THE 2012 GEOPHYSICAL SURVEY AT ANTINOUPOLIS

Abstract

The following paper gives an account of a preliminary geophysical survey conducted at Antinoupolis in the Spring of 2012. The survey was initiated with the aim of locating and mapping buried remains associated with the street plan and buildings within the walled area of Antinoupolis itself, and to indicate the extent and nature of the necropolis associated with the settlement. Four trial areas of magnetometry were surveyed during the season, together with three Electrical Resistivity Tomography profiles. The paper describes the methodology applied during the course of the survey, and presents the first results of the ongoing survey project. The results from the 2012 survey season revealed the extent of substantial structural remains associated with the east gate and northern part of the walled city, and the necropolis located to the north. Survey results also provided information on the depth of archaeological deposits in the city area close to the modern course of the Nile, and the hippodrome located in the northern extramural area.

Introduction

Between 11th and 14th February 2012 a geophysical survey was conducted at Antinooupolis, in El Minya Governorate, Egypt. Work was carried out as part of the fieldwork of the Florentine archaeological mission at the site directed by Prof. Rosario Pintaudi of the Istituto Papirologico at the Università di Firenze (see Pintaudi 2008). The survey was undertaken on the premise that no geophysical survey had been conducted previously at the site. In spite of the current topography of the Roman city, and the limited accessibility of certain parts of the settlement, it was noted that the application of geophysical survey would prove fruitful in several zones of the ancient city and the surrounding necropolis, as a way of mapping the nature and full extent of buried archaeological features.

The 2012 geophysical survey season was designed to test two specific survey techniques at the site. Survey was initiated with a view to commissioning future geophysical survey to map buried archaeological deposits associated with the Hadrianic, Late Antique and early medieval city and its associated necropolis. The techniques of magnetometry and Electrical Resistivity Tomography (ERT) were applied at the site to trial the effectiveness of the methods, the former for use in mapping the structural remains at the settlement and necropolis, and the ERT to assess the depths of deposits and nature of construction of the hippodrome, in addition to investigating the presence of remains associated with Wadi el-Gamous, the main wadi running through the city, and the possible port frontage facing the River Nile.
Four areas were surveyed using magnetometry (Figure 1) to assess the effectiveness of the technique over differing geological and archaeological deposits (Strutt et al. 2012). Area 1 focused on part of the ancient city in the immediate vicinity of the mission house, adjacent to an open Ministry of State for Antiquities (MSA) excavation trench. Area 2 was located over deposits in the smaller wadi to the north of the city coming from the area of Deir Sumbat and the north cemetery to assess the use of magnetometry in locating mud-brick tombs and ceramics in sandy deposits. Area 3 was located at the northern end of the Cardomaximus to assess the tell deposits in the area associated with a large depression at the end of the principal street of the site, and Area 4 focused on the East Gate of the city, to assess the mixed sandy and tell deposits in the area, and find the possible remains of a large structure supposedly located in the area.

In addition three ERT profiles were surveyed at the site, to assess the application of the technique, and to measure the depth of archaeological deposits across the harbour edge of the city (Profile 1), the wadi crossing along the Cardomaximus (Profile 2) and the remains of the hippodrome to the east of the city (Profile 3).

Survey work was conducted by Kristian Strutt with James Heidel, Angus Graham and Reis Omer Farouk assisting.

The Geology and Archaeological Deposits at Antinoupolis

Antinoupolis is located on the east bank of the modern course of the river Nile on the Middle and Late Eocene Minya Formation limestones (Coli et al. 2011, 2698; Klemm and Klemm 2008, 4, 83-5; Said 1962, 19, 96-7, 135-6, 138 table VII; Sampsell 2003, 84). The underlying geology of the site is therefore limestone, although the city is located on the edge of the Nile floodplain where the broad Nile channel, and the narrower Bahr Yusuf run (Bunbury and Malouta 2012). Westward migration of the Nile river is occurring downstream from Antinoupolis as can be seen in the area of Deir el-Dik where the river has silted up in the area of a former harbour (Coli et al 2011, 2704, figs. 4, 14) and hod boundaries upstream of Antinoupolis suggest westward migration in this area (Bunbury and Malouta 2012, 120 fig. 1). However, Bunbury (2011 Bunbury and Malouta 2012) argues that the river has not
migrated away from its present course in the vicinity of the city and that it must have been anchored by the city perhaps by revetment of the banks and reduction in the erosive power of the Nile through removal of water for irrigation.

The archaeological materials used in the construction of Antinoupolis include limestone quarried from the surrounding Minya Formation (Coli et al. 2011), together with buildings formed from fired brick and mud-brick. Some of the earlier structures at the site, including the pharaonic temple to the north of the modern village of El Sheikh Abada indicate the massive scale and nature of the structures using limestone and sandstone potentially located across the site. Limestone construction is particularly evident along the Cardo-maximus and at important municipal locations of buildings in the city. In addition an incredible proportion of the construction of the city is also formed from fired brick and mud brick. Most of the area within the walls of the city is dominated by piles of fired brick and ceramic fragments, the remnants of the process of removal of mud brick for fertiliser or sebkah. While the presence of the fired building material provides useful conditions over parts of the city for geophysical survey (see below) the massive nature of many of these zones of deposits makes survey practically impossible.

The Geophysical Survey Methodology

Although a number of different geophysical survey techniques could have been applied at Antinoupolis, the nature of the deposits, and the presence of mud brick and fired brick suggested that magnetometry would provide the best results. Magnetometry has been applied at numerous sites in Egypt and has provided variable results on tell sites in the Nile delta and along the Nile. However, generally the contrasting nature of the structural remains in brick and occasionally limestone are generally visible in the results. It was also deemed useful to assess the application of ERT at the site. Although the technique represents a more time-consuming method for locating archaeological features, its application in a geomorphological context in relation to archaeological deposits, and their association with fluvial material and changing sediments, meant that ERT provided a vital method to investigate the presence of deep archaeological stratigraphy, and assess the relationship between Antinoupolis and the river Nile. For future surveys the application of Ground Penetrating Radar (GPR) would provide a useful complement to the techniques applied in 2012, giving an indication of the variations in the depth of structural remains and other deposits (Conyers and Goodman 1997; Imai et al. 1987; Nishimura and Goodman 2000).

Magnetic prospection of soils is based on the measurement of differences in magnitudes of the earth’s magnetic field at points over a specific area. Principally the iron content of a soil provides the basis for its magnetic properties. Presence of magnetite, maghaemite and haematite iron oxides all affect the magnetic properties of soils. Although variations in the earth’s magnetic field which are associated with archaeological features are weak, especially considering the overall strength of the magnetic field of around 48,000 nanoTesla (nT), they can be detected using specific instruments (Gaffney et al. 1991).

The Antinoupolis survey was conducted using a fluxgate gradiometer. Fluxgate instruments are based around a highly permeable nickel iron alloy core (Scollar et al. 1990, 456),
which is magnetised by the earth’s magnetic field, together with an alternating field applied via a primary winding. Due to the fluxgate’s directional method of functioning, a single fluxgate cannot be utilised on its own, as it cannot be held at a constant angle to the earth’s magnetic field. Gradiometers therefore have two fluxgates positioned vertically to one another on a rigid staff. This reduces the effects of instrument orientation on readings. Archaeological features such as brick walls, hearths, kilns and disturbed building material will be represented in the results, as well as more ephemeral changes in soil, allowing location of foundation trenches, pits and ditches. Results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials.

Application of magnetometry has been essential on a number of sites in the Nile Delta, and on some complexes in Upper Egypt. Surveys at Qantir (Abdallatif et al. 2003) and at Tell Toukh El-Qaramous (Ghazala et al. 2003) illustrate the advantages of magnetometry on level floodplains and alluvial sediments, with survey at Myos Hormos (Peacock and Blue 2006) indicating its application on coastal limestone sediments. The use of the technique is however best illustrated with recent survey work undertaken at Deir el Barsha. At this site a magnetometer survey was conducted over the area of a necropolis consisting of mud-brick structures cut into a cone of sediment deposited by a wadi (Herbich and Peeters 2006, 14). The archaeological deposits at Antinoupolis, and their relationship to the underlying geology and geomorphology and overlying fluvial and wind-blown deposits, create a different set of conditions to those experienced in the floodplain of the Nile. However in the areas where magnetometry can be conducted the deposits comprise either limestone and basalt foundations, or mud-brick walls, overlying the limestone geology of the Minia Formation, with overlying sand. This provides optimal conditions for the application of the technique, similar to the conditions at Gebel Ramla, Quesna (Rowland and Strutt 2007; 2011) or the recent magnetometer surveys in the vicinity of the Montu Enclosure at North Karnak (Ashton et al. forthcoming).

By contrast resistivity survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. All materials will allow the passing of an electrical current through them to a greater or lesser extent. There are extreme cases of conductive and non-conductive material (Scollari et al 1990, 307), but differences in the structural and chemical make-up of soils mean that there are varying degrees of resistance to an electrical current (Clark 1996, 27). The technique is, however, best based on the passing of an electrical current from probes into the earth to measure variations in resistance over a survey area. Resistance is measured in ohms (Ω), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (Ωm). Four probes are generally utilised for electrical profiling (Gaffney and Gater 1993; Gaffney et al. 1991, 2), two current and two potential probes. Survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

The application of resistivity survey usually takes one of two forms; either the use of a mobile probe array with a set spacing for taking multiple measurements over an area at a fixed depth to produce a plan of resistivity values, or the use of expanding probe arrays used in profiles to create resistivity tomography sections through an area. In standard resistivity surveys a fixed probe array is utilised, either affixed to a frame for the taking of measurements, or built into a mobile system. Measurements are taken on traverses at equal intervals
The 2012 Survey Season

For the 2012 survey magnetometry, grids of 30 m by 30 m were set out using a Leica TC 307 total station, with the same instrument being utilised for measuring out the ERT profiles (Figs 2 and 3). The grid was located on a north-south axis, utilising the Italian mission local grid survey (Pintaudi 2008), with the grid established using fixed survey stations on the excavation house and the Chapel of Theodosia. The magnetometer survey was conducted using a Bartington Instruments Grad601-2 dual sensor fluxgate gradiometer (Fig. 4). Data were collected along traverses spaced 0.5 m apart at 0.25 m intervals.

The magnetometer survey data were imported into and processed using Geoplot 3.0 software. The processing of data was necessary to remove any effects produced by changes in the earth’s magnetic field during the course of survey, and to minimise any interference in the data from surface scatters of modern ferrous material and ceramics. Data were despiked to remove any large peaks or ‘spikes’ from the data produced by material on the surface of the field. A mean traverse function was then applied to average out any changes in the data produced by the ‘drift’ in the earth’s magnetic field. Filters were subsequently applied to smooth out any high frequency, small disturbances in the data. Finally, 0.5 m values were interpolated from the existing readings to improve the spatial resolution of the results across the traverse lines.
Figure 2 – Set up of the Leica total station for gridding out.

Figure 3 – Surveying of the principal points along the ERT profiles using a total station.
The ERT survey was conducted using an Allied Associates Tigre 64 multi-probe resistivity meter (Fig. 5). Probes were spaced at 2m intervals, with over 230m of profile being collected across the harbour edge of Profile 1, and 129m of profile being surveyed at the wadi and hippodrome. Data were collected to a depth of approximately 12m in Profile 1, and to 6m in profiles 2 and 3.

Survey Results

The Magnetometry

Four areas of magnetometry were conducted in 2012: In Area 1 to the north east of the SCA excavations near the excavation accommodation, Area 2 in the necropolis to the north of the ancient city, Area 3 in the western portion of the city and Area 4 close to the east gate within the walls of the city (see figure 1).

In Area one, a series of linear and rectilinear positive anomalies (Figs 6 and 7) are vis-
ible. These comprise a wall running alongside the excavation trench [m1.1] measuring 20m in length, a large structure [m1.2] to the north of the excavation area, a second [m1.3] 20m long linear anomaly and two sets [m1.4] and [m1.5] of rectilinear anomalies marking possible structures. These features are repeated [m1.6] and [m1.7] further to the east, suggesting a continuation of the buildings found in the excavation.

In Area 2 a large concentration of small rooms or chambers are visible (Figs 8 and 9) in the results [m2.1] with two straight sides to the complex including that to the west [m2.2], and several main concentrations of chambers [m2.3]-[m2.5]. The valley to the east is represented by a broad band of quiet measurements [m2.6] with some possible structures to the east [m2.7]. A series of dipolar discrete anomalies [m2.8] mark dumped deposits to the north of the complex, with other concentrations [m2.9] and [m2.10] of chambers to the north, all situated on a low ridge of natural bedrock.

Area 3 (Figs 10 and 11), as with area one, is dominated by a lot of modern disturbance although a series of possible structural remains can still be seen. A series of rectilinear anomalies [m3.1] and [m3.2] run alongside a possible road [m3.7] marking buildings. Similar anomalies [m3.3] and [m3.4] are visible to the south around a broader open area, with the latter anomalies seemingly related to a large depression in the modern topography. A further set of rectilinear structures [m3.5] and [m3.6] are located to the south.
Area 4 (Figs 12 and 13) shows the line of the ancient city walls [m4.1]. A series of linear structures stand behind the walls, formed by two parallel linear anomalies [m4.2] and [m4.4], and at least two rectilinear structures [m4.3]. A possible road surface is visible behind these [m4.5], followed by a series of rectilinear structures [m4.6] – [m4.8] surrounding an open courtyard [m4.9] measuring 37m by 30m, with a possible corridor or rooms running along its north-west side [m4.10]. A second courtyard with structures [m4.11] is located to the south-west with a series of structures [m4.12] and [m4.13] to the west. Two parallel positive linear anomalies [m1.14] run from northeast to southwest indicating a possible corridor or portico in the south-western part of the survey area.

The Electrical Resistivity Tomography

Three Electrical Resistivity Tomography (ERT) profiles were surveyed at Antinoupolis in 2012; the first between the excavation house and SCA trench on the edge of Sheikh Abada, the second along the line of the cardi maximus across the wadi in the centre of the city, and the third across the southern portion of the hippodrome (see figure 1).

Profile 1 (Fig. 14) indicates a broad high resistivity area measuring some 74m in length (1) and (2) and several metres deep, with a very deep central section, all corresponding to possible structures of the ancient city. This overlays a low resistivity deposit (3) which seems to be derived from fluvial deposits from the Nile, continuing (4) towards the Nile. A shallow high resistivity feature (5) marks the modern river revetment of Sheikh Abada, and a series of low resistivity readings (6) seem to indicate deposits of the modern foreshore of the Nile.

Profile 2 (Fig. 15) along the Cardomaximus indicated the remains of structures and paving to the west of the wadi (7) extending for 40m. There is a break in the high resistivity measurements as the terrain falls into the wadi (8), but an area of high resistivity is visible in the centre of the wadi (9), possibly associated with a crossing of the wadi itself. A break in the high resistivity (10) occurs with the slope out of the wadi. The structural remains continue to the east (11), with low resistivity values occurring (12) some 5-6m below the high resistivity values, possibly associated with a variation in deposits underlying the archaeology, or the level of the water table.

Profile 3 (Fig. 16) indicates several anomalies associated with the construction of the hippodrome. The high ground to the west (13) shows incredibly high resistivity readings, generated by the sedimentary rock and sand forming the seating area for the hippodrome. This material seems to slump to the east (14) and a series of low resistivity readings (15) mark the central area of the hippodrome. Two areas of high resistivity (16) and (17) indicate remains of the construction for the hippodrome seating to the east, with slumping inside of the monument. To the east of this the readings become low resistivity as the profile goes into the wadi sediments (18).

Discussion

The results of the survey indicate that both techniques of magnetometry and ERT work effectively at Antinoupolis, and their application should be considered for future field seasons. The magnetometry in Areas 1 to 4 indicates the presence of buried archaeological de-
Figure 6 – Greyscale image of the magnetometer survey results from Area 1.
Figure 7 – Interpretation plot derived from the results of the magnetometer survey from Area 1.
Figure 8 – Greyscale image of the magnetometer survey results from Area 2.
Figure 9 – Interpretation plot derived from the results of the magnetometer survey from Area 2.
Figure 10 – Greyscale image of the magnetometer survey results from Area 3.
Figure 11 – Interpretation plot derived from the results of the magnetometer survey from Area 3.
Figure 12 – Greyscale image of the magnetometer survey results from Area 4.
Figure 13 – Interpretation plot derived from the results of the magnetometer survey from Area 4.
Figure 14 – Results of ERT profile 1, running from north (left) to south (right).

Figure 15 – Results of ERT profile 2, running from west (left) to east (right).
posits in varying degrees of preservation. Area 1, adjacent to the SCA excavations, indicates the presence of limestone walls running parallel and orthogonally to the remains of structures in the trench stretching to the north and east. Two large stone and mud brick buildings are visible in the results among other features. Results were however less clear than in other areas due to the high level of disturbance and dumping of ceramic material in the area.

Results from the cemetery and wadi in Area 2 indicate the presence of extensive mudbrick tombs across the shoulder of land at the entrance to the wadi, corresponding with dumps of ceramics and human and animal bone in the area. The bottom of the wadi itself appears to be devoid of structural remains, although some tombs are present in the results along the channels on the east side of the wadi.

Area 3 at the northern end of the Cardomaximus indicates the presence of limestone foundations, with at least two sides of a substantial structure visible in the results. Several smaller rooms and buildings are visible in the southern and eastern portions of the survey area.

Results from Area 4 in the vicinity of the East Gate provide the most impressive example of the response to magnetometry from the 2012 season. The line of the city wall is visible, with an inwardly curving entrance at the East Gate. Within the walled area two sets of triple foundations mark the northern and southern sides of a massive peristyle or
structure with outer paving and structures immediately to the north-east. A line of possible column bases marks the north-eastern side of the structure, with two large rooms or chambers marking the sides of the entrance to the feature. An open area in the centre of the structure is visible, together with a number of smaller rooms. The dimensions of the structure, at 95m across and at least 130m in length, gives an indication of the scale and nature of possible buried archaeological features associated with the city.

The ERT results from profiles 1-3 in general indicated that the technique is applicable at the site. Results from Profile 1 indicated the presence of archaeological deposits along the MSA excavation trench to a depth of 3-4m. These end abruptly, close to the western edge of the excavation house, with river and kom sediments dominating the western portion of the survey. There appears to be scant evidence of a harbour edge or wharf in the results further to the west of the excavations. Profiles 2 and 3 both indicate the presence of archaeological deposits across the wadi along the cardo maximus and over the hippodrome. It is interesting to note the lack of archaeological structures along the cardo maximus in the wadi itself except in the wadi’s centre where high resistivity responses may indicate the presence of possible archaeological remains. The presence of foundations for the structure of the hippodrome were also visible in Profile 3.

The results of the 2012 season survey are of limited scope and scale, meeting the initial trial objectives of the first season of survey work. It is apparent from the results that more extensive magnetometer survey across the northern part of the walled city area, and further survey of the necropolis areas of the surrounding landscape, would yield the most fruitful results in terms of mapping buried archaeological remains.

Acknowledgements

Considerable advice and assistance was received from a number of sources in the completion of this survey. Permission for work at Antinoupolis was kindly granted by the MSA. Our warm thanks go to Prof. Rosario Pintaudi, director of the Istituto Papirologico mission to Antinoupolis, for his continued support of the survey. Funding for the geophysical survey was provided by the Antinoupolis Foundation, Inc.
References

Fieldwork to Investigate the Canals and Harbours on the West and East Banks at ancient Thebes (Luxor), Egypt, ISAP News: The newsletter of the International Society for Archaeological Prospection 31, 6-7.