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GEOPHYSICAL EXPLORATIONS ON AND NEAR THE ISMENION HILL, THEBES, GREECE, 2011

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Abstract: Το άρθρο αυτό παρουσιάζει τις πρώτες κοινές έρευνες στη Θήβα, στην περιοχή του ναού του Απόλλωνος Ισμηνίου, που κρίθηκαν επιβεβλημένες, πριν από την υποβολή μιας ολοκληρωμένης και τεκμηριωμένης πρότασης Συνεργασίας, για τη διενέργεια εργασιών πεδίου και πιό συγκεκριμένα ανασκαφών. Οι έρευνες αυτές έλαβαν χώρα το καλοκαίρι του 2011, μετά από ευγενική πρόσκληση του Διευθυντή τότε ένατης Εφορείας, Καθηγητή κυρίου Βασίλειου Αραβαντινού, που χρονολογείται το 2010. Σκοπός μας ήταν ωα αναλάβουμε μαζί την προσπάυεια διερεύνησης τοπογραφικών και αρχαιολογικών ζητημάτων, σχετικών με την παλαιά ανασκαφή του Ισμηνίου και τη νεώτερη του Ηρακλείου των Θηβών.

The 9th Ephoreia of Prehistoric and Classical Antiquities has made important discoveries within the last decade in southeast Thebes in the area now identified as the Herakleion. The western remains of the nearby Ismenion temple and the use of the Ismenion hill as a cemetery in various periods is well known. The synergasia on the Ismenion hill aims to put these discoveries and features into a larger context and to explore the life of the Ismenion hill throughout time.[1]

To pursue these goals, the project began with the help of two specialists from the Polytechneion in Athens, Lisa Lamprou and George Pantazis, who helped to establish three new fixed local survey points with known geodetic coordinates. We then developed a local, translatable grid meant to provide exacting three-dimensional referencing for all of greater Thebes. Much good and ambitious Geographic Information Systems (GIS) data has been collected in recent years using multiple ad-hoc local grid coordinates within Thebes,[2] and we hope the establishment of this translatable grid will contribute to this future work in greater Thebes.

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[1] The project has received support from the Stavros Niarchos Foundation, Bucknell University, the Loeb Library Foundation, the American Philosophical Association, the Gladys Delmas Foundation, Randolph-Macon College, and the contributions of many individual donors.

[2] E.g., Andrikou, Aravantinos, Dakouri Hild and Kountouri 2003.

With this grid in place, in 2011 we completed three geophysical surveys: micro-topographic, magnetic, and electromagnetic, all directed by geophysicist Dr. Rob Jacob of Bucknell University and assisted by Emily Bitely, also of Bucknell University.[3] The team investigated not only the hill itself but also the vacant parking lot immediately to its northwest, which stretches toward the ancient Strophia riverbed, the Herakleion and the Electra Gates beyond; the surveyed area *in toto* measures c. 14,450 sq. m. (*Figure 1*). Excluding the east side of the parking lot and areas on the hill that were too steep for survey, full topographic, electromagnetic, and magnetic coverage was obtained.

Microtopographic Survey

The microtopography survey was conducted with a robotic total station (Trimble 5600) and a wheel attachment for surveying rod to facilitate rapid continuous data collection. The data were collected along local grid lines spaced at 1 m intervals and an in-line sampling interval of 1 point per 0.25 m. Additional data were collected in order to generate a digital elevation model (DEM) with a desired sampling density of at least one point per 1 m^2 for most of the survey region with the exception of steep slopes along the western periphery of the hill and the exposed portion of the temple which was surveyed separately. De-sampling and the manual removal of erratic points were used to effectively minimize noise and survey defects.[4] The data were de-sampled using a radial search distance threshold of 0.5 m between points (*Figure 2a*). A triangulated irregular network (TIN) was generated via ArcGIS's Delaunay triangulation algorithm, and this is presented in full color for the lot (*Figure 2b*) and the Ismenion hill (*Figure 2c*). A greyscale version of the TIN serves as the background for all digital plans and electronic plotting of new features and finds in the field (*Figure 2d*).

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[3] In 2012 Dr. Apostolos Sarris (Foundation for Research & Technology, Crete) and his team continued with ground penetrating radar (GPR) and resistivity studies; these results will be published in future work.

[4] To achieve this, ASCII files of the topographic data were imported to ArcMap 10, saved as individual shapefiles according to *xyz* values, and merged together. Redundant points were removed via IDRISI Taiga's GENERALIZATION module using a 0.5 m tolerance between points. A triangular integrated network (TIN) was generated from the de-sampled data to create a surface model, which was vertically exaggerated in ArcScene. Two major survey defects (a linear artifact and a data spike) were manually removed, and the procedure was repeated to create a new TIN. Also, in order to improve results, other minor yet erroneous data points could be removed, and custom hillshades could be explored to emphasize different surface features. Because trees and tree roots undoubtedly affected the surface topography, a digitized layer of present tree locations would also be very useful for interpretation of minute topographical features.

The long linear feature trending east-west on the west of the hill (*Figure 2c*) is related to the 1900s excavation. This linear feature continues on the top of the hill, cutting across the temple platform and extending ~10 m east of the exposed temple blocks before terminating with a small branch extending <5m toward the north.

Magnetic Survey

Total magnetic field measurements were taken with a cesium-vapor magnetic gradiometer (G-858), which consists of two sensors aligned vertically: a bottom sensor (~0.3 m above grade, +/- 0.1 m due to walking over rough topography) and a top sensor (located 1 m above bottom sensor). As such, the dual sensor setup provides a means to eliminate sources of noise above the ground surface and to discriminate between large magnetic masses typically associated with the natural geology and small magnetic objects typically associated with anthropogenic origins. The measurements from the top sensor are subtracted from the bottom sensor to obtain the magnetic gradient, which emphasizes small magnetic objects in the subsurface. Meanwhile, total field data from the top sensor provides an understanding of natural magnetic field variations over the field site. The magnetic data were collected along parallel grid lines spaced 1 m apart using an alternating (snake) pattern at a sample interval of 10 readings per second. In order to minimize line-to-line variations in the position of the magnetometer due to the alternating line direction pattern, the gradiometer position represented the the data location for every line.

The magnetic gradient data from the Ismenion hill (*Figure 3*) reveal several interesting trends. Soil accumulation from old excavations, fortification mounds, or tombs appear with high linear magnetic gradient anomalies, as shown by rose color contours on the west side of the hill, which correspond with high elevations in the topographic data. While anthropogenic trenches made in last 100 years are not the focus of this research, such observations can be useful as there are few records for recent activity on the northern side of the Ismenion hill. Additionally, the magnetic gradient data indicate that exposed blocks of the Ismenion temple have low magnetic response relative to the surrounding material as represented in blue and green color contours (*Figure 3*). Interestingly, east of the exposed blocks, the low magnetic response continues in locations separate from topographic lows in the north-central region of the hill. The magnetic gradient data also reveals a series of small magnetic dipoles surrounding the 1900s excavation area, as highlighted by dash-dot box. The linear anomaly (labeled 1) is most likely a pipe or recent anthropogenic addition to the subsurface at the site. In addition to subsurface features, three dotted boxes indicated on the hill portion of the survey data show metallic surface material (two guide wires for telephone poles and one buried portion of fencing material). Three dotted boxes appearing in the parking lot also correspond with surface metal and other material (telephone poles, cans, and bolts protruding above ground).

Two dominant observations can be seen in the total magnetic field readings from the top sensor (*Figure 4a*) and the bottom sensor (*Figure 4b*). First, the Ismenion hill as a whole has a much higher magnetic signature than does the vacant lot. Second, the 1900s excavation as well as more recent excavation for ditches, corresponding to the long linear topographic depressions or ridges in the DEM (Figure 2c), affected the hill's magnetic signature. This suggests a contrast between the magnetic properties of the topsoil and underlying soil layers. Surprisingly, one would expect potential trash accumulation in these ditches to increase the magnetic response, but this does not appear to be the case. The series of small magnetic dipole anomalies that appear to make a rectangle around the 1900s excavation are stronger in the bottom sensor (*Figure 4b*) than in the top sensor (*Figure 4a*). This suggested that these anomalies were not buried very deep (<1 m) and were later revealed to be the fence posts for a 1960s fence installation. As expected, the same anomalies identified from the magnetic gradient data are also observed in these data (e.g., linear anomaly 1 on the west slope of the hill, the wires and buried fencing material on the hill, and the surface metal in the parking lot). Far more important, the magnetic data from both the bottom and top sensors together suggests that the north and northcentral area of the temple should be further investigated, as planned for summer 2013.

Electromagnetic Survey

Electromagnetic (EM) surveying detects changes in resistivity or magnetic susceptibility within subsurface material. In the 1960s Pharaklas had noted that the hill’s remains, even of periods as early as the archaic, lay very close to the surface.[5] The EM instrument, a GSSI Profiler EMP-400, was chosen accordingly for the 1.21 m coil separation in order to detect shallow anomalies. The Profiler was used in vertical dipole mode which leads to the EM data being sensitive to the material from the ground surface to an approximate depth of 1.8 m.

The EM instrument also transmits multiple frequencies in order to evaluate the EM response of the subsurface material to different frequencies. The team collected EM data at three frequencies (1000 Hz, 6000 Hz, and 13000 Hz) based on instrument response over a test area at the site, and the in-phase component was zeroed on site. Each of these frequencies consists in an in-phase and a quadrature phase component. The in-phase component of the EM response is most sensitive to materials with high conductivity or strong magnetic susceptibility, while the quadrature phase component is more sensitive to changes at low conductivity (or weak magnetic susceptibility) values. The EM data were collected along parallel grid lines spaced 1 m apart using an alternating (snake) pattern at a sample interval of 2 readings per second. In order to minimize line-to-line variations in the position of the transmitter of the EM instrument due to the alternating line direction pattern, the Profiler orientation remained constant for every line.

The 13,000 Hz and 6000 Hz quadrature data (*Figure 5*) had less noise than the 1000 Hz quadrature data, hence the 1000 Hz quadrature data is not presented here. Many of the modern features identified from the magnetic survey also appear in the EM data. The linear anomaly in the northwestern portion of the hill interpreted as subsurface infrastructure is apparent in the 13000 Hz quadrature (*Figure 5a*) and 6000 Hz quadrature (*Figure 5b*). However, neither the surface metal locations (shown by dashed boxes in Figures 5 and 6) nor the 1960's fence posts (shown by dashed-dot box) create large EM responses in either quadrature or inphase data. The two most striking large scale observations from the quadrature data are the NE-SW trending zones of low EM response on the hill (indicated as dark blue to blue-green in Figures 5a and 5b), which may relate to underlying geology, and the high EM response in the vacant lot (indicated by rose colors in Figures 5a and 5b).

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[5] Pharaklas 1963, 232; see also Symeonoglou 1985, 238.

Figure 6 demonstrates the data from the lowest electromagnetic frequency and the in-phase component. These data further support the observation from the magnetic data that the soil on the hill has a greater magnetic susceptibility than the subsoil, as shown by the 1900s excavation on the hill's west side. That the exposed blocks have a low in-phase response (*Figure 6*) also agrees with the magnetic data. In general, the EM data support the magnetic data and provide additional locations for future archaeological explorations.

Comparison of Magnetic, Electromagnetic, and Topographic Data

Figure 7 offers a comparison between the magnetic gradient, electromagnetic 6000Hz in-phase, and microtopography data with a number of key features highlighted as ovals or boxes. As expected, the exposed temple blocks appear with a homogeneous magnetic and EM response, as the blocks are composed of a single material. The combined magnetic and EM response further suggests that the blocks have little magnetic susceptibility and are not conductive. Oval 1 shows an interesting eastward extension of both a low magnetic gradient and low EM response. Box 2 demonstrates a correlation between isolated locations of low magnetic gradient data and a linear low EM response; this correspondence may indicate additional temple blocks and also parallels Keramopoullos' projected drawing of the temple foundations.[6] Both sets of correlations in Oval 1 and Box 2 also match linear depressions in the microtopography data. Oval 3 is characterized by both low EM response and low magnetic gradient well defined within higher magnetic gradient locations; this anomaly corresponds to the far eastern limit of the temple and thus its entrance. Given these correspondences and Herodotus' and Pausanias' ancient accounts of the processional way to the temple, this area will be explored in season 2013.[7] The low magnetic response (green color contours) along the west side of Box 4 corresponds with a longer linear high EM response (red color contours). In addition, a magnetic dipole exists in the center of Box 4 and corresponds to a circular low EM response. These characteristics may indicate the

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[6] Keramopoullos 1917, 33.

[7] Hdt. 5.59-61; Paus. 9.10.2-6.

presence of metal here. Anomaly 5 (circled) is apparent in both EM and magnetic gradient data and corresponds to a surface depression. The geophysical response maybe related to the magnetic nature of the geologic material or may indicate that there are metal objects (or other objects having dipolar magnetic responses) within the depression or within the walls of the depression. Oval 6 appears to connect to a previously explored depression on the south side of the temple (north of oval). The low magnetic and EM response may indicate that material within this depression bears little similarity to material on the rest of the hill which shows a high magnetic and EM response. Anomaly 7 is complicated by the signatures of at least two dipoles associated with the 1960s fence. However, the correspondence of slight (<10 cm) changes in topography and the generally low magnetic and EM response are the interesting characteristics and are similar to anomaly 6. These numbered anomalies will be explored in future field seasons. Together with these future investigations, we are hopeful that the range of geophysical surveys involved in this project will help situate the life of hill and its environs through time.

Figures

Figure 1. Aerial image of Ismenion hill and parking lot, after Google Earth

Figure 2a. Desampled microtopography data, Ismenion Hill

Figure 2b. Final microtopography data for parking lot, colored elevations

Figure 2c. Final microtopography data for Ismenion hill, colored elevations

Figure 2d. Final microtopography data for Ismenion hill, greyscale

Figure 3. Vertical Magnetic Gradient Data, Ismenion hill and parking lot

Figure 4a. Magnetometer, Top Sensor, Ismenion hill and parking lot

Figure 4b. Magnetometer, Bottom Sensor, Ismenion hill and parking lot

Figure 5a. Electromagnetic Data, Highest Frequency, 13000 Hz quadrature, Ismenion hill and parking lot

Figure 5b. Electromagnetic Data, Medium Frequency, 6000 Hz quadrature, Ismenion hill and parking lot

Figure 6. Electromagnetic Data, 1000 Hz in-phase, Ismenion hill and parking lot

Figure 7. Topographic, Magnetic, and Electromagnetic Data Compared

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