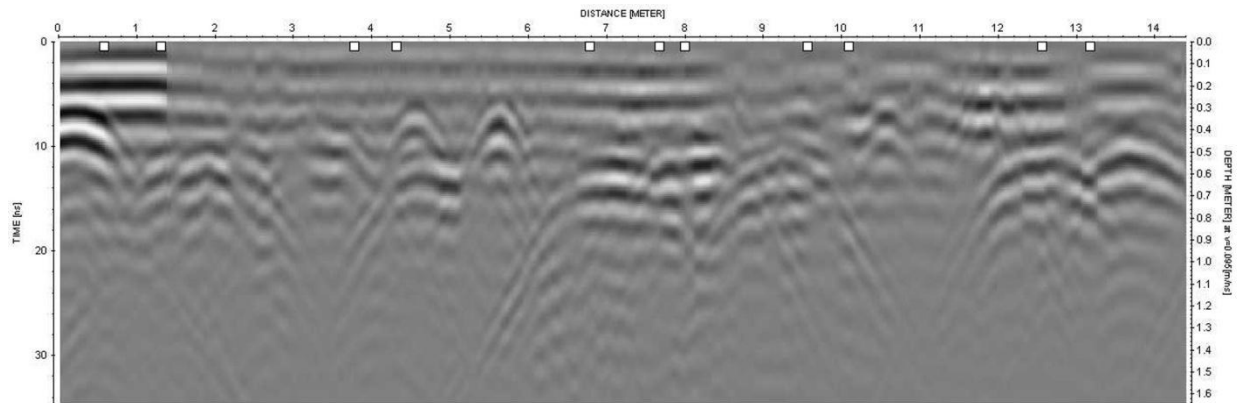
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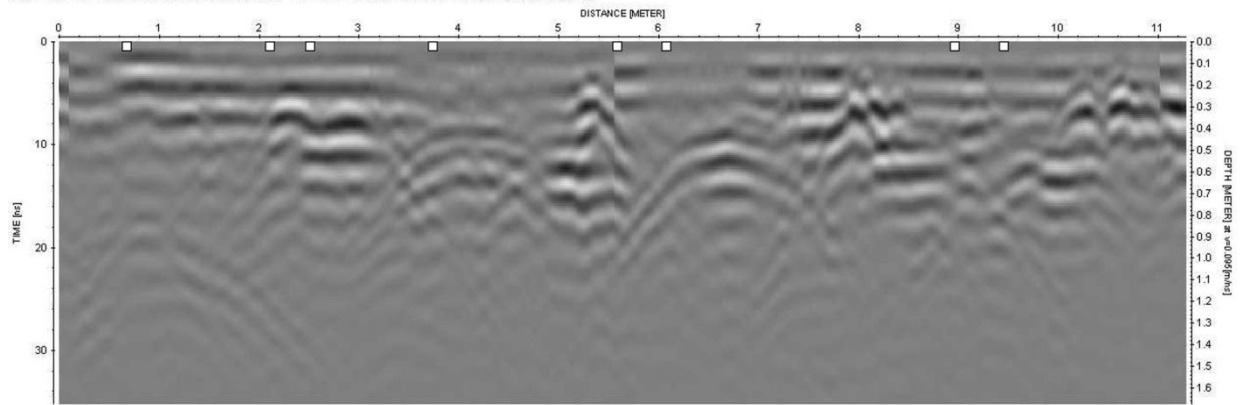
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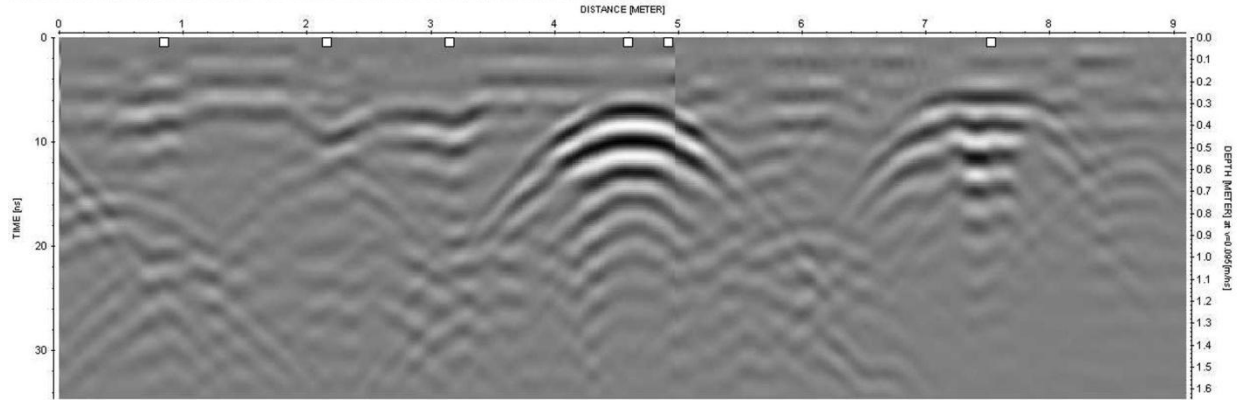
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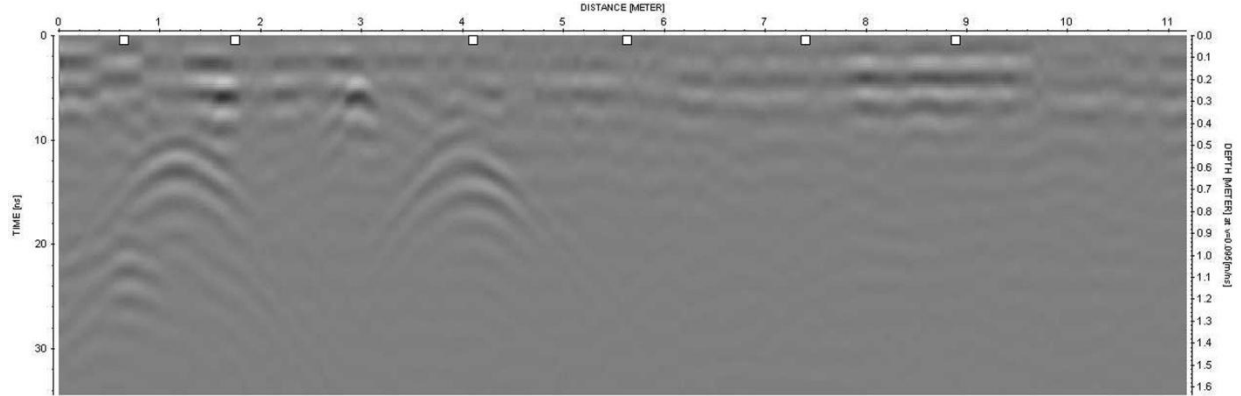
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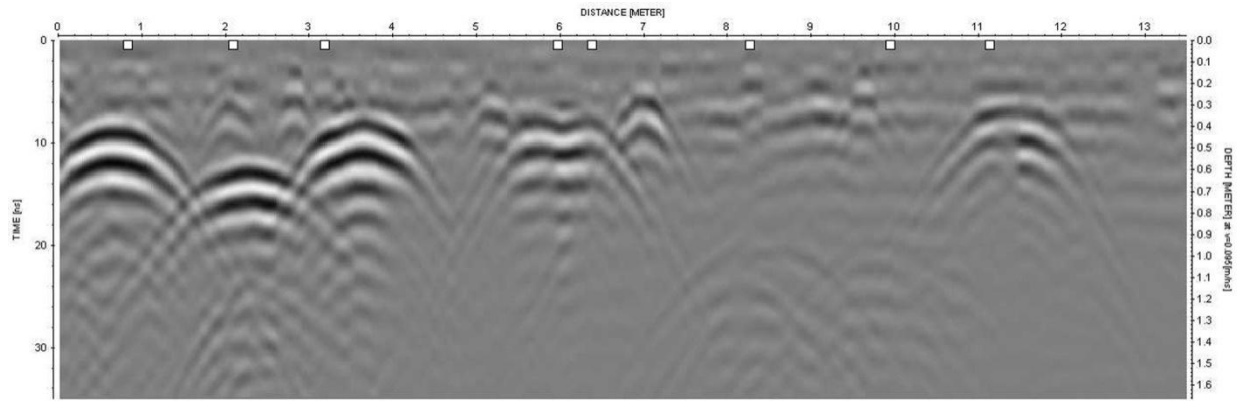
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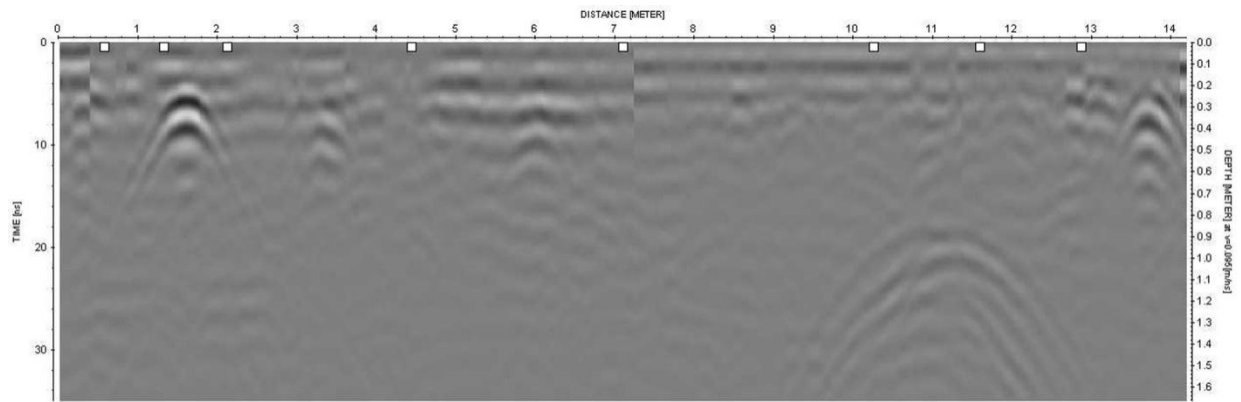
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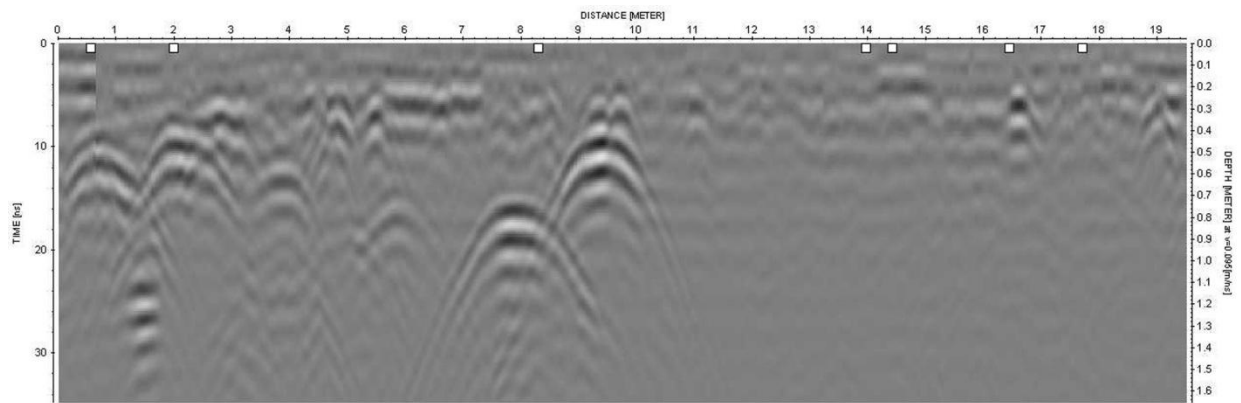
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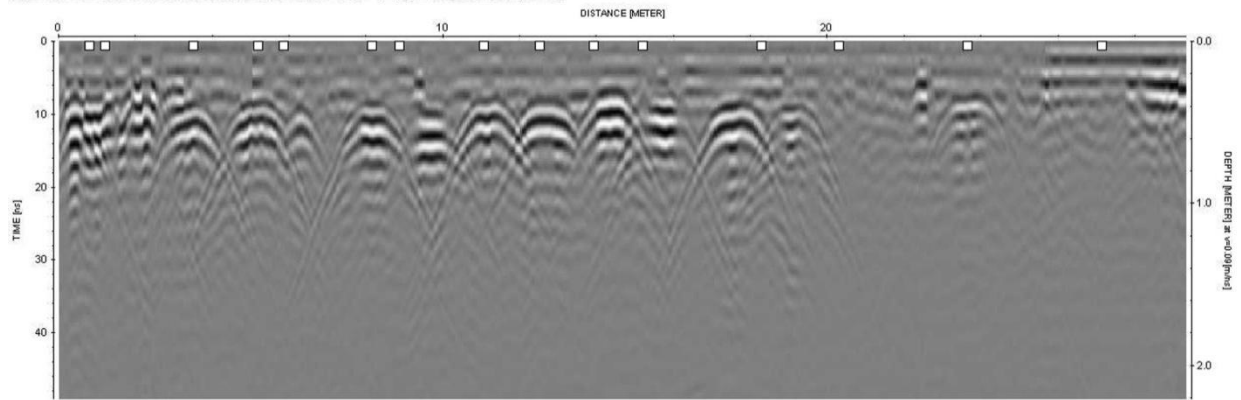


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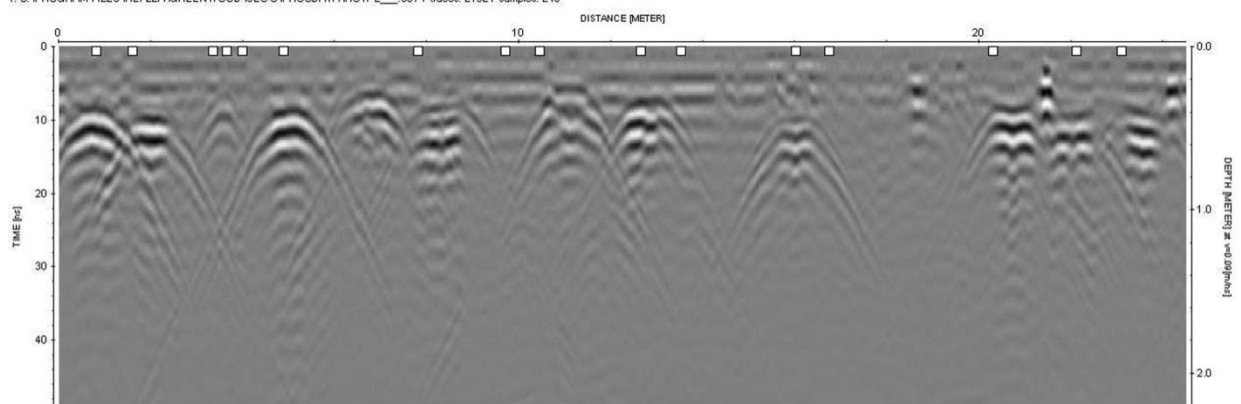


Section C

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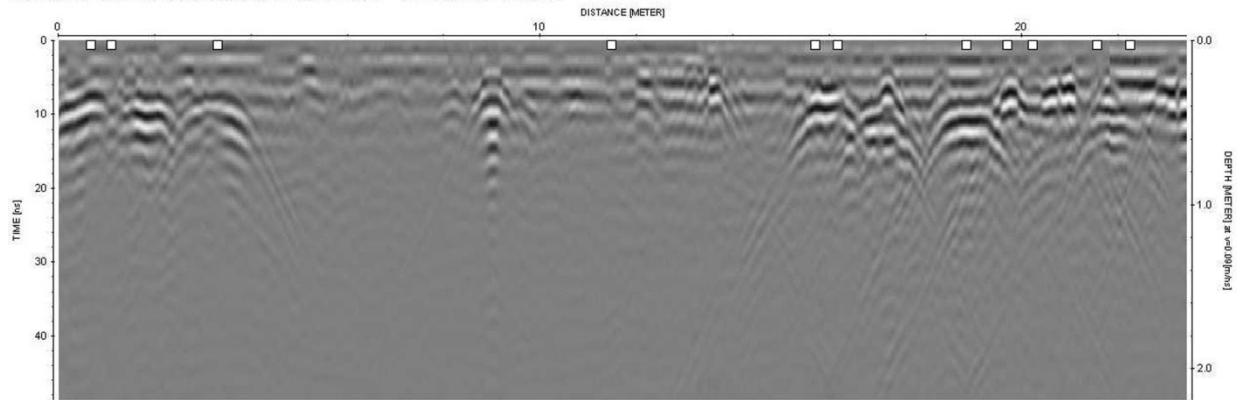


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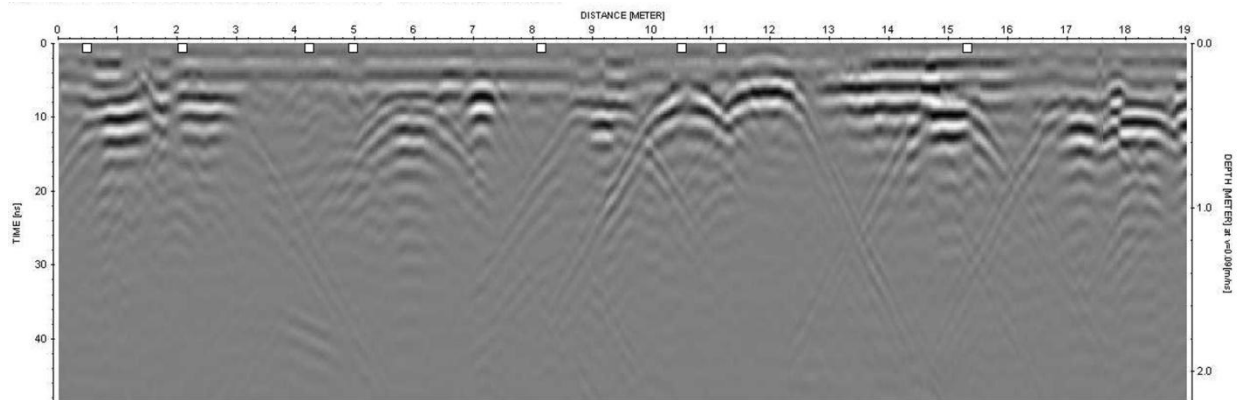


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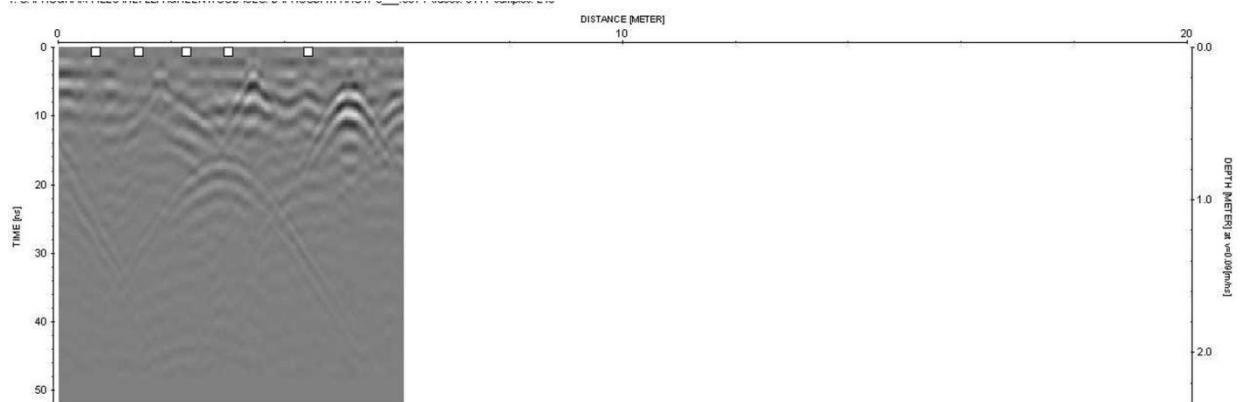
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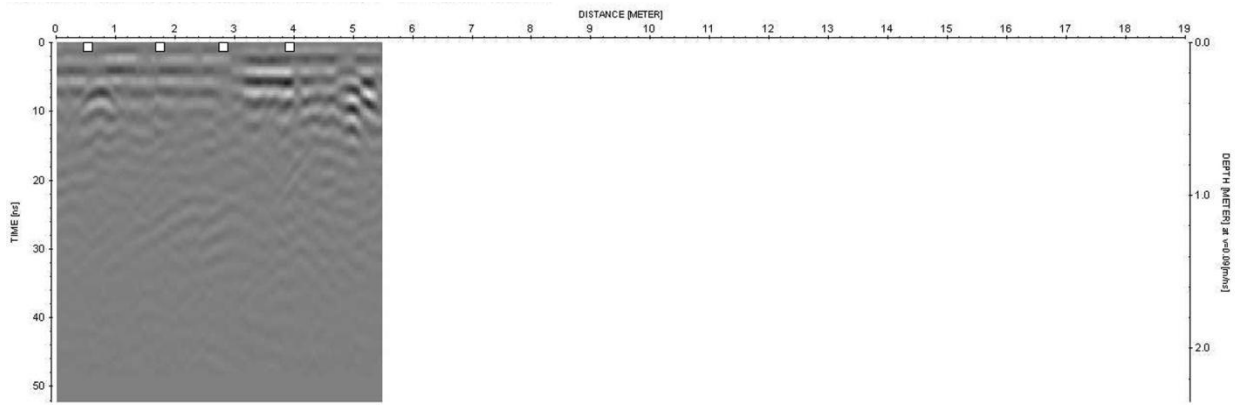
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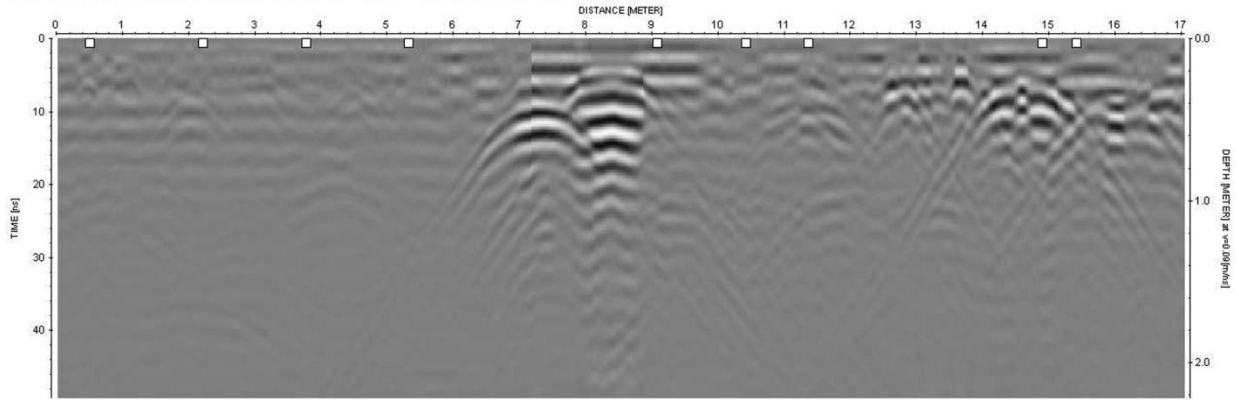


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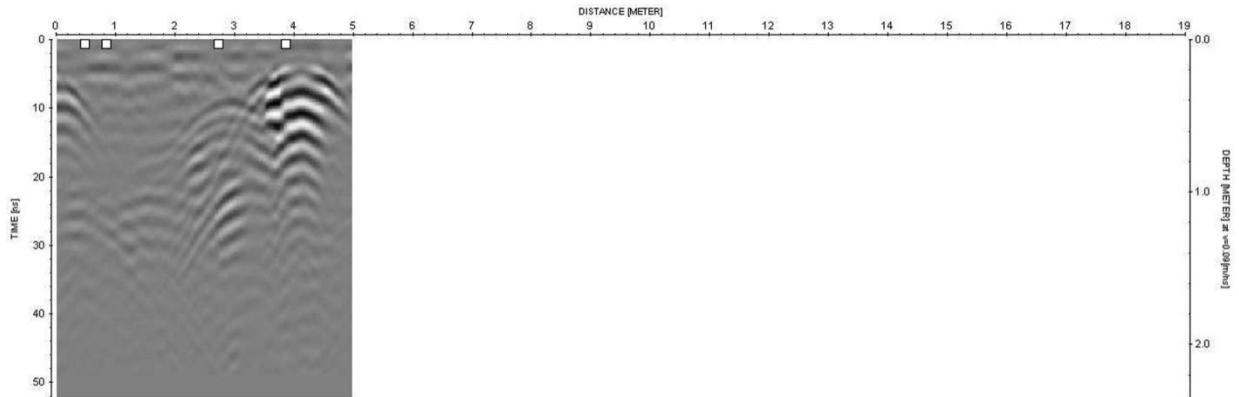


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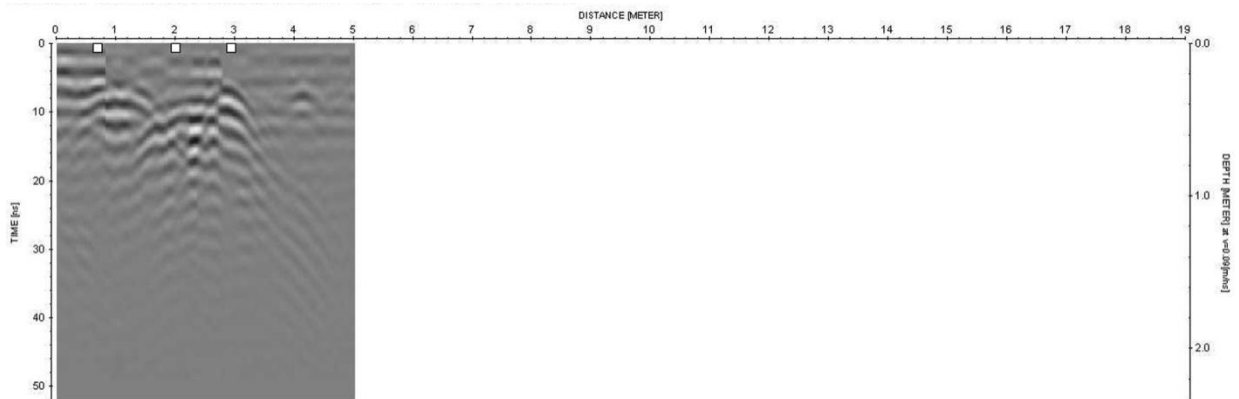
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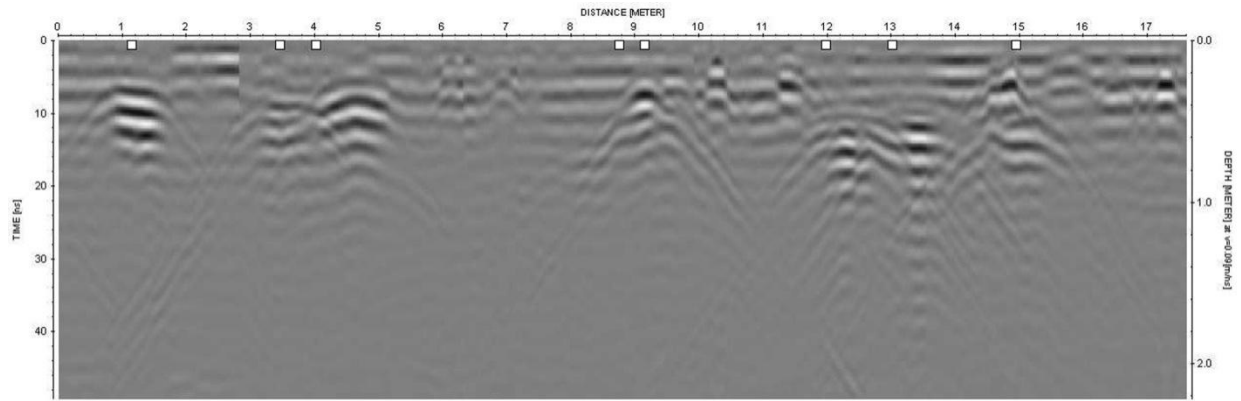
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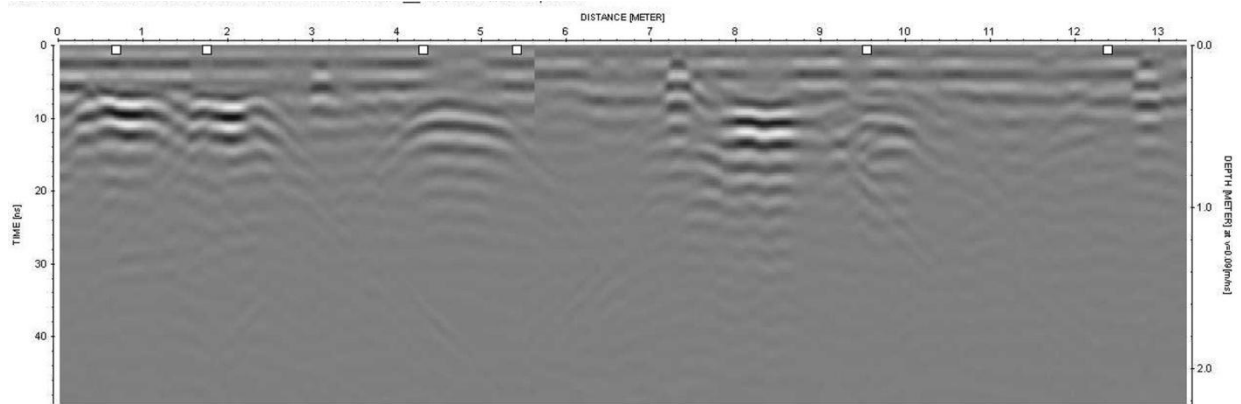
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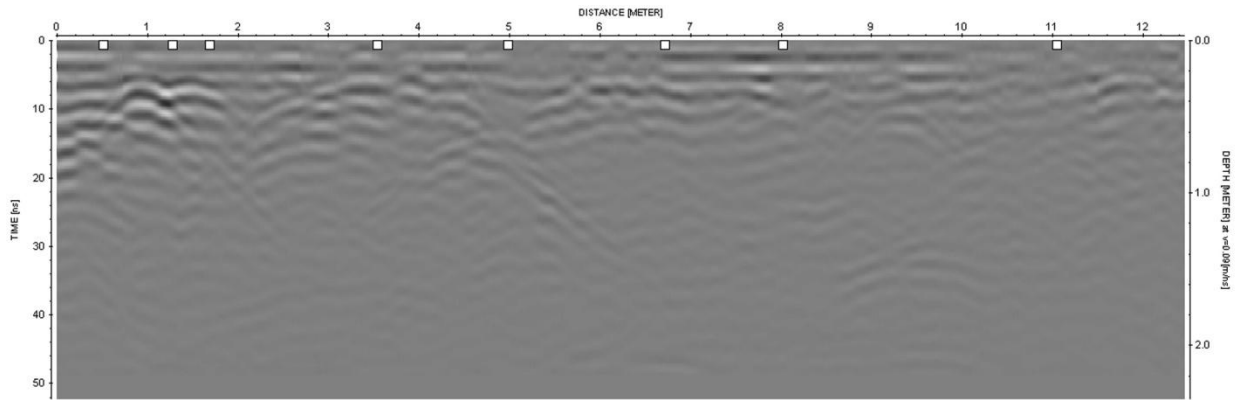


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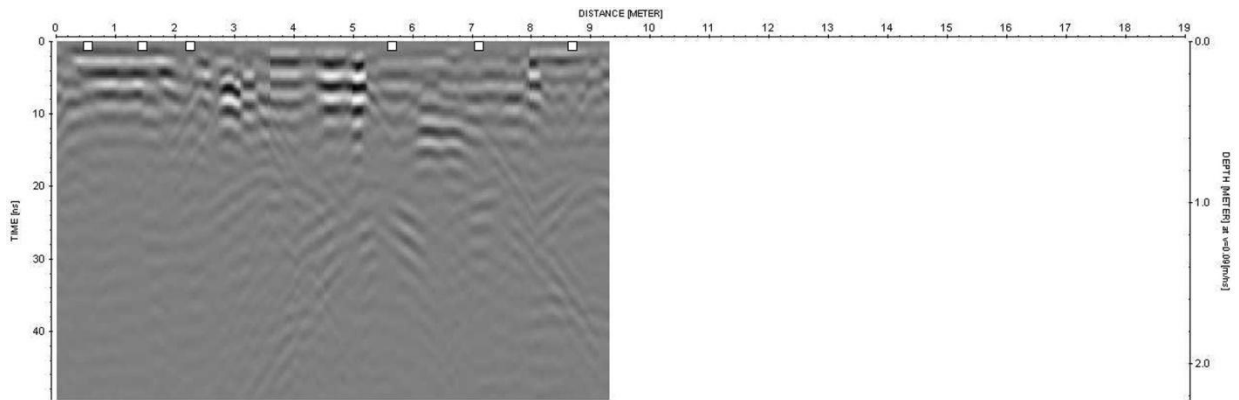


Section F

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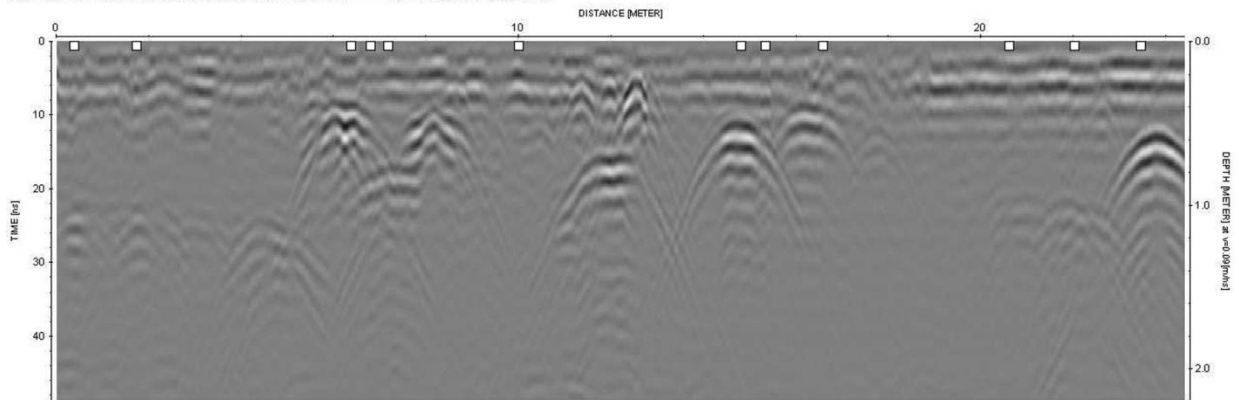


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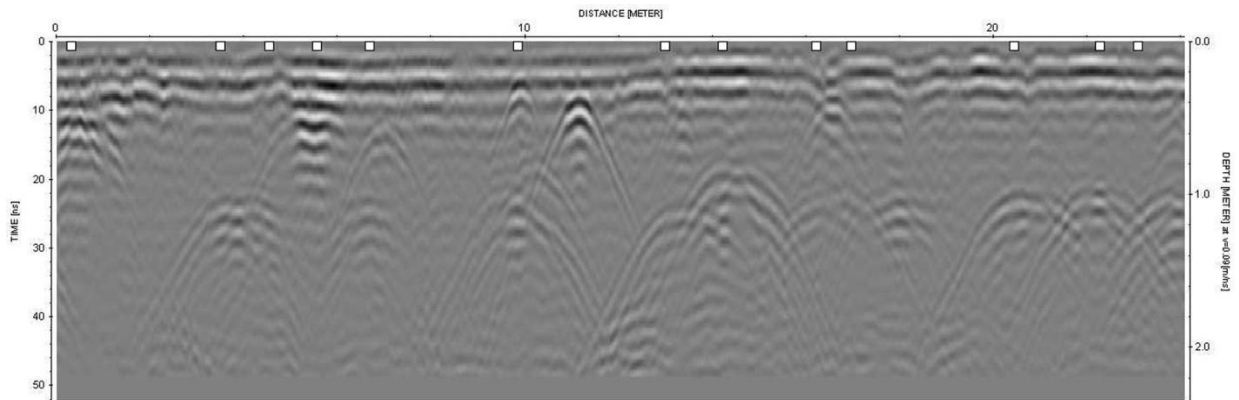


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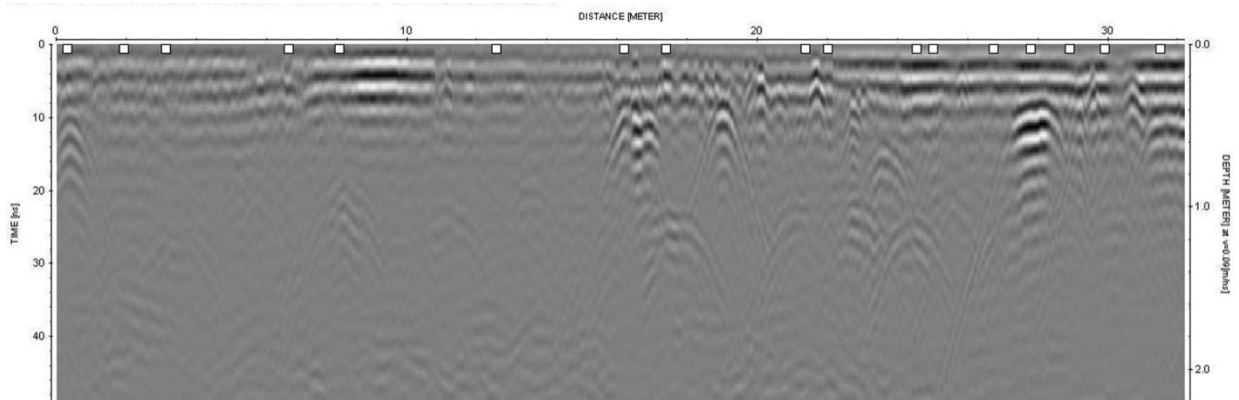
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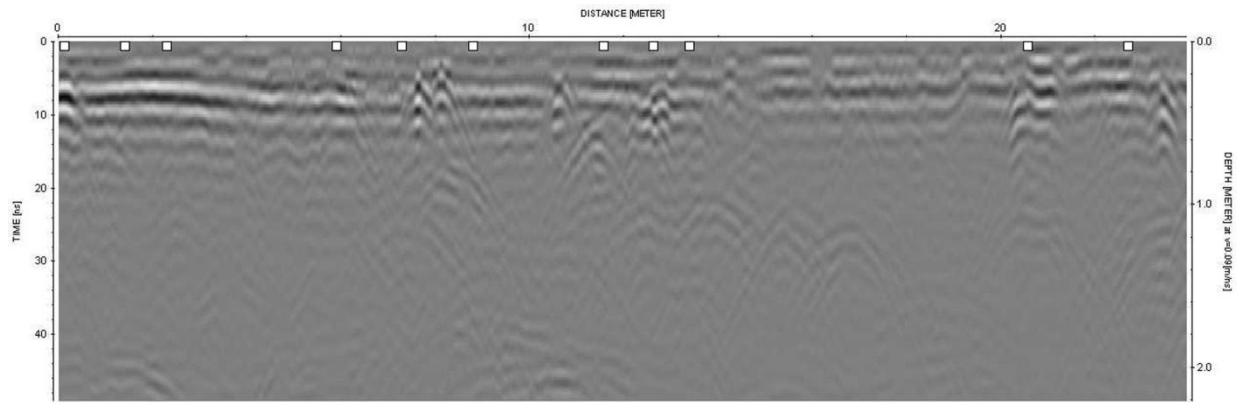
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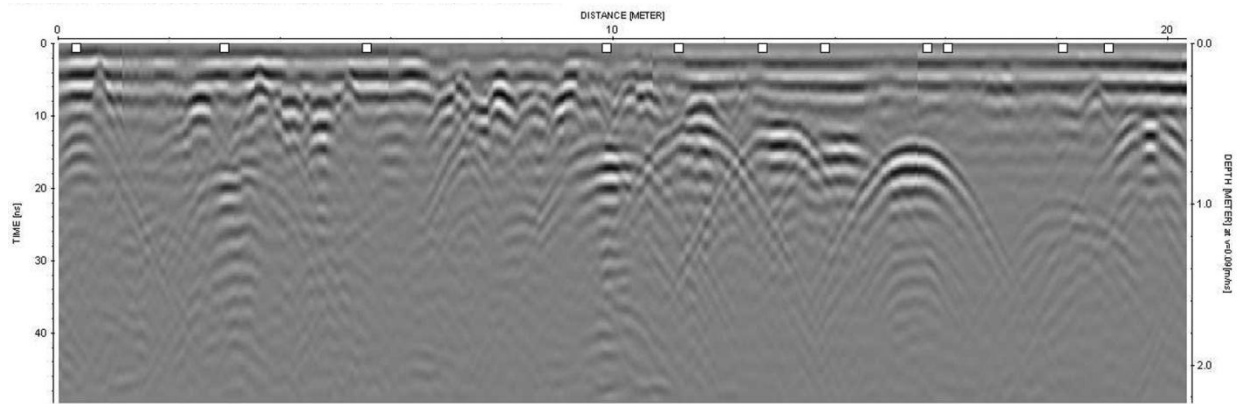
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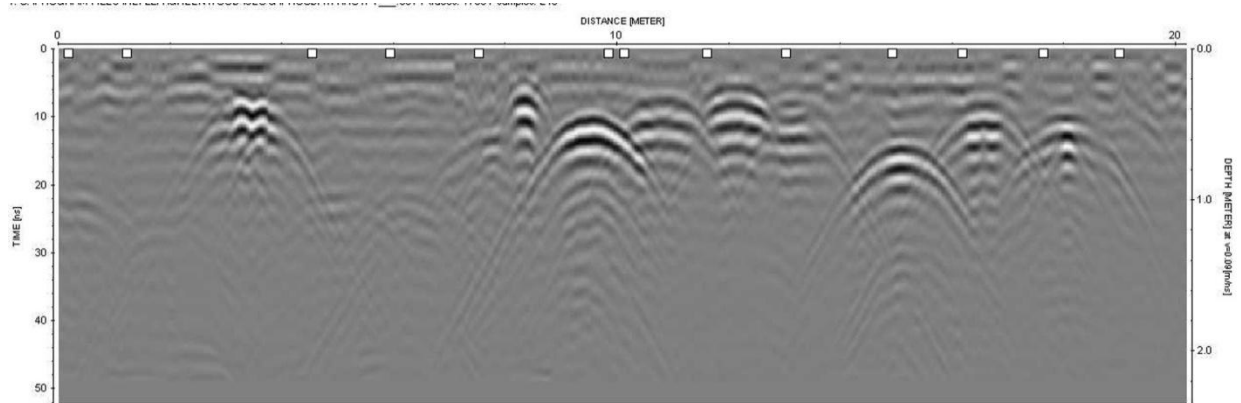
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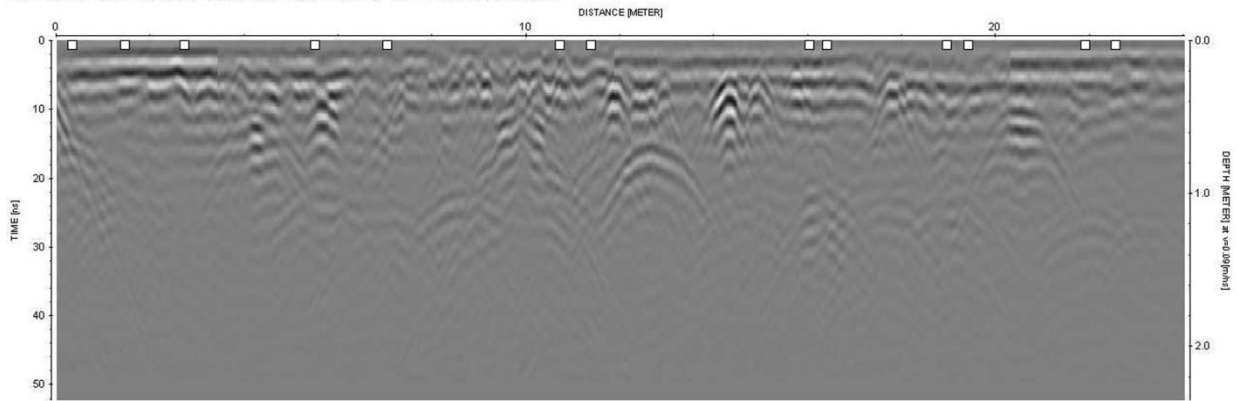
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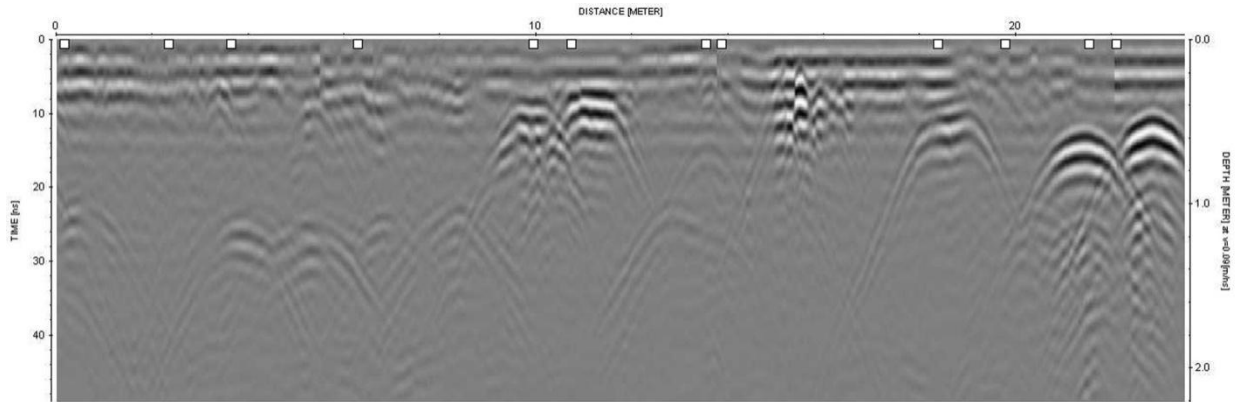
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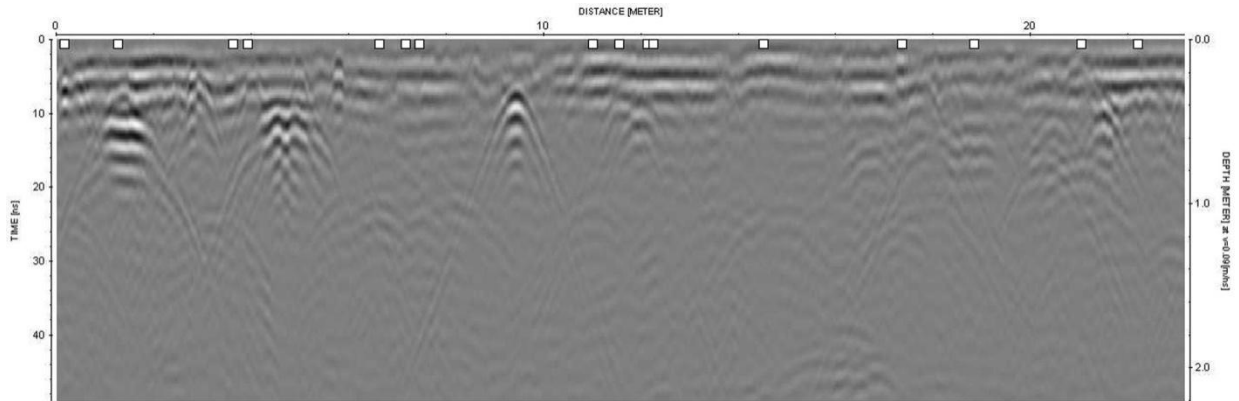
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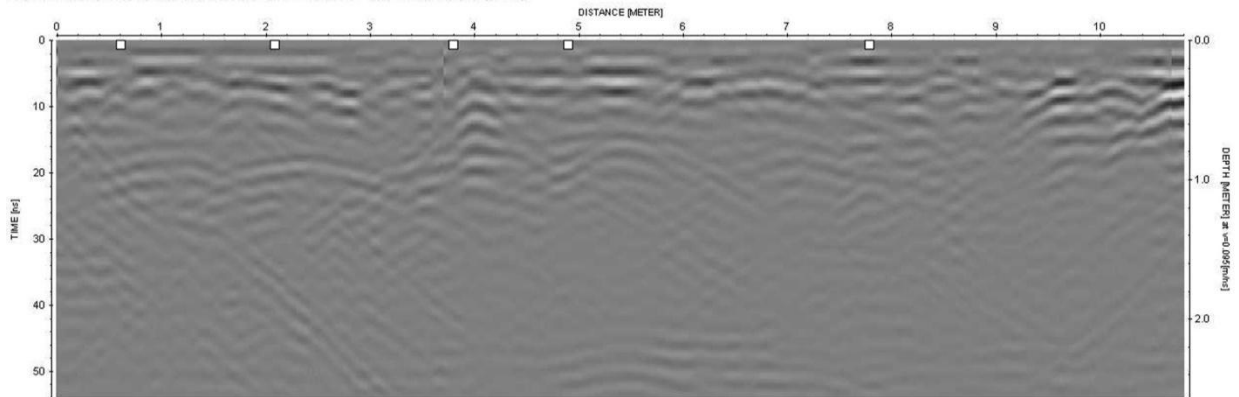


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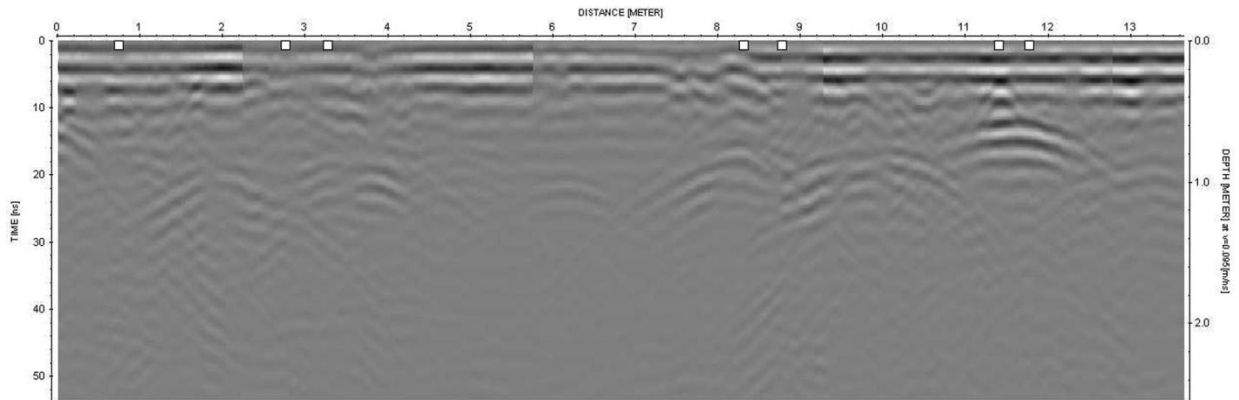


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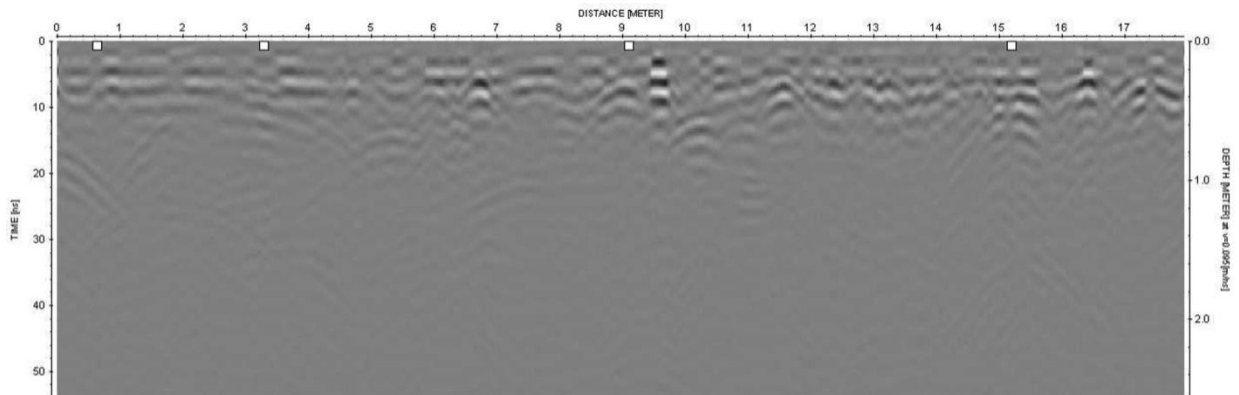
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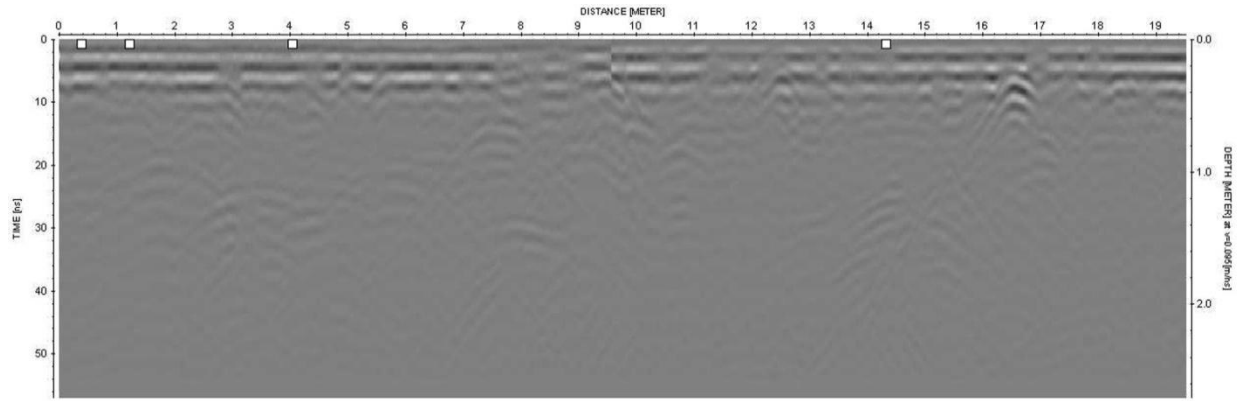
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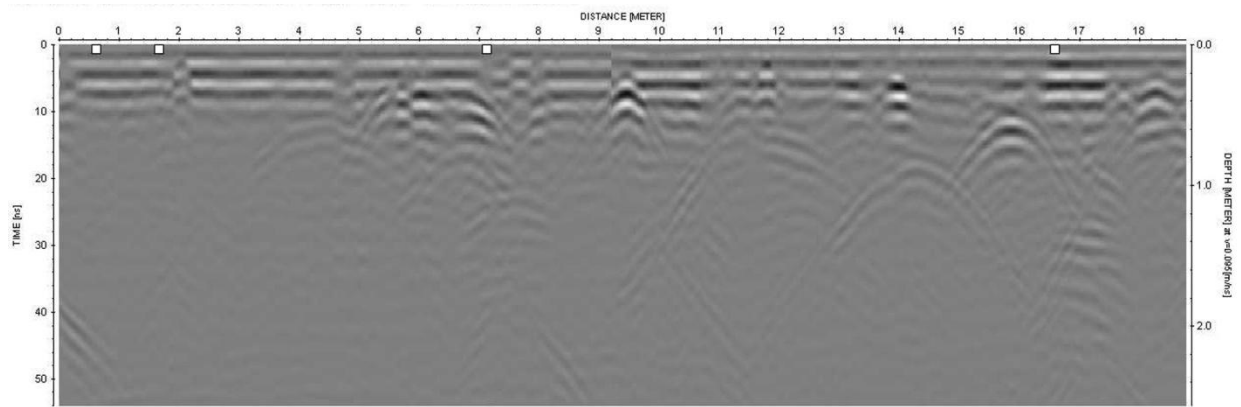
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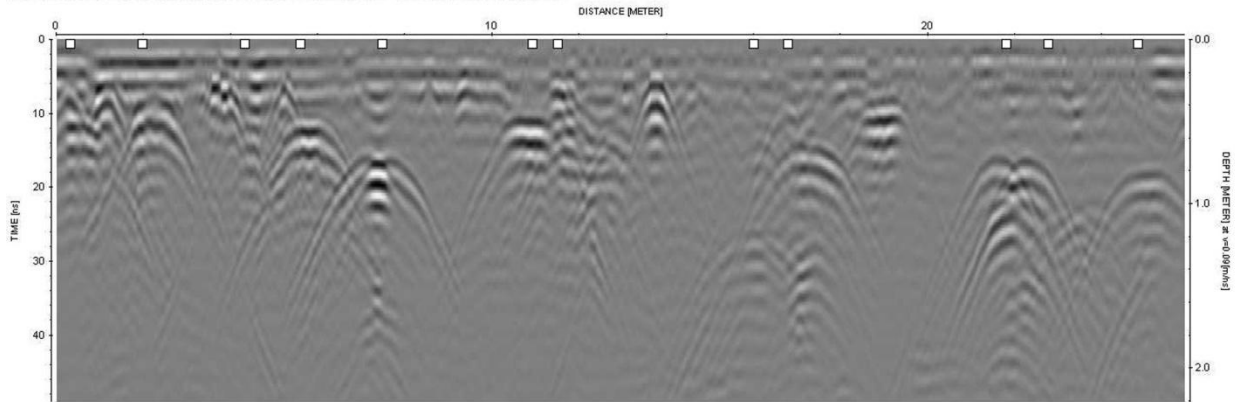


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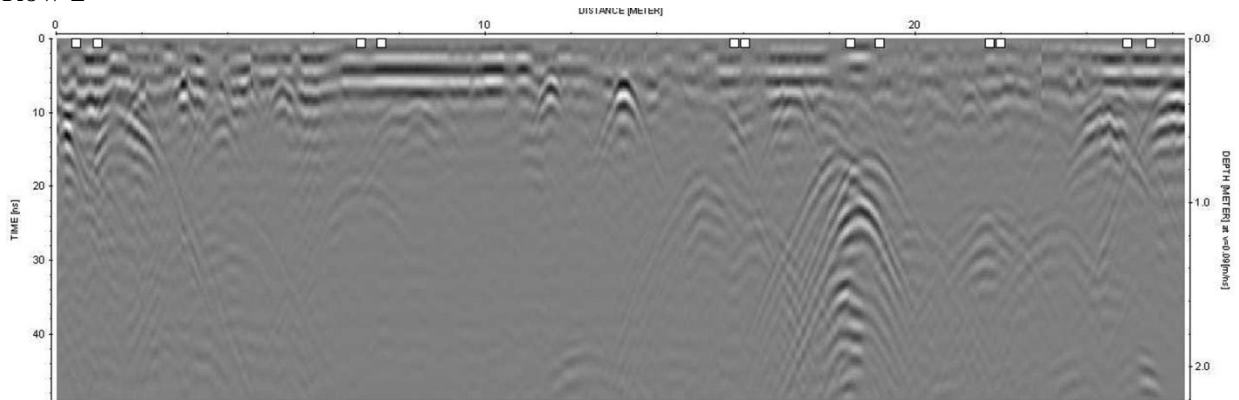


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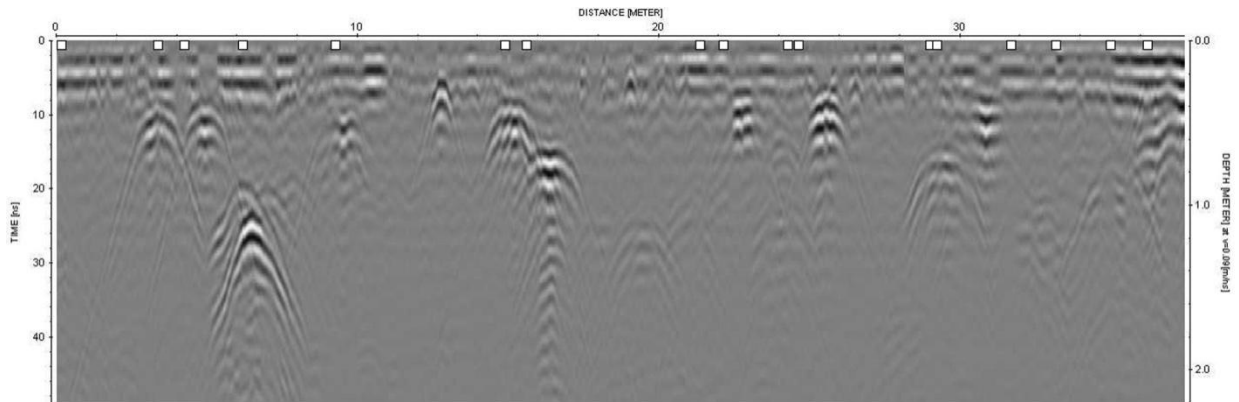
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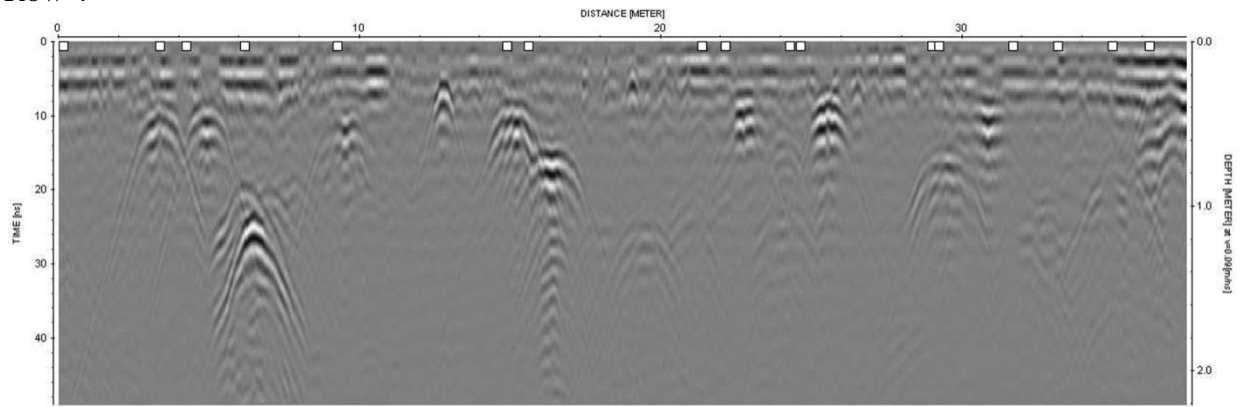
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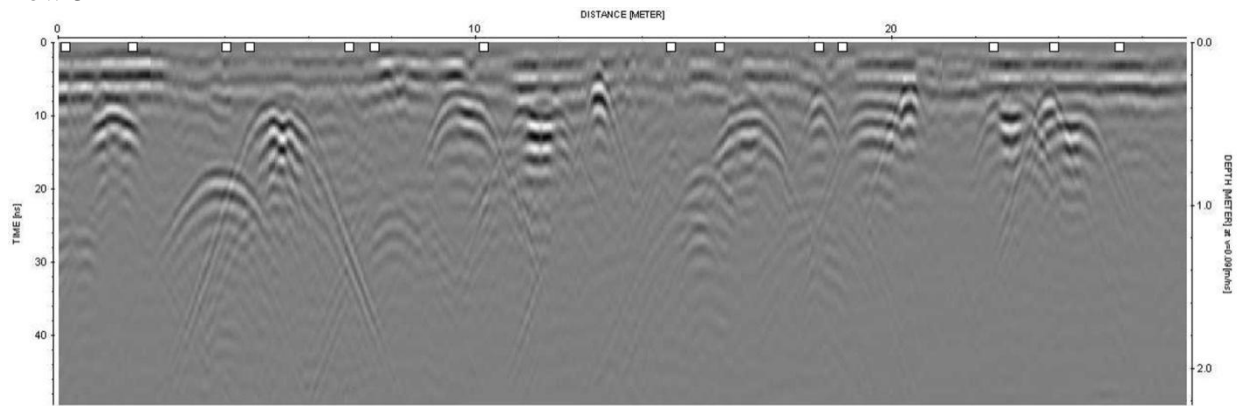
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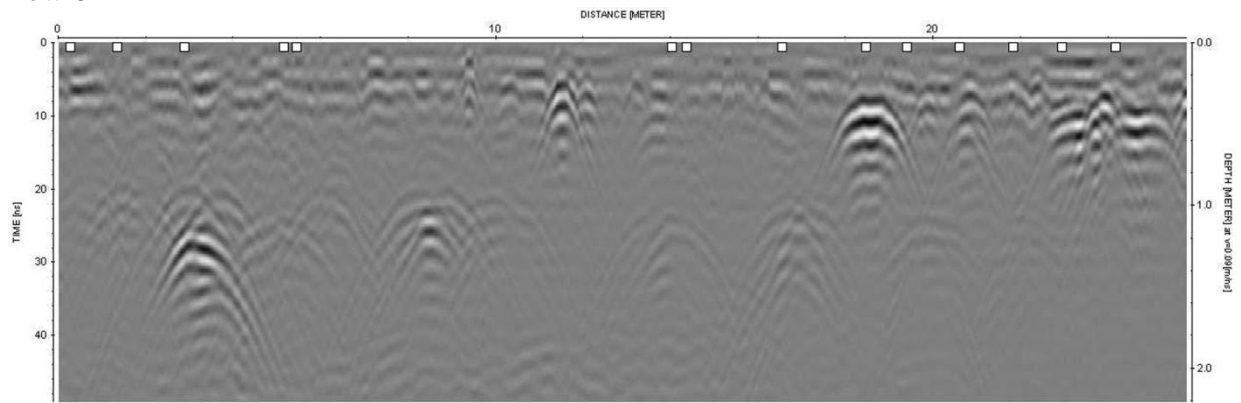
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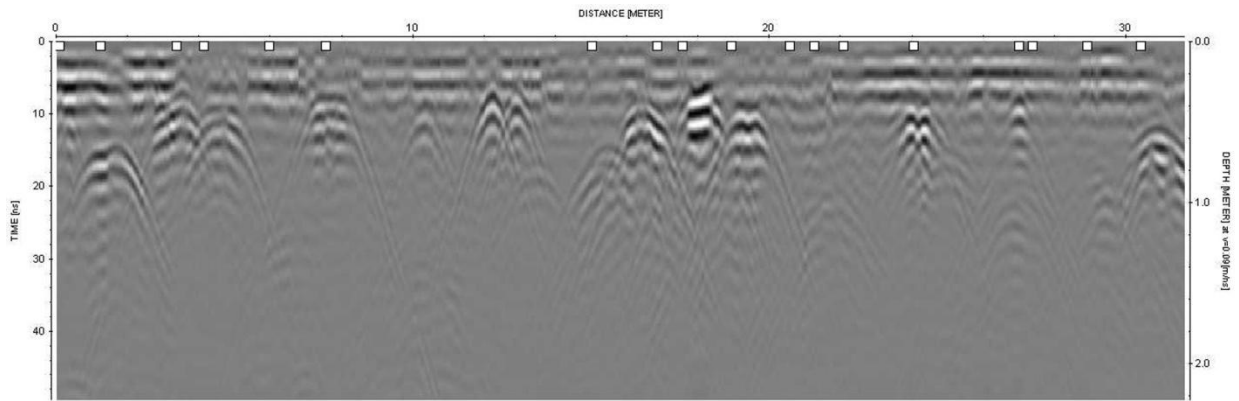
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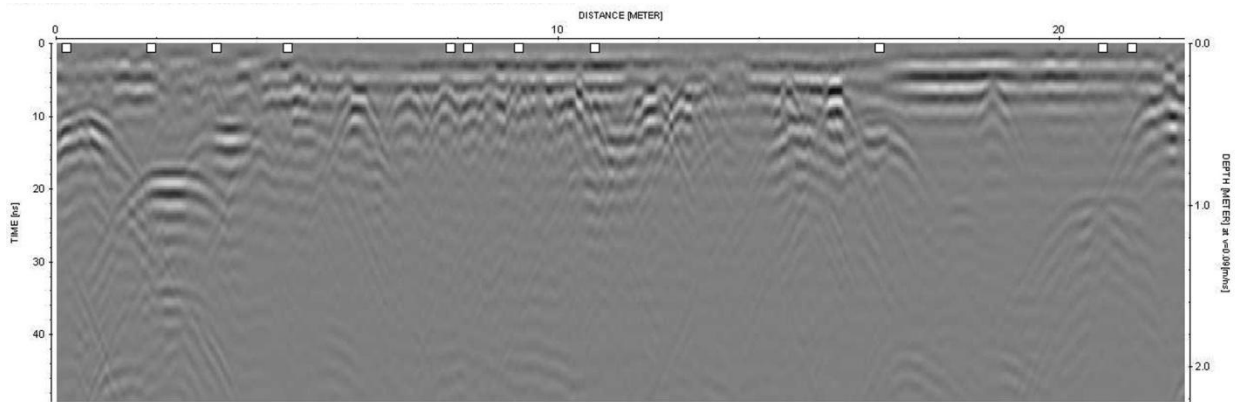
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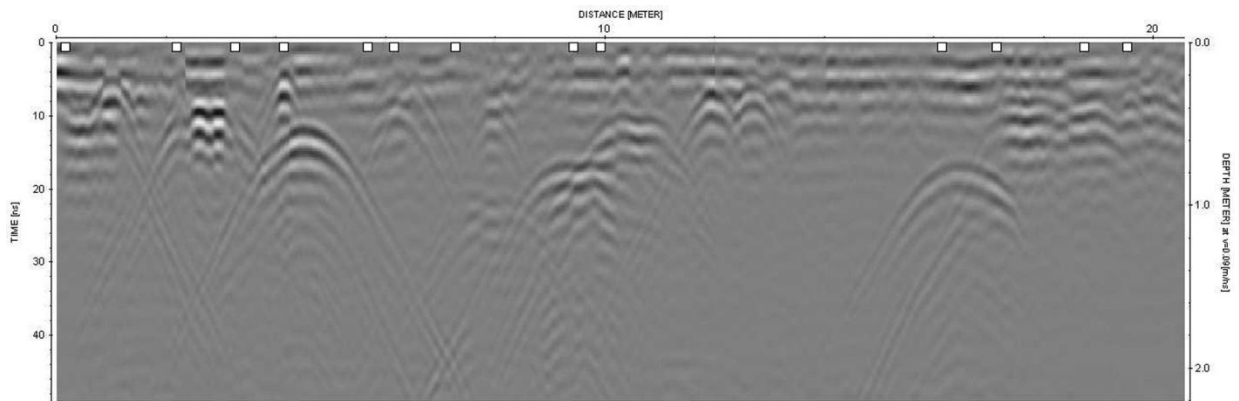
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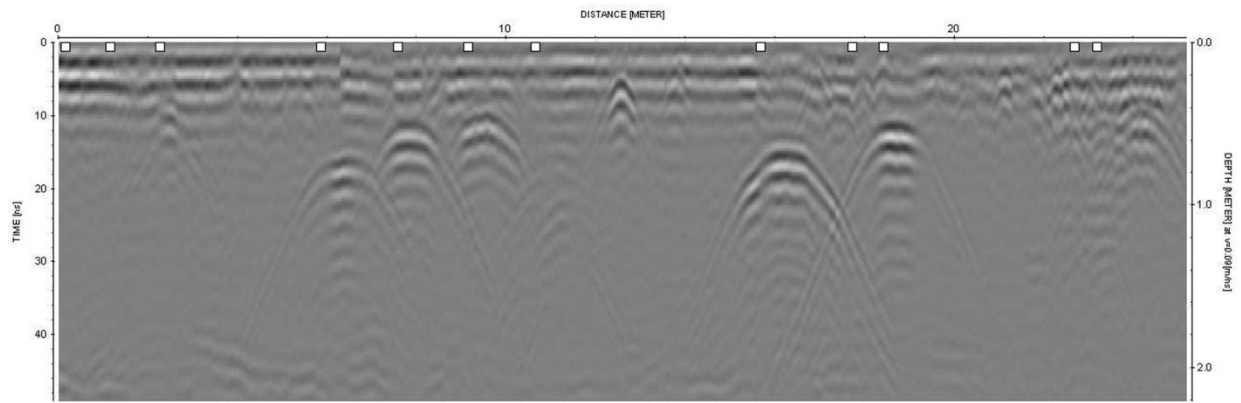
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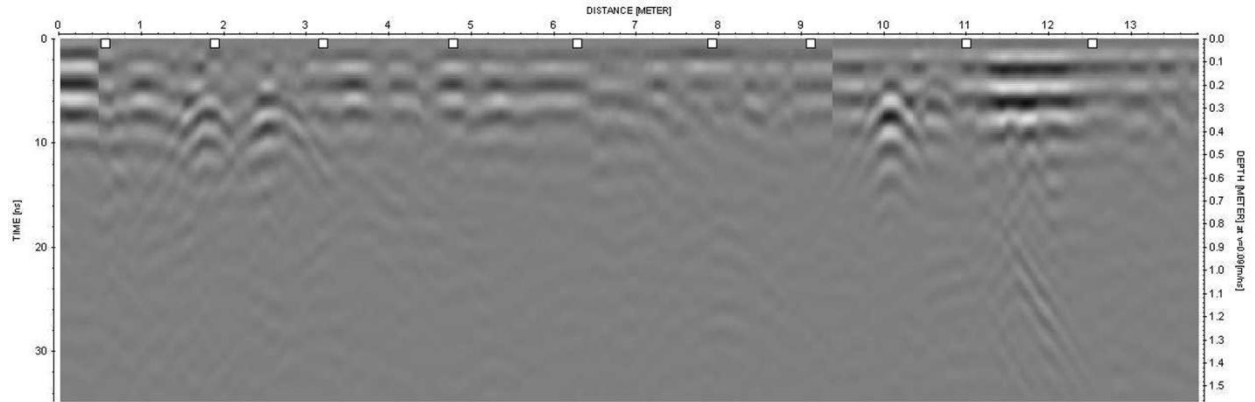


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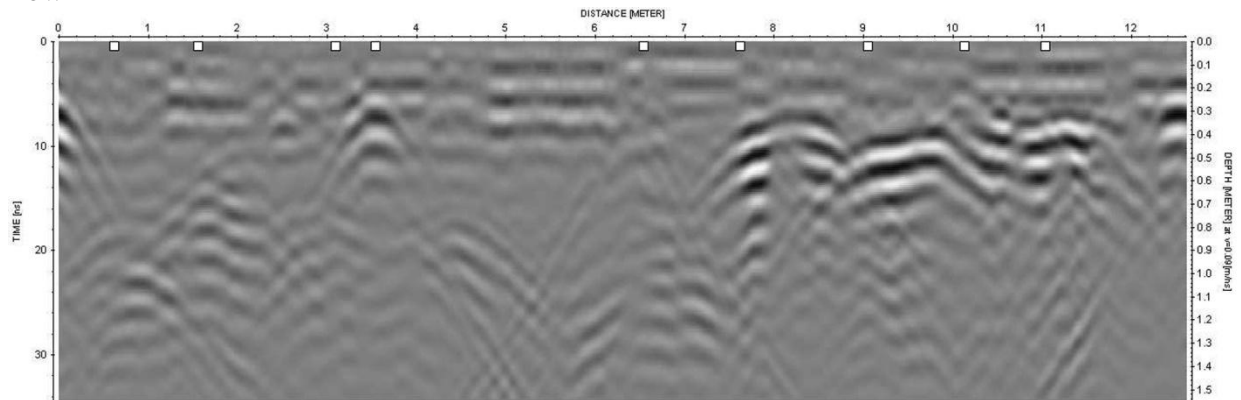


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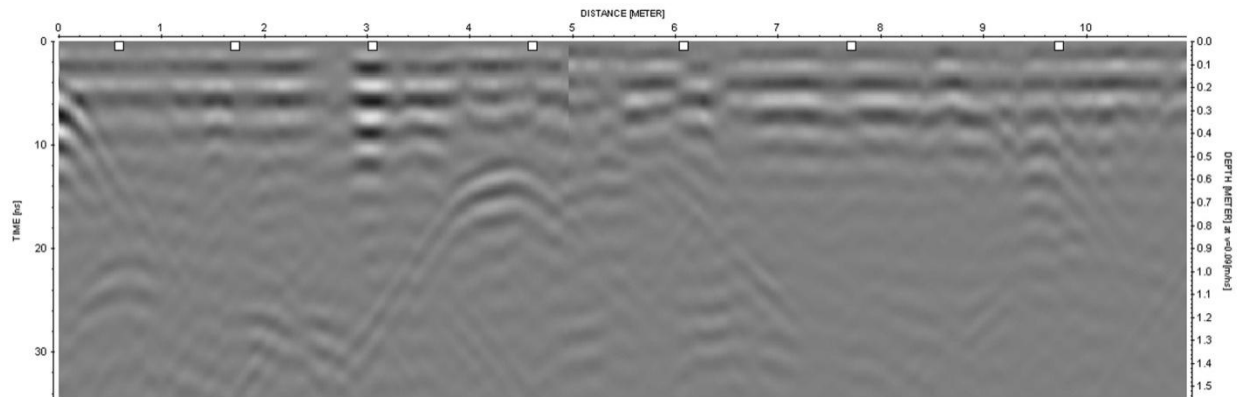
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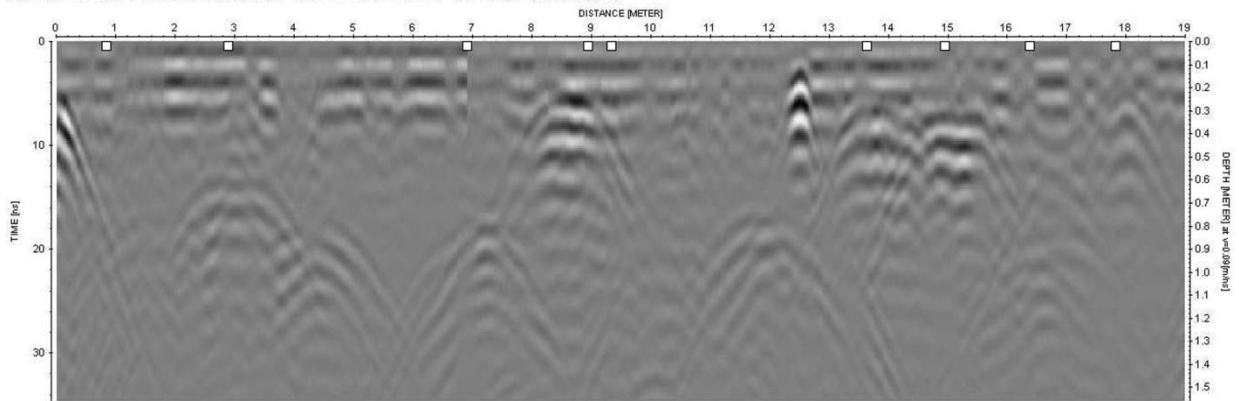
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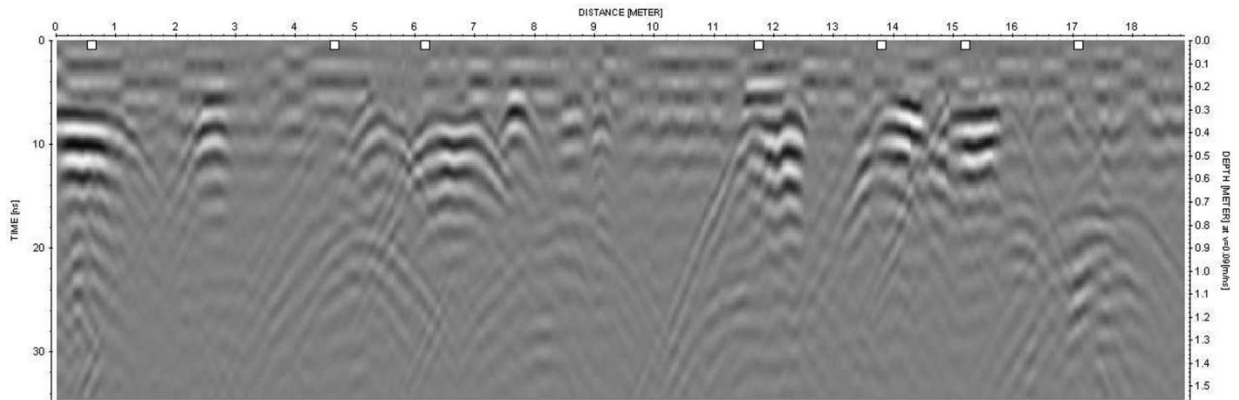
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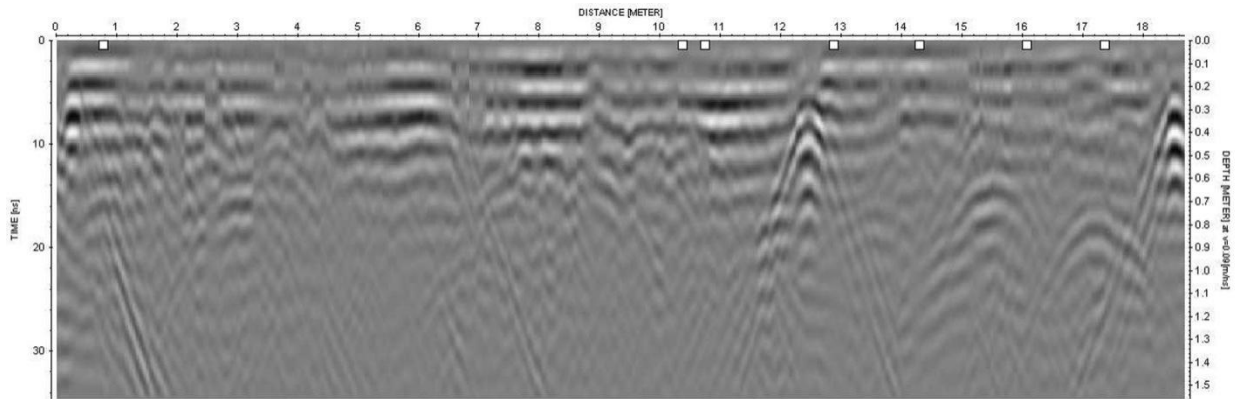
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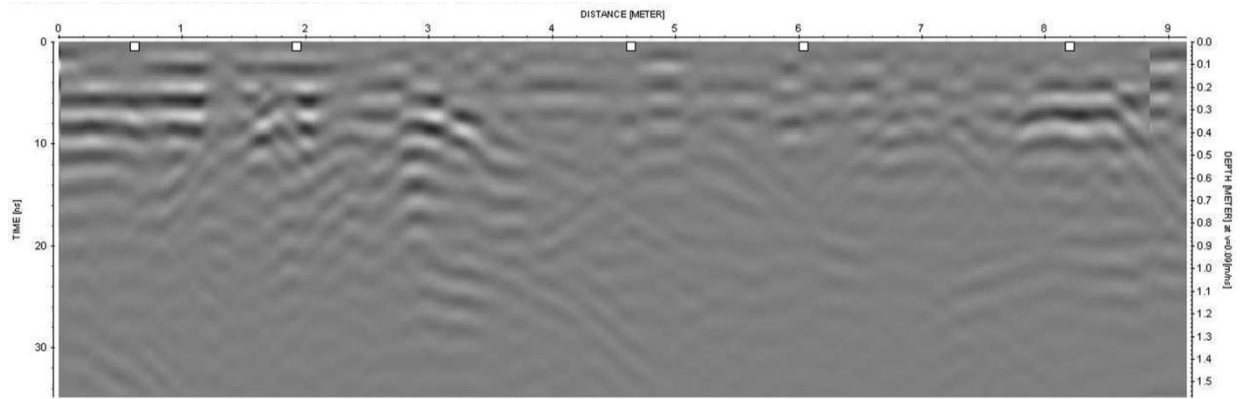
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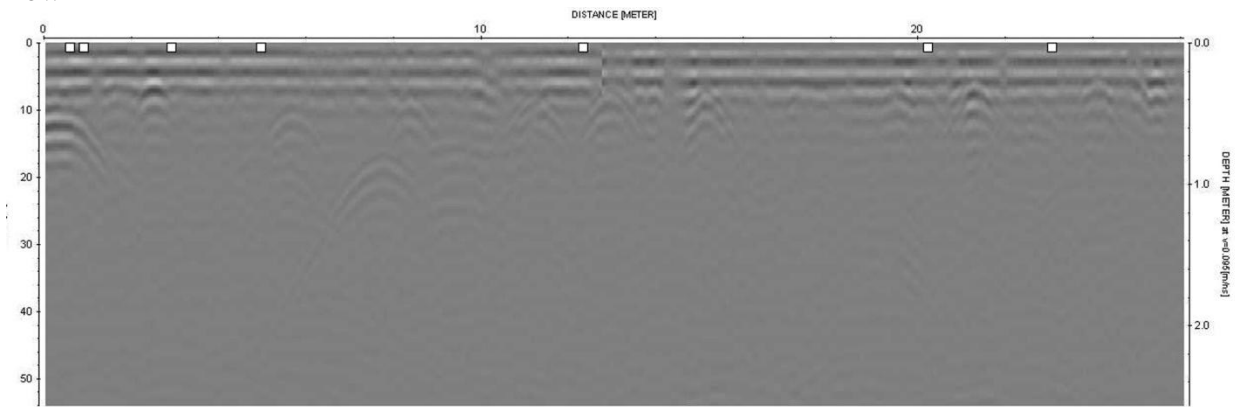


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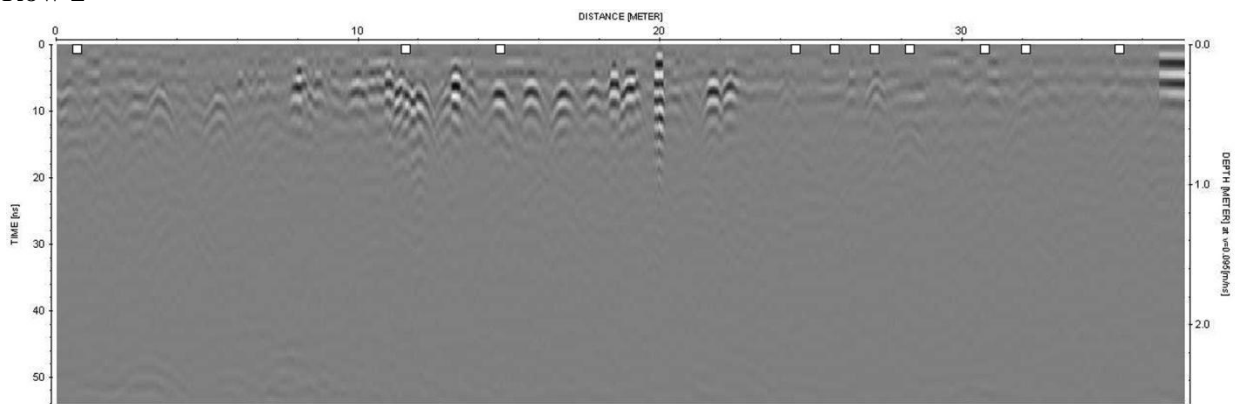


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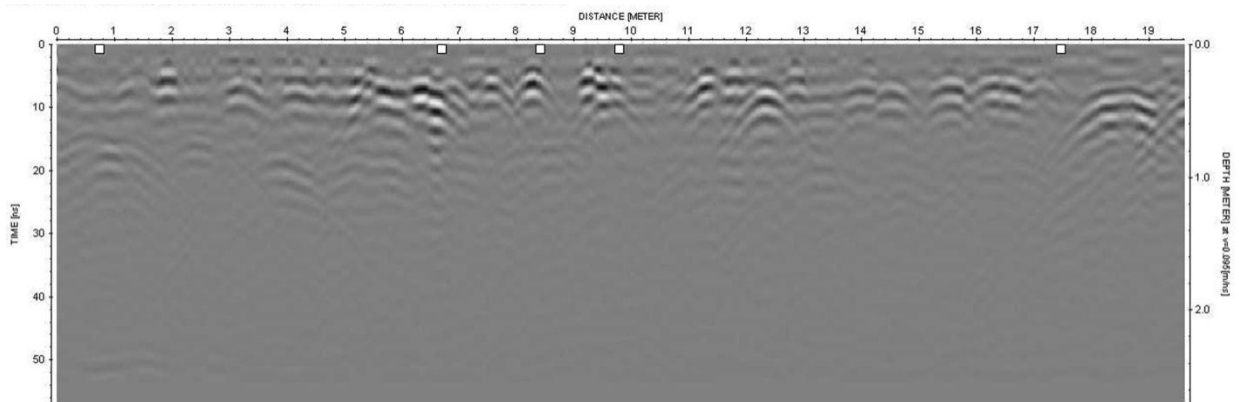
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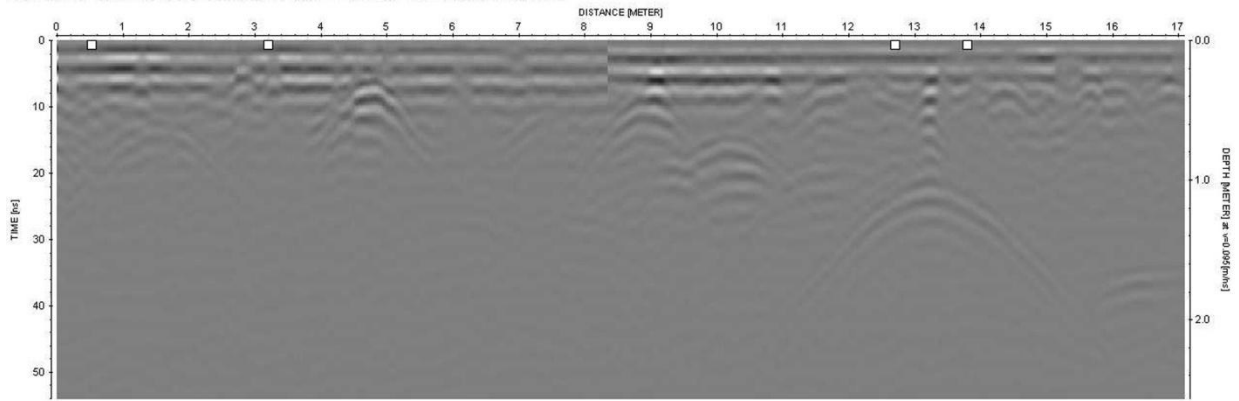
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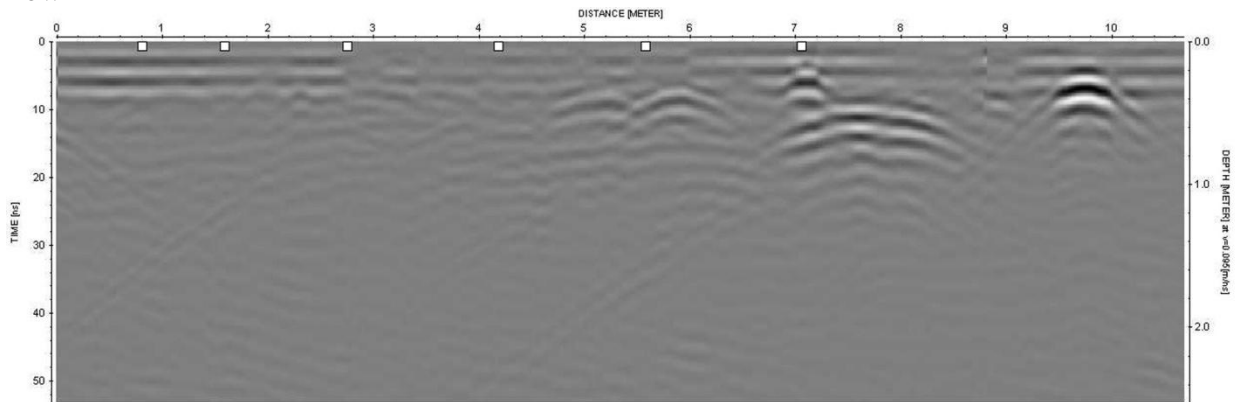


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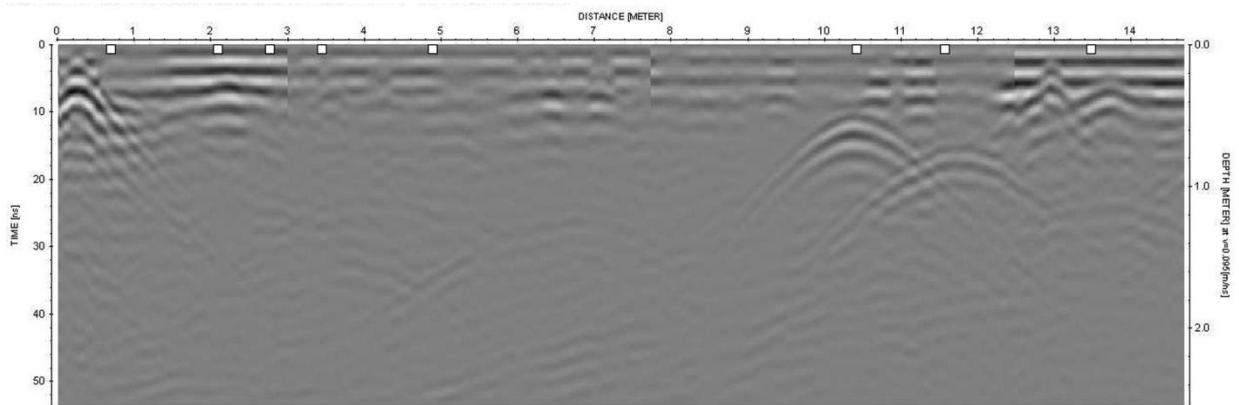


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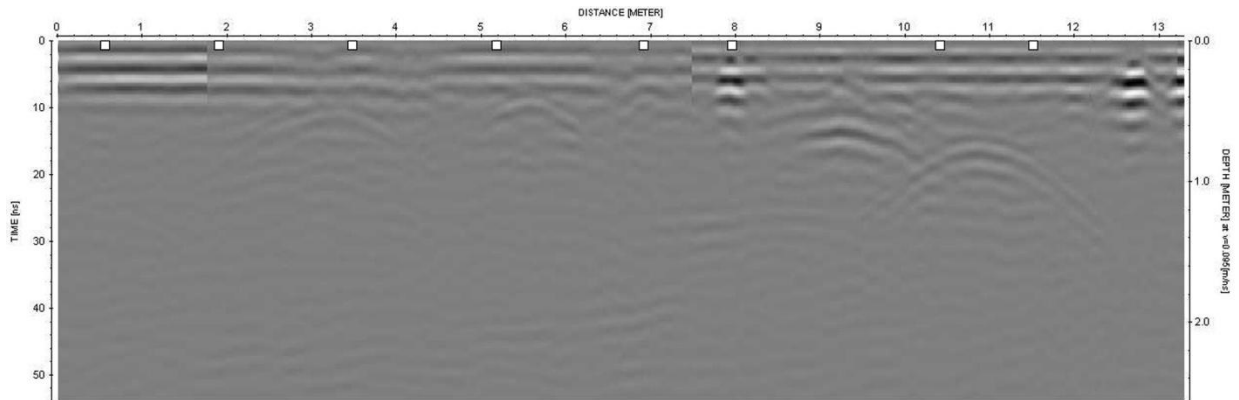
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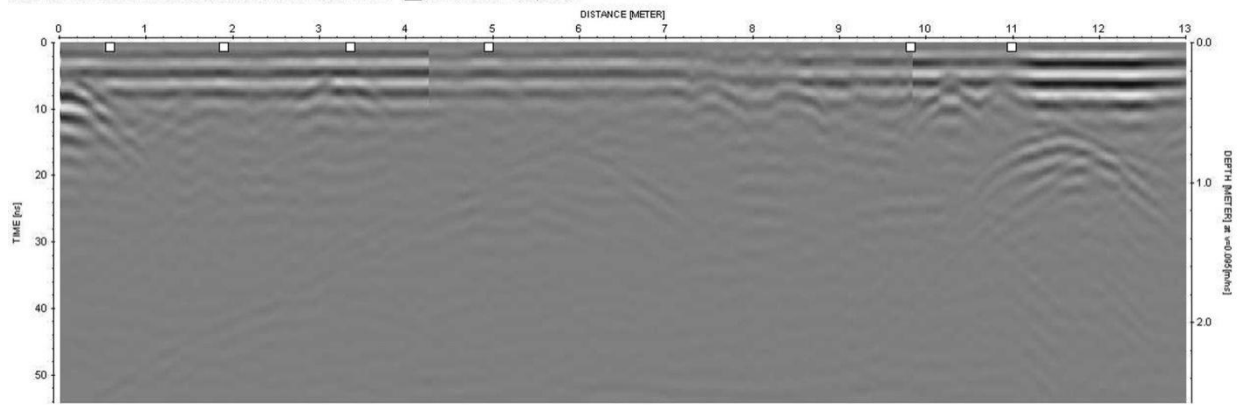
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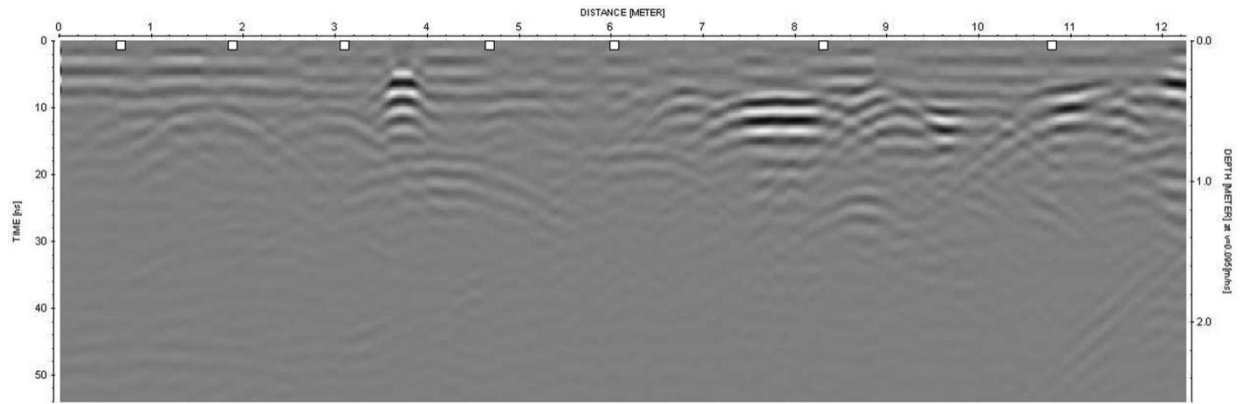
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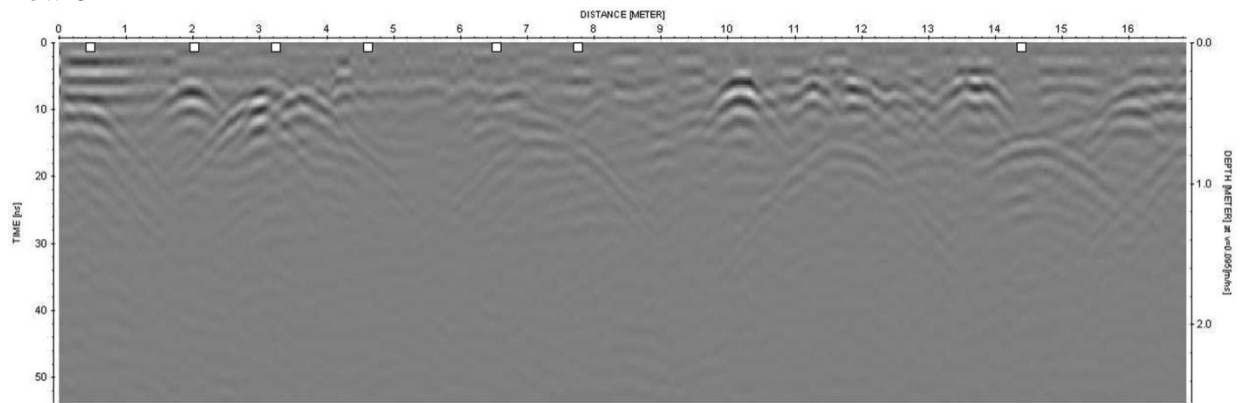
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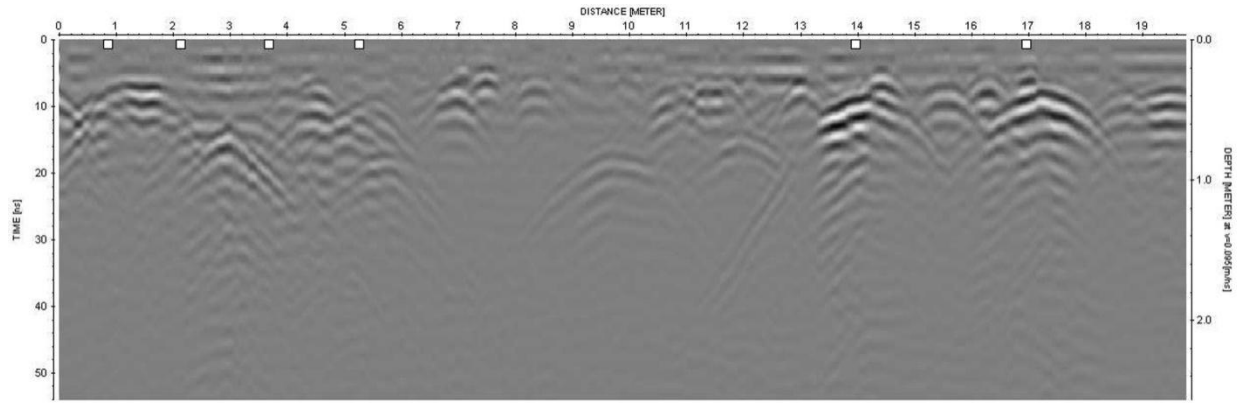
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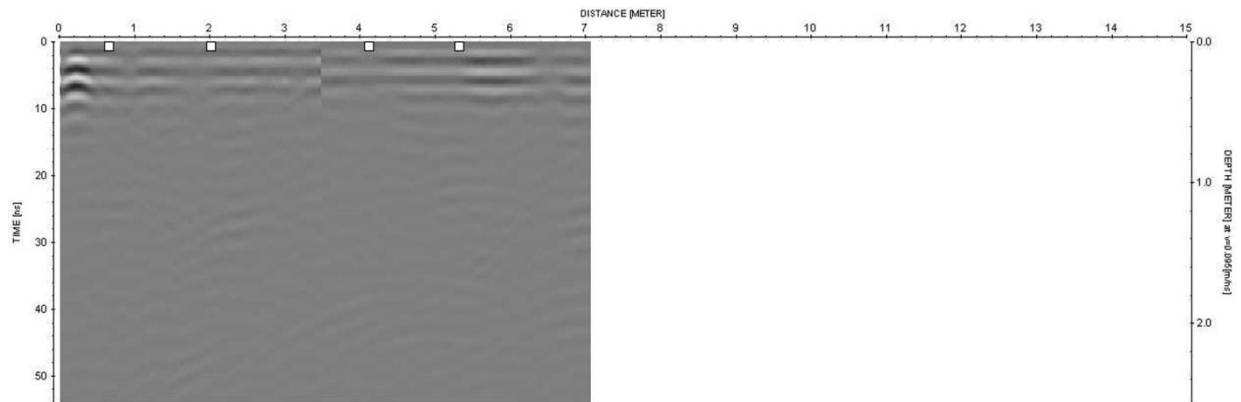
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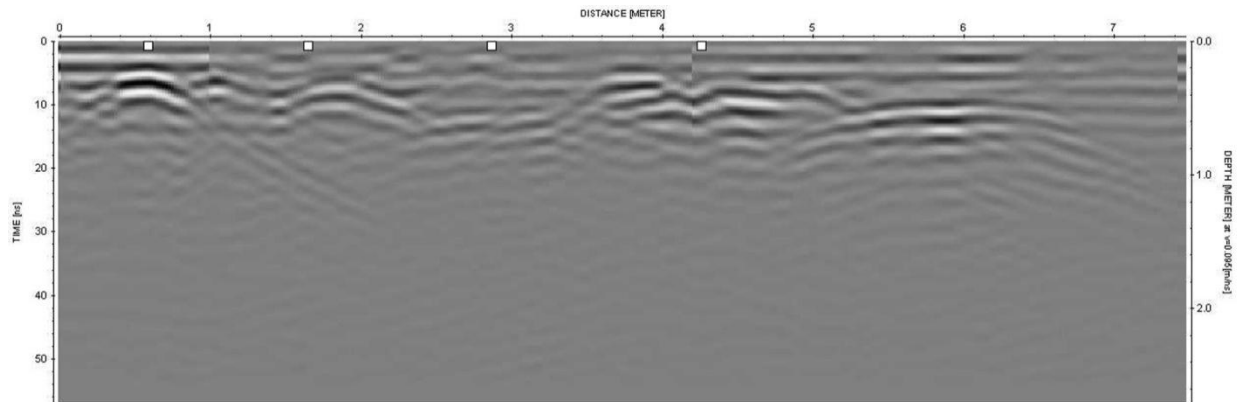


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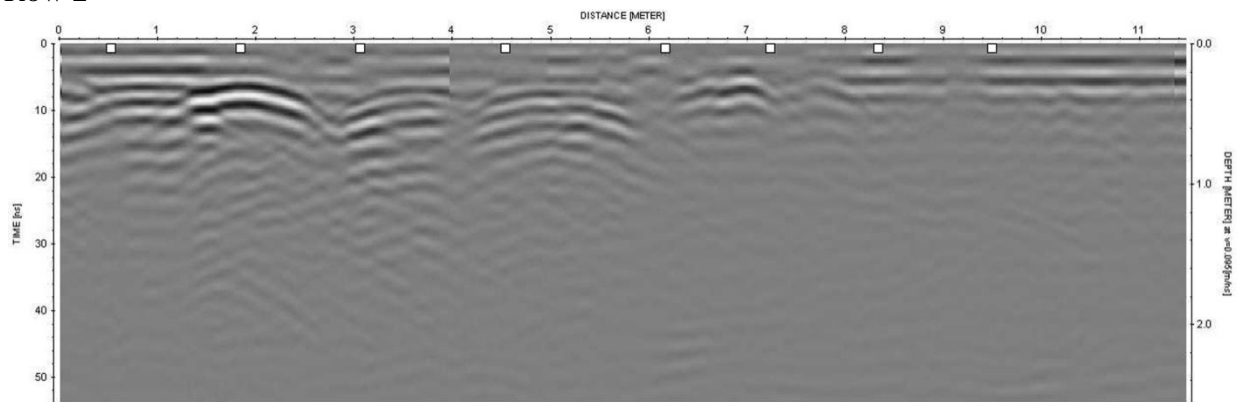


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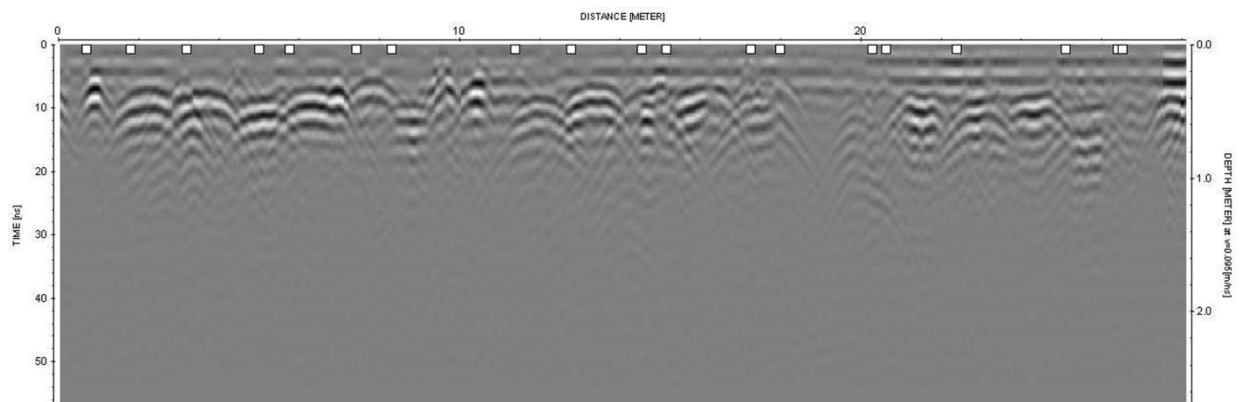
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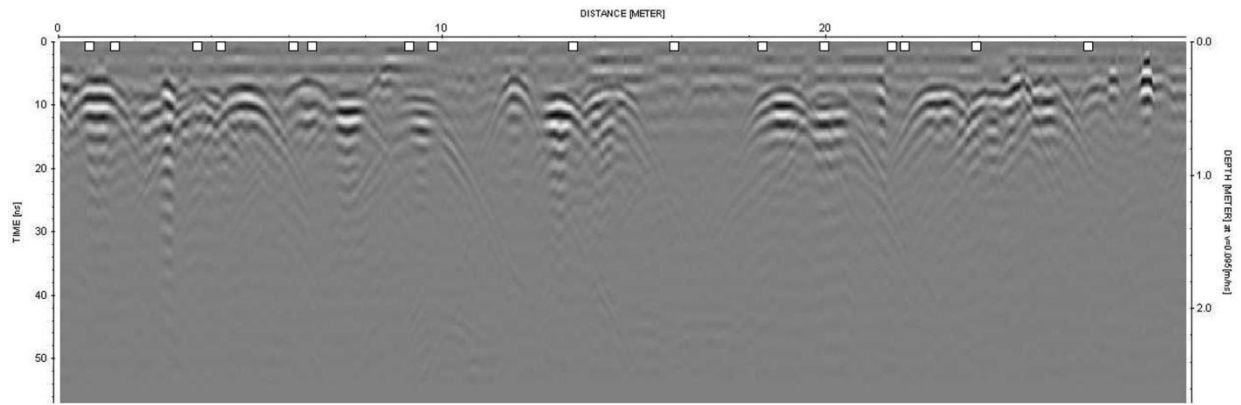
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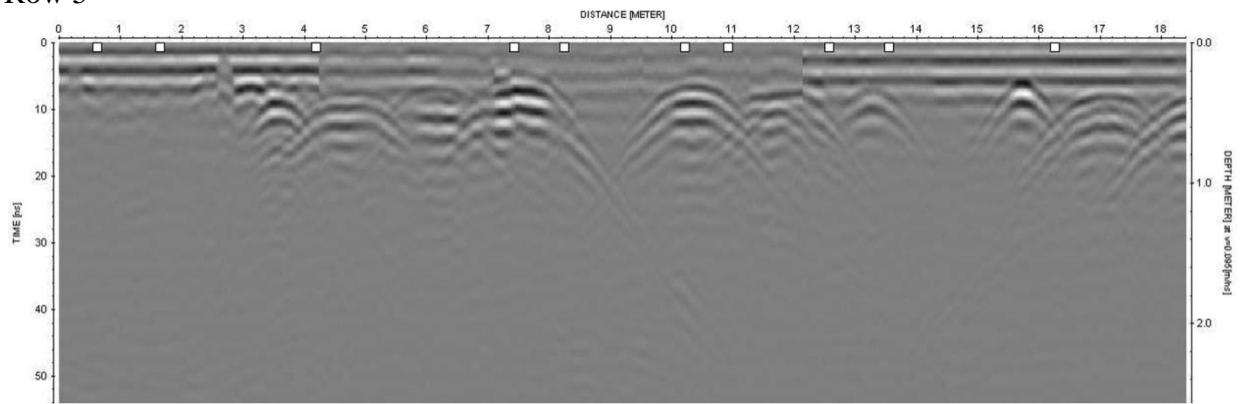
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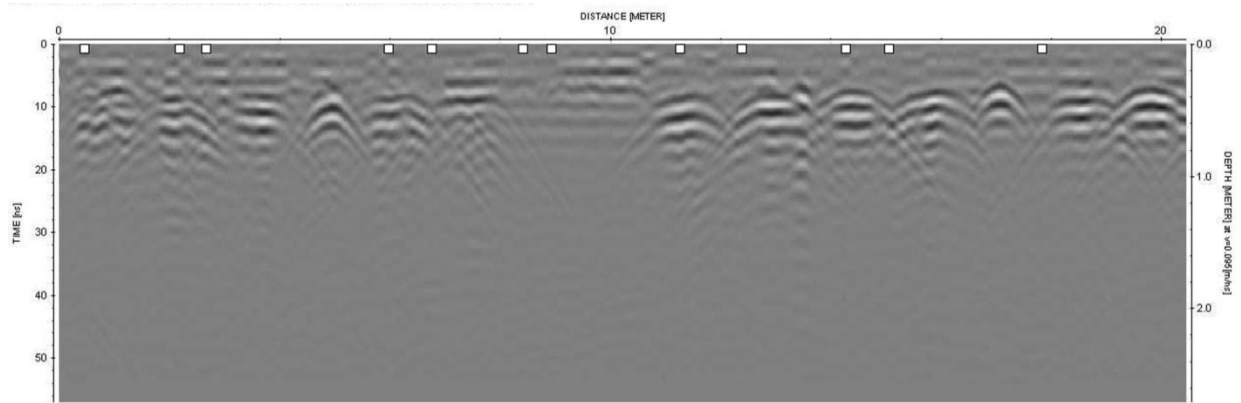
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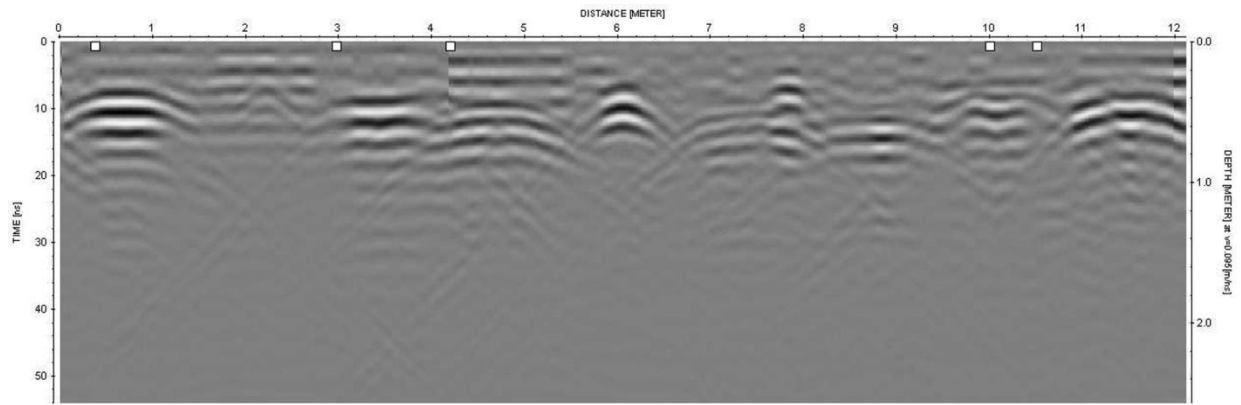
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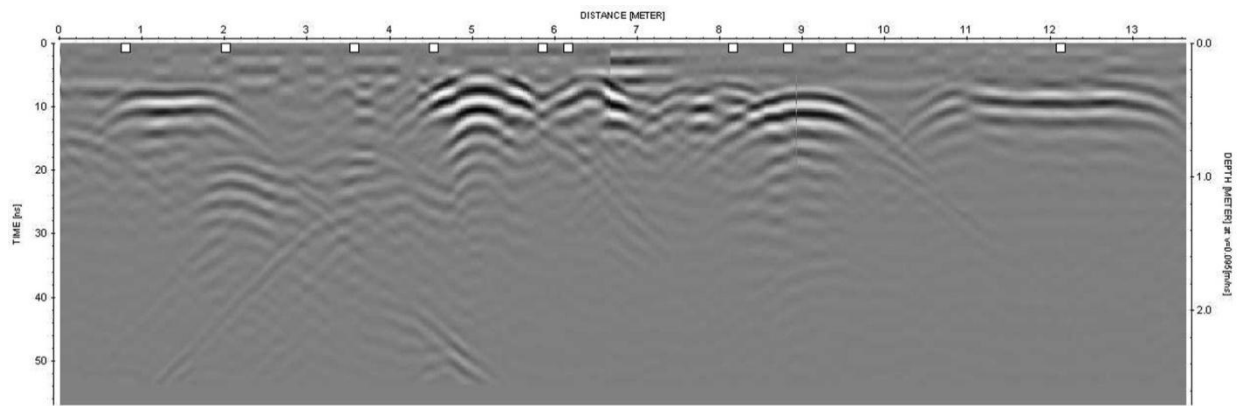
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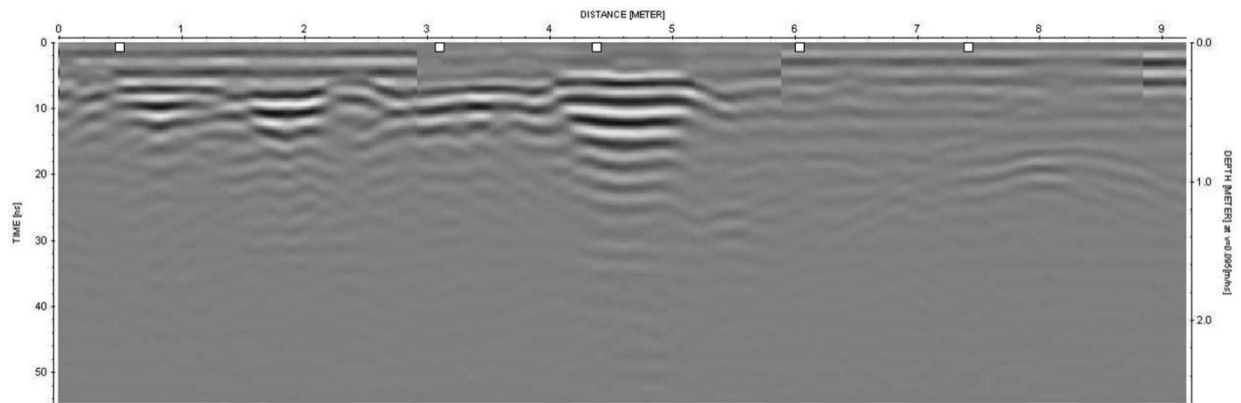
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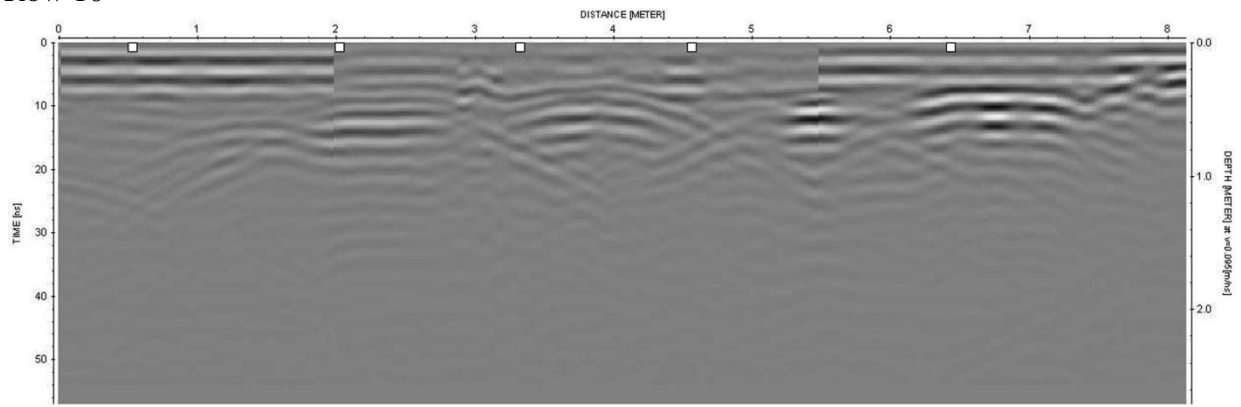
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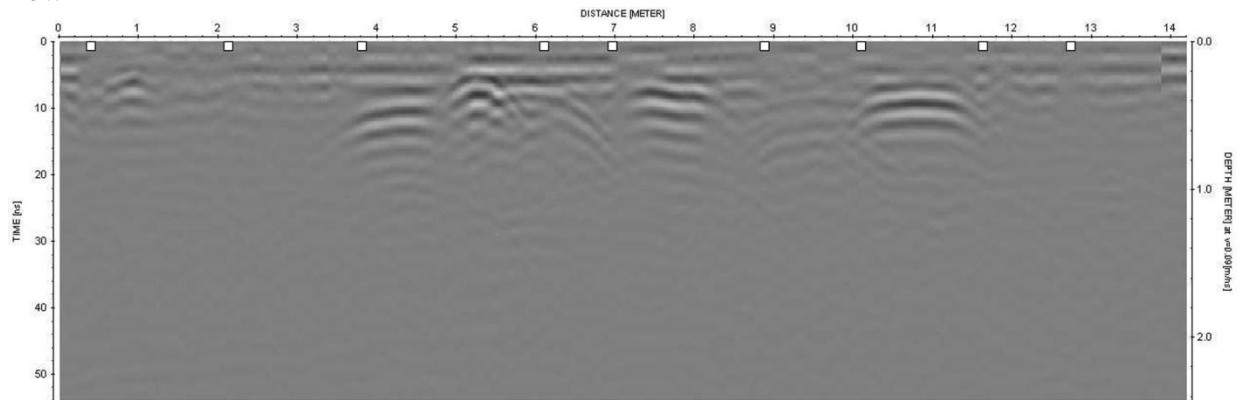


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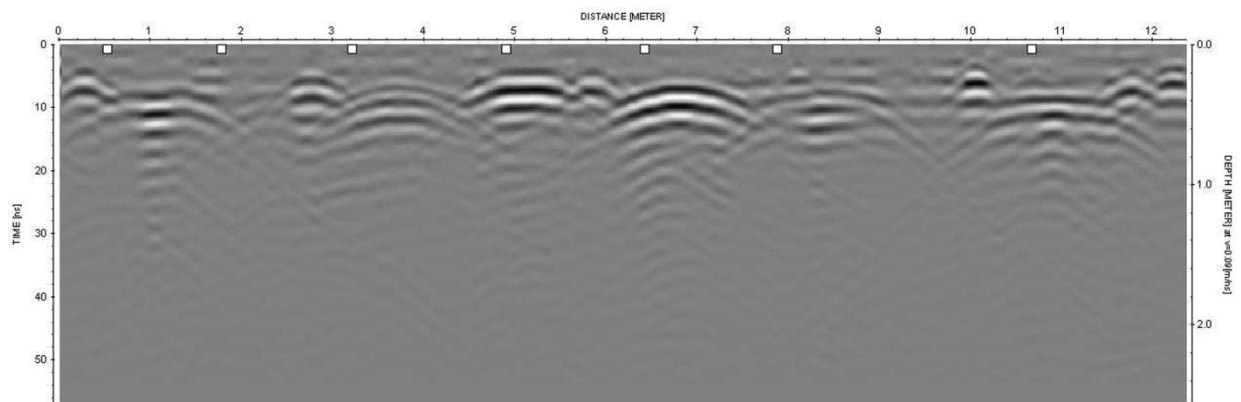


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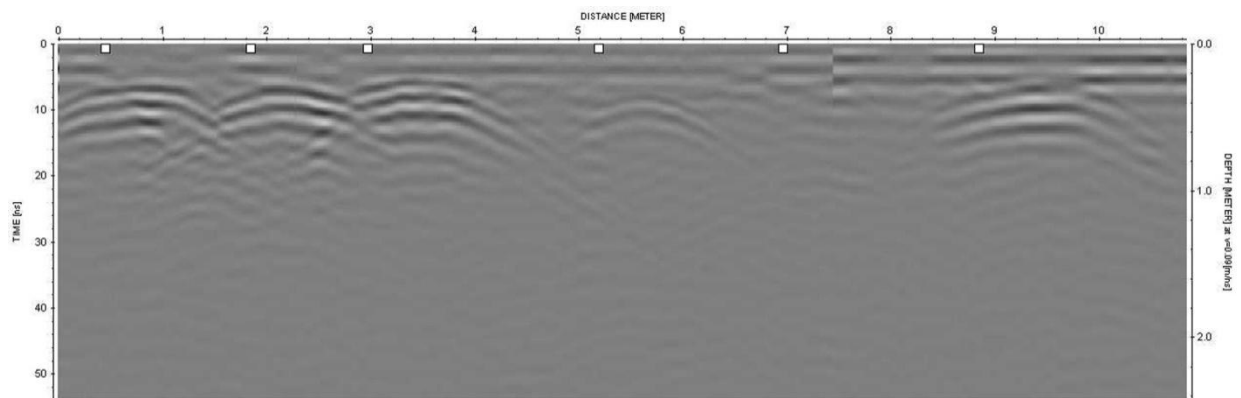
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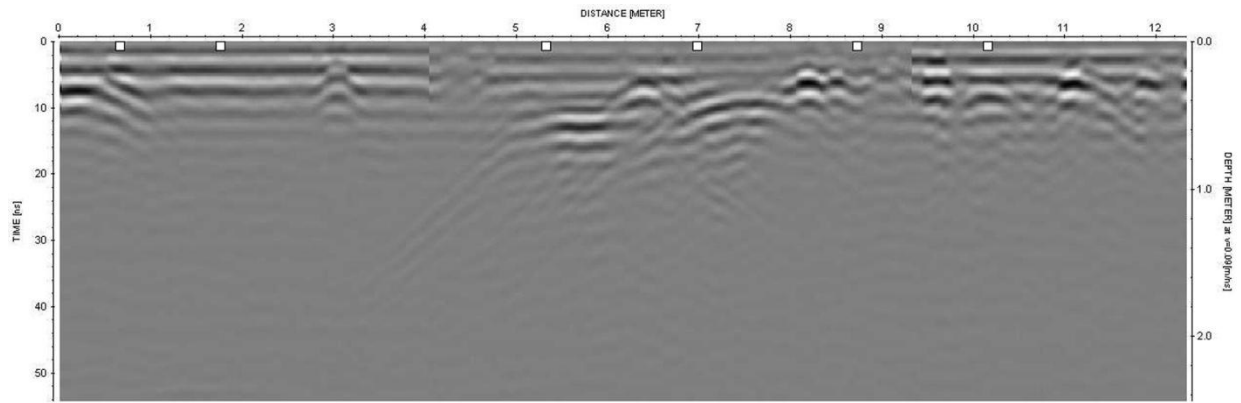
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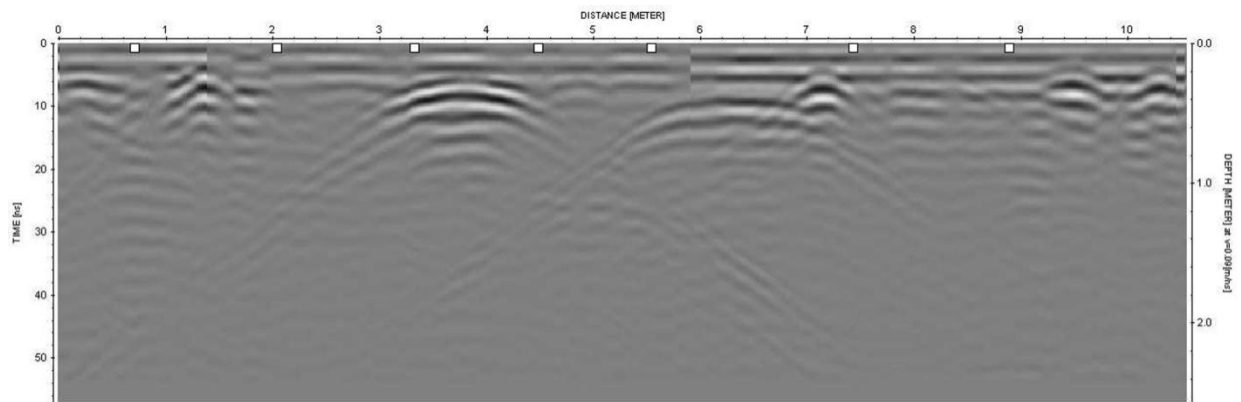
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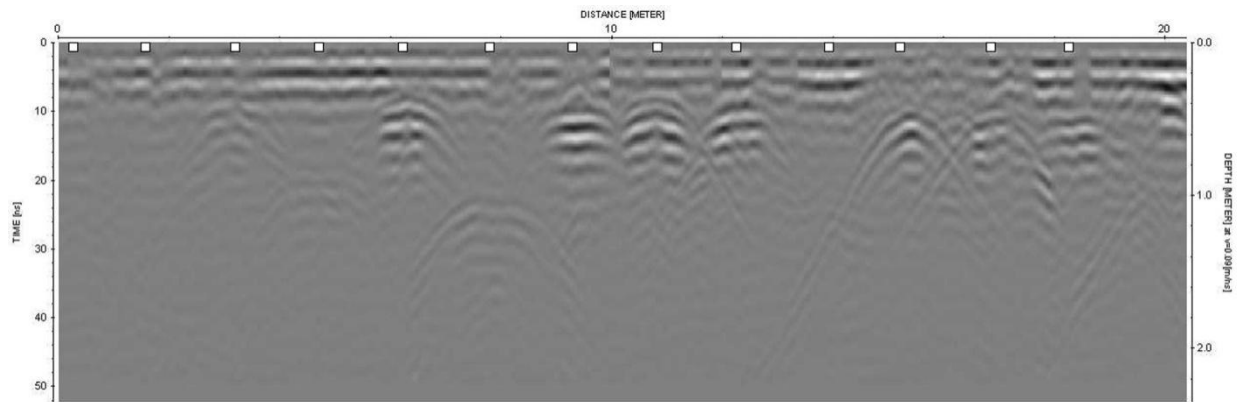


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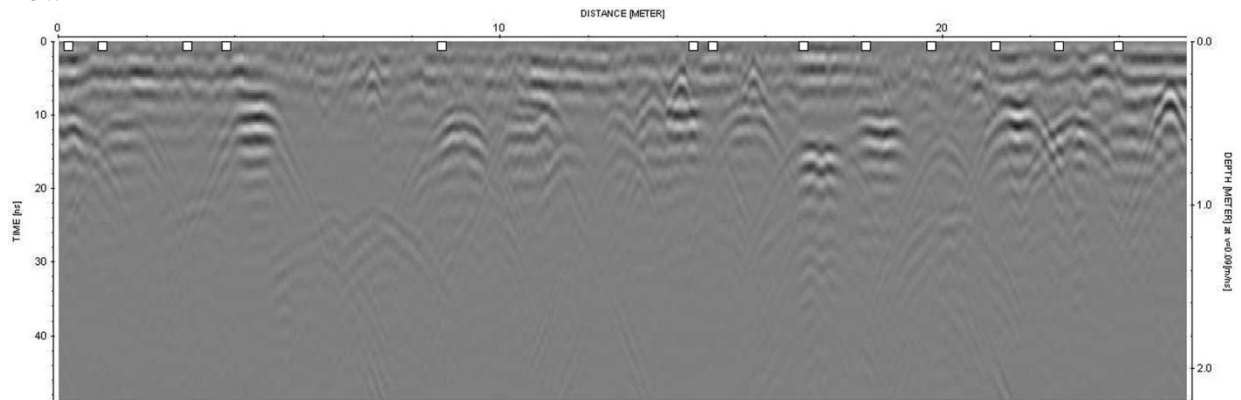


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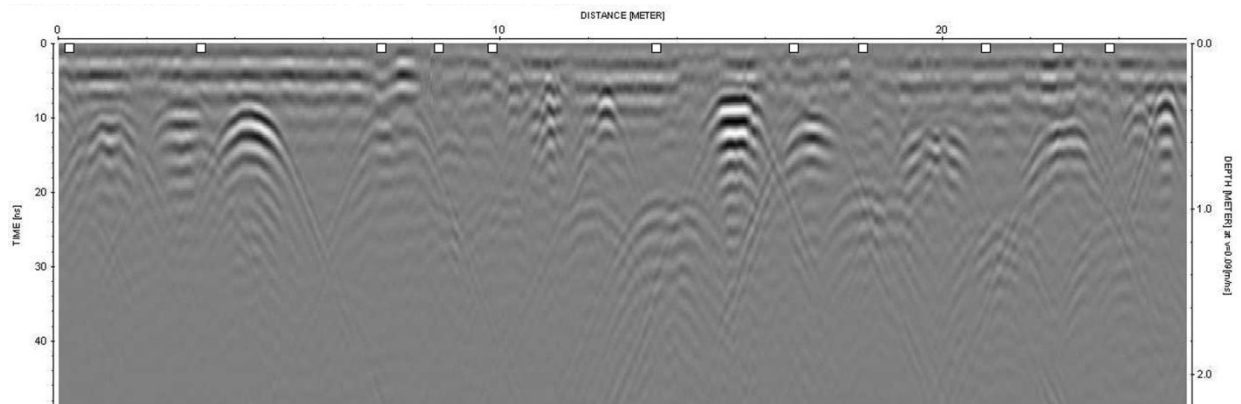
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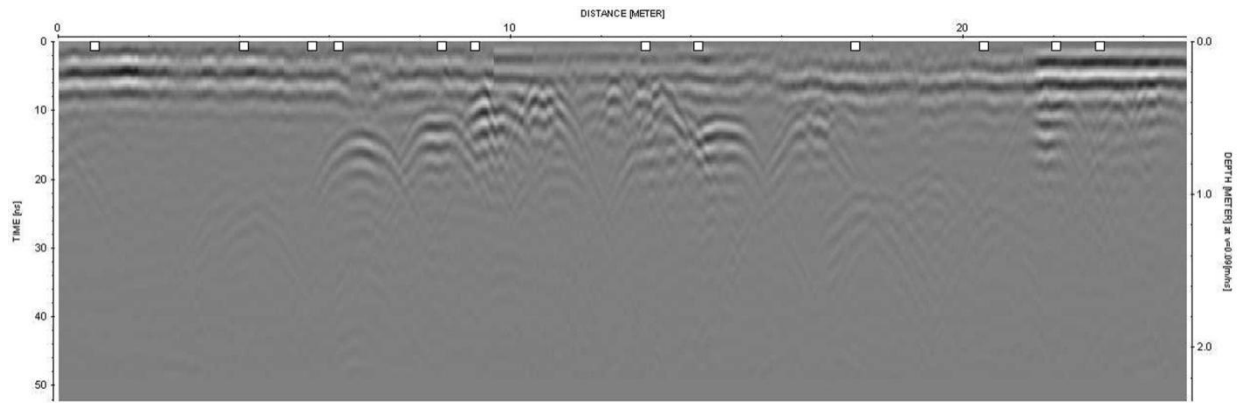
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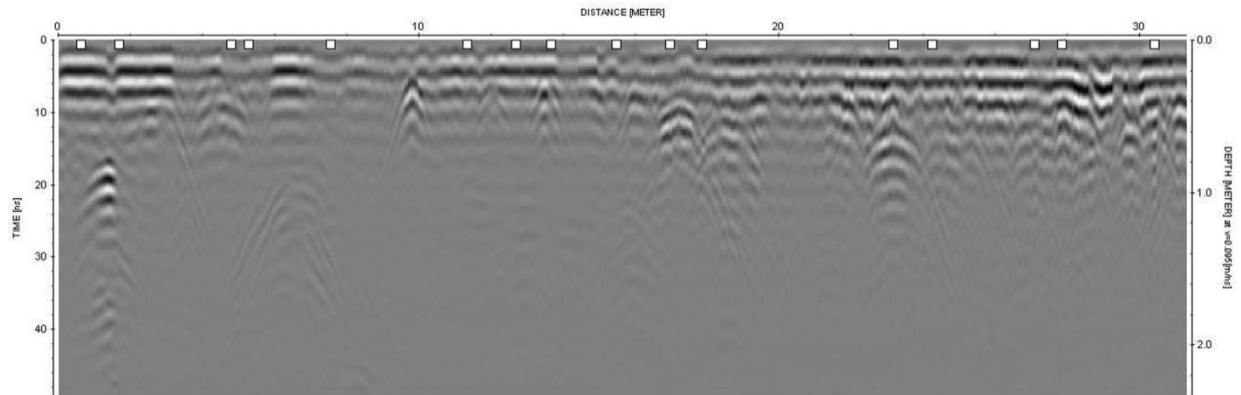


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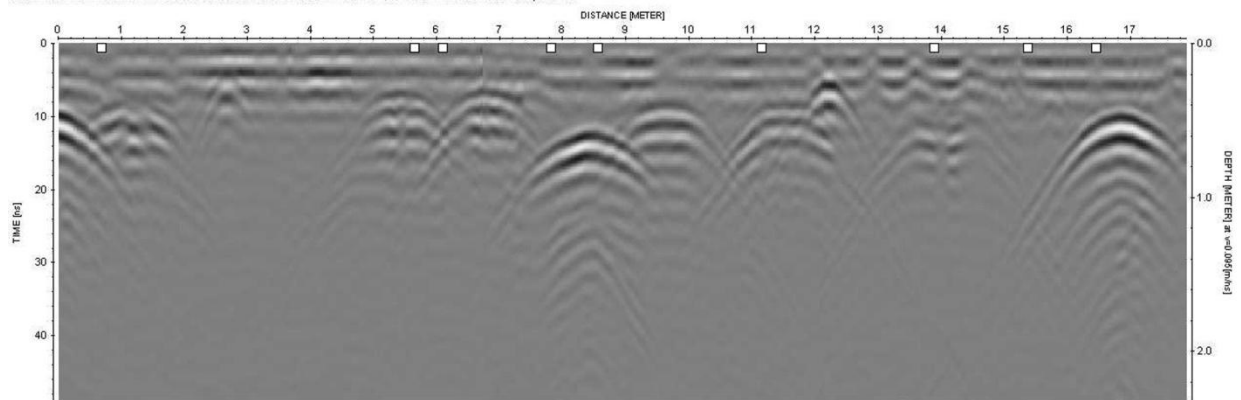


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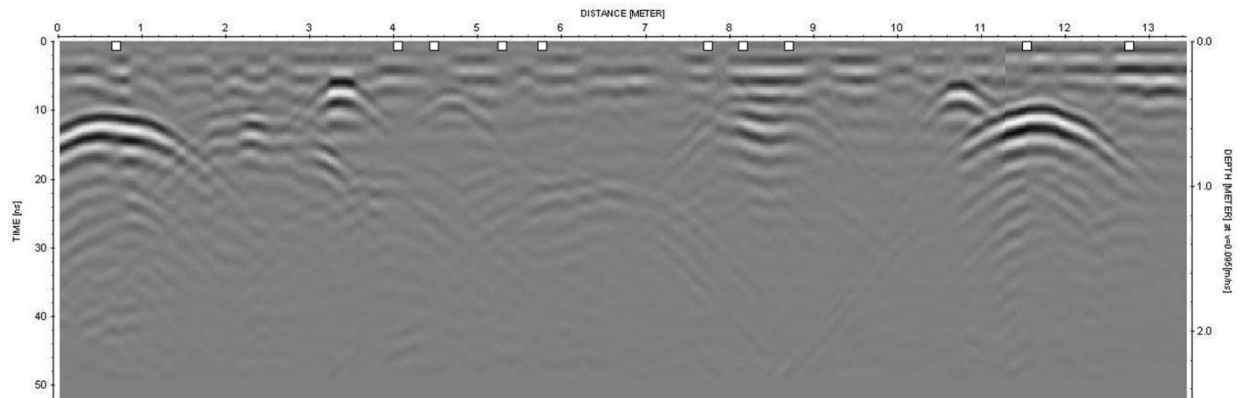
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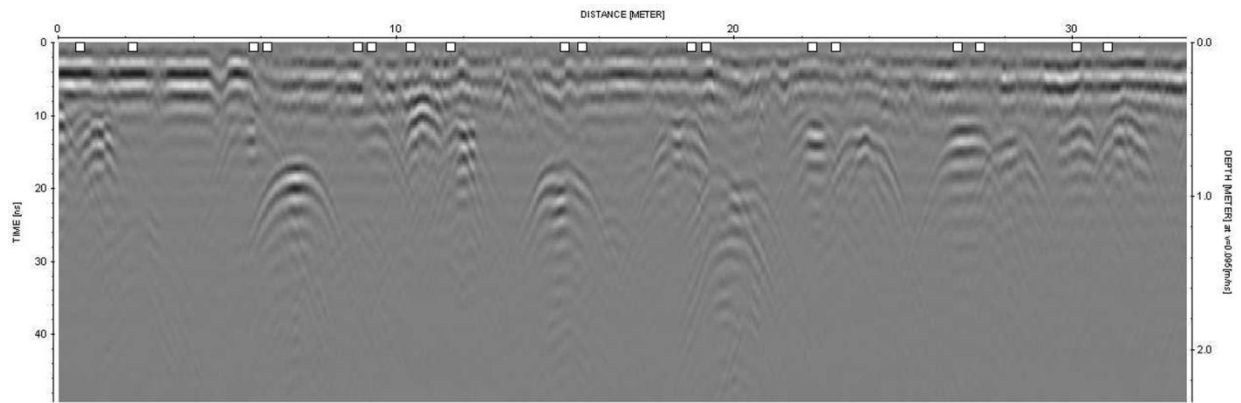
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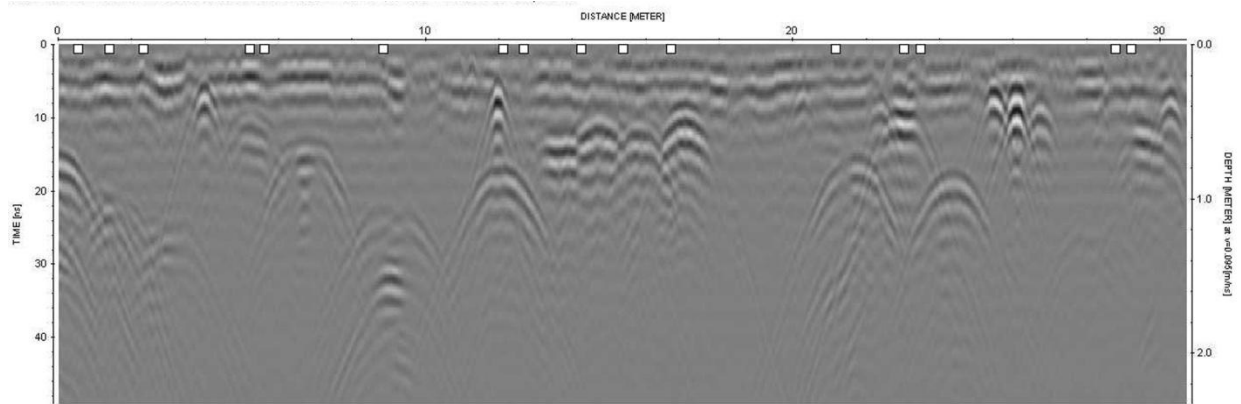
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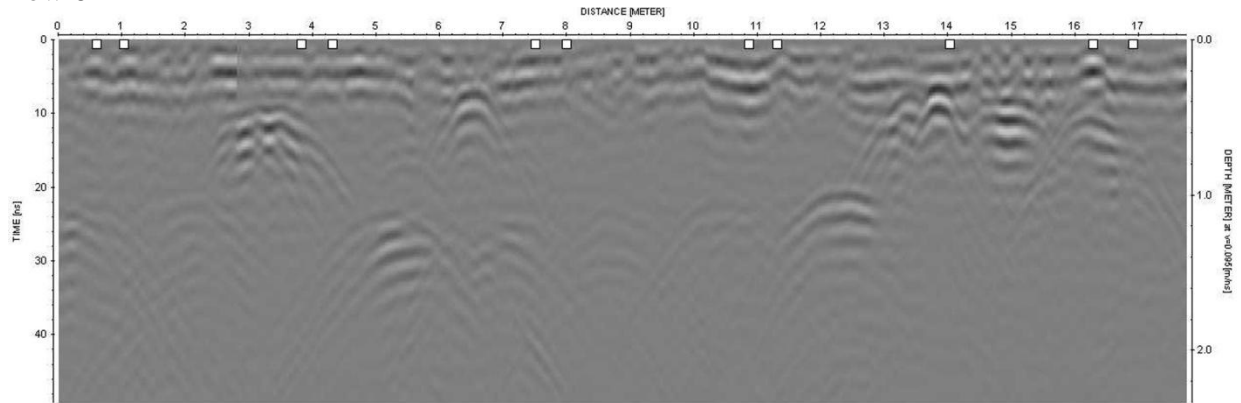
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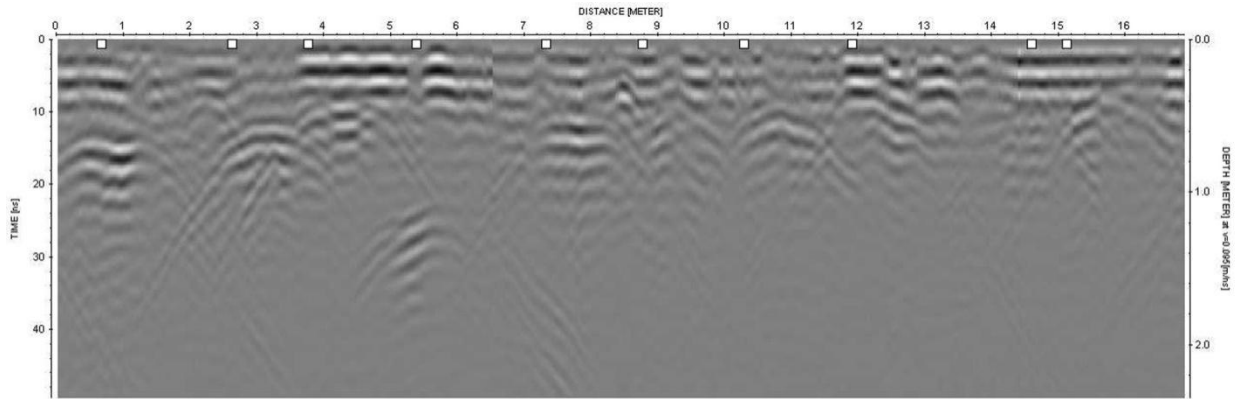
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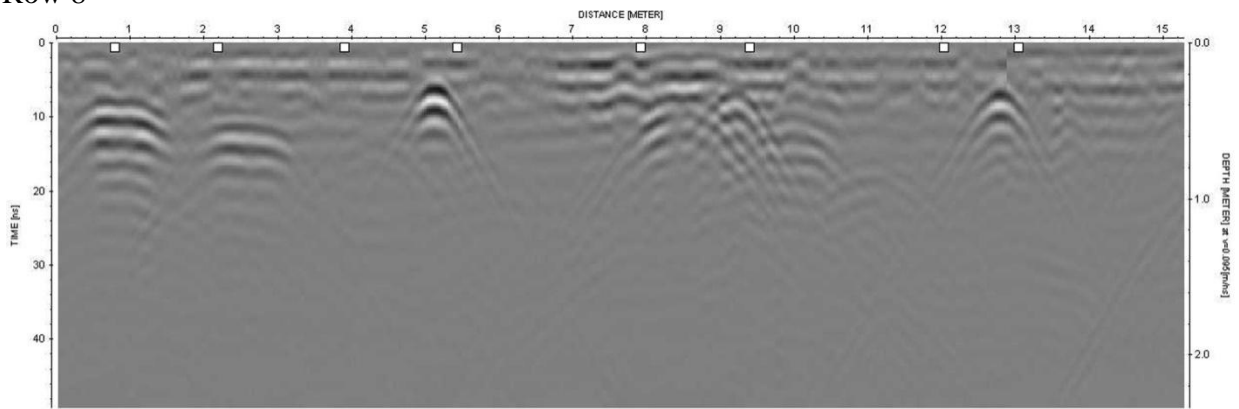
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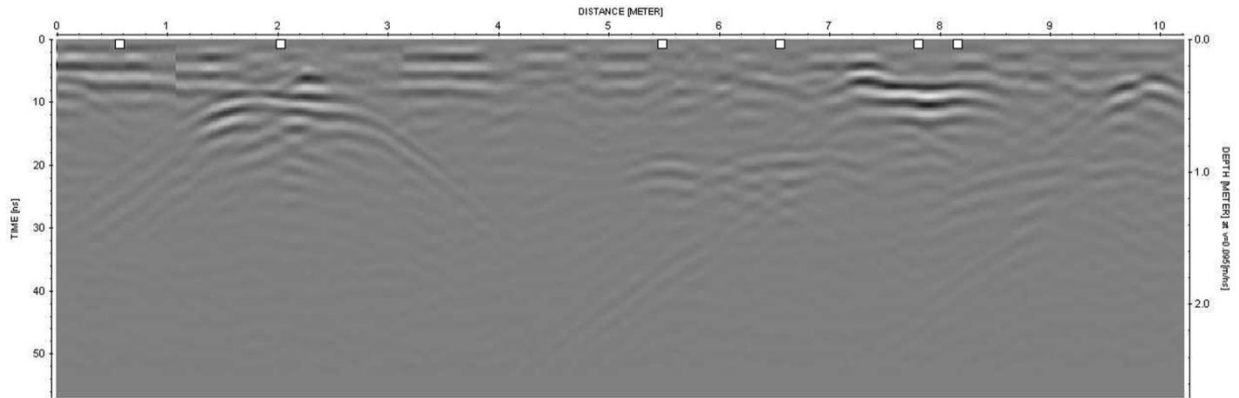


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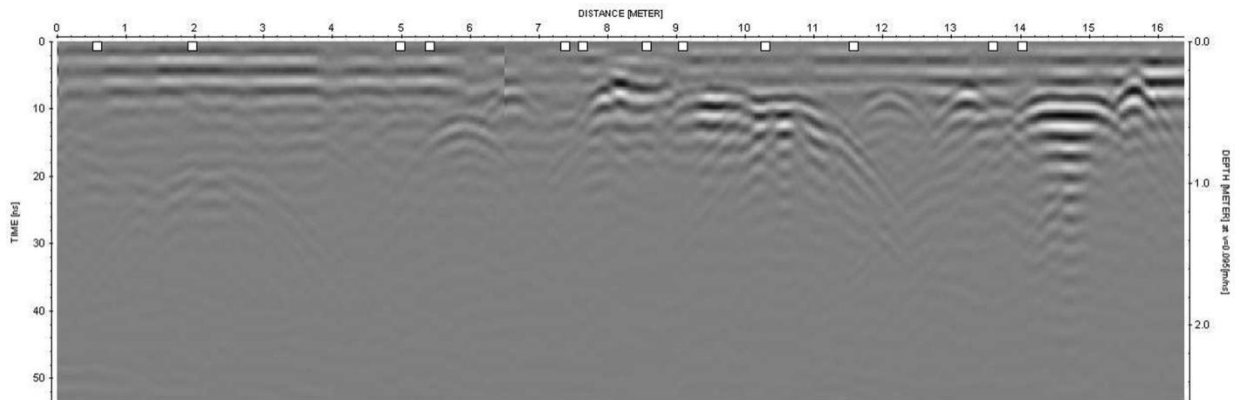


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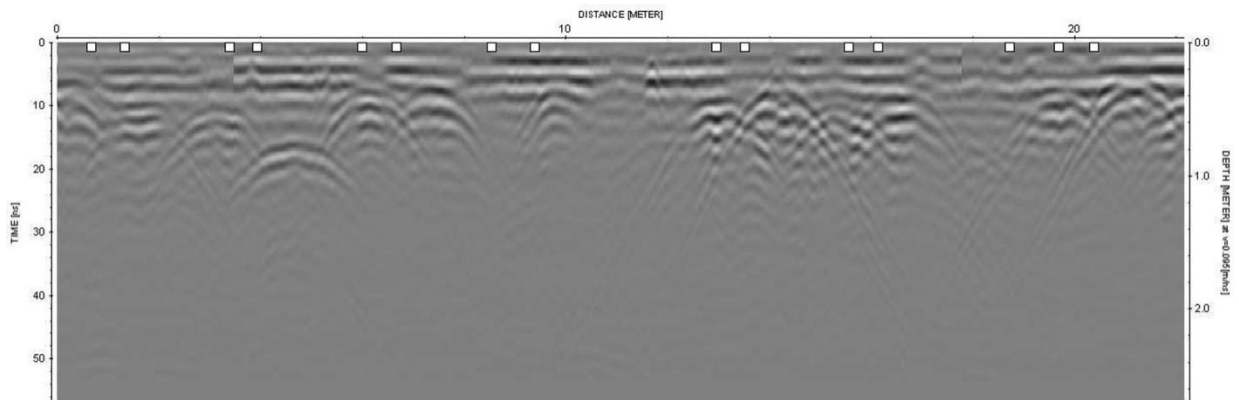
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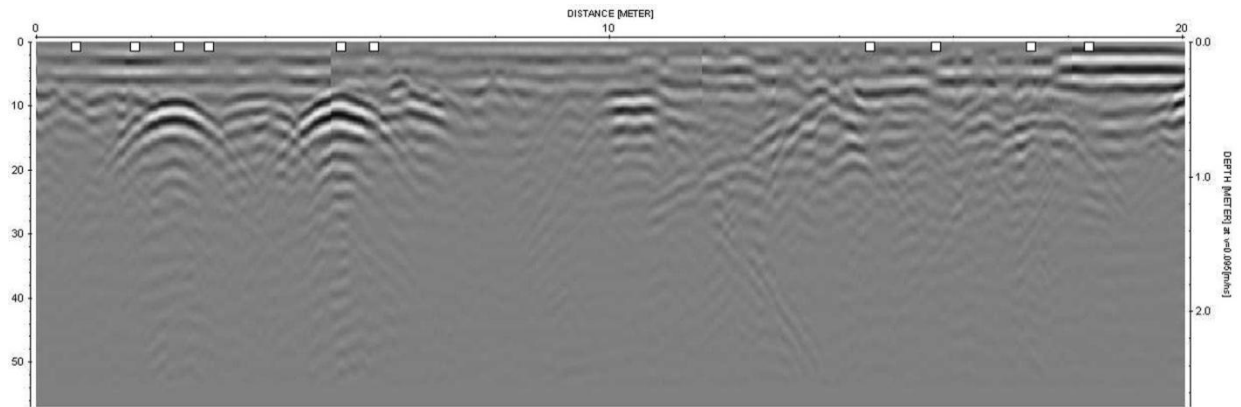
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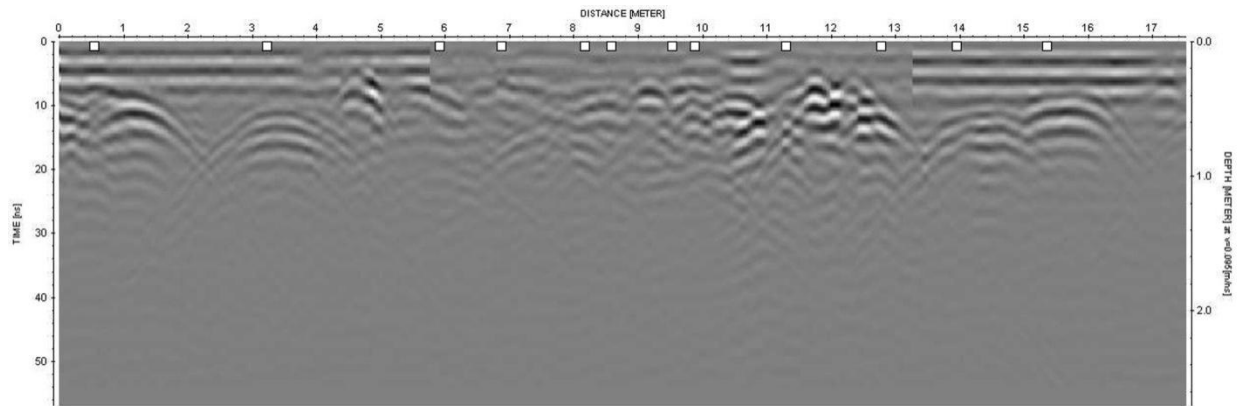
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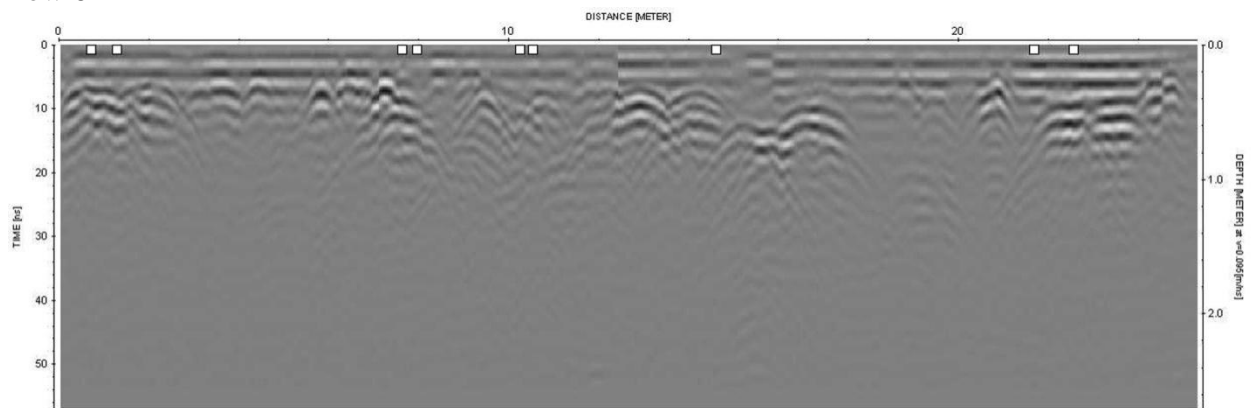
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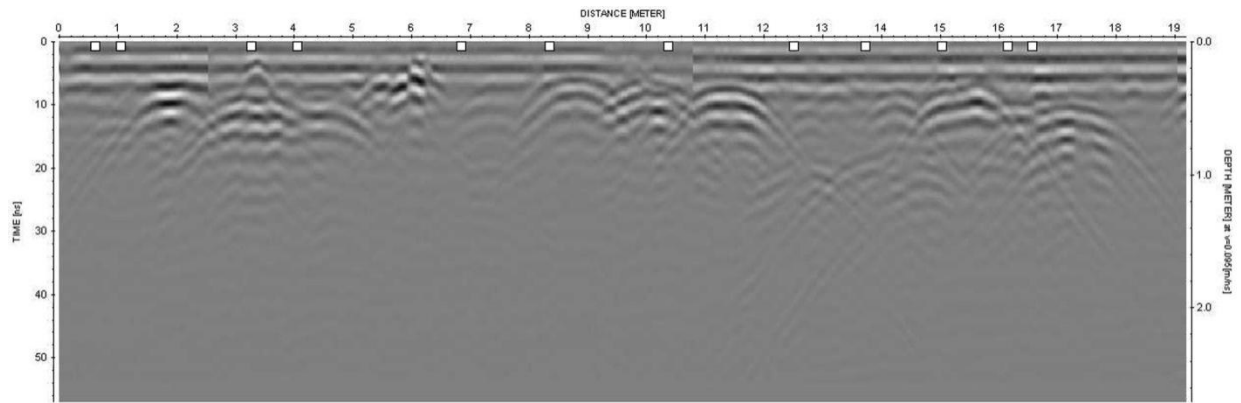
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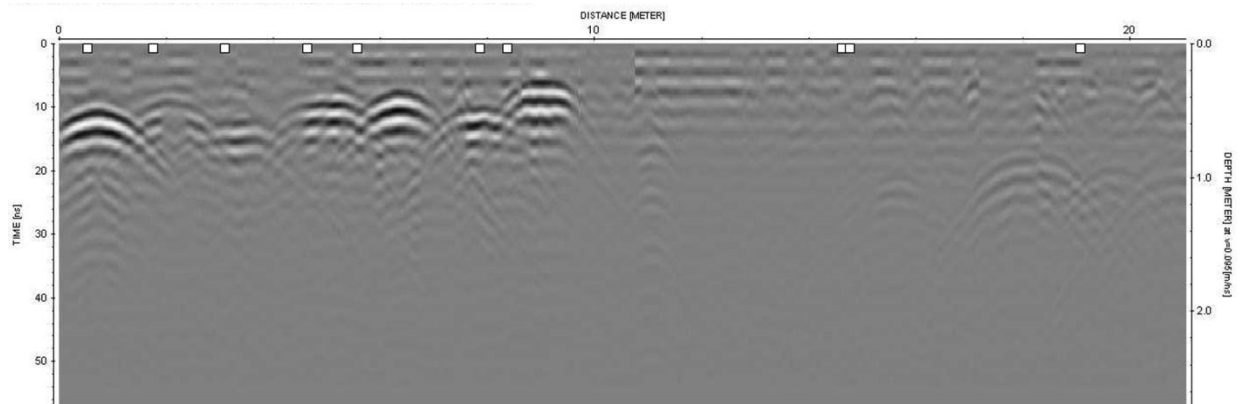
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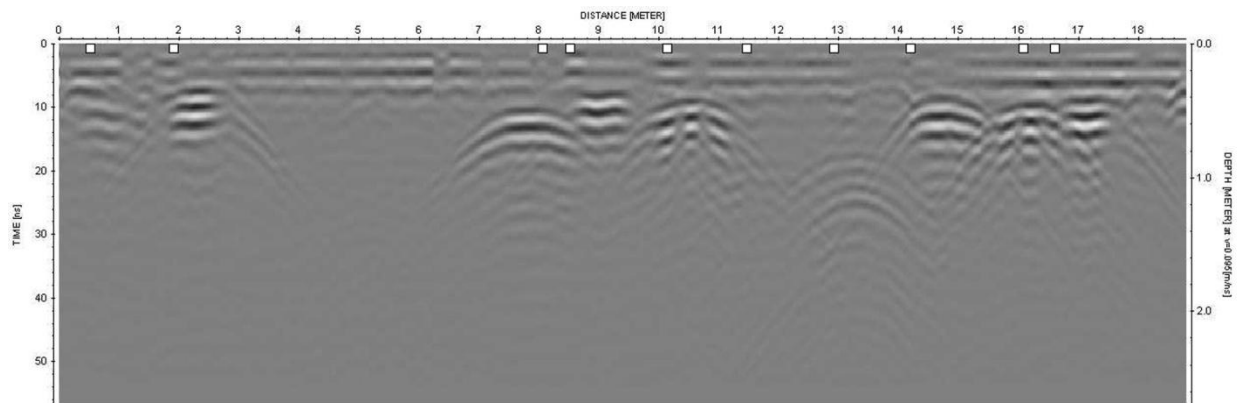
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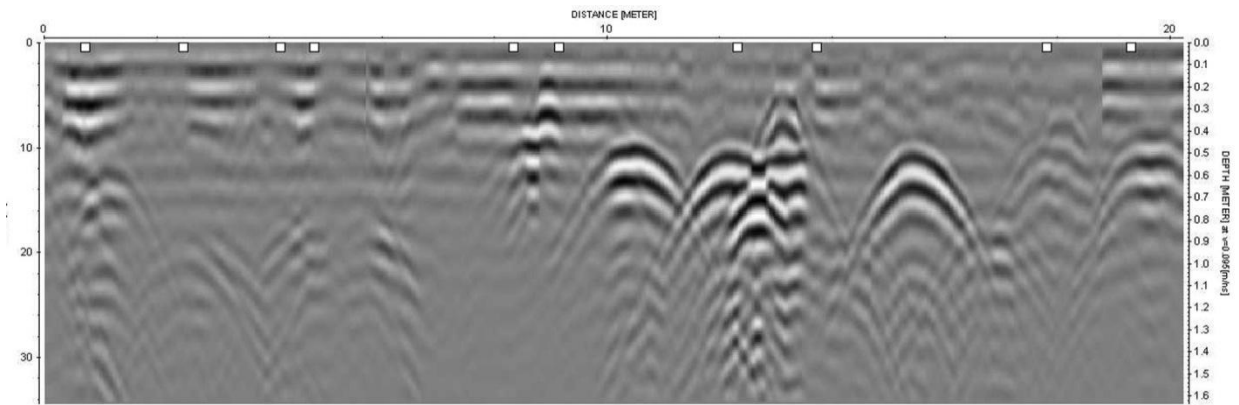


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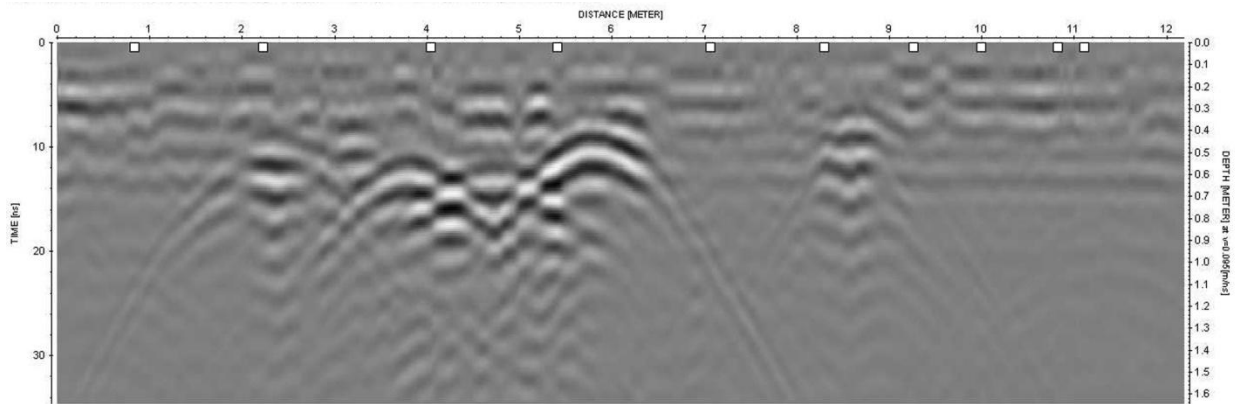


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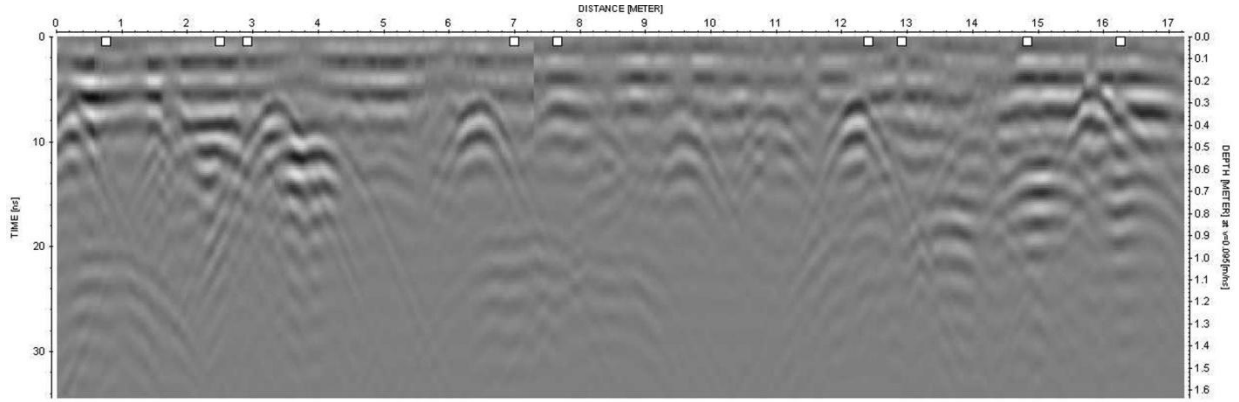
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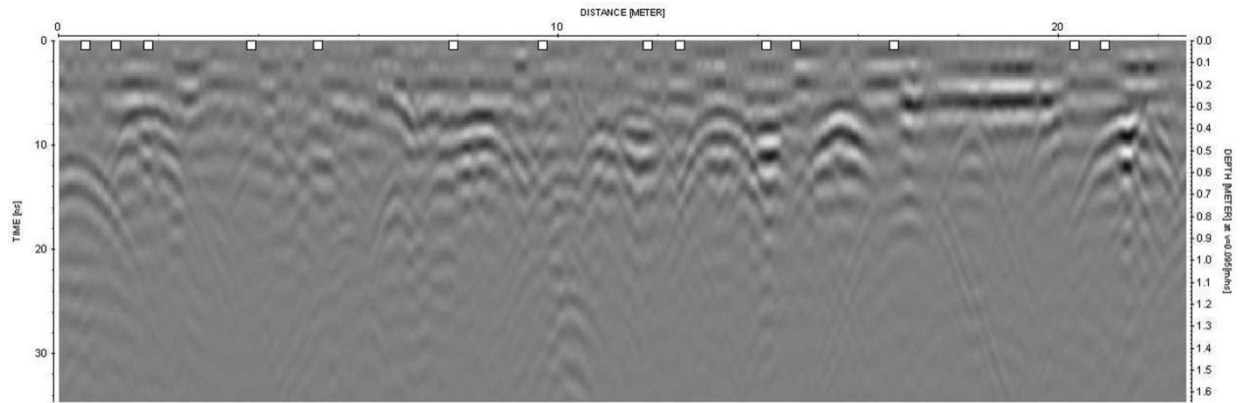
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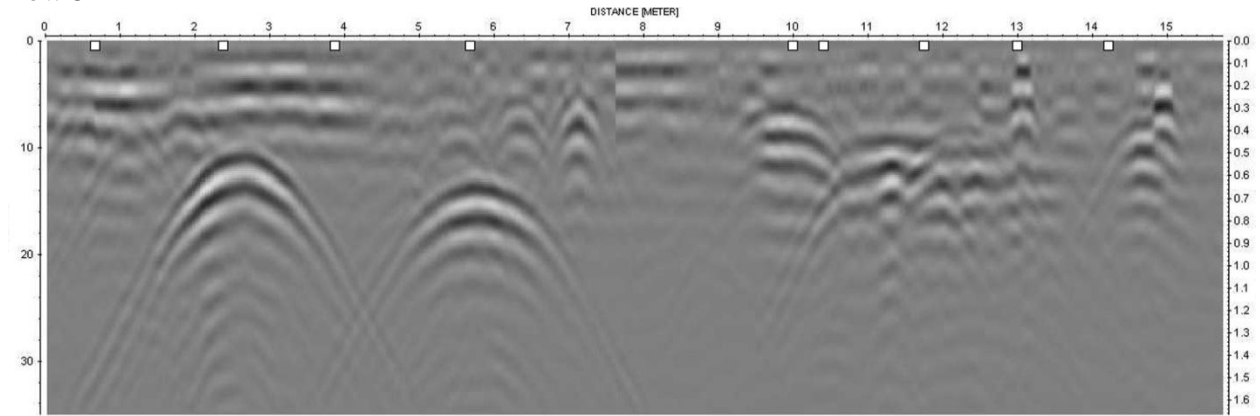
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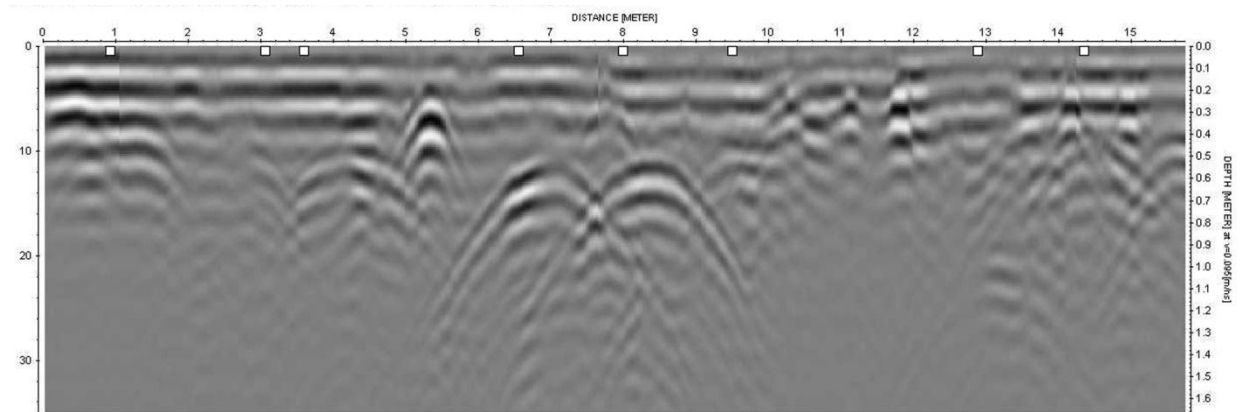
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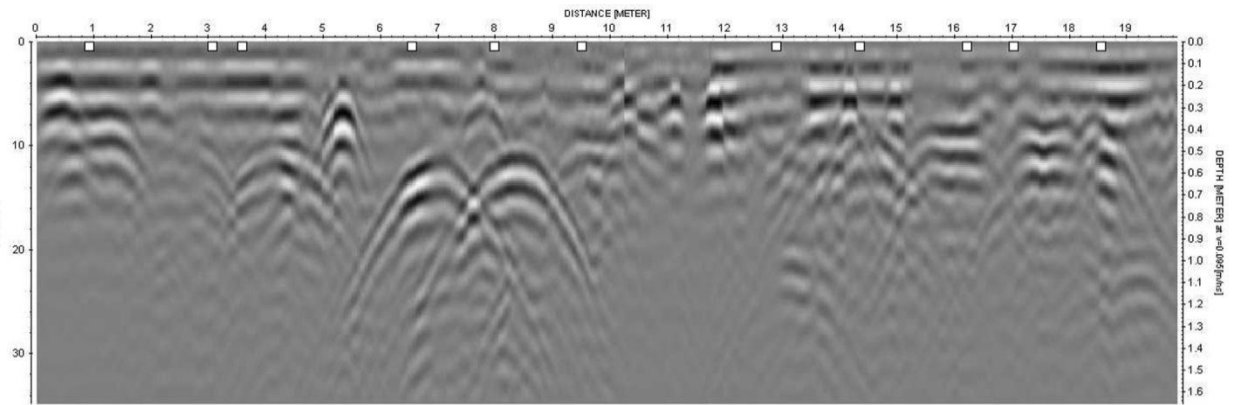
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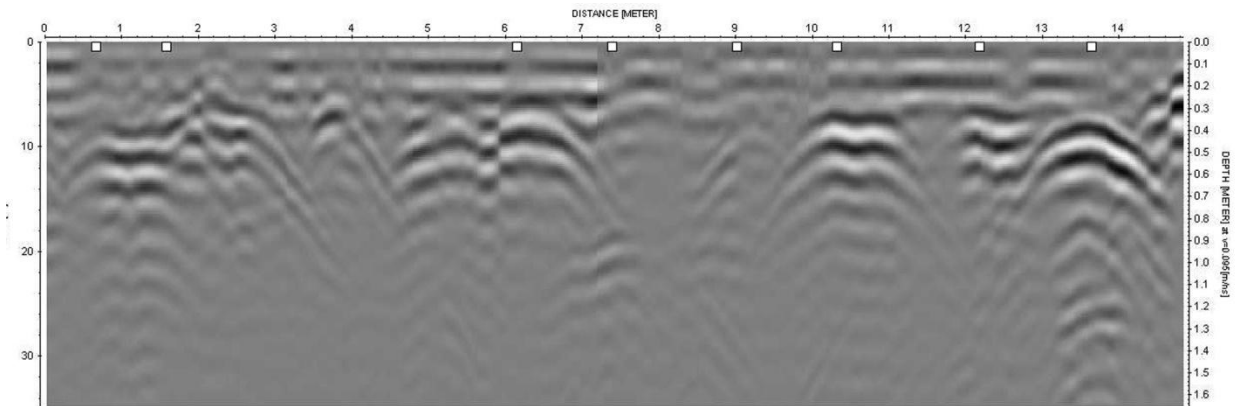
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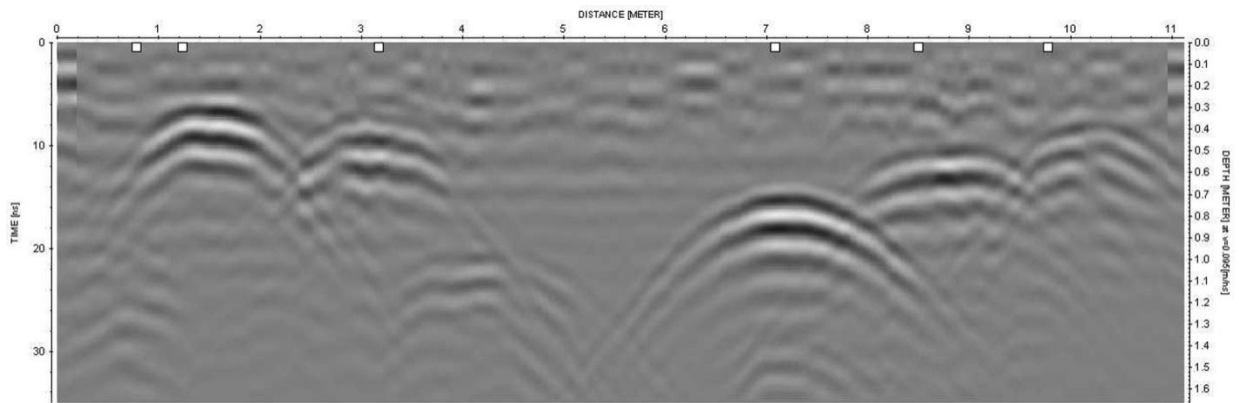
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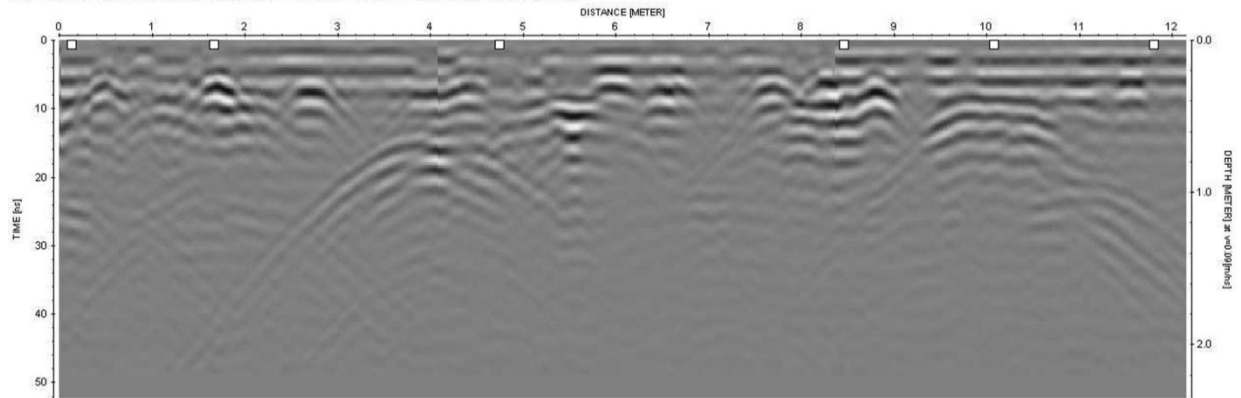


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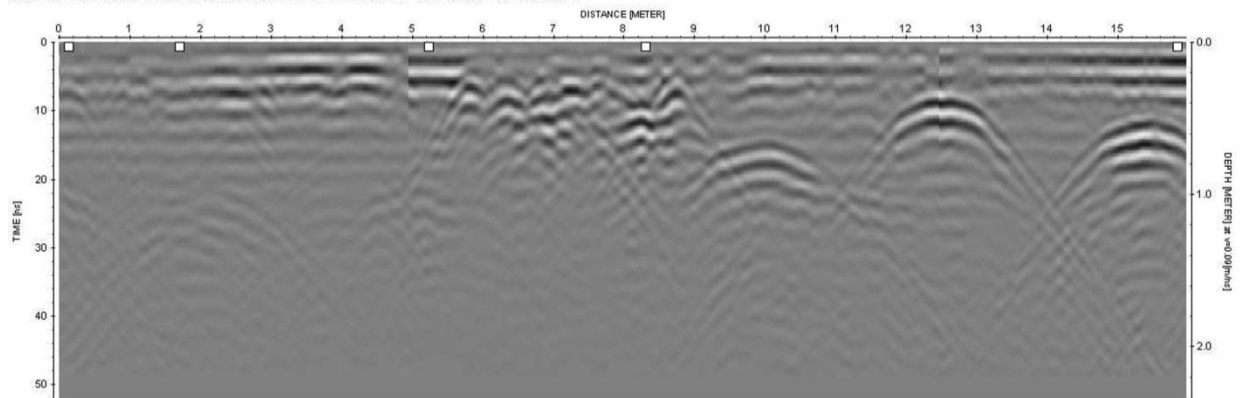


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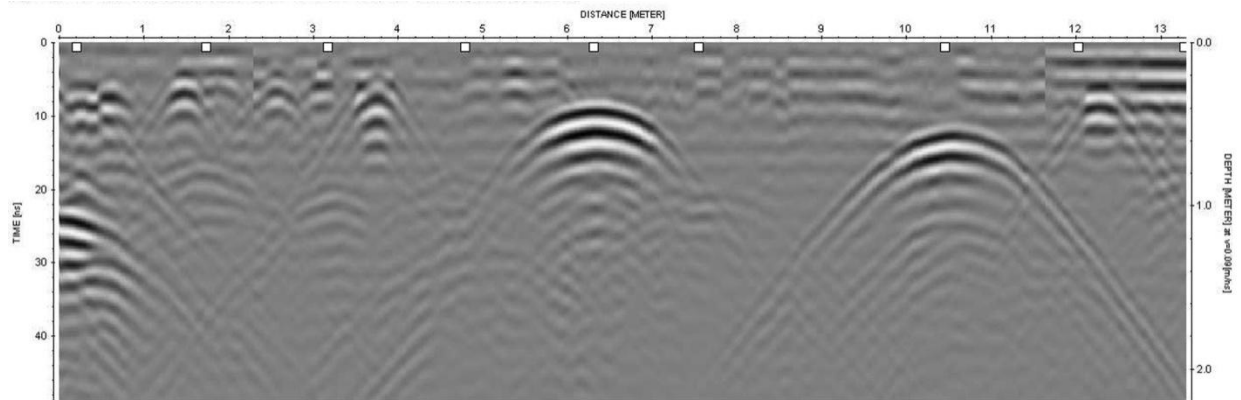
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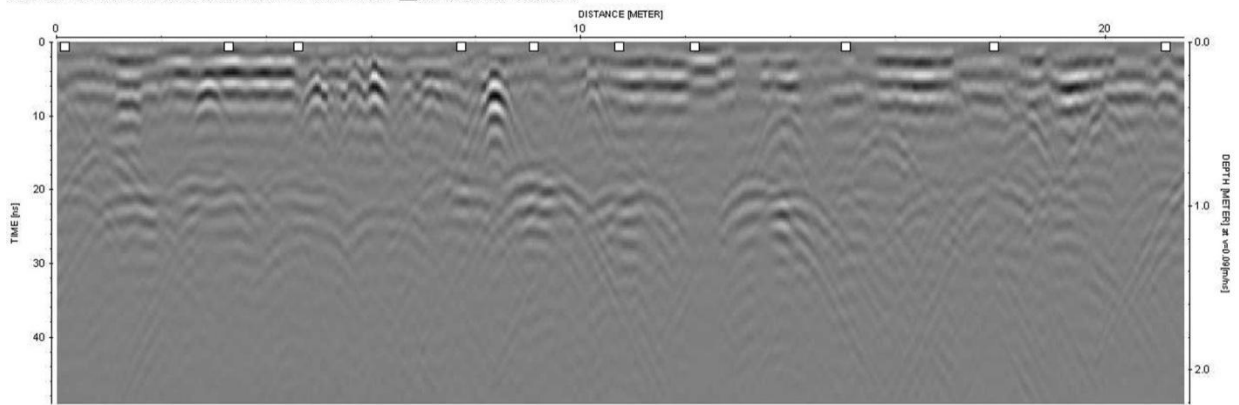
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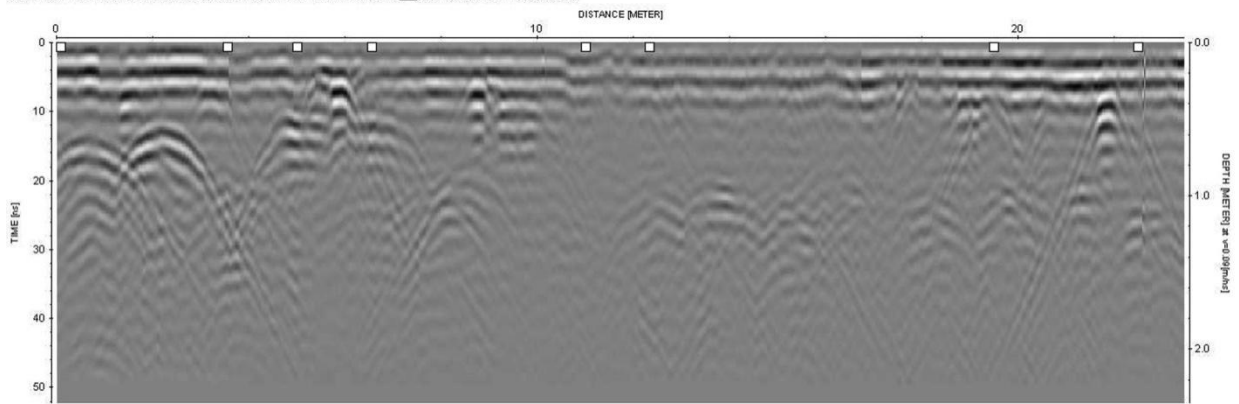
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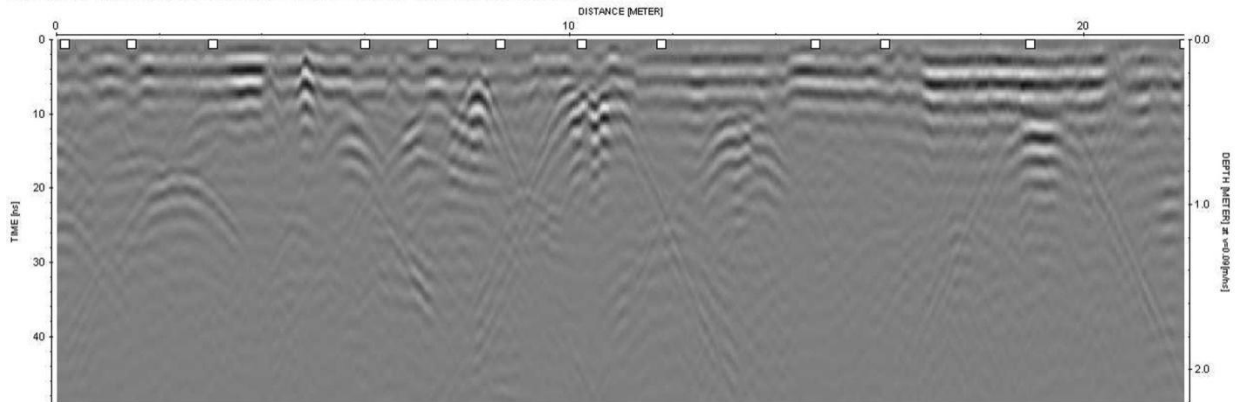
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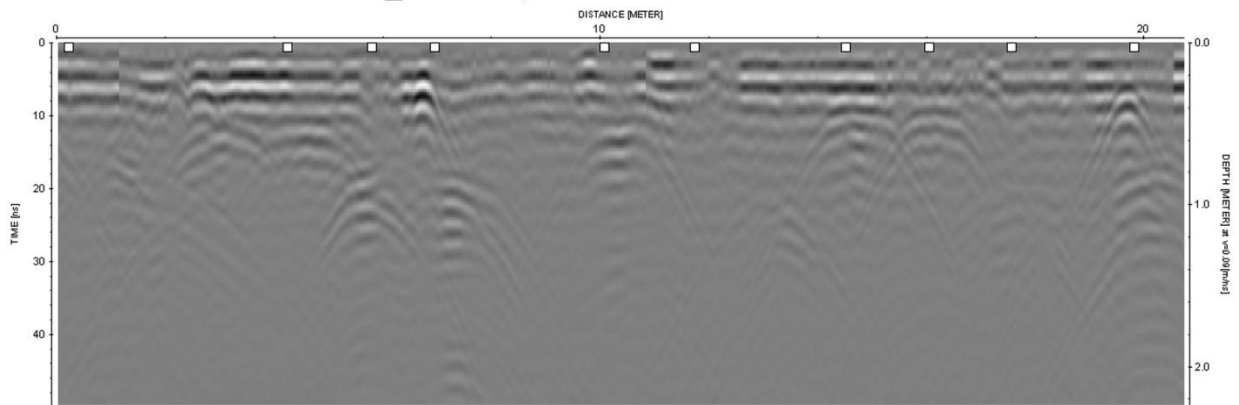
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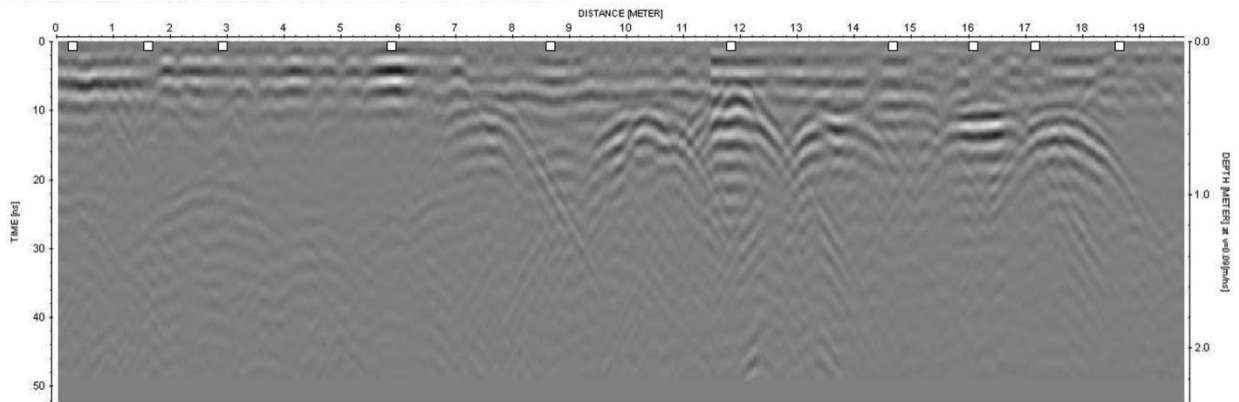
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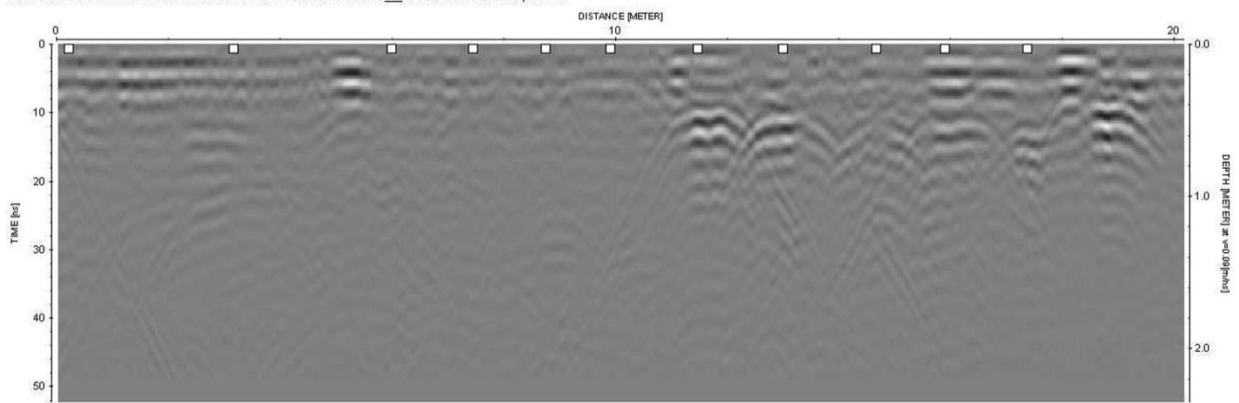
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