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SURFACE GEOPHYSICAL INVESTIGATIONS AND PRELIMINARY EXCAVATIONS AT THE DIVRIGI CITADEL, SIVAS (TURKEY)

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ABSTRACT

A geophysical survey including magnetic and electromagnetic conductivity survey were made on the Divrigi Citadel in Sivas, Turkey. Eight areas were surveyed according to archaeologists' suggestions for the initial geophysical research. Derivatives of the magnetic data provide well identified images. There were two circular anomalies with 7-7.5 m in diameter and probably a buried channel anomaly with 9 m length. A schematic image map was prepared for next excavation campaign and interpreted as snow wells for this area. ElectroMagnetic Conductivity Profiler Survey (EM-CPS) measurements were made on the some low intensity anomalies in two areas. In these measurements, conductivity and in-phase quantity values were recorded. There was a good correlation between magnetic anomalies and conductivity measurements. A conductive area (19-28 milliSiemens per meter, mSm^{-1}) overlies the magnetic anomaly with low intensity. A trench is excavated and that excavation allowed us to reveal the geophysical survey results. Preliminary results show that the Divrigi Citadel could be used as the workshop area. Correlation of geophysical surveying and the excavation results show that the geophysical data and advanced processing methods are valuable tools to gather spatial information about individual buried archaeological objects.

KEYWORDS: Divrigi citadel, magnetic, EM conductivity, Medieval age, Middle age archaeology, Anatolia

INTRODUCTION

Divrigi city is in the inner of the East Anatolia, Turkey (Fig. 1). Divrigi and its neighbourhood have been ruled by several different people, the Hitites, Persians, Macedonians, Romans, Sasanians, Paulicians, Byzantines, Seljuks and Ottomans, since 2000 B.C. It reflects the cultural inheritance of the city from different periods which are reflected in the old names: 'el Abrig' (Arabic), 'Tephrica' (Byzantine), 'Difrigi' (Seljuk), 'Divrik' or 'Divrigi' (Ottoman) (Fig. 1).

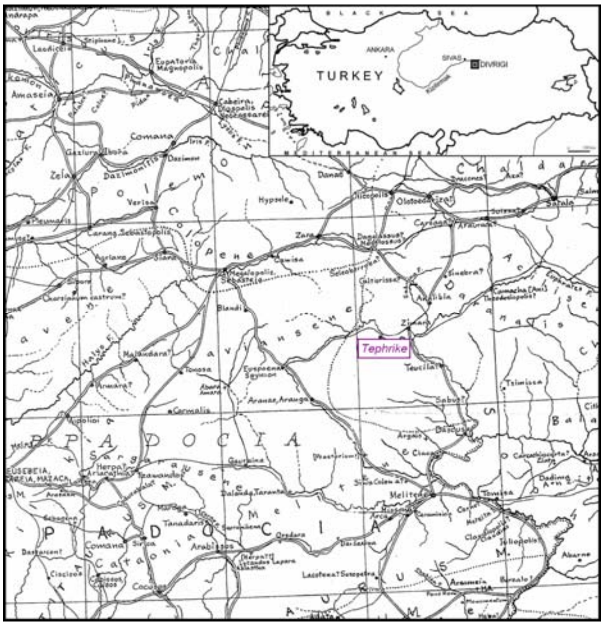


Figure 1. Ancient detailed location map of the Tephrike (Divrigi) and surrounding area (Calder and Bean, 1958). A classical map of Asia Minor. Scale-1:2.000.000

The city functioned as a border region between Macedonian, Roman, Sassanid, Byzantine and Arab lands. Paulician sect dominated the region in the 9th century. Tephrike was built under their leaders Sergius and his son Karbeas (Garsoïan, 1971). That Paulicians, were being against churches, rituals, clergy and sermons, were regarded as deviant by the Byzantine central authority, and this facilitated the Paulicians' alliance with Arabs. They fought together with Arabs against Byzantine. Their leader Sergius had the ramparts and watercourses repaired in Tephrike (Divrigi) Citadel, which was located on the Divrigi rocks (Figs. 2a, b). For the sake of getting the support of the Malatya leader, some of the Paulicians turned to Islam. Under Karbeas Tephrike continued to be a buffer zone both in the Easternmost of the Byzantium lands and in the Westernmost of the Arabic lands. The power of the Paulicians was broken in 872. Basileos who was the Emperor in 868, managed to conquer Tephrike Citadel, which resembled an eagle nest, and wiped away the supportive Arab forces (Arpee, 1906; Garsoïan, 1971). There is no historical data when Turks inhabited the Divrigi area, but it was probably after the Malazgirt Battle in 1071, conquered by Mengucek Gazi and his sons, who decided to settle there after the battle (Sakaoglu, 1971; Turan, 1981). In 1142, Menguceks separated into 2 branches, Erzincan and Divrigi, and Divrigi became a capital of Divrigi branch, with the leader of Divrigi Menguceks, Suleyman Shah. Divrigi was captured by the Mamelukes in 1277 A.D. after Mamelukes, Mongol Abaka Khan came to Divrigi and ordered to destroy the walls (Sakaoglu, 1971; Turan, 1981; Sumer, 1997). Divrigi entered the Ottoman Empire borders during the period of Yavuz Sultan Selim, after the victory of Mercidabik in 24th of August, 1516 (Eken, 1993).

Figure 2. (a) General view of Divrigi and Divrigi Citadel, (b) View of Divrigi Citadel from Kesdogan Castle.

Divrigi Citadel is 400 meters long and 200 meters wide (Figs. 2a and 2b). It is located in the north-east of Divrigi town, which has inner and outer walls. Inner and outer walls have many bastions. Outer wall length is almost 1000 meters, the height is between 5-8 meters and it has two gates. A restorated mosque and ruins of two churches can be seen on the hill (Fig. 3). West and north part of the citadel is very steep and surrounded from north and east sides by Calti River (Figure 2b).

Geophysical survey in archaeology most often refers to ground-based physical sensing techniques used for archaeological imaging or mapping. The selection of geophysical methods varies depending on the physical properties of the buried materials. Magnetic and EM conductivity methods are chosen in this Project. Both of them provide a great amount of high-resolution data in a very short time.

GEOPHYSICAL DATA ACQUISITION

In this study, the site was investigated by several different kinds of archaeological survey: Magnetic Survey (MS) and EM Conductivity Profiler Survey (EM-CPS). The MS was performed in eight areas (Fig. 3) and referenced to the local co-ordinates system.

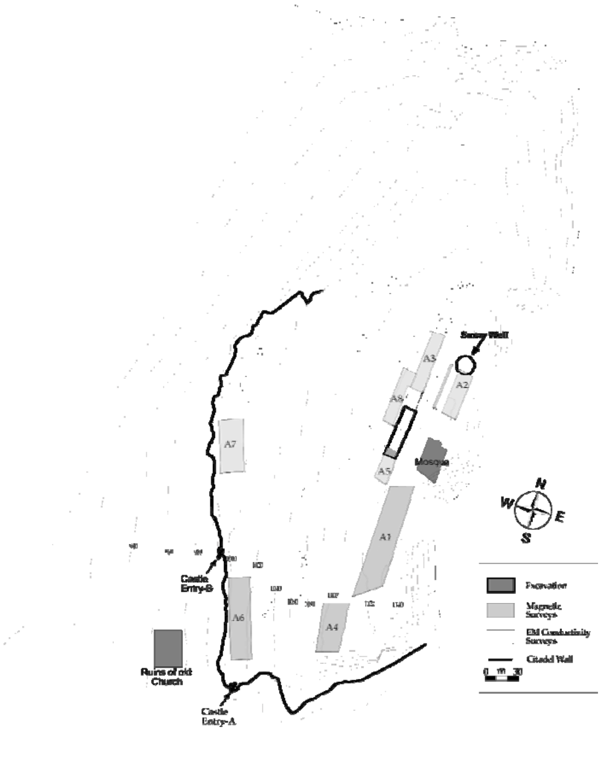


Figure 3. Topographic map including Divrigi Citadel, locations of excavation and geophysical surveys.

Magnetic data were collected along the lines using a Scintrex EnviMag magnetometer with 0.1 nT sensitivity at 2 second sampling rate. The data were collected sequentially in the continuous mode at 0.2 m sample intervals along parallel profiles with 0.5 m profile intervals and the height of the sensor was 0.5 m from the surface. The inclination angle between horizontal and total field vectors is 55^{o} for project area. We used the tie-point correction for magnetic diurnal variations instead of the conventional base station method. Tie-point corrections involve the use of one magnetometer and the repeated measurement of magnetic values at a single survey station throughout the day's survey operations (SCINTREX, 1996).

It was not possible to scan all places on the hill due to steep topography in the Citadel. Although we measured eight different areas in the Citadel, we could not get useful anomalies for all except Area-2 and 3. Probably, settlement and housing were mainly lower levels of the Citadel. That's why we could not meet anomalies including buried materials.Area-2 (Fig. 4) and Area-3 (Fig. 5) carried information about buried archaeological substances.

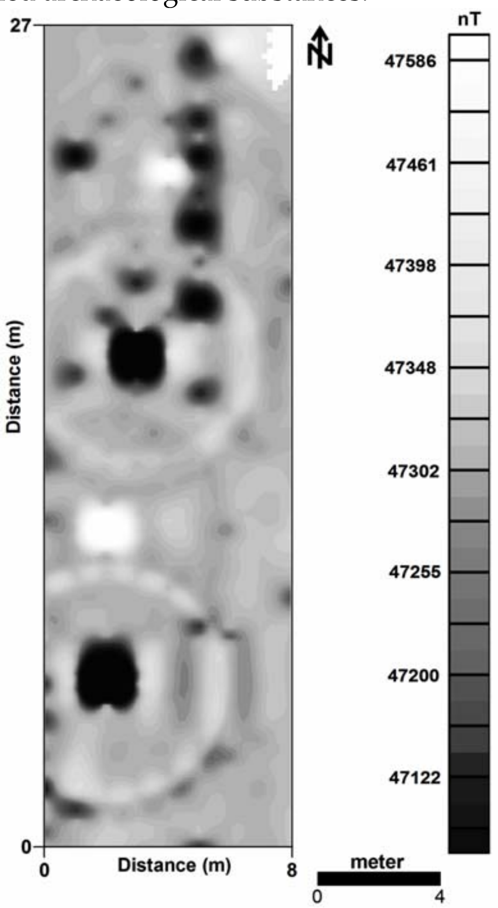


Figure 4. Distribution of the total magnetic field in the Area-2.

In the Area-2, two clear circular anomalies can be observed at the top of the hill. They have approximately same size and diameter of these anomalies is 7-7.5 m. There are low intensity values inside of these circular anomalies (Fig. 4). In the Area-3, there is an anomaly with very low intensity at the south of area. Size of this anomaly is 10 m length and 4 m wide (Fig. 5). The project area does not contain geologically magnetised rocks. The autochthonous unit as geologically is conglomerate with crystallised limestone gravels in Eocene age. There was a cover soil on the surface.

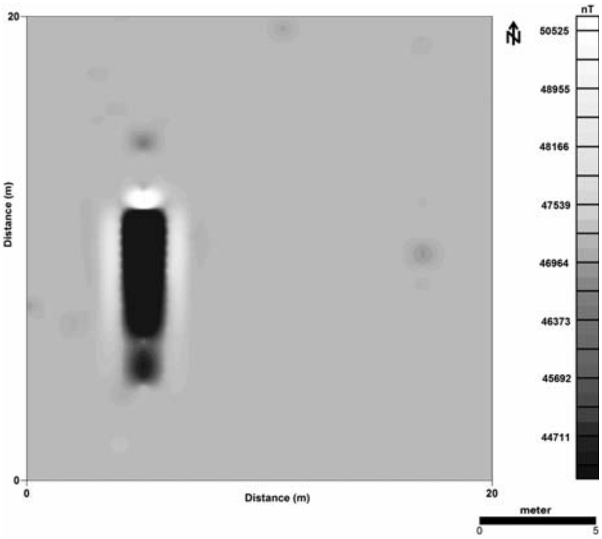


Figure 5. Distribution of the total magnetic field in the Area-3.

EM-CPS measurements were made on the anomalies belong to Area-2 and 3 (Fig. 3). A GF-CMD conductivity meter that dipole electromagnetic instrument was used in surveys at the Divrigi Citadel. Earth conductivity meters measure the ability of below-surface material to conduct an electromagnetic signal (Clay, 2001; Dalan, 1995; Bevan, 1983). It measures the flow of a generated electrical current through a substance. This type of surveys measure contrasts in the electrical conductivity of subsurface deposits. In essence, the difference in the electromagnetic wavelength is proportional to the conductivity of the ground material (Beauchaine and Werdemann, 2006). Automatic recording mode with 0.5 s spacing (approximately 20 cm horizontal space) was used. Conductivity readings, to prevent variations when changing walking direction, were taken in a zigzag pattern while walking along each transect.

The conductivity meter (GF-CMD) also gives measurements for its inphase component and conductivity and inphase are measured simultaneously. The inphase parameter measures the relative size of the real component of the vertical magnetic field which permits detection of buried metal objects.

EM-CPS measurements in Area-2 presented low conductivity values around circular magnetic anomalies less than 6 mS m^{-1} (Fig. 6a). On the other hand, in-phase quantity was zero and negative in this area (Fig. 6b). In Area-3, there was a good correlation between magnetic anomalies and conductivity measurements. A conductive area (19-28 mS m^{-1}) overlies the magnetic anomaly with low intensity in the Area-3 (Fig. 7a). We cannot see an anomaly on the in-phase map in the Area-3 due to probably lack of metals in this area (Fig. 7b). In-phase quantity is closely depending on magnetic susceptibility.

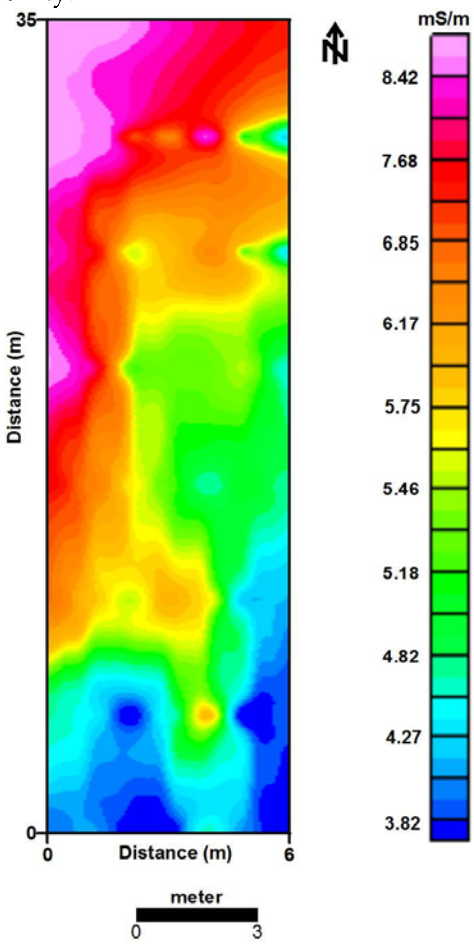
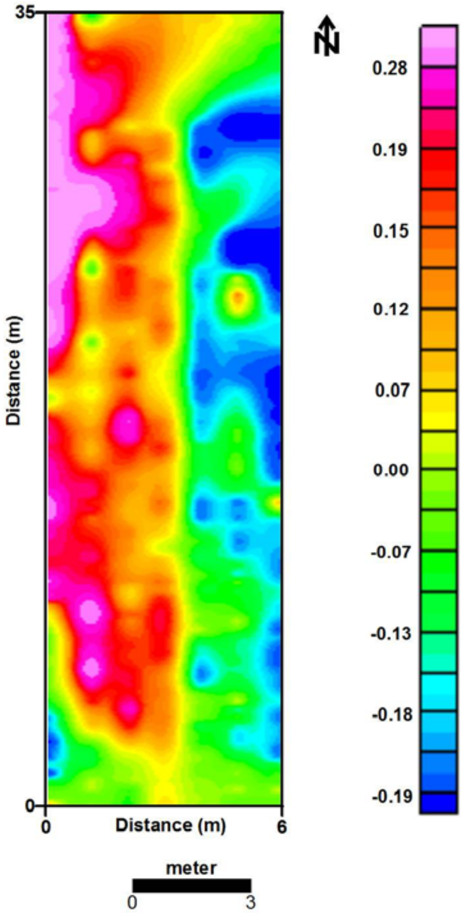
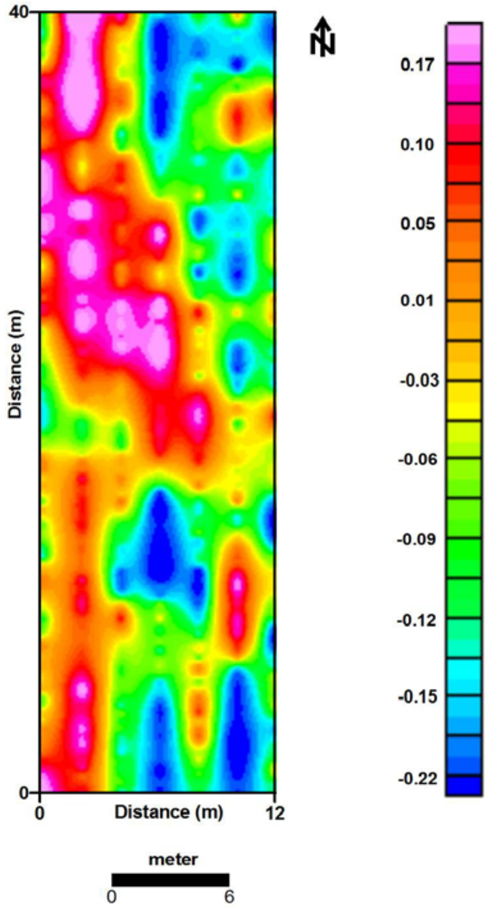


Figure 6. (a) Unprocessed conductivity map of Area-2,



(b) Unprocessed in-phase quantity map of Area-2.



(b) Unprocessed in-phase quantity map of Area-3

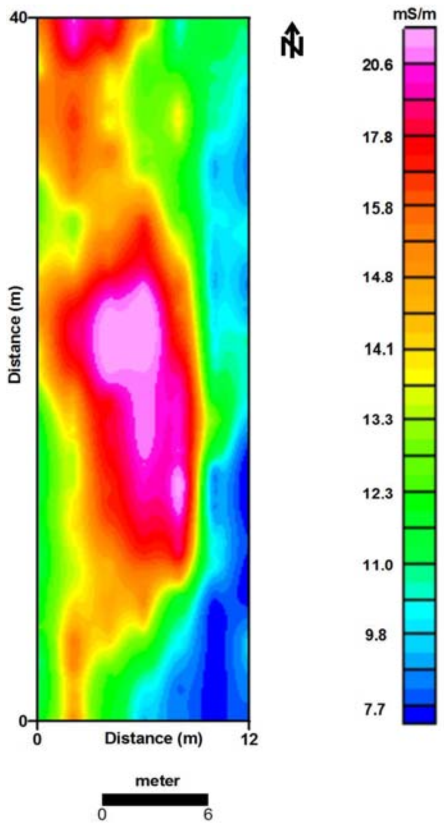


Figure 7. (a) Unprocessed conductivity map of Area-3

DATA PROCESSING

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 (Büyüksaraç et al., 2008). Before computation of derivatives, magnetic anomalies should be reduced to the magnetic pole. We got the derivatives in three dimensions X, Y and Z in the Area-2 (Figs. 8a, b and c). Analytic Signal Method (ASM) is also very successful in potential data to determine horizontal location of buried bodies. Archaeological buried materials can be determined in their correct positions after ASM stands for transformations of the magnetic anomalies. Analytic signal transformation determines the maxima over magnetization contrast; thus the locations of the maxima assist the mapping of outlines of the magnetic sources. In the ASM, the amplitude of transformed anomalies is independent from inclination and declination angles and body magnetization. The generalization of the 3-D analytic signal transformation is an improvement that allows for the analyses of much larger volumes of data. The analytic signal method poses some attractive features for buried materials during magnetic prospecting. That's why it is very useful in archaeological prospection (Tsokas and Hansen, 2000; Tsokas and Hansen, 1995; Roest et al., 1992; Nabighian, 1972, 1974). Recently, ASM was applied successfully to archaeological areas in Turkey (Milea et al., 2010; Buyuksarac et al., 2008; Arisoy et al., 2007; Buyuksarac et al., 2006).

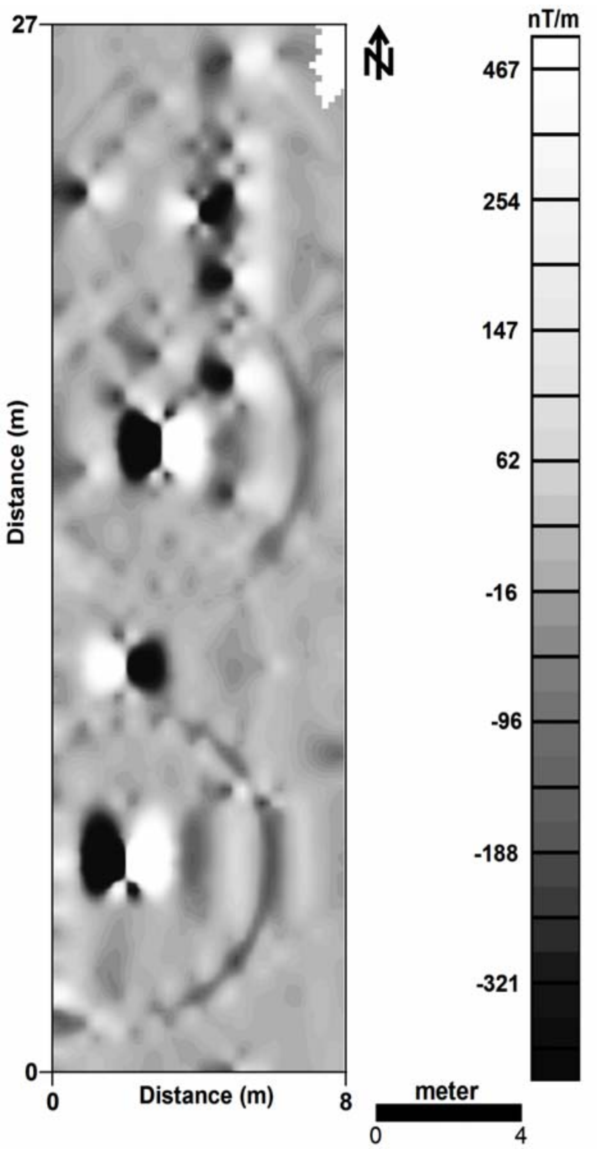
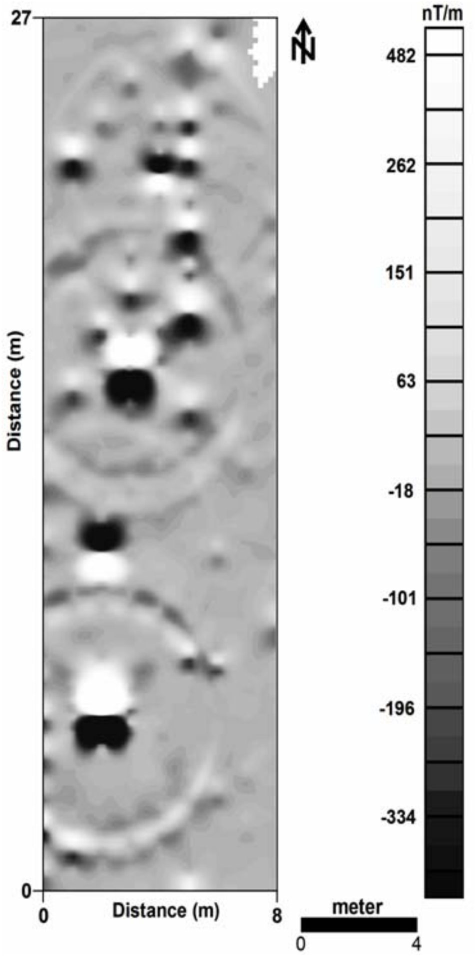
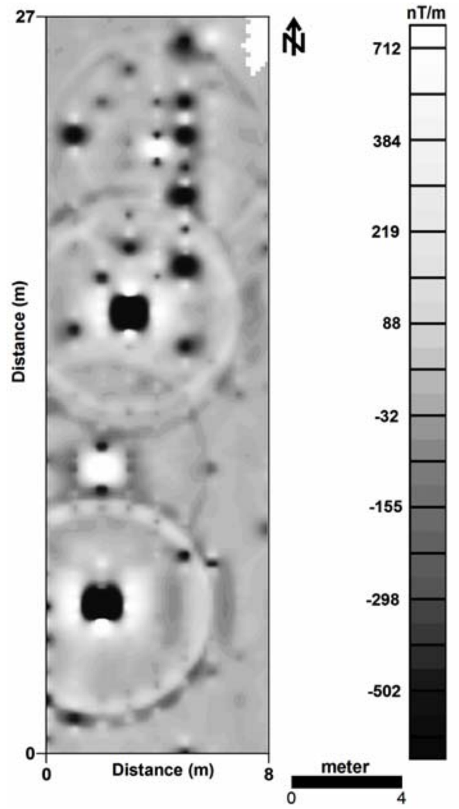


Figure 8. Derivatives of magnetic anomalies of Area-2
(a) X-Directional derivative



(b) Y-Directional derivative



(c) Z-Directional derivative

The amplitude of the three-dimensional ASM is given by the square root of the squared sum of two horizontal and vertical derivatives of the magnetic field (Roest et al., 1992). ASM application for Area-2 anomalies is presented in Fig. 9. There were two circular anomalies in that area and also a linear anomaly could be seen (Fig. 9).

The magnetic anomaly of the Area-3 presented low intensive values in magnetic measurements. We thought it could be a buried cavity in this area and limited the area to concentrate on this anomaly. We applied X, Y and Z derivatives, respectively (Figs. 10a, b and c).

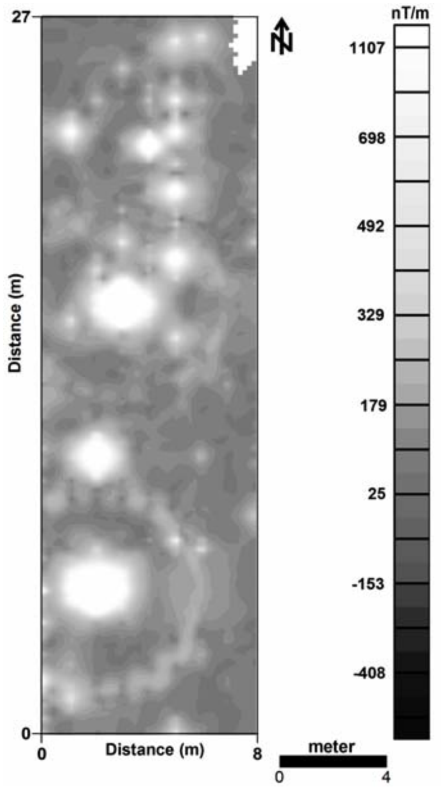


Figure 9. Analytic signal-transformed anomaly map of the Area-2.

GEOPHYSICAL RESULTS AND EXCAVATION

The project has started with archaeological survey in 2006 (Eser, 2007). Firstly, rubbles were cleaned in the mosque and its environment in seasons 2007-2009. Eight areas have been chosen according to archaeologists' suggestions for the initial geophysical research, which was done in 2006, and the general research of the area was made in summer season 2009 (Fig. 3). When we looked at the magnetic anomalies on the Area-3, we saw very low magnetic intensity and interpreted as cavity of this area. Conductivity values of this area were low and considered as also cavity. After interpreting the results of geophysical research, the exact area (Area-3) to dig was chosen in 2009 (citadel area on the hill).

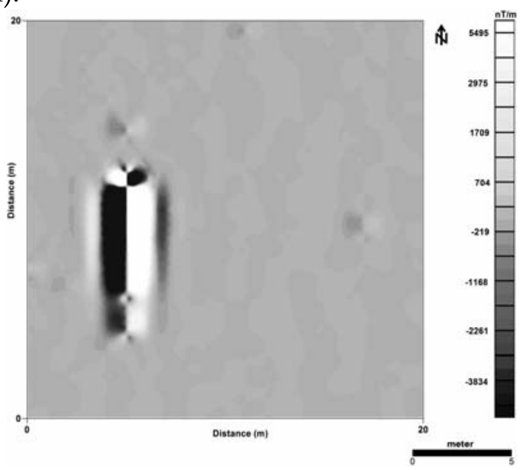
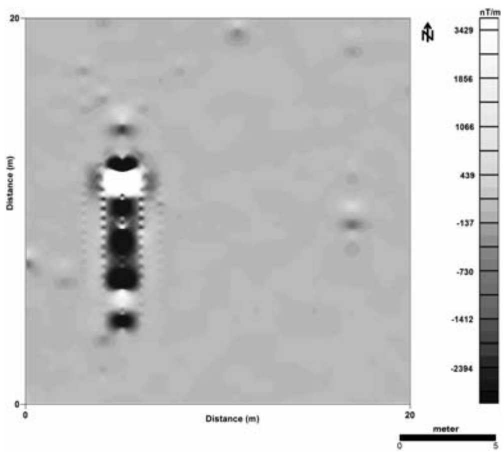
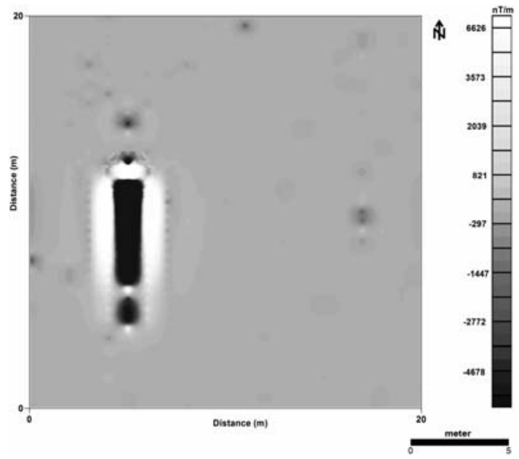


Figure 10. Derivatives of magnetic anomalies of Area-3 (a) X-Directional derivative



(b) Y-Directional derivative



(c) Z-Directional derivative.

The excavation of the citadel started in summer season 2009. This area is codified as K1, and the excavation had been going on for almost one month. Five rooms were found during excavation. Two of them were on the west side and the others were on the east side of the area K1 (Fig. 11).

Figure 11. General view of the excavation area in the Area-3.

The rooms were shaped in the rectangular form, but in different sizes, depending on the usage. All walls of the rooms were made from rubble stone, and the ground is from uncultivated rock, which suggests that the purpose of the rooms was not for living, but probably for workshop in making arts and pottery. There are five tandırs (kilns), all of them different sizes; two of them in *the room* K1A (west one is 0.66 m, and east one is 0.71 m in diameter), and three in *the room* K1B (from north to south: 0.30 m, 0.66 m and the south one is in elliptic shape- 0.90 m). All of the kilns contained only some ashes, so no solid trace was found, but some findings were found in the room. All findings from those rooms came from wide period; most of them date from 12^{th} -13^{th} centuries, especially ceramic findings, but also before 12^{th} - 13^{th} centuries. One of them was a coin from 6^{th} century, from the Byzantine period. Another important finding was a little stone stamp seal with a cross motive, probably also from same period. When the excavation and geophysical results were compared, good correlations were obtained. However, some figures such as Figs. 10b and 10c were more precisely correlated with the findings. The Fig. 10b presents Y-derivative of magnetic anomaly and when it was compared with the K1 excavation, all cavities show low intensity and walls show high intensity. The conductivity of the Area-3 has also good correlation presenting low conductivity on the excavation. West part of K1 area could not see on the geophysical maps due to lack of data. That area could find during the excavation. The kiln in K1A and K1B stages of the excavation could be explained the high intensity of the magnetic anomalies.

DISCUSSION AND CONCLUSION

In this study, two geophysical methods were applied to constrain the ambiguity in the reconstruction of a complex archaeological site. The complexity of the study area is due topography and to the poorly preserved structures. On the basis of the physical characteristics of the archaeological ruins the magnetic and EM-CPS was evaluated to be the best tools to use.

Firstly, eight areas were surveyed by using the magnetic method in the frame of geophysical investigations on the Divrigi Citadel. However, we observed the anomalies only for two areas, Area-2 and 3. The reduced to pole magnetic (RTP) maps of Area-2 and 3 have been derived from the observed magnetic anomaly map. In the Area-2, there were two circular anomalies and probably a buried channel anomaly (Fig. 4). In the Area-3, a low intensive magnetic anomaly was measured (Fig. 5). Derivatives of the magnetic data provide well identified images. Derivatives of the magnetic data provide well identified images and enable an interpretation map for Area-2 and 3. EM-CPS measurements were made on the anomalies in Area-2 and 3. In these measurements, conductivity and in-phase quantity values were recorded.

In the Area-2; there is a snow well with circular geometry in the North direction of Divrigi Citadel (Fig. 3). It was probably used to supply water for the people in summer time. Size of that snow well is 4.50 m height and 9.89 m diameter. We observed the circular magnetic anomalies behind of that snow well. Diameters of those circular anomalies are 7-7.5 m. It means observed circular anomalies can be other snow wells. Conductivity and in-phase are measured simultaneously. Conductivity measurements showed low values around 6 mSm^{-1} and in-phase quantity is zero and negative in this area (Figs. 6a and b). The in-phase parameter measures the relative size of the real component of the vertical magnetic field which permits detection of buried metal objects. Another finding is a probable buried channel connected with first buried snow well (Fig. 4). The Amplitudes of the edge of the circular anomalies and buried channel are enhanced by analytic signal transformation (Fig. 9). We prepared a schematic image for Area-2 (Fig. 12). It is planned to excavate for next excavation campaign.

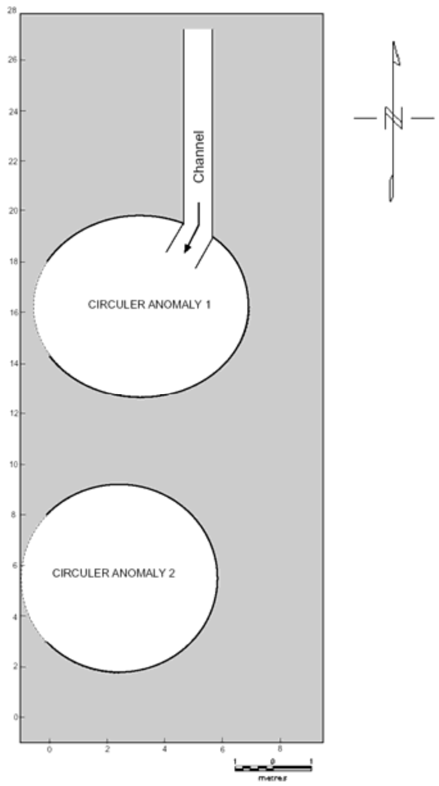


Figure 12. Schematic image of Area-2. It is planned to excavate for next term.

A conductive area (19-28 $mS\ m^{-1}$) overlies the magnetic anomaly with low intensity in the Area-3. We cannot see an anomaly on the in-phase map in the Area-3 due to probably lack of metals in this area. The magnetic anomaly of the Area-3 presented low intensive values in magnetic measurements. We thought it could be a buried cavity in this area and limited the area to concentrate this anomaly. We applied X, Y and Z derivatives, respectively (Figs. 10a, b and c).

A trench is excavated and that excavation allowed us to reveal the geophysical survey results. Preliminary results of excavation on trench suggested the period of Divrigi Citadel as being the workshop (Fig. 13).

Correlation of geophysical surveying and the excavation results show that the geophysical data and advanced processing methods are valuable tools to gather spatial information about individual buried archaeological objects.

Figure 13. Schematic image of preliminary results of excavation on trench suggested by geophysical results for Area-3 on the Divrigi Citadel.

The rooms K1A and K1B were used for some sort of manufacture, and today only 5 kilns are visible. However, there should be probably some more kilns in the rest of the area which still needs to be explored.

There is another indication that originally *the rooms* K1D and K1E were in one room, later separated with the wall into two rooms, and this is visible on the West side of the separation wall, which has a building scar.

There is not any physical evidence for the usages of *the rooms* K1D and K1E. There is a possibility that they might be used as the storage.

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