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Determination of grave locations with high resolution Ground Penetrating Radar (GPR) in War Cemeteries: Sample study of Biga (Çanakkale) War

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A R T I C L E I N F O

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A B S T R A C T

The most important turning point in Turkish history of the Çanakkale War, known in English as the Dardanelles Campaign, the Battle of Gallipoli, or the Battle of Çanakkale, involves many omissions in terms of historical records due to the situation facing the country at the time and the threats from both internal and external enemies. Though there is very valuable information like notes and maps left by officers in the Ottoman army (Col. Şevki Paşa etc.), due to the intense severity of the war much important information has not been transferred directly to the present day. Most probably, one of the areas with greatest omissions is the location of war grave sites (martyr's cemeteries). The main reason for this is considered to be the excessive number of fallen soldiers or martyrs and the extreme loss of life in a very short period. In spite of these negative aspects, the locations of many war grave sites have been determined by detailed research by historians and the use of maps drawn during wartime. However, in these cemetery areas, approximate locations were defined for war graves and in line with this, areas were fenced off as war cemeteries. Using the same logic, an area closes to the location used as Biga War hospital during the Çanakkale War was renovated and opened to visitors as Biga War Cemetery with gravestones in certain locations. The high-resolution, non-destructive shallow geophysical method of ground-penetrating radar (GPR) has been widely used with the aim of identifying structural elements that are buried (graves, tunnels, archeological remains, etc.). In line with this, its use to research war grave sites in areas known as war cemeteries will illuminate the past and contribute to reorganizing war cemeteries according to war grave locations and providing the necessary importance and respect that war cemeteries deserve.

1. Introduction

The reason for the excessive losses during the Çanakkale War is that no hospital could be built on the Gallipoli peninsula due to the war. In this period, all towns and villages in Trakya as far as Tekirdağ and the settlement areas of Lapseki, Çardak, Karabiga, Biga and Gümüşçay on the Anatolian side were used as hospital regions for those injured in the war. Those injured were taken by sea to the Anatolian side and then brought to these hospital areas using horses and ox carts (Gürsu and Gürsu, 2017). In a report of the Ministry of Health and Army Command by the 5th Army Command, the total number of beds was 5050 in May, with 1450 beds in Tekirdağ, 400 beds in Şarköy, 150 beds in Gelibolu, 300 beds in Lâpseki, 500 beds in Ezine, 450 beds in Dümrek village, 1300 beds in Biga, and 500 beds in Dimetoka hospital (Esenkaya, 2011).

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The Biga War Cemetery (Figure 1), located close to the hospital used as Biga War Hospital during the Çanakkale War, was destroyed during the Greek invasion in 1920, both in terms of nameplates used to identify the martyrs and some graves themselves. The cemetery was restored in 2013 with a ceremonial area formed and opened for use without determining the locations of the existing graves.

Biga District Governorship asked the university about the importance of the situation and with the desire to identify the possible grave locations of the fallen. In previous years our team performed many cemetery location identification studies in Gelibolu, Polatlı and Erzurum and completed measurements on this war cemetery area in line with the wishes of Biga District Governorship with ground penetrating radar (Figure 2). The measurement regions were prepared by dividing the area with a grid. Measurements were performed in a total of 8 different areas, with no measurements taken in areas with nameplates and existing grave sites.

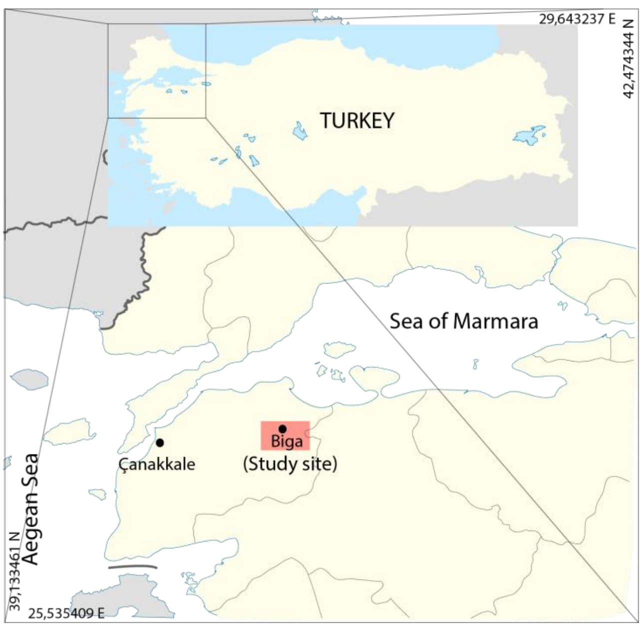

Figure 1. Location map of the study area (coordinates in WGS84).

1.1. Aim and Scope

With the aim of identifying the locations of martyr graves buried underground, a high resolution GPR MALA HDR PRO 450 MHz system was used. The device is designed to image areas underground using non-destructive methods. The GPR system is based on collecting data with electromagnetic frequencies. The speed of GPR signals is determined by the physical and chemical properties of the travel environment and these signals reach the target and collect information about it. The travel durations of GPR signals are determined in nanoseconds (10-9 s) (Yalçıner et al. 2009).

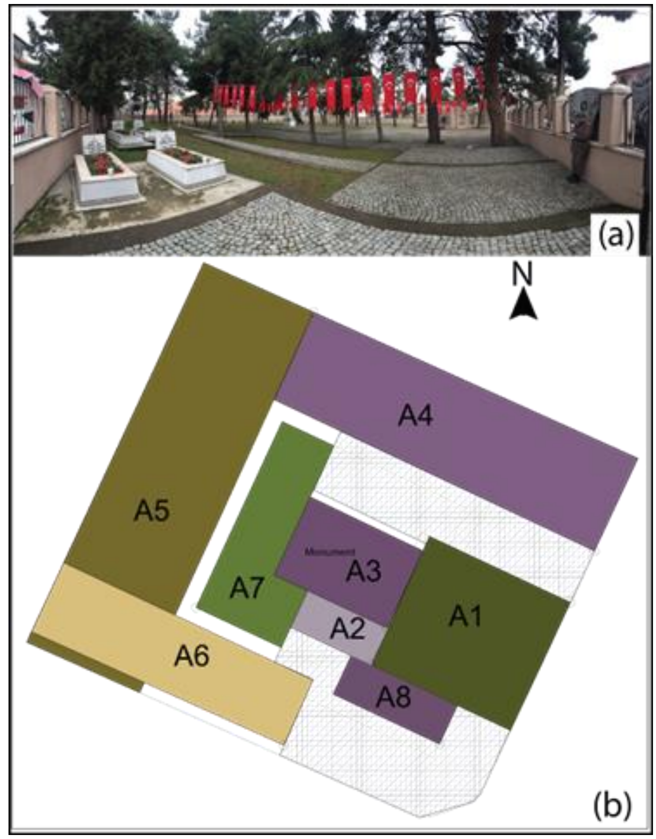

Figure 2. Study area showing (a) general appearance of war grave site (b) measurement areas

2. Method

Within the scope of the study, a high dynamic range (HDR) system with 450 MHz central frequency antenna and broad band interval ground-penetrating radar was used.

2.1. Ground-penetrating Radar (GPR)

Known by many names such as underground research, underground penetration and underground radar, ground-penetrating radar (GPR) systems are based on collecting information from under the ground with electromagnetic frequencies. The design of the GPR system includes a broad range and generally the antenna is chosen with appropriate frequency for the application. In selecting the antenna, target depth, target size and the area of research are considered. In this way, there is a broad range of systems for the GPR method that can be chosen for application areas.

Generally, GPR data are applied at certain intervals with a defined grid area. The method is generally related to the variation caused to electromagnetic signals produced by an antenna during two-way underground travel and the difference compared with the original signal (Conyers, 2004; Yalçıner et al., 2009; Büyüksaraç et al., 2014; Yalçıner et al., 2017). The speed of GPR signals is determined by the physical and chemical properties of the travel environment and these signals reach the target and collect information about it. In situations where the travel time is known, the velocity of the medium is known so the depth of the target can be sensitively determined. The travel time for GPR signals is determined in nanoseconds (10-9 s). In this way, antennae above the ground are moved at fixed or variable intervals from 2-20 cm and collect information. The depth penetrated by the radar is linked to two main factors; 1) the frequency of the antenna and 2) the soil structure characteristics of the area (generally water content). The second factor generally affects the choice of antenna. The most important elements are environments that may affect the travel of the electromagnetic signal and signal backscatter. Two important components of energy transfer are electric and magnetic constants. Independently reflected waves (called wave forms) are collected by digital reflection from underground and in this way, many traces are obtained and collected together to form the profile of a 2-dimensional vertical section. By obtaining many traces on profiles within the grid, 2-dimensional or 3-dimensional underground images are obtained.

GPR comprises both transmitter Tx and receiver Rx antennae. The transmitter antenna produces short high frequency radio signals (generally polarized) (Figure 3). Signals hit a target or layers with different dielectric constant and return to be recorded by the receiving antenna (Figure 3).

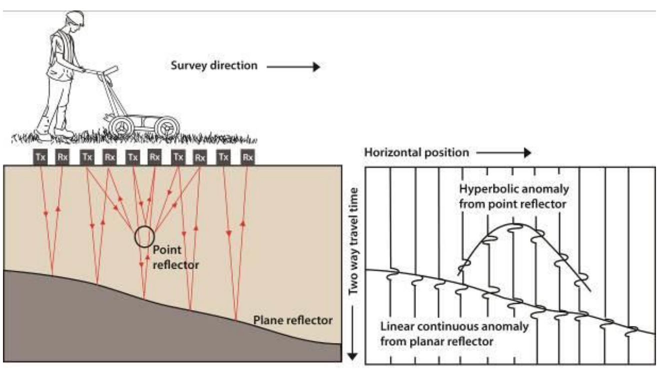

Figure 3. Schematic of antennae in the GPR system (modified from Kaidong, 2018).

3. Field Studies and Findings

Field studies were completed on existing grave sites and at the same time detailed measurements were used for the ceremonial area (Figure 2). For measurements, the aim was to collect data from parallel lines in order to create 3-dimensional data (Figure 4). In line with this, in 8 separate regions, measurements were completed on parallel profiles at 50 cm intervals. The parameters used during measurements are shown in Table 1. The data were processed with the aid of the ReflexW (Sandmeier, 2003) program and prepared for interpretation (Table 2).

Figure 4. HDR-PRO 450 MHz antenna ground-penetrating radar device

Table 1. GPR measurement parameters used during field studies

Antenna frequency	450 MHz HDR
Sampling frequency	5120 MHz
Time window	133 ns
Antenna opening	18 cm
Measurement interval	5 cm
Profile interval	50 cm

Table 2. Filter parameters used during data processing

Antenna frequency	450 MHz HDR
Air correction	4.5 ns
DC value (dewow)	3 ns
Band-pass filter	225 / 360 / 720 / 900 MHz
Energy delay	0.512
Mean value correction	31 trace / 0 to 82.7352 ns
Velocity analysis	0.10 m ns-1
Migration	11 trace / 0.10 m ns-1 / 0 to 82.7352 ns / εr = 9

Measurements completed in a total of 8 areas were combined into 3 dimensions to form depth sections (Figure 5). The depth thought to best represent anomalies on the obtained depth sections was determined (120 cm) and combined in the Autocad environment (Figure 6). When the GPR depth sections are investigated on the base map, an attempt was made to determine possible war grave sites by marking the dark colors on the sections which indicate anomaly regions (Figure 7). The findings were placed on the base in terms of area. The locations of the areas were determined with the aid of GPS data and drawn. Generally, the GPR profiles along parallel straight lines cannot be applied on very flat or very vertical ground linked to field and ground conditions. When the measurements taken every 5 cm are considered, this explains why the shapes of the identified anomaly regions are not regular. As a result, anomalies were corrected again in the shape of possible graves and recreated for the best representation (Figure 8).

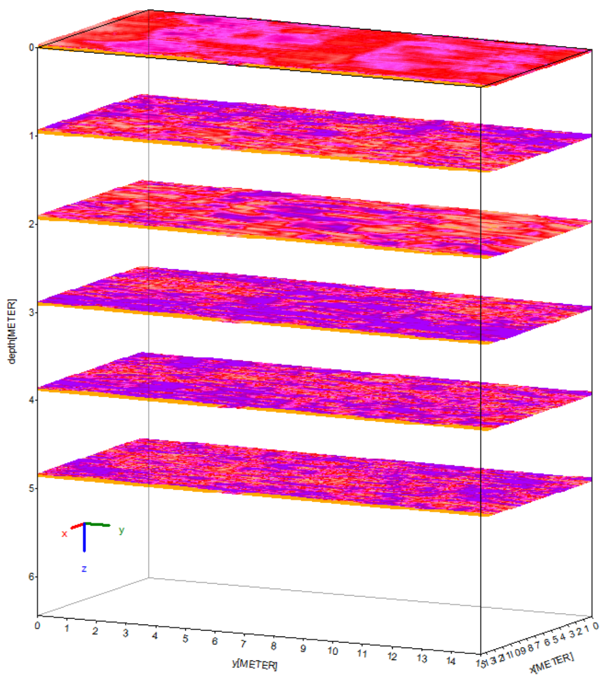

Figure 5. Depth section (layer map) created after data processing.

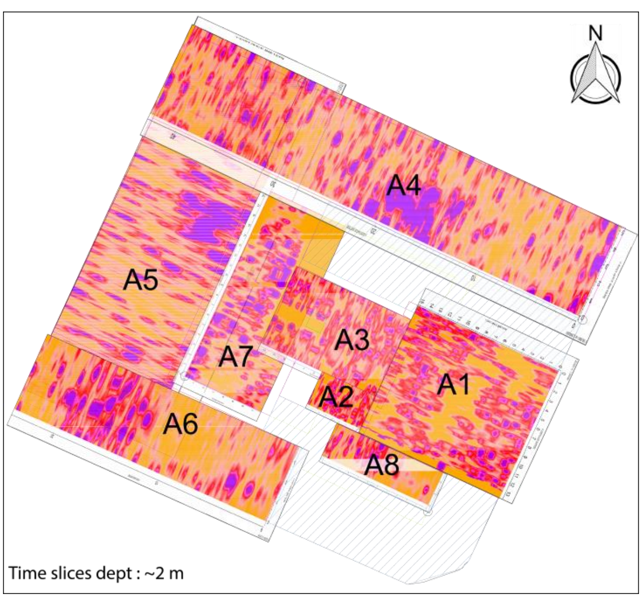

Figure 6. View of GPR results on the plan view (dark areas show possible anomalies).

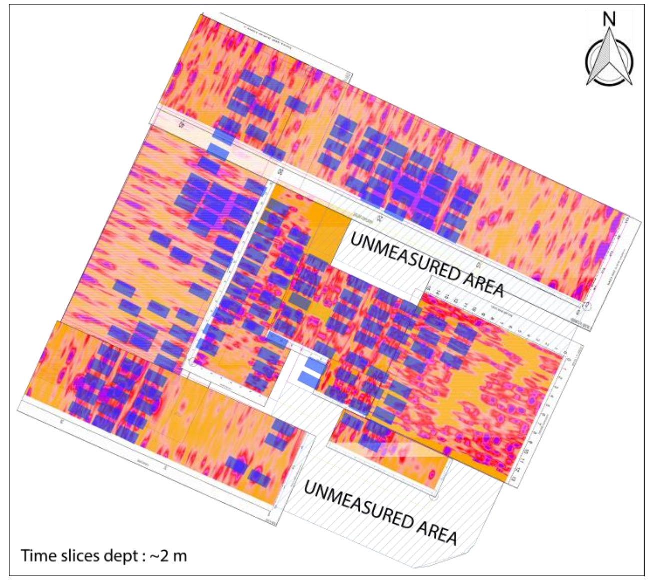

Figure 7. Marking of possible findings (anomalies) on GPR results (blue areas show possible war graves).

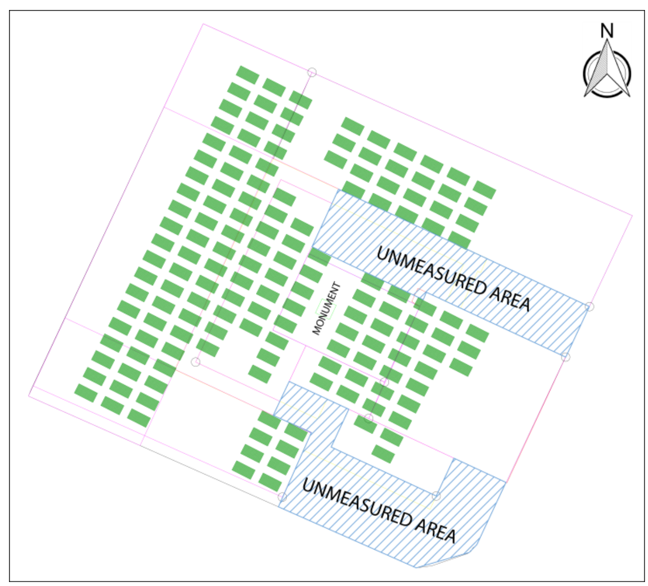

Figure 8. War grave sites identified according to corrected results (green areas).

4. Conclusion and Discussion

The data revealed by assessing high resolution underground data obtained by non-destructive ground-penetrating radar measurements determined war grave sites buried in the existing war cemetery and ceremonial area.

An attempt was made to screen all surfaces possible in the area with 8 different regions determined during the study (Figure 2b). Generally, data identified on a rectangular grid area were placed on a base to obtain holistic data (Figure 6). Measurements in the area generally identified anomalies (possible grave sites) at 120 m depth so the holistic data sections were combined and interpreted at this depth (Figure 7). When interpreting GPR data, areas with high amplitude values and dark colors are defined as anomalies (possible grave sites) in the represented regions. However, non-flat surfaces found along the ground during measurements within the regions caused changes to the measurement wheel of the device and changes to the antenna which caused the identified structural elements to be unclear and shapeless. The reason for this is that these types of error form at 5 cm measurement intervals which were a requirement of high sensitivity. Considering the noise/resolution ratio, measurements using the most appropriate parameters and after interpretation taking account of the known orientation and dimensions of war graves, the war grave locations that best represent each anomaly are shown in Figure 8. According to this image, 150 possible war grave sites were identified in the area (Figure 8). The most noteworthy element of this identification is the identification of possible grave sites in the region used as a ceremonial area (A1-A2-A3 on Figure 2b). In light of this new identification, it is necessary to reorganize the war cemetery. Determination of the definite locations of war graves with this type of non-destructive method will prevent people from unknowingly walking on the graves of fallen soldiers and ensure organized martyrs' cemeteries are created.

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