IDENTIFICATION OF BURIED ARCHAEOLOGICAL RELICS USING DERIVATIVES OF MAGNETIC ANOMALIES IN OLYMPOS MOUNTAIN WEST ANATOLIA: A CASE STUDY

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ABSTRACT

Nif (Olympos) Mountain is a wide archaeological site in west Anatolia (Turkey). Surface investigations and excavations have been done in the area since 12 years. The magnetic method as a geophysical prospection method was applied on an area of 500 m2. This method was chosen because such a prospecting technique provides a great amount of high-resolution magnetic data in a very short time. A correlation could be made between the derivative methods used in this study. Analytic signal (AS) method revealed not only grave but also surrounding stones. The total derivative method could not separate stones and grave. Normalised Standard Total Derivation (NSTD) method gave similar results with AS.

Magnetic investigations in Dagkizilca sector of Nif (Olympos) Mountain revealed some interesting results. We expected all anomalies to belong to buried archaeological materials in this area due to the surface disturbances of this site The data processing identified interesting magnetic anomalies that lead to test excavations, which in turn resulted to the unearthing of a grave, as well as, illegal intervening by antiquity robbers.

INTRODUCTION

West Anatolia of Turkey has a big archaeological potential. There are a lot of archaeological well known settlements such as Ephesus, Sardis, Philadelphia, Thyatira, Pergamum, Laodicea, Didyma around Aegean Sea (Fig. 1).
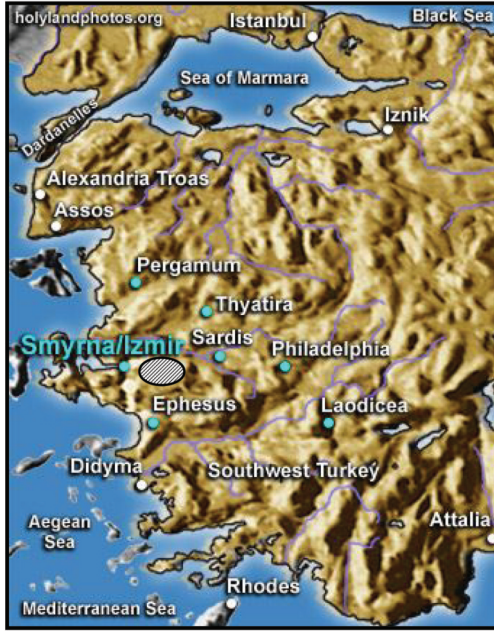
in Nif (Olympos) are scattered due to mountainous morphology. The Nif is located between east of Izmir (Smyrna) Bay and south of Sipylos Mountain (Fig. 1). In this study, we investigated a part of area around 500 m² named Dagkizilca (Fig. 2).
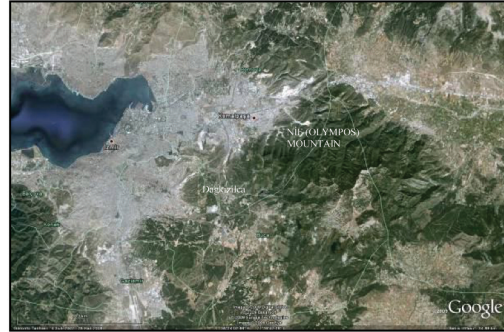

Figure 1. Archaeological settlements around Nif (Olympos) Mountain, West Turkey (http://www.holylandphotos.org/). The elliptic hatched area presents the study area.

Figure 2. Dagkizilca sector of Nif (Olympos) Mountain (Googleearth map, 2008).

However, Nif (Olympos) Mountain has insufficient archaeological knowledge in literature. Although there are some ancient structures and monuments belong to Hellenistic and Byzantine periods, between 6th and 13th centuries BC, they have not been reported until now. However, illegal excavations damaged many necropoleis and monuments in that area. That's why scientific investigations and excavations had to be carried out in Nif (Olympos) to protect the archaeological heritage against to illegal excavators. The settlements and necropoleis

Our aim was to find new buried graves in Dagkizilca section of the mountain. There were two types of graves. First one was huge and complex and second type was basic carved in rocks (Figs. 3a, b).

Total magnetic field measurement method was used to explore the underground. Magnetic method is sensitive to determine edge of buried magnetised rocks, archaeological relics etc. Many researchers such as Theocaris et al. (1997), Tsokas and Hansen (2000), Fedi and Florio (2001), Ciminale and Loddo (2001), Ates (2002), Ciminale (2003), Verduzco et al. (2004), Wijns et al. (2005), Cooper and Cowan (2006), Fairhead and Williams (2006), applied the magnetic method for edge detection of buried structures. Büyüksaraç et al. (2008) applied the magnetic method to some archaeological sites in Turkey.

Figure 3. Grave types in Nif (Olympos) Mountain (a) Huge and complex, (b) Carved in the rock.

ARCHAEOLOGICAL INFORMATION AND EXCAVATIONS

A scientific team lead by Prof. Dr. Elif Tul Tulunay from Archaeological Department of Istanbul University started to investigate around Nif (Olympos) Mountain. They completed pre-investigations and excavations between 1999-2008. Dagkizilca, Karamattepe, Baspinar are investigated areas around Nif (Olympos) Mountain. Findings were important for study area. Multicultural findings such as Hellenistic and Byzantine periods provided the most important knowledge for the study area. On the other hand, ages of the findings were dated from 6th century to 13th century, BC.

Excavations around Nif (Olympos) Mountain can be summarised as an unknown settlement and grave contexts in Karamattepe, graves in Dagkizilca and a church belong to Laskaris in Baspinar. Especially classic Hellenistic graves, depending on inhumation and cremation traditions, consist of basic tub, sarcophagus, room, coins, Hydria etc in Karamattepe and Dagkizilca necropoleis are important to investigate grave typology and funeral ceremony around Nif (Olympos).

MAGNETIC DATA AND PROCESSING

The magnetic survey was performed in two surveys and referenced to the local co-ordinate system. A scaled map of the site including the location of the survey areas and the excavated trenches is illustrated in Fig. 4. A sensitive proton magnetometer (Scintrex Envimag System with 0.1 nT sensitivity at 2 second sampling rate) was used to acquire the total intensity of the magnetic field. The data were collected sequentially in the continuous mode at 0.2 m sample intervals along profiles with 0.5 m profile separations. The height of the sensor was 0.5 m from the surface. 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). Recorded data sets were gridded using the kriging method. The inclination angle of the ambient field is 55° for project area. Initially, reduction to the pole magnetic (RTP) map was produced (Fig. 5) from the magnetic anomaly map. Two anomalies annotated with circles were selected (Figs. 6a and b) to analyse by using derivative methods.
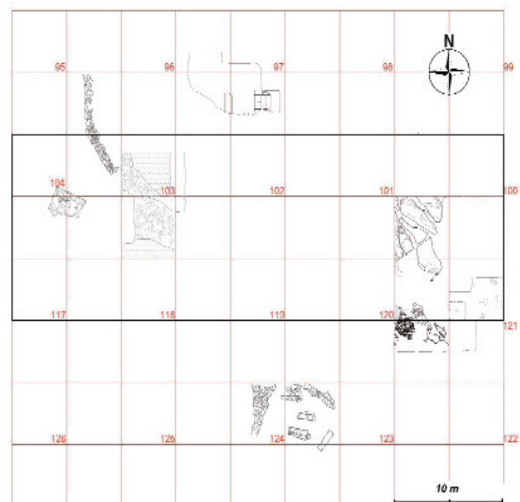

Figure 4. A scaled map of the site includes the location of the survey areas and the excavated trenches. Frame with solid black line presents geophysical surveys.
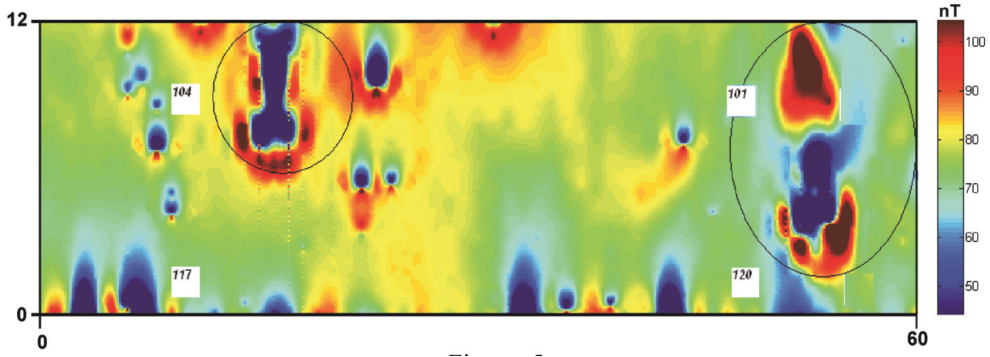
Figure 5. The Reduction to the pole magnetic (RTP) map was derived from the magnetic anomaly map.
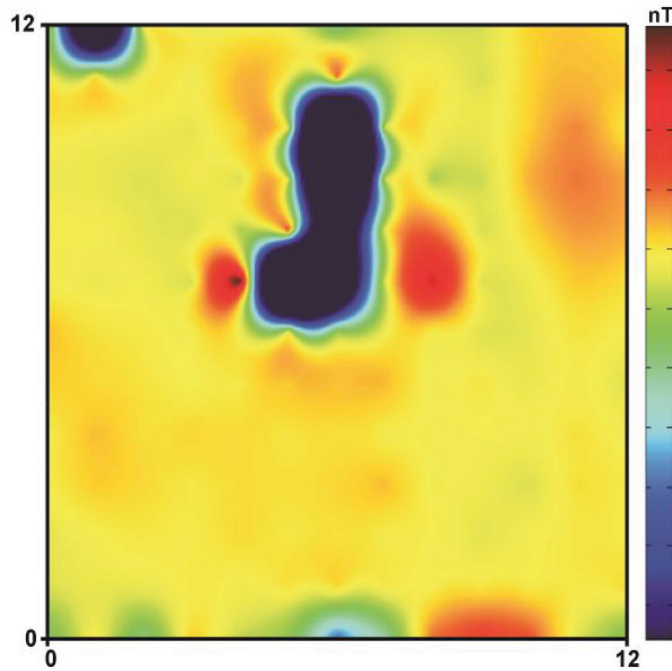

Figure 6. RTP anomaly maps (a) The anomaly map is belong to first anomaly between the number 104 and 117

Derivatives of the magnetic anomalies are commonly used for interpretation. Interpretation of magnetic field derivatives, separately or together, provides images of shallow magnetic bodies and suppresses the deep source fields. 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. Before computation of deriv-

atives, magnetic anomalies should be reduced to the magnetic pole. There are several important filters Such as Analytic Signal (AS), Total Horizontal Derivative (THD), Normalised Standard Total Derivation (NSTD) methods to determine causative body in potential field data.

The Method of Analytic Signal (AS) is very successful to process the potential data to determine horizontal location of buried causative bodies. Archaeological buried materials can be determined in their correct po-

sitions after AS transformations of the magnetic anomalies. Recently, AS was applied successfully to archaeological areas in Turkey (Büyüksaraç et al., 2006, 2008; Arisoy et al., 2007). 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 (Roest et al., 1992). AS application for two anomalies are presented in Figs 7a and 8a.
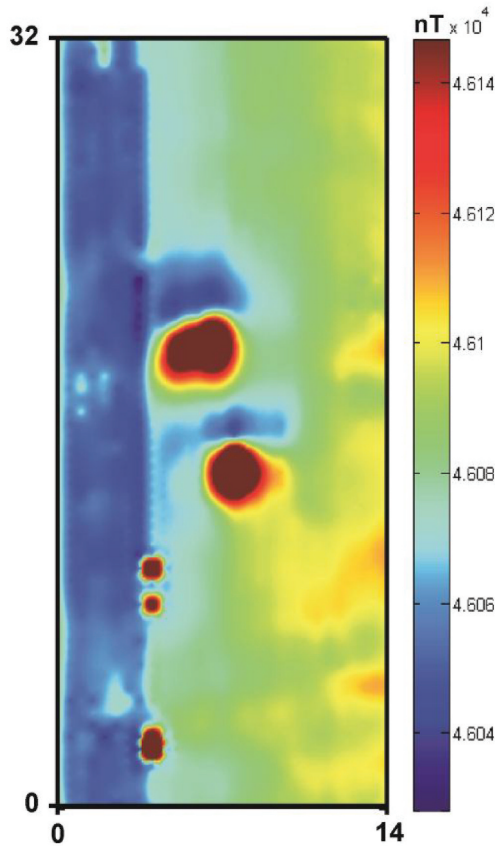

(a)

Figure 7 (a) Analytic Signal (AS) transformation, (b) Total Horizontal Derivative

Figure 6. (b) The anomaly mab is belong to second anomaly between the number 101 and 120

Total Horizontal Derivative (THD) commonly is used for edge detection. THD presents maximum values over the edge and negative values outside the source region. The amplitude of THD is given by the square root of the squared sum of two horizontal derivatives of the magnetic field. THD presents difference according to ASM (Fig. 7b and 8b)
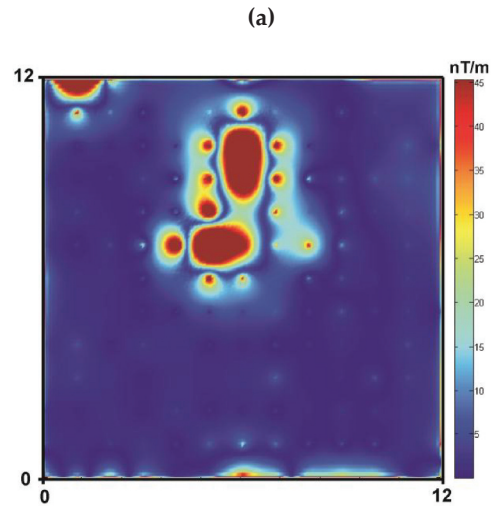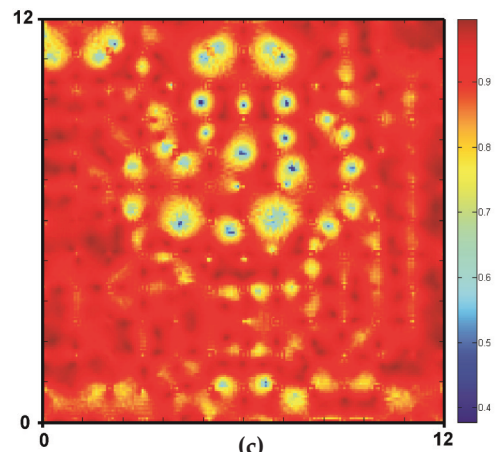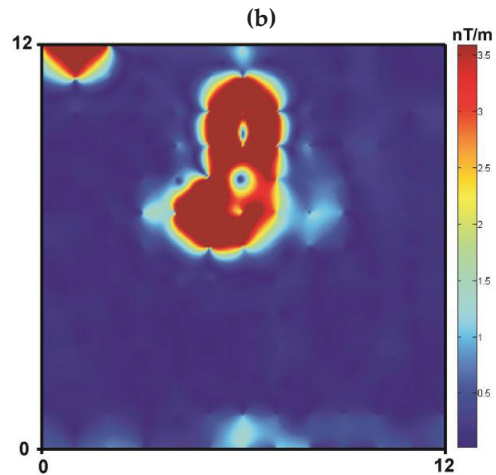
(b)

(c) Normalised Standard Total Derivative (NSTD).

$$NSTD = \frac{\sigma\left(\dfrac{\partial T}{\partial z}\right)}{\sigma\left(\dfrac{\partial T}{\partial x}\right) + \sigma\left(\dfrac{\partial T}{\partial y}\right) + \sigma\left(\dfrac{\partial T}{\partial z}\right)}$$
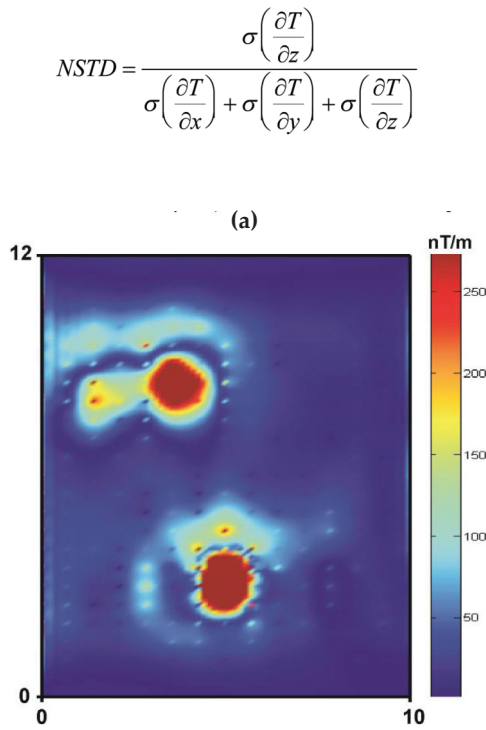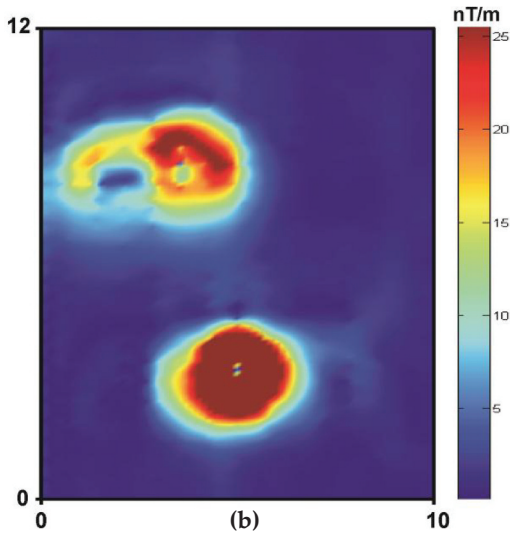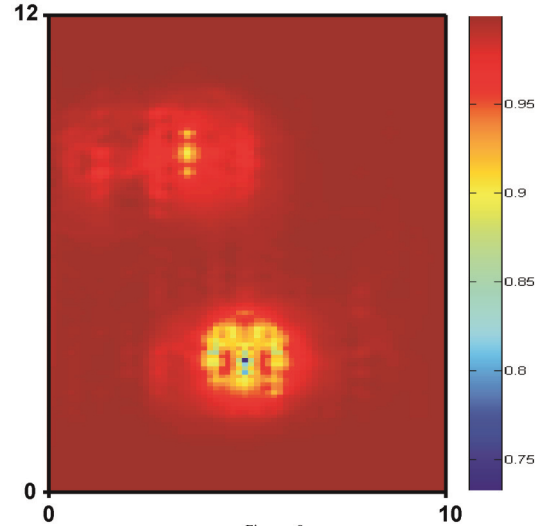
(a)

Figure 8. Second magnetic anomaly between the number 101 and 120, (a) Analytic Signal (AS) transformation

(b) Total Horizontal Derivative,

Normalised Standard Total Derivation (NSTD) edge detector is produced by Cooper and Cowan (2008). They suggest a new edge filter NSTD based on the win-

(c) Normalised Standard Total Derivative (NSTD)

dowed standard deviation of the derivates of potential data to make high and low amplitude edges visible. The standard deviations σ shown in Equation 1 is computed using a moving square window of data points. The standard deviation can be computed in a given direction. If a larger window size chooses, the NSTD method is less sensitive to noise than are smaller ones but smear out edges smaller than the window size. NSTD shows more detail when the data are relatively smooth (Figure 7c and 8c), as follows:

DISCUSSION and CONCLUSIONS

The magnetic method is chosen in this project because such a prospecting technique provides a great amount of high-resolution magnetic data in a very short time. The effectiveness of the magnetic method depends upon susceptibility contrast between buried archaeological substances and their surroundings.

Magnetic investigations in Dagkizilca sector of Nif (Olympos) Mountain presented interesting results Magnetic derivatives showed clearly a buried material in Figs 7 and 8. We found a grave according to suggestions of magnetic results (Fig. 9).

Figure 9. Excavation of a grave in Dagkizilca sector in Nif (Olympos) Mountain.

The grave and surrounding stones were determined by analytic signal method. On the other hand, the total derivative method could not separate stones and grave. The Normalised Standard Total Derivation (NSTD) method gave similar results with the Analytic Signal (AS) (see, Fig.8). We expected all anomalies belong to buried archaeological materials in this area due to disturbed area Therefore a second anomaly was suggestive to excavate the area. It was revealed. illegal excavations had taken place whereas the robers inserted two iron piles to explore buried materials and left them in the soil (Fig. 10).

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Figure 10. Excavation of the iron piles in Dagkizilca sector in Nif (Olympos) Mountain.

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