



GEOPHYSICAL INVESTIGATION OF BURIED CANNONS IN KUMKALE (DARDANELLES), TURKEY

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ABSTRACT

Kumkale that is an old Ottoman fort is located near the ruins of ancient Troy. Cannons throwing huge balls were placed in the fort of Kumkale such as other forts on the side of Dardanelles in the period of Ottoman Empire. Ottoman Empire attended to the World War I against Allied Forces in 1914. The Allied forces attacked as bombarding Ottoman's batteries in Dardanelles. Firstly, the British began their interest in Kumkale with an unsuccessful bombardment on 19th of February, 1915. They followed this up on 25th of February with a bit more success, their warships staying out of range as they pounded the area.

When they were leaving from Kumkale, Allied Forces destroyed the cannons. Since then, the destroyed cannons were buried in the ground. However, approximate places of them were recorded in military archives. Here, buried cannons were successfully investigated by magnetic and ground penetrating radar (GPR) methods in three regions, where pieces of cannons, phone cable between array of cannons, equipment used in maintenance and repair of the cannons and pieces of cannons were located.

KEYWORDS: Canakkale, World War I, Kumkale, Cannons, Magnetic, Ground Penetrating Radar (GPR)

1. INTRODUCTION

The old Ottoman fort of Kumkale lies on the road of the ruins of ancient Troy. Ottoman Empire constructed forts both sides of Dardanelles to defend the capital city Istanbul against to enemies. The forts of Kumkale, Cimenlik and Nagra in Asian side and Seddulbahir, Kilitbahir and Bigali in European side were built and placed cannons throwing huge cannon balls. Because of the forts lost their importance as a defender in time, array of cannons (battery) such as Orhaniye, Camlik, Hamidiye, Cimenlik, Mecidiye in Asian side and Yildiz, Mecidiye, Hamidiye, Namazgah and Degirmenburnu in European side were built both sides of Dardanelles (Fig. 1). The cannons were bought mainly from Germany and Austria. From the Kumkale area there are fine views to Gallipoli, and throughout the campaign Turkish batteries hereabouts bombarded allied positions at Hellas.

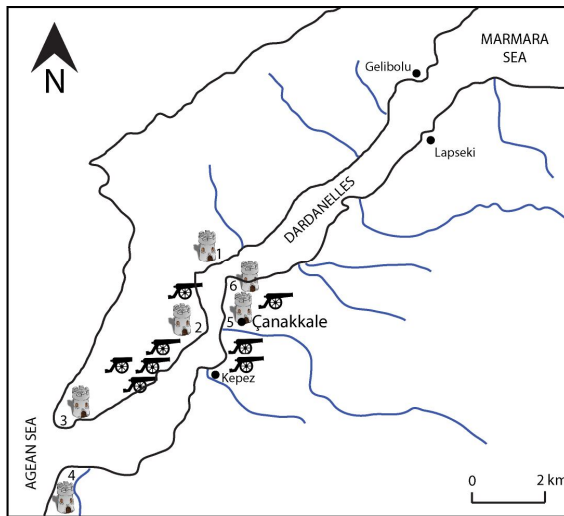


Figure 1 Locations of forts and batteries. 1-Bigali, 2-Kilitbahir, 3-Seddülbahir, 4-Kumkale, 5-Çimenlik, 6-Nar (redraw from Acioglu, 2006).

Ottoman Empire attended to the World War I with together Germany and Austria against Allied Forces and bombarded Russian harbours on 3rd of November, 1914. The Allied forces counteracted that attack by bombarding Ottoman's batteries in Dardanelles. Firstly, the British began their interest in Kumkale with an unsuccessful

bombardment on 19th of February, 1915. They followed this up on 25th of February with a bit more success, their warships staying out of range as they pounded the area. To complete the destruction of the guns, a party of Royal Marines was landed on 26th of February. Secondly, the French fleet had stationed in front of Kumkale shore, Çanakkale on 25th of April, 1915. The first French wave landed under protective bombardments of the navy targeting Kumkale and Orhaniye (Fig. 2). When the Turks had made a counter-attack to recapture Kumkale, a harsh war had begun in the village's streets. On the night of 26th of April, French troops evacuated the Kumkale and reinforced the British landings. When they were leaving from Kumkale, they destroyed the cannons (Figs. 3a, b). The destroyed cannons buried in the ground due to loose soil and meteorological conditions in time. However, approximate places of them were recorded in military archives (Fig. 4). We decided to explore correct places of the buried cannons in the frame of a joint project with historians. Magnetic method was applied in the project.



Figure 2 The first French wave landed under protective bombardments of the navy targeting Kumkale and Orhaniye (Asci, 2008)

2. METHODS

2.1. Magnetic Method

Magnetic method is a very rapid and effective tool for buried materials. The method works on the principle that ferrous (iron-steel) objects cause localized distur-

bances “anomalies” in the Earth's total magnetic field that are measurable with the magnetometer. In case of materials including steel or iron can be detected easily. Iron or steel objects may be detected to depths, depending upon the magnetic mass of the target(s) in question and the type of magnetometer used. The greater mass, the larger the disturbance recorded in the Earth's field. Most can measure both the Earth's total magnetic field and the magnetic field gradient.

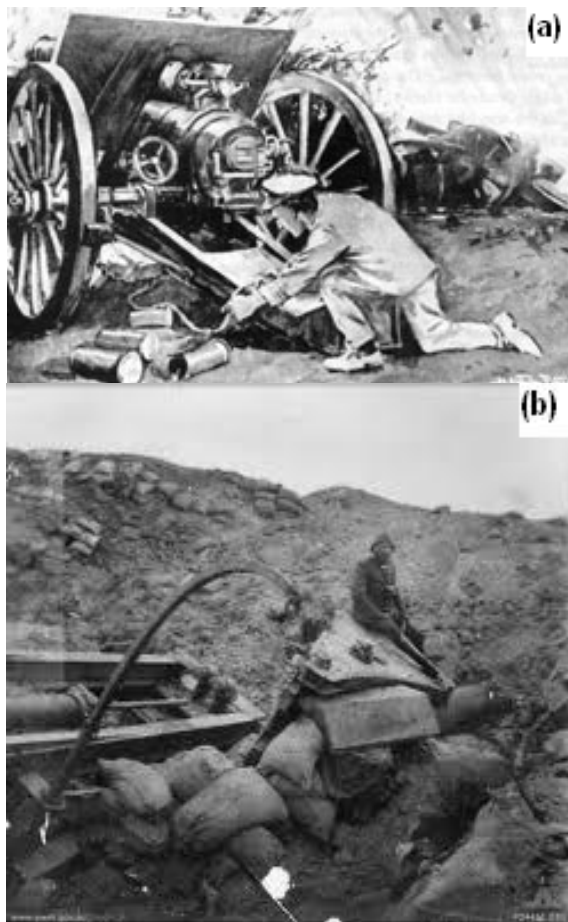


Figure 3 (a) Artist's impression of Lieutenant Commander Eric Robinson placing charges to demolish the Turkish cannons at Kumkale (Stroud, 1999), (b) A destroyed canon

In the absence of buried iron or steel objects, the magnetic gradient (or the change in the magnetic field from one station to another) is negligibly small. However, when there are buried steel and iron objects the magnetic field gradient is very large. For total field measurements, it may be

necessary to correct for daily fluctuations in the Earth's total magnetic field (called diurnal variations), depending upon the magnitude of the target for which one is searching.

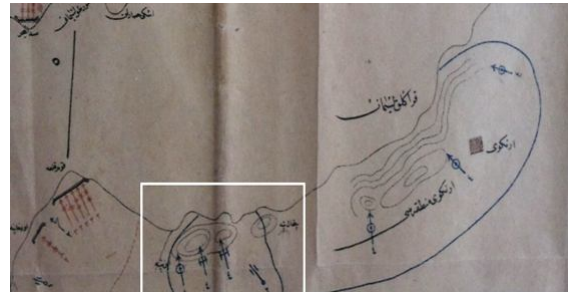


Figure 4 A Historical document belong to Turkish Military Service showing the places of cannons in Kumkale (Sayilir, 2006).

2.2. Magnetic Data and Processing

The acquisition of magnetic data is done using a Geometrics-G858 Cesium Magnetometer with 0.01 nT sensitivity. The data were collected sequentially in the discrete mode at 1 m sample intervals along parallel profiles with 1 m intervals and the height of the sensor was 0.5 m from the surface in three regions in the study area (Fig. 5). Recorded data sets are set in grid by using kriging grid method processed using Geosoft software (Geosoft, 2004). Magnetic anomaly maps shown in Figs 6a, b and c belong to Regions 1, 2 and 3, respectively.

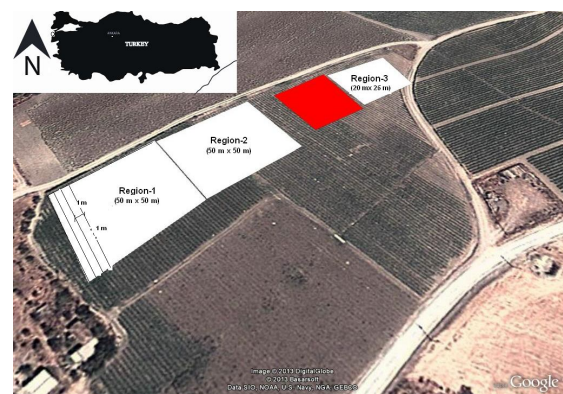


Figure 5 Location of project area and measured regions. White shadows present measured regions by geophysical methods, red shadow presents unmeasured region by geophysical methods.

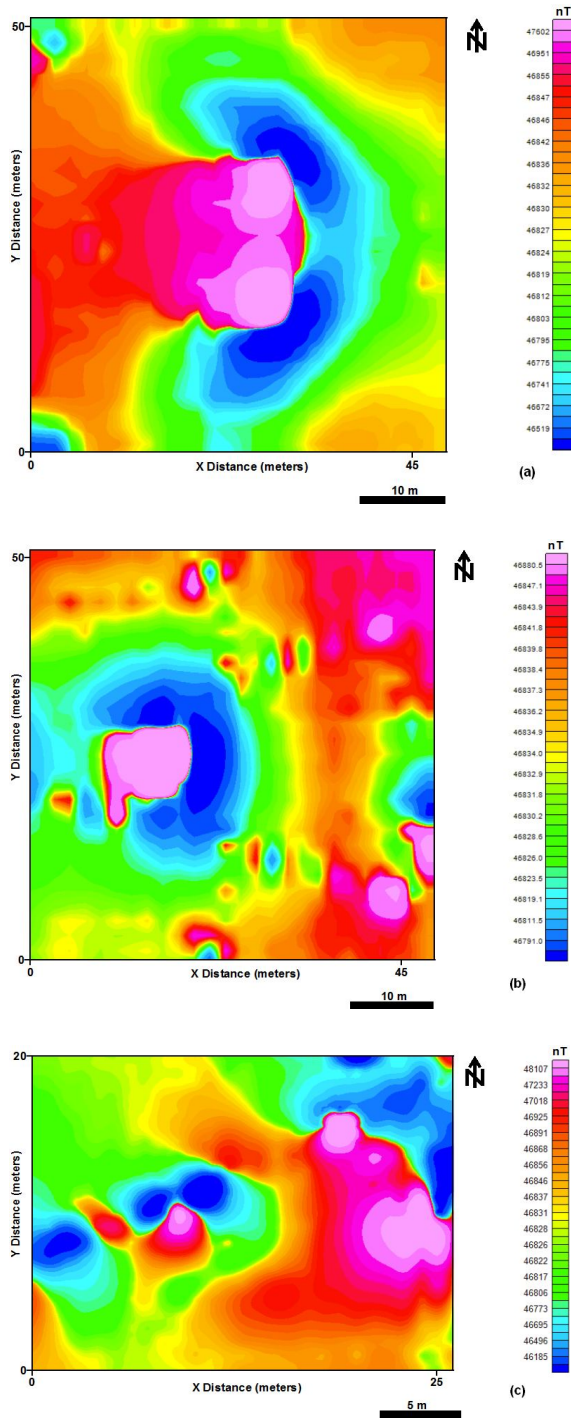


Figure 6 Magnetic anomaly maps, (a) Region-1, (b) Region-2, (c) Region-3

At the next stage, reduction to the pole transformation (RTP) was carried out to remove distortion of magnetic anomalies caused by the Earth's magnetic field by assuming 55° and 4° for the Earth's magnetic inclination and declination angles, respectively. We assumed that the magnetic anomalies were centred over their

respective sources by this way (Blakely, 1995). RTP transformation was applied to the magnetic anomalies by using Geosoft software (Geosoft, 2004). in Figures 6a, b and c (see, Figs. 7a, b and c). In this figures, Pink-red colors present intensive magnetic anomalies, blue-green colors present low magnetic anomalies.

2.3. Analytic Signal and Euler Deconvolution Methods

Derivatives of the magnetic field are common and useful tools for interpretation of magnetic anomalies. Interpretation of magnetic field derivatives, separately or together, provides images of shallow magnetic bodies, and reduces the field from deeper sources. Horizontal derivatives of the total magnetic field are computed in the space domain by means of finite-difference relationships, and vertical derivatives are computed in the frequency domain by using fast Fourier transform (FFT) filtering. There are many filters to determine causative body in potential field data. However, Analytic Signal Method (ASM) is very successful in potential data to determine horizontal location of buried causative bodies. Archaeological buried materials can be determined in their correct positions after ASM transformations of the magnetic anomalies. Recently, we applied successfully the ASM to archaeological areas in Turkey (Buyuksarac *et al.*, 2006; Arisoy *et al.*, 2007; Buyuksarac *et al.*, 2008; Milea *et al.*, 2010; Buyuksarac *et al.*, 2013a, b). The amplitude of the three-dimensional AS is given by the square root of the squared sum of two horizontal and vertical derivatives of the magnetic field (Eq. 1) (Roest *et al.*, 1992).

$$|AS| = \sqrt{\left(\frac{dT}{dx}\right)^2 + \left(\frac{dT}{dy}\right)^2 + \left(\frac{dT}{dz}\right)^2} \quad (1)$$

Technique of Euler Deconvolution (ED) can be used to compute depth of magnetic source and it depends on the Euler equation. The Euler equation is given by Equation 2 (Thompson, 1982),

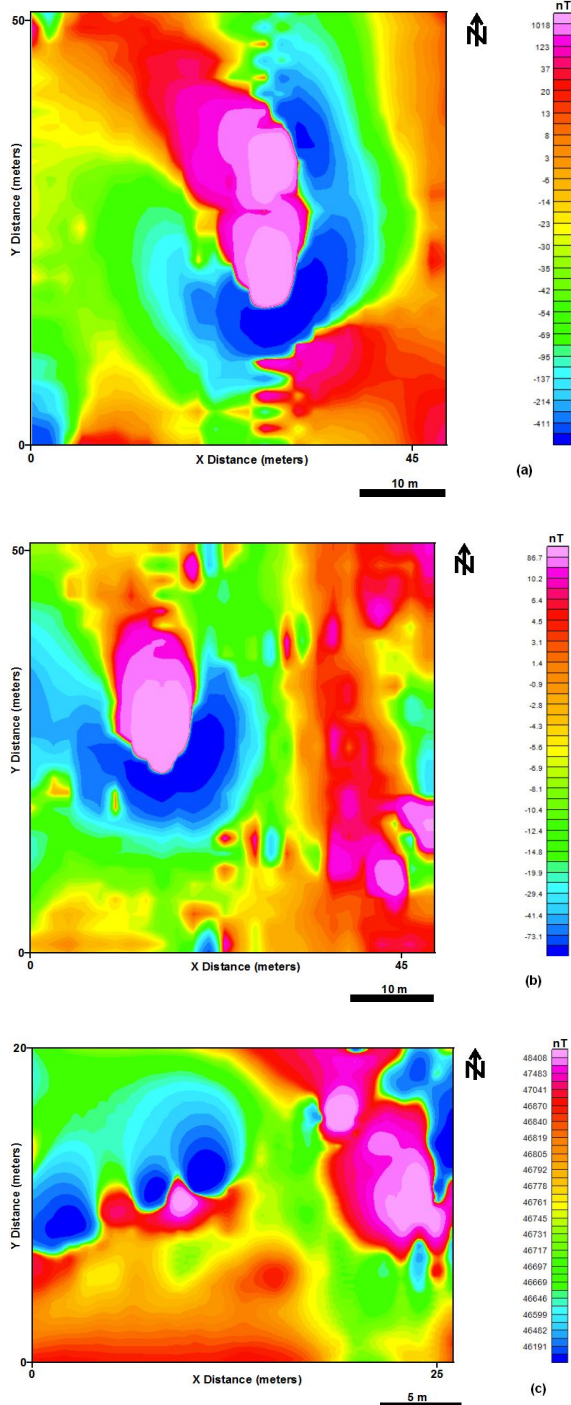


Figure 7 Reduction to Pole (RTP) transformation of magnetic anomalies, (a) Region-1, (b) Region-2, (c) Region-3

$$(x - x_0) \frac{d\Delta T}{dx} + (y - y_0) \frac{d\Delta T}{dy} + (z - z_0) \frac{d\Delta T}{dz} = -N\Delta T(x, y) \quad (2)$$

Where,

T: The magnetic field due to a point source such as a pole or dipole at a position (x_0, y_0, z_0) is of the form.

N: structural index

EULDEP computer program was improved by Durrheim and Cooper (1998) for computing ED of magnetic and gravity data. EULDEP uses profile data and assumes that the field is symmetric transverse to the profile, so $\partial\Delta T / \partial y = 0$. Then from Equation (2)

$$x_0 \frac{\partial T}{\partial x} + z_0 \frac{\partial T}{\partial z} + N.B = x \frac{\partial T}{\partial x} + N.T \quad (3)$$

Where,

T: Total magnetic field.

B: Regional magnetic field

So the position x_0 , depth z_0 and anomaly base level B of a specific magnetic source can be solved if the total magnetic field and the horizontal and vertical gradients are known at three points along the profile. Because real magnetic and gravity bodies are more complex than simple poles and dipoles, and because real data is contaminated by noise, seven data points are used (Eq. 4).

$$S = (A^T A)^{-1} A^T G \quad (4)$$

Where, A is a 7×3 matrix that contains seven data points from the profile for horizontal and vertical gradients and S is the solution matrix that contains the depths and horizontal positions of the solutions (Durrheim and Cooper, 1998). ASM and ED applications for three regions are presented in Figs 8, 9 and 10. In these figures, “(a)” shows results of analytic signal transformation, “(b)” shows graphics of Euler Deconvolution and “(c)” shows findings in excavations.

2.4. Ground Penetrating Radar (GPR)

GPR is one of the most widely applied geophysical methods for underground investigations. Its success depends on the specific site conditions. High-frequency electromagnetic waves are sent into the ground from a transmitter antenna. These waves are reflected back to the surface as they encounter changes in the dielectric permittivity of the matrix through which they travel and are then detected by a receiver antenna.

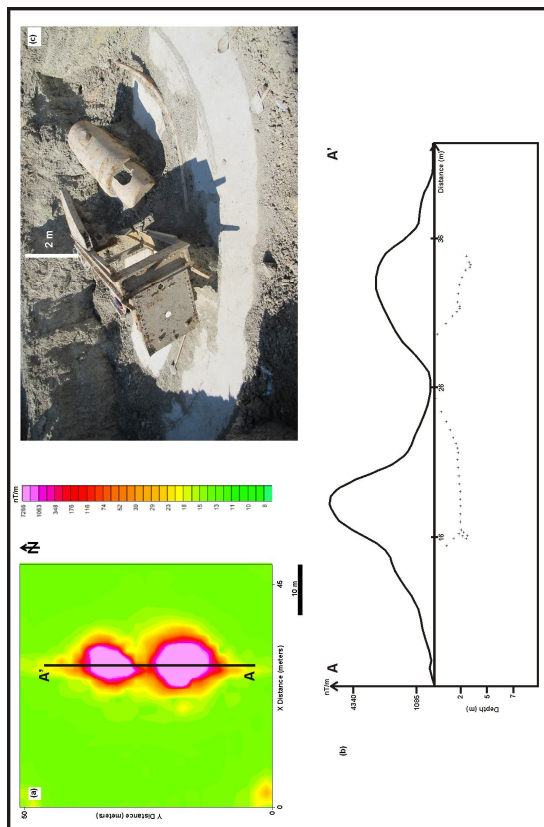


Figure 8 In Region-1: (a) Analytic signal transformation of RTP anomalies, (b) 1D Euler Deconvolution graphic, (c) Cannon remains with rail on the concrete floor.

The study areas of this study, 30×38 m, 22×26 m, 30×32 m in size (Region-1, 2 and 3, respectively), were scanned with a Mala RAMAC ProEX GPR unit with a 250-MHz shielded antenna. 2D plots of horizontal distance versus travel time were constructed from the two-way travel times of these reflections (Figs. 11a,b, 12a,b and 13a,b for Region 1, 2 and 3 respectively). The most widely used method for display-

ing 3D radar data is as 'time slice' maps (Conyers, 2004).

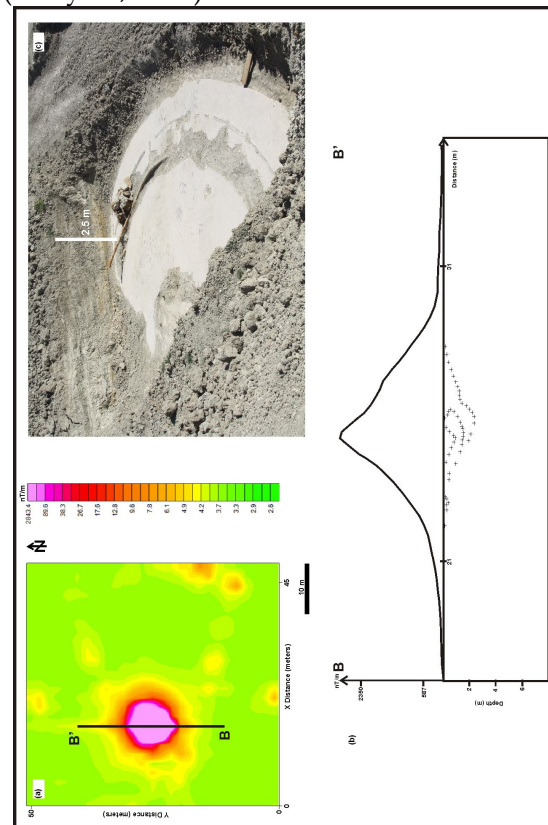


Figure 9 In Region-2: (a) Analytic signal transformation of RTP anomalies, (b) 1D Euler Deconvolution graphic, (c) Cannon remains with rail on the concrete floor.

Time slices are the easiest and most rapid way to provide a synthetic plan of the anomaly pattern, especially for large areas. The time slicing technique constructs plan-view maps of an area at specific isolated depth ranges (Figs. 11c, 12c and 13c). The data for time-slice analysis must be collected systematically at closely spaced (generally ≤ 100 cm) transect intervals. In this study, cut off time is 150 nanosecond for time slices. Depth slice is approximately 2 m. Reflections may be caused by heavy iron pieces and concrete floor.

3. GEOPHYSICAL RESULTS AND EXCAVATIONS

Array of cannons (Battery) in Kumkale placed parallel to Dardanelles are revealed as a result of the geophysical investigation and excavations in that area.

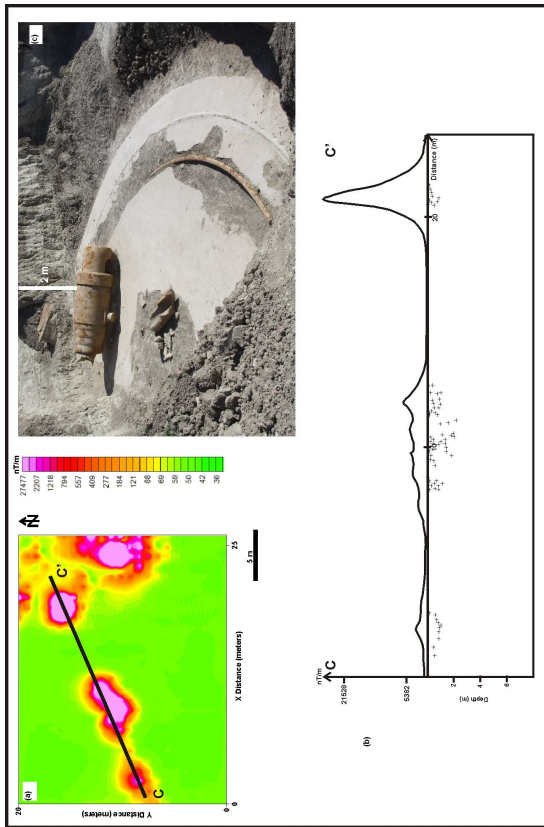


Figure 10 In Region-3: (a) Analytic signal transformation of RTP anomalies, (b) 1D Euler Deconvolution graphic, (c) Cannon remains with rail on the concrete floor.

The south part of them is the main cannon. After excavations, it was observed that the cannons placed at intervals ranging from 30 to 50 m for the protection of the Dardanelles. However, during excavations rails and concrete in the bottom of the cannons were found on the floor. Phone cable between batteries, equipment used in maintenance and repair of the cannons and pieces of cannons, a little gun powder were found in the excavation pits.

There were two type anomalies in the magnetic data. In the first type of anomalies has more than one magnetic anomaly and higher amplitude such as in Region-1 and Region-3 (Figs. 6a and 6c, respectively). In the second type of anomaly, there was just one magnetic anomaly and lower amplitude such as Region-2 (Fig. 6b).

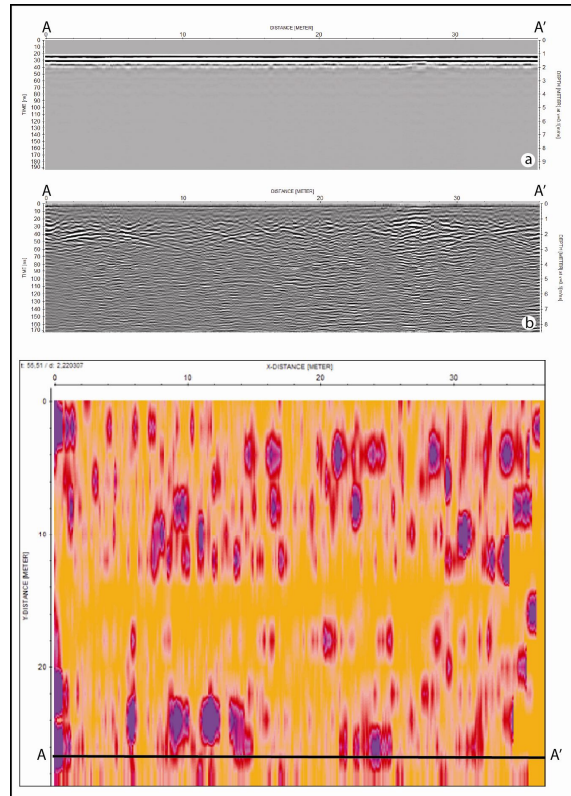


Figure 11 GPR measurements in Region 1, (a) Raw data, (b) Time Slice, (c) Depth Slice

Main pieces of bench of cannon and rails were on the floor in the first excavated battery (Region-1). However, the destroyed barrel was found in pieces (Fig. 8c). Size of excavated areas was 15×15 m and depth of pit was around 2.5 m. That depth was compatible with Euler Deconvolution results (Figs. 8b, 9b and 10b). GPR anomalies were also gave anomaly in approximately depth (Figs. 11c, 12c and 13c). This battery was revealed the main point of all batteries in the area. Starting the phone lines here and distribution to other batteries is the most important sign of that idea. Ceramics belong to phone lines, wires, etc. were uncovered in this excavation. There were some articles showing angles to facilitate the shot up and down for the convenience of staff on the concrete floor written in Ottoman Turkish terms (Fig. 14).

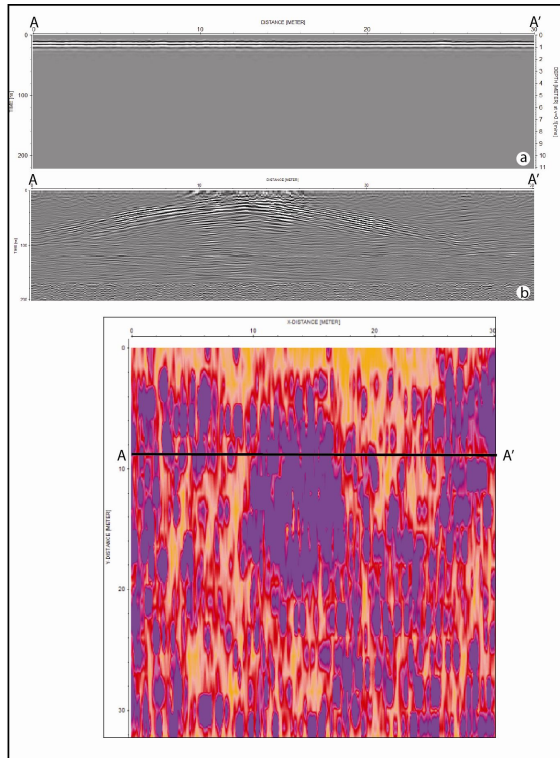


Figure 12. GPR measurements in Region 2, (a) Raw data, (b) Time Slice, (c) Depth Slice

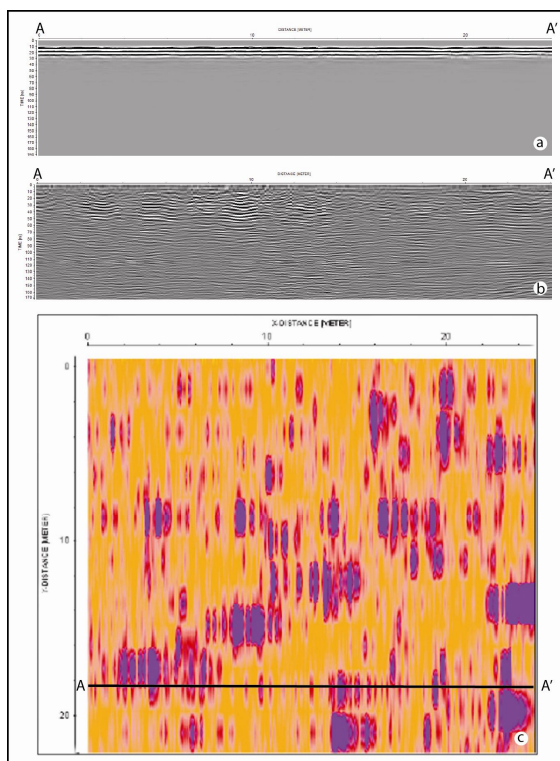


Figure 13. GPR measurements in Region 3, (a) Raw data, (b) Time Slice, (c) Depth Slice

In the Region-3, the cannon with two parts were found as fragmented cannon ball barrel on the concrete floor in the excavation. The articles were not available anywhere on the concrete floor (Fig. 10c).

In the second group anomaly, just to the concrete floor and rail tracks were found in the second area (Region-2) (Fig. 9c). There were no more pieces of cannon. In Figure 12c, concrete floor reflect spread anomaly such as magnetic anomaly in Figure 9a. The anomalies sourced concrete presented a new information despite of common belief in Turkey was using of concrete after 1923 and the concrete was not used during Ottoman Empire.

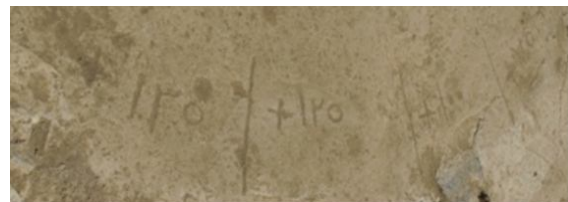


Figure 14 Articles showing angles on the concrete floor written in Ottoman Turkish terms.

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